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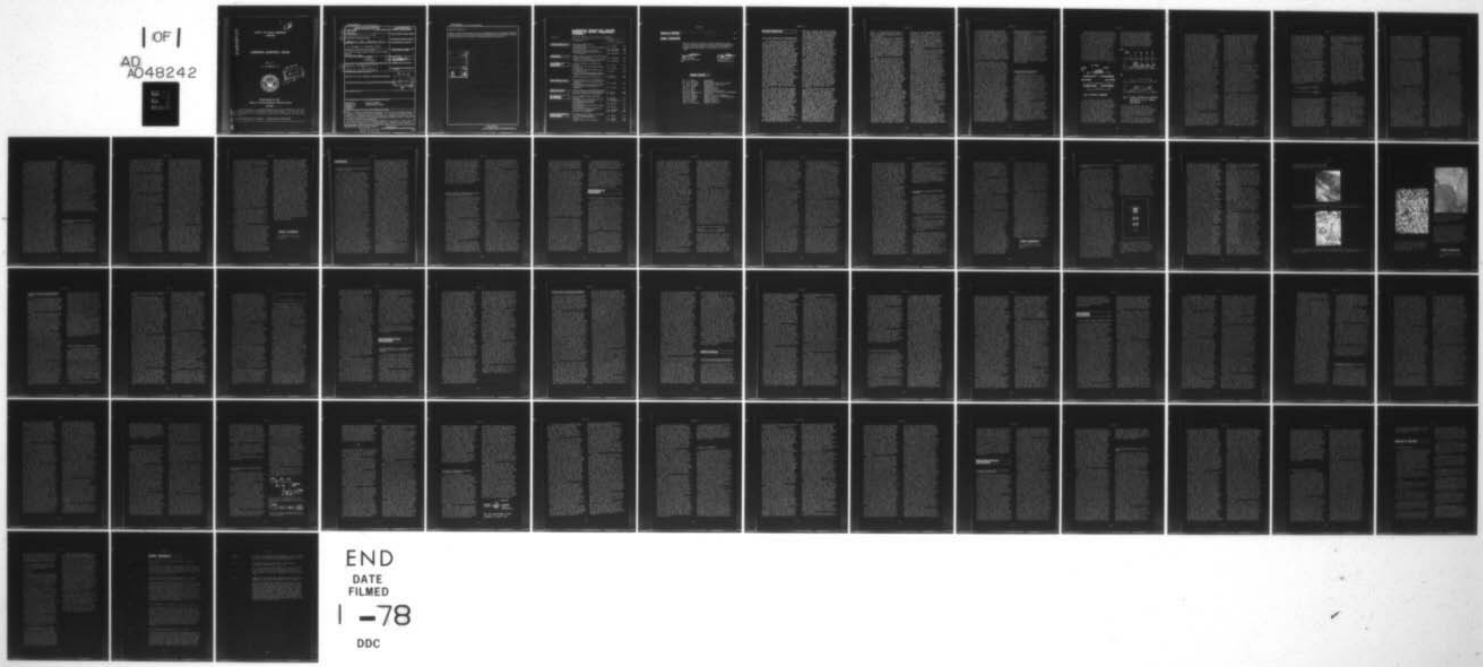

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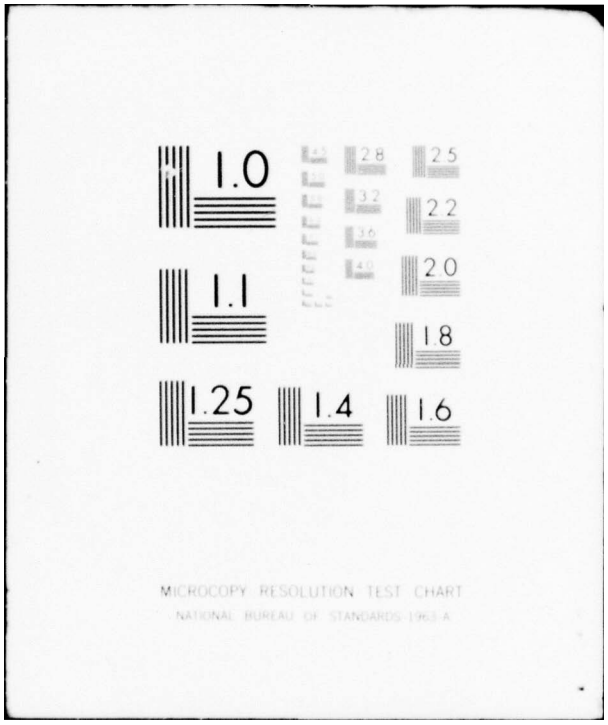
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This is a monthly publication presenting brief articles concerning recent developments in European Scientific Research. It is hoped that these articles (which do not constitute part of the scientific literature) may prove of value to American scientists by disclosing interesting information well in advance of the usual scientific publications.

The articles are written primarily by members of the staff of ONRL, with certain articles prepared by, or in cooperation with, members of the scientific

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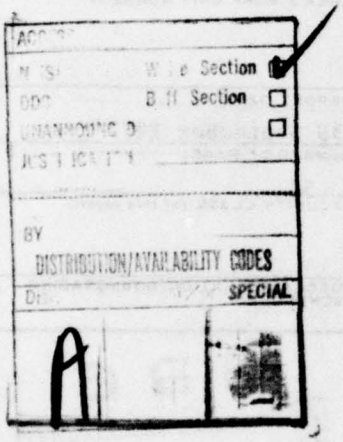

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ELECTRONICS

DEEP-LEVEL IMPURITIES IN SEMICONDUCTORS

The properties of defects and impurities in semiconductors that lead to energy levels isolated deep in the energy-band gap have been of concern for many years. These deep levels, in contrast to the more familiar shallow levels that have made semiconductors so useful, have not yielded very far to theoretical and experimental analyses. Because of these difficulties, the deep-level problem had not been very popular until recent years. As with most areas of physics, the appearance of some successful studies and the wide acceptance of the practical importance of the problem have brought renewed interest and enthusiasm to this area of semiconductor physics. The most recent evidence of this was the convening of an International Conference on Deep-Level Impurities in Semiconductors held in Ystad, Sweden, from 30 May to 3 June 1977. Ystad is a small summer-resort town on the southernmost coast of Sweden. Summer had not arrived; so the conferees, established at a beachside resort hotel on the outskirts of town, were able to spend all of their time involved with the problem. As for the good news, the weather wasn't really too bad; evidently it might have been much worse.

The Conference format was unusual. There were 6 half-day sessions spread over the 4 days. Each session began with a 45-minute presentation followed by 45 minutes for comments, questions, and short contributions (3-5 minutes). After a break, the same procedure was followed for the second half of the session. In practice, this format created an extremely stimulating and interesting atmosphere which carried over to lunch and dinner conversations. I found it a very successful method, and Professor Herman Grimeiss of Lund University is to be congratulated for instituting these arrangements. Also to be congratulated are the very able session chairmen who controlled the emotions and enthusiasm of 80 scientists during the discussion periods.

The opening talk was by J. van Vechten of IBM (Yorktown Heights, N.Y.) on "Thermochemical Properties of Defects." Dealing with simple vacancy and substitutional defects in an otherwise ideal lattice, he calculated chemical heats of formation and employed thermodynamical arguments to predict the stablest configurations that can occur. By applying these concepts to self-interstitials and vacancies in silicon, the prediction is that a precipitation of vacancies explains the so-called "swirl defects" that are common in the growth of silicon. Other researchers have argued that precipitation of interstitials accounts for the swirl defects identified by electron microscopy. The controversy has not been resolved. (See also *ESN* 30-12:555 and ONRL Report C-39-76.)

Another important problem area discussed was that of the dark-line defects that occur in GaAs lasers and GaP light-emitting diodes (LEDs). These are considered to be vacancy loops which grow during operation and lead to serious device degradation. Van Vechten has also used his thermochemical approach to predict the existence of antisite defects in III-V (A-B) compound semiconductors. These occur when the B-type atom appears on the A-type lattice site and vice versa. (See *ESN* article and ONRL Report cited above.) From these antisite defects that form in the cooling of the grown crystal, it is possible to construct vacancy loops that lead to the dark-line defects. For GaP, he predicts concentrations up to $10^{17}/cm^3$.

The second paper was of an experimental nature by D. Lang of Bell Labs (Murray Hill, N.J.), who discussed capacitance and current techniques developed to examine the deep-level defects. (See *ESN* and ONRL Report cited above.) Basically, a capacitor or junction structure is formed in the material, and the resulting changes in capacitance or current are monitored during photoemission or thermal emission processes. Transient and steady-state excitation are applied to give different effects. The variations available permit trade-offs for investigating fast transient effects, for improving the signal-to-noise ratio, for varying sensitivity, or for looking at differences between majority- and minority-carrier effects. Some examples of the kind of information that can be deduced are (1) a measure of the lattice relaxation around a

defect, (2) photoionization cross sections, (3) trapping cross sections, and (4) energies of deep donor and acceptor levels.

Lang described a very interesting experimental result that is found in tellurium-doped GaAlAs; it is a large persistent photoconductivity after cessation of illumination. He explains the results in terms of a model in which photoexcitation of the deep level results in a strong lattice relaxation. The resulting local environment forms traps that are easily excited to produce the persistent photoconductivity. The phenomenon is controlled somewhat by the alloying ratio of aluminum to gallium.

Despite the successes of the new deep-level spectroscopies there is a fundamental limitation due to the lack of a microscopic picture of the defect. For example, of eight levels seen in transient-capacitance spectroscopy of GaAs, only one has been modeled—it is the arsenic vacancy. There are abundant data on the other seven energy levels, but their origins—whether due to interstitial, vacancy, impurity, or whatever—have not been determined.

Other experimental work discussed was that of the group from Lund University under Professor H. Grimeiss. Their main efforts are to measure photoionization cross sections. In order to interpret their results, recourse to a theory by Lucovsky has been made. However, the validity of this theory is very questionable. M. Jaros (on leave at the Univ. of Massachusetts and supported there by ONR) has recently made some progress in this area by using a pseudopotential calculation in a many-band theory. He is just beginning to apply the theory to deep-level problems.

Jaros discussed some of the conclusions that he feels are significant. In any band-theory calculation, it is important to consider many-valence bands and conduction bands in determining the impurity wave functions. As a result of localization of the wave function, Franck-Condon shifts will be large. The wave functions are relatively insensitive to the strength of the potential. The theory has been applied successfully to the oxygen-impurity level in GaP, which is 0.9 eV below the conduction band. Energy levels are in agreement with experiment as are photoionization cross sections. The photoionization cross sections for gold in silicon are also in agreement with experiment. The results for oxygen in GaAs are not good. This may be a result of choosing the wrong model, since other evidence suggests that oxygen does not appear as a substitutional atom but rather is displaced along one of the high-symmetry axes. This demonstrates once again the great need for better identification, i.e., microscopic models of various defects and impurities.

The application of effective-mass theory (EMT) to the deep-level problem was thoroughly discussed and reviewed. Since EMT has been so successful in shallow-level problems, applying it to the deep-level problem was an obvious thing to do. The electron-localization concepts, where dielectric-screening effects are so important, raise serious problems since the net binding potential has to be strong to bind electrons; this requires large q components in the Fourier transform of the potential and immediately violates the effective-mass approximation. S.K. Pantelides (IBM, Yorktown Heights, N.Y.), in his presentation reported that he then turned to the use of pseudopotentials in EMT and was able to develop effective calculations for those impurities that have the same core atomic shells, apart from the valence electrons. He terms these *isochoric* impurities in elemental semiconductors. For compound semiconductors the pseudopotential approach falls apart since there seems to be a lattice-site-dependent screening effect as well as a need for site-dependent Bloch functions. The conclusion follows that EMT is not the approach to use for the general problem. It fails for compound semiconductors, nonisochoric impurities, transition-metal impurities, complexes, and vacancies, and it can't deal with lattice-distortion effects.

Transition-metal impurities in semiconductors present a separate problem. John Allen (Univ. of St. Andrews, Scotland) discussed some of them. Because there is a new dimension to the deep-level problem as a result of the highly correlated electrons, Hartree-Fock theory is not useful, being a one-electron theory. The picture is very unclear, and so Allen was able to discuss only very general and qualitative features of the problem. He made a point about crystal-field theory and transition-metal impurities in some

II-VI and GaP compounds. He showed a smooth monotonic increase in the crystal-field-splitting parameter with increasing d-shell occupancy in some transition metals. He suggested that the impurity atom retains its identity in all the systems studied. These and other empirical observations suggest some possible theoretical models worth trying. In each case they will be calculations in real space and not the k-space formulation from usual band theory. One model starts with a free atom modified by crystal-field splitting (transition model), with the Stark effect and bonding-charge distribution included. Other approaches suggested are the Xα cluster and the LCAO (linear combination of atomic orbitals) methods. All of these make calculations in real space.

Professor G. Watkins of Lehigh University (an ONR contractor) elaborated on the use of the LCAO approach, feeling most strongly that this technique is very well suited for the deep-level problem. It gives energy levels and wave functions, handles lattice distortion, will account for many electron effects, and is a practial calculational scheme. The LCAO technique applied to solids has been denigrated in the past as not giving good band-structure results, particularly conduction bands. Watkins countered this by giving examples and saying that, if done properly, both conduction- and valence-band calculations give good results. Some of his comments relative to cluster-model calculations were seconded by M. Stoneham but with reservations about availability of appropriate input-parameter values and geometries.

The concluding presentation was titled "Unsolved and Bizarre Phenomena Related to Deep Levels," and given by C. Henry of Bell Labs, Murray Hill, N.J. He discussed the multiphonon, nonradiative decay process proposed by Lang and Henry to explain phenomena in GaAs lasers. The effect is correlated with large lattice relaxations and is related to large motion of defects. He then extrapolated his observations on large-lattice relaxations by saying that even many substitutional species (i.e., oxygen in GaAs, sulfur in GaAsP, etc.) must be associated with surprising amounts of lattice relaxation. Other areas discussed were the dark-line defect in GaAs, which has been discussed elsewhere. Further mention was made of the low-temperature, persistent photocurrents in GaAlAs, discussed by Lang.

My personal reactions are summarized by saying that the research area of defect chemistry in semiconductors has a new potential for growth. Theory and experiment have developed a long way and now need to get closer together. There are numerous scientific problems of interest with great relevance to technological developments. The outstanding problem is that of knowing the structure and environment of the defect. One can do all kinds of experiments and make all kinds of model calculations, but, until one knows exactly what the nature of the defect is—i.e., simple, complex, deformed, or whatever—little understanding will result. (Larry R. Cooper, ONR, Arlington)

SOME ELECTRONICS AT CHALMERS UNIVERSITY OF TECHNOLOGY

There are three Departments of Electron Physics among the twelve included in the School of Electrical Engineering at Chalmers University of Technology, Gothenberg, Sweden. "Elektronphysik III," headed by Professor J. Torkel Wallmark, deals with the physics and applications of solid-state electronics, emphasizing the development of novel semiconductor sensors for special uses, the understanding of semiconductor surfaces, and the exploitation of some relatively straightforward electronic means for medical and biochemical studies. A few selected developments in these areas, observed during my recent visit, will be described.

Wallmark himself was the originator of the use of the "lateral" photoeffect in semiconductor photocells to perform "position-sensitive" detection, i.e., detection of the position of a light spot imaged on the cell surface [*Proceedings IRE* 45, 474 (1957)]. Although W. Schottky had discovered the lateral photoeffect almost thirty years earlier, he had confined his attention to its theoretical implications and had not proposed any application for it.

The photoeffect usually dealt with in semiconductor detectors is the "transverse" effect, wherein voltage (or current) is developed across a p-n junction that constitutes the essential part of the detector. A potential difference can be set up parallel to the p-n junction, as well, under certain circumstances, and it is this "lateral" voltage that gives the effect its name. The lateral voltage is due to the diffusion properties of free charge-carriers along the p-n junction. The so-called "surface-recombination" or "barrier-injection" mechanism of this effect is most easily illustrated in Wallmark's original example of a zero-biased germanium photocell, such as that shown in Fig. 1, illuminated by a spot of light focused at the junction.

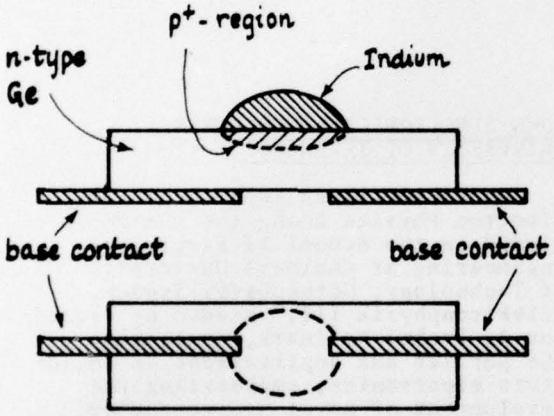


Fig 1. Wallmark photocell.

The figure illustrates a junction between an n-type region and a more heavily doped p^+-type region, the conductivity of the latter being so high that it is effectively an equipotential region. When a light spot is focused on the junction at the point A in Fig. 2(a) below, free electrons and holes are formed and injected into the n and p^+ regions, respectively; this separation of charges gives rise to the normal "transverse" photoeffect. In the highly conducting p^+ region, however, the holes will quickly redistribute themselves uniformly. At points such as B, B', B", therefore, the n-p^+ junction will not be at its "dark" equilibrium potential, and holes will flow back into the n region, where they constitute minority carriers. Thus, as shown in 2(b), a lateral field V_ℓ is set up in the n region, attracting the majority carriers, the electrons, towards the point where the holes have been reinjected, and the two charge carriers recombine.

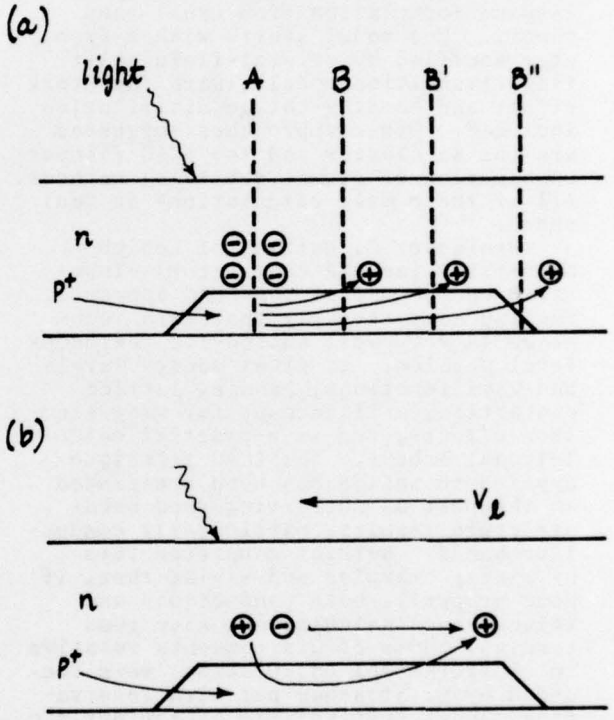


Fig. 2. Charge movement and potential distribution V_ℓ for lateral photoeffect.

Similar considerations hold for an n^+-p junction, but the direction of the lateral field will have the reverse sense. Wallmark showed that corresponding results are obtained from any general kind of junction between materials of different conductivity—n^+-n, p^+-p, etc.

Returning to the cell shown in Fig. 1, we see that position-sensitive detection is accomplished by measuring the net voltage that appears across

the two ohmic-contact base tabs. If a spot of light is imaged exactly at the center of the cell, the lateral voltages set up between the center point and each contact will cancel each other, and the measured voltage will be zero; but if the light spot is moved nearer to one tab than the other, a voltage of the appropriate sign and magnitude will be measured, which is the difference between the two lateral voltages. If the cell is provided with another pair of ohmic-base contacts at right angles to the first set, an appropriate voltage will similarly be developed between the second pair, depending on the displacement of the light spot from the center along this axis. In principle, then, a "dual-axis" Wallmark-type cell, used as the detector in an optical system with appropriate circuitry, can locate the position of a point light-source in the object plane.

Similar lateral photoeffects can be obtained when the photocell is used with a biasing potential, but in this case the surface-recombination mechanism is not necessarily the operative one and other effects can dominate. The photocell parameters—the magnitude of the bulk semiconductor resistance and other added resistances, and the boundary shape—are involved and strongly affect the linearity of the lateral photoeffect in this mode of operation [see analysis by H.J. Woltring, *Transactions IEEE* ED-22, 581 (1975)].

L.E. Lindholm and G. Petersson (Division of Applied Electronics and Research Laboratory of Electronics, Chalmers, respectively) have described extremely linear (within 0.1%), highly sensitive (0.6 A/W), and high-resolution (1 part in 5×10^4) position-sensitive detectors made by careful attention to the resistivity of the silicon used, by use of ion-implantation doping to form the junctions, and by precisely defining the active area by means of appropriate photomasking and etching techniques [*International Electron Devices Meeting Technical Digest*, pp. 408-410 (1976)].

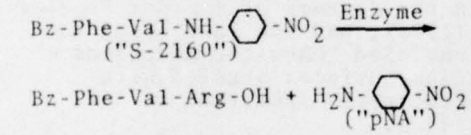
Special cells of this type are used in the SELSPOT ("Selective Spot Recognition") system, a complete optoelectronic movement-monitoring system marketed by the Selective Electronics Company, Box 30, Mölndal, Sweden. In this system light-emitting diodes (LED) are attached to points on the object being investigated—a tensile specimen, a ship, or a person—and a camera focused on a lateral photocell detector allows the positions of the diodes to be followed in real time. By time-division multiplexing, the system can be used to monitor the positions of up to 30 LEDs simultaneously. The company's literature describes a number of interesting applications of the system, and H.J. Woltring (Laboratory of Psychology, Univ. of Nijmegen, Holland) has explored a simplified version of this device, constructed from other commercially available position-sensitive cells, as well as the SELSPOT system itself, and has illustrated the possibilities for human-motion studies by this means [*Biotelemetry* 1, 132-146 (1974); 3, 65-97 (1976)].

Another clever application of semiconductor devices in Elektronphysik III is the development of a hydrogen-sensitive MOS (metal-oxide semiconductor) transistor. M.S. Shivaraman has recently completed a doctoral thesis on this research (Chalmers Technical Report No. 68, December 1976), carried out in collaboration with K.I. Lundström, C.M. Svensson, and others. The thesis is an introduction to and summary of six papers which Shivaraman has co-authored on this subject, the first being the initial description of the device in the *Journal of Applied Physics* 46, 876 (1975), and the last being a paper entitled "Chemical Reactions on Palladium Surfaces Studied with Pd-MOS Structures" submitted to *Surface Sciences*.

The initial paper described an MOS transistor in which the conventional aluminum gate is replaced by palladium. Hydrogen molecules dissociate in contact with the Pd, and the H atoms dissolve in the Pd metal and migrate rapidly to the metal-SiO_2 interface, where they are adsorbed and give rise to a dipole layer. This layer changes the work-function difference between the metal and the semiconductor and hence changes the threshold voltage of the transistor by as much as 0.5 V; this change is a measure of the hydrogen concentration in the ambient atmosphere. The reaction is reversible, the response time is rapid (of the order of a minute or so when the device's temperature is 150°C), and 1 ppm of hydrogen in air is easily detected, with still greater sensitivity when the major component gas is nitrogen

or argon. Gases containing hydrogen as a constituent (NH_3, H_2S, and others) can also be detected, the Pd evidently catalytically decomposing these gases to give hydrogen, with the effect described above. Also, since a small amount of hydrogen is evolved when most ordinary materials burn, the possibility of using the Pd-MOS transistor as a fire alarm was investigated and found to be feasible. As is evident from the title of the second paper cited above, Shivaraman has investigated the fundamental chemistry and physics of the processes involved in addition to exploring potential applications of the device.

The interest of Elektronphysik III in surface effects has led Lundström and Hans Arwin to develop a simple electric method for measuring enzymatic activity [*Rev. Sci. Instr.* 47, 1394 (1976)] in conjunction with the Peptide Research Group at AB KABI in Mölndal. The latter group is interested in detecting serine proteases (thrombin, trypsin, plasmin, etc.), and they have developed a substrate material, "S-2160," (N-benzoyl-L-phenylalanyl-L-valyl-L-arginine-P-nitroanilide), a synthetic polypeptide. The substrate is hydrolyzed by the proteases as indicated in the equation



and the para-nitroaniline (pNA) formed can be detected by its light absorption at 405 μm. Arwin and Lundström use a simple electrical method for measuring activity so low that it is barely detectable by the optical method. They observed that the substrate S-2160 is adsorbed on Pt electrodes inserted into a solution containing the material, the adsorption being detectable as a change of the capacitance between the two electrodes in the solution. If a small amount of enzyme is added to the solution, hydrolysis takes place at once, the coverage of the electrodes by adsorbed molecules decreases, and the capacitance between the electrodes changes again; this change can be used to measure the enzyme concentration over a wide range. The method is not limited to the particular type of material studied but could probably deal with any other reactions involving adsorption or desorption of molecules on electrodes.

Lundström and G.A. Corker, a visiting scientist on sabbatical from the IBM Watson Research Center (Yorktown Heights), have recently completed extensive studies of photovoltaic "sandwich cells" containing microcrystalline chlorophyll α. In Research Report No. 42, Chalmers Research Laboratory of Electronics, June 1977, they compare cells made with chromium and mercury electrodes with those made with gold and mercury electrodes. The results of their study of the ac and dc electrical properties of cells of both types lead to very interesting conclusions, among which are the following: the chlorophyll layer is not a semiconductor but an insulator with a large number of traps; holes are the principal dc charge carriers and are also responsible for the ac response; the current, whether ac or dc, due to the hopping or tunneling of holes. Other papers based on this research work have been submitted to the *Journal of Photochemistry and Photobiology*.
(James H. Schulman)

THE GEC HIRST RESEARCH CENTRE

The Hirst Research Centre in Wembley, Middlesex, UK, is the central research facility of the General Electric Company Limited (unconnected with GE but sometimes using a logotype just like GE's except for the addition of a C). It has been thoroughly described in the September 1972 and 1974 issues of *European Scientific Notes* (*ESN* 26-9:246 and 28-9:322). The present report therefore merely updates some of the previously published information, with particular emphasis on the Telecommunications Division, one of the six now comprising the Centre.

The Microwave Division is responsible for research, development, and pilot production of microwave components and subsystems for communications, radar, and avionics use, while the Electro-Optics Divison is concerned

with displays, optical fiber and associated components, lasers, and lamps. The Microelectronics Division is involved with the use of integrated-circuit and piezoelectric technologies and their applications, particularly in the field of medical diagnostics. Systems work of all types, including large-scale automation, is handled by the Engineering Division, which also provides engineering support for the Centre, while the science and technology of metals and alloys, ceramics, glass, and polymers, together with physical and chemical-analytic techniques, are covered by the Materials Science Division.

The Telecommunications Division, with a total of 60 people working in effect for the manufacturing organization GEC Telecommunications Limited, consists of seven Groups entitled System Theory, Microwave Radio, Digital Switching, High-Speed Digital Coaxial Transmission, Optical Communication, Terminals, and Computer Applications. This last group deals with the computer-aided design (CAD) of printed-circuit-board (PCB) logical circuits and with the computer control of communication networks. Terminals for domestic data service and built-in TV-set adapters for Viewdata and Teletext (*ESN* 31-2:72) are some of the concerns of the second-last group.

The Digital Switching Group is currently working on two-way digital transmission over a single pair of wires by means of time division, i.e., alternating in time between the two directions. Another of their tasks is the development of inexpensive devices for the conversion of signals between analogue and digital forms in exchanges and telephone sets for homes and offices, as a part of the wholly digital network which the British Post Office is developing. This team is also developing an adaptive echo-canceler for local analogue networks that include "loop-extender" amplifiers; echos with short delays result here from imbalance in the "hybrid" circuit that enables the amplifier to serve both directions of transmission simultaneously without (undue) feedback into itself.

The Microwave Radio Group is developing high-speed digital radio equipment to operate at 11 GHz and 19 GHz, and is currently using locally installed test links to assess the effect of propagation phenomena at 75 GHz. They are also involved in research studies to improve the performance of analogue radio systems in lower-frequency bands, at present concentrating on 2-GHz integrated transistor amplifiers and low-noise preamplifiers at 6 GHz.

A 120-Mbit/sec digital coaxial line system, for which the original research work was carried out in the Digital Cable Project, is now going into production for the British Post Office and will be upgraded to the 140-Mbit/sec standard. Meanwhile the group is developing system designs and circuit techniques for coaxial-cable transmission at 560 Mbit/sec, the next higher standard multiplex rate. Their expertise is also available to the Optical Communications Project team, which is incorporating fiber produced by the Electro-Optics Division in an 8.448-Mbit/sec optical-transmission system, that has a potential use in the junction telephone network. A 140-Mbit/sec system is also under development.

The Systems Studies Project, led by F. Michael Clayton, comprises four mathematicians and two physicists, and is concerned with investigations covering a variety of communication systems. Two members of the team, Dr. Peter Collins (with a Cambridge doctorate in high-energy physics) and Peter Fawcett, are at present working towards more efficient use of bandwidth for digital radio systems carrying time-division-multiplexed (TDM) telephone communications and are comparing the performance of partial-response systems with that of systems employing decision feedback. The latter technique involves subtracting the future intersymbol interference that results from the already determined symbols, while the former technique aims at shaping the intersymbol interference (due to using an unusually small bandwidth) so as to have more than two (e.g., three) different possible signal voltages at the decision times, each representing some unique combination of present and preceding symbols. The use of more than two levels reduces their spacing (called the "eye opening") and so increases the susceptibility to noise. Decision feedback is more immune to weak noise, but, as the noise grows stronger and causes incorrect decisions, the effects of these errors can propagate, causing a sharp drop in performance.

Other work in progress under System Studies concerns error-rate monitoring for coaxial transmission, jitter and its accumulation in regenerator chains, performance studies of low- and high-speed optical-fiber transmission, and approximation techniques in queuing theory with application to the computer control of telephone exchanges.

Recent problems involving nonlinear signal processing have included the direct digitalization of a frequency-division-multiplexed (FDM) signal together with pilot tones (which were predictably found to be transmitted satisfactorily despite their being weaker than the quantization-step size), and the characterization of a nonlinearity in terms of its measured response to a pair of tones rather than its output-versus-input voltage curve. Such a characterization is closely related to the nonlinearity's actual performance in producing intermodulation and is thus much more accurate for this purpose. This latter work on nonlinearities was done for the European Space Research Organization (ESRO, now an integral part of the European Space Agency), Nordwijk, the Netherlands, through GEC-Marconi Space & Defence Systems as prime contractor.

An interesting little problem that had been given to the System Studies team was the generation of a sinusoid of some desired frequency by low-pass filtering a voltage that is switched optimally between ±1, the criterion of optimality being the elimination of as many lower-order harmonics is possible for a given number of transitions (between ±1) per cycle so as to minimize the demands placed on the filter. Clayton found that the third harmonic can be eliminated by using 4 instead of the minimum of 2 transitions per cycle, and the fifth and seventh harmonics, too, can be removed by appropriately locating 6 or 8 transitions per cycle, but the fundamental component is then reduced by about 2 dB in amplitude from its maximum value $4/\pi$, which is obtained with 2 transitions per cycle. It is my conjecture that, as the number of transitions per cycle is increased and more harmonics are eliminated, the fundamental amplitude will approach unity, representing a loss of 2.1 dB. The switching between ±1 then becomes very rapid and might be arranged to produce a short-term average value equal to that of a fundamental sinusoid of unit amplitude.

The Hirst Research Centre has served as a training ground for many well known people in the field of communications, such as Professor Colin Cherry of Imperial College, London. R.G. Medhurst had headed the System Theory Group (now called System Studies) for many years before his death in 1971. Among those he helped to train was John H. Roberts, now at Plessey Avionics and Communications, Roke Manor, Romsey, Hampshire, the author of the monograph *Angle Modulation*, just published by the Institution of Electrical Engineers (IEE). Another author, at the Hirst Research Centre since 1968, is Donald Bear, whose book *Principles of Telecommunication Traffic Engineering* was published last year by the IEE. Still another 1976 IEE monograph, *Digital Transmission Systems*, was written by P. Bylanski, who has been at the HRC since 1965, and D.G.W. Ingram, who was there from 1948 to 1974.

It can thus be seen that the Centre continues to be an exciting place for engineers and mathematicians to work, though some of them move elsewhere for advancement, thus enriching other organizations' capabilities and broadening GEC's contacts. (Nelson M. Blachman)

GEC-MARCONI RESEARCH LABORATORIES, GREAT BADDOW

The Marconi Research Laboratories in Great Baddow near Chelmsford, Essex, UK, antedate Marconi's merger with the General Electric Company, English Electric, AEI, and Elliott Brothers Automation. They serve GEC-Marconi Electronics Limited in such diverse areas as broadcasting; marine, terrestrial, and aerospace communication; ground-based, shipborne, and airborne radar; navigation satellites; aircraft control; and weapon guidance. In addition, they undertake research for such bodies as the European Space Agency (ESA) defense ministries, and postal-and-telephone agencies.

My one-day visit to the Laboratories concentrated on their Theoretical Services Support Group (TSSG), which

is headed by Mr. Joseph K. Skwirzynski, the author of *Design Theory and Data for Electrical Filters* (Van Nostrand-Reinholt, 1965). He is also well known for having organized several NATO Advanced Study Institutes, the latest being that on Communication Systems and Random Process Theory, 8-20 August 1977, in Darlington, County Durham, England.

The TSSG, with 30 engineers, mathematicians, and physicists, comprises five sections: Advanced Communications and Control, Antennas, Electromagnetic Theory, Filters and Logic, and Microwave Devices. The first of these, with 3 or 4 people in advanced communications and 6 or 7 in control, is headed by Dr. Gordon A. Richards, whose own work for the European Space Agency's Technical Center, Noordwijk, the Netherlands, on the output signal and noise from a nonlinearity was of particular interest to me.

His approach is to express the nonlinearity as an odd power-series (with complex coefficients to take account of *any* amplitude-dependent phase shift) in terms of its complex-amplitude signal-plus-noise input $u = s + n$; he then expands the product of powers $(s + n)^{k+1}(s^* + n^*)^k$ appearing in the kth term of the power series and averages over the statistics of the noise to obtain the output signal (* denotes the complex conjugate). The remainder of the output represents noise, and Richards obtains its conditional correlation function in terms of the input signal. The Fourier transform of the average value of this correlation function is the output-noise spectrum, and its evaluation has been incorporated into software for the simulation of communication systems.

In addition, Richards is considering approximations for the probability distribution of the complex output noise as the sum of a small number (as few as two) of normal distributions, for use in determining the error rate of a digital communication system after taking account of output filtering. The approximations are based on matching a suitable number of moments of the distribution; the effect of linear filtering upon a sum of normal random variables is then determined by means of characteristic functions with the aid of the fast Fourier transform (FFT). To find the joint distribution of the output noise at several times for use in getting the single-time distribution after filtering, Richards represents the input noise at the several times in terms of independent normal random variables (with different variances) by means of sequential Schmidt orthogonalization. He conjectures that it will be useful to apply the nonlinearity to these independent input-noise values and then to regard the output noise as being produced by passing the resulting independent output values through a filter that will produce the output-noise spectrum determined from the output correlation function.

Other work in Richards' Section includes radar tracking, estimation, and dynamic simulation, e.g., simulation of rocket launching from shipboard or automatic landing for Concorde by the integration of nonlinear differential equations. The MODSIM high-level computer language (utilizing FORTRAN) developed by this Section for simulating communication systems has been sold to the ComSat Corp., to ESRO, and to groups in Sweden, Italy, and elsewhere. It is being used in determining the effects of intermodulation, adjacent-channel interference, noise, and imperfections in filters and modulators upon the error rates in digital communications so that the necessary design specifications for systems and their components can be determined in advance of procurement. MODSIM includes the FFT, which permits going to the frequency domain to take account of the effects of filters and to the time domain for nonlinearities, but a Monte Carlo approach is generally required in order to average over the fluctuations of signals and noise in finding such quantities as the output signal-to-noise ratio (SNR) or the resulting digital error rate.

Barry West has been applying MODSIM to MAROTS, the Marine Orbital Test Satellite, which retransmits quaternary phase-shift-keyed (QPSK) signals after nonlinear amplification involving an amplitude-dependent phase shift. The analysis is simplified by noticing that a high SNR is required in order to keep the error probability below 10^{-6}, and errors are due principally to down-link noise, which is processed linearly. Thus, it is necessary only to determine the system's complex responses to a representative variety of message sequences and to evaluate the probability that down-link noise will move the worst of these to the wrong side of the boundaries of the

decision region (a quadrant of the complex plane for QPSK) associated with the transmitted digit. The predictions of analyses of this sort have been verified experimentally.

The Electromagnetic Theory Section, headed by Mr. E.A. Pacello, deals with scattering and diffraction problems, particularly by means of the geometric (ray-tracing) approach. Some of this work, done by Miss Marjorie Sadler, aims at finding the optimum placement of aircraft antennas for the Royal Aircraft Establishment (RAE) in Farnborough, which verifies the Marconi theoretical predictions by measurements on physical models of the aircraft and its antenna. For long-wave modeling, the Marconi people have developed a wire-grid program, which involves matrix inversion, to represent the conducting surface of the vehicle, and for intermediate wavelengths they are writing software to represent the approach of Dr. S. Cornbleet (Physics Dept., Surrey Univ.). Two people are currently involved in a one-year analytic study of the currents produced in an aircraft by an electromagnetic pulse (EMP), such as might result from a nuclear explosion, in order to find the resonances that are most likely to lead to damage of electronic systems.

The Antenna Section, the largest of Skwirzynski's Group, designs ground-based and satellite-borne antennas. For the MAROTS, which is stationed over the Congo, they have developed a Cassegrainian antenna that will cover the Atlantic and Indian Oceans to provide maritime communications there, eliminating irradiation of Africa by introducing suitable interference in its direction.

The Microwave Device Section carries out the computer-aided design (CAD) of stripline, semiconductor, and ferrite devices as well as microwave filters, antennas, and systems in the frequency range from 0.25 to 100 GHz. Finally, in the Filter and Logic Design Section algorithms are devised for the testing of logic boards, and numerous computer programs have been developed and are in constant use for filter and logic design and analysis. It is thus clear that the TSSG offers vast CAD resources that are found useful not only in Marconi's own work but also in other organizations, both in the UK and abroad.

In addition to the TSSG, the Laboratories include several other divisions, among them the following. The Applied Physics Laboratory develops microwave solid-state devices, low-noise amplifiers, laser applications, ultrasonic devices, and acousto-optic modulators; the Autonomics Laboratory investigates data-processing techniques for such applications as vehicle location, radar-plot processing, vehicle tracking, data transmission and presentation, and automatic testing; and the Materials Applications Laboratory develops extremely high-frequency integrated circuits and devices, surface-acoustic-wave devices, digital memories, displays, and detectors for acoustic, infrared, and visible radiation as well as providing various related services. The Mechanical Engineering Laboratory handles control engineering, electromechanical devices, fiber optics, environmental testing, optical gratings, and data print-out equipment; the Microcircuit Assembly Techniques Laboratory produces thin- and thick-film circuitry as well as printed-circuit-board designs; and the Radar Laboratory pursues new radar techniques (e.g., clutter reduction) for military and air-traffic-control applications, and spread-spectrum approaches involving surface-acoustic-wave filters, coders, and decoders. The foregoing facilities, with occasional help from the Hirst Research Centre (*ESN* 26-9:246, 28-9:322, and 31-9:344) and other GEC laboratories, are providing Marconi Electronics and its customers the research and development needed to keep up with advancing technology and changing problems.
(Nelson M. Blachman)

ONRL REPORTS

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GENERAL

CHALMERS UNIVERSITY AND THE NEW SWEDISH EDUCATIONAL REFORMS

Under the patronage of William Chalmers, Manager of the East India Company, a "school of industry for poor children who can read and write" was founded in Gothenberg, Sweden, in 1829 and named the Chalmers School of Arts and Crafts in honor of its patron. It concentrated on technical instruction, and during the nineteenth century became a technical institute of higher education, achieving the status of a University of Technology in 1937. It is now a state-supported institution with an annual budget of $50 million; an enrollment of about 3,500 undergraduates and 500 graduate students in 6 Schools: Engineering Physics, Mechanical Engineering (including Naval Architecture), Electrical Engineering, Civil Engineering, Chemical Engineering, and Architecture; a faculty of about 300, 80 of whom are professors; and a total complement of about 2,000 employees, including research workers, assistants, technicians and administrative personnel. About 1,000 guest lecturers and consultants come to the University each year as temporary staff members.

The history and technological character of Chalmers are partly responsible for the University's relatively calm reception to the new reforms in higher education instituted in July of this year. These reforms, which are intended to make the educational establishment a better tool for achieving Sweden's social goals, are egalitarian (some would say, antielitist) in spirit and call for participation of the nonacademic community in determining educational policy and program content. These aspects of the reform have aroused concern among many native and foreign observers about the future quality of Swedish higher education (*ESN* 30-5:212).

Another reason why the Chalmers academic community is less apprehensive about the reforms is the skillful leadership of the University's Rector, Sven Olving, who prefers to "accentuate the positive." Olving, a very competent, tactful, and articulate 50-ish physicist, is a Professor of Electron Physics and was a member of the Cornell University faculty during the early 1960s. While there is no question in his mind about the value and importance of basic research, Olving recognizes that Chalmers has always been stimulated by connections with practical applications of science. Moreover, he believes that, in the present age, coupling to practice requires even further educational steps: students intending to go into industrial work must be taught about management, production, and marketing during their university careers rather than relying on on-the-job experience to provide these essentials.

The University's intimate connection with technology and Olving's understanding of the needs of the industrial world thus combine to produce more sympathy for the reforms, including even the provision that permits a candidate for university admission to substitute vocational experience for academic credits. The Chalmers faculty feels that it would be a disservice to these people and to the University if they were to be exposed immediately to the work-level and tempo faced by the usual group of entering students, who are academically better qualified and whose standards the University intends to maintain at the traditionally high level. So special efforts are made to make the former group of entrants feel at home in the university environment, and special introductory courses are employed to cope with their deficiencies in academic background. Olving has had experience with students in this Swedish "upward mobility" category and he recounted his great satisfaction in seeing people from the shop floor returning to their establishments as supervisors or white-collar workers. As for the increased democratization and participatory management required by the reforms, Olving has confidence that politicians and other community figures will exercise their new roles in University affairs responsibly rather than in doctrinaire fashion, and that the vast majority of the Chalmers student body are realistic, hard-working, technically involved individuals, not social activists trying to make their point by pressure on the University.

It is stated (Report of "Seminar on Higher Education and the Community," Malmö School of Education, Jan. 197[illegible]) that the new reforms were not rushed through Parliament precipitately, the ideas behind them having been first propounded many years ago and publicly

debated quite extensively. It appears that the advocates of the reforms were tireless crusaders who overcame the resistance of their academic opponents, many of whom finally became reconciled to the inevitability of the reforms and even came to see some virtue in them. One would ordinarily consider this to be an admirable illustration of community development of public policy, but a substantial proportion of the people I talked with in Sweden view it as a commentary on how persistent repetition can wear down opposition and create the conventional wisdom of the day. (James H. Schulman)

SWEDISH SCIENCE ATTACHES AND THE ROYAL SWEDISH ACADEMY OF ENGINEERING

The Royal Swedish Academy of Engineering (IVA = Ingenjörsvetenskapsakademien), founded in 1919 to promote engineering science and industry, is the youngest scientific academy in Sweden but the oldest organization of its kind in the world. It is a learned society consisting of elected fellows (there are at present about 400 Swedish and more than 60 foreign fellows) and serves as a forum for connecting different scientific fields as well as for promoting interaction among science, technology, government, business, and the humanities.

The Academy is an autonomous organization with semiofficial status; it is chartered by the government, which approves its by-laws, contributes about 45% of the Academy's SKr 15 million (approximately $3.4 million) budget, and appoints the president, the three vice-presidents, and the managing director. The rest of the financing comes in the form of grants from the business community, project-oriented grants and contracts for investigations from a variety of sources, and income from conference fees and sales of publications.

The Academy's work is carried on largely through its eleven divisions, some of which deal with specific technologies (mechanical engineering, electrical engineering, building and construction) and others with broader areas such as industrial management and work environment, research planning, and economics. The Academy also has an Industrial Council consisting of representatives of about 230 private companies interested in R&D, and this Council promotes interaction with the business community.

The IVA participates very energetically in all aspects of the interaction of science with society. Thus, it is heavily engaged in studies and evaluations of the Swedish energy problem and has put forth proposals in this area for more efficient energy use. Environmental problems and the sound economic management of raw materials are other areas of intense IVA activity. The Academy is involved in "futures" studies and in technology assessment through a separate company, the Swedish Institute of Futures Studies, which provides information on these topics to subscribers and will undertake contracts for studies. In the area of the more classical technical disciplines, the IVA monitors research in chemistry and physics with the objective of promoting closer contact between academic circles and private enterprise; it coordinates research in areas of interest to different organizations (e.g., welding, applied mathematics) and ultimately promotes the establishment of commissions or consortia to support these types of research. In the area of the worldwide social responsibility of science, the Academy has helped initiate the International Foundation for Science, which supports researchers in developing countries by means of scholarships and other aid.

Although in some respects the IVA thus resembles our own National Academy of Engineering, it has one aspect that is most unusual—the IVA, rather than the Ministry of Foreign Affairs, manages the operations of the Swedish technical-scientific attachés in foreign countries, the attachés being located in the appropriate Swedish embassies, where they are apparently part of the embassy complement in all other respects. Attachés are placed in the eight foreign countries that together account for over 90% of the world's R&D: US, UK, France, Canada, Federal Republic of Germany, Japan, USSR, and the People's Republic of China. Long-term planning of the attaché program is done by a group with members representing IVA, the Ministry of Industry,

the Swedish Board for Technical Development (one of the major government R&D-funding agencies organizationally under the MOI), and the Ministry for Foreign Affairs, but the program was originated and is now administered by the Academy.

A feature of the program is that each overseas attaché has a corresponding international secretary at IVA headquarters in Stockholm, the pair operating as a team to cover technological developments in their assigned country and report on them back home. Once a year the entire contingent gives a joint presentation at an "Attaché Day" in Stockholm. The attachés and international secretaries visit Swedish companies and other domestic establishments and brief them on the attaché services. Another important provision of the program is that the attachés can carry out work under contract to private businesses or other establishments. Reports prepared in this way for a specific client are always sent directly to him and may even be stamped "classified." Costs of the contract services range from about 100 to 175 SKr/hour depending on the experience of the researcher involved and the services required, which encompass almost anything from coverage of an overseas technical conference or exhibition, to looking into foreign patent information and licensing possibilities, or establishing contact with experts in universities or other institutions abroad.

Information from the foreign attachés is distributed in six publications (in Swedish) for a variety of purposes and readerships. The principal publications are a monthly newsletter (called *Snabbnytt*), which gives short running accounts of current scientific events and new foreign R&D developments, and the *Special Reports* (*Specialrapporter*), which give analyses of trends in specific disciplines or research policy in the country where the attaché is stationed. These publications are available free to Swedish scientists, engineers, and decision makers, although the distribution of the *Special Reports* is selective. The IVA, of course, also puts out a variety of reports on other matters besides the foreign attaché program, i.e., on meetings held under its auspices or investigations it has sponsored.

Supplementing the international contact network afforded by the attachés, the Academy has a few bilateral research agreements with France, the FRG, and Japan, under which information and specialist exchanges are arranged.

Sweden, despite its extensive and competent research establishments, carries out only about 1% of the world's total R&D, and technical liaison with the rest of the globe is therefore considered to be an obvious necessity. The IVA foreign attaché program seems to be a well-organized, vigorous, and flexible mechanism for keeping Sweden in touch with world science and technology. (James H. Schulman)

MATERIALS SCIENCE

ELECTRON TRANSPORT AND MOLECULAR SOLIDS

The juxtaposition of nearly unrelated terms like *electron transport* and *molecular solids* in a conference title may seem odd. It is the result of a pattern established by the Condensed Matter Division of the European Physical Society in designing meetings. In this pattern the Division meets only every third year, and each meeting features topics chosen by two of the six sections into which the Division is subdivided. Thus, no special connection between the fields is implied. The conference organizers made an attempt to bridge the gap between fields and to educate each group of specialists about the other area by having plenary sessions for the twelve invited talks. There were two parallel sessions for most of the remaining time.

This conference, held 26-29 July 1977 at the University of Leeds, was the third in the series of Condensed Matter Division Conferences and marks the end of a cycle, since the last two of the six sections were involved. The first conference in 1971 attracted about 500 participants; the second in 1974 about 400; this third one only about 200. For the conference organizers this was a disappointingly small number. Perhaps travel funds were short this year, or perhaps Leeds did not seem especially attractive as a

host site, or perhaps there were other competing conferences that reduced attendance. Whatever the reasons, it was clear that the Condensed Matter Division Conferences have not as yet acquired a strong and loyal following. At the end of this article there is a brief report on some plans proposed at the Conference for improving this situation in the future.

It was apparent that much of the work in molecular solids had profited greatly from the use of the neutron-scattering facility in Grenoble. This facility is international in character and in financial support. It was designed expressly for neutron-scattering experiments, and its flux is several times that of any similar facility. A typical experiment uses a "cold" neutron source with wavelengths near 1 Å, a neutron guide that is 150 meters long, and a velocity selector. The beam then goes through an entrance slit, is diffracted from the sample, and the diffracted beams are detected. The beam diameter is about 1 cm; typical sample thicknesses are about 0.5 mm. For an isotropic sample, a run may require only 30 min of beam time.

H. Benoit (CNRS, Strasbourg, France) discussed the use of neutron diffraction in polymer physics. Using the parameter $q = 4\pi\lambda^{-1} \sin\theta$, where θ is a diffraction angle, Benoit pointed out that with light q has a maximum of 10^{-3} Å^{-1} and with x-rays a maximum of 10^{-2} Å^{-1}. For neutrons, however, the range of q values extends from 10^{-2} Å^{-1} to 10 Å^{-1}. In polymers this range of values allows scattering from hydrogen and deuterium atoms. Furthermore, by properly choosing q, the scattering from deuterium can be made much larger than from hydrogen. For deuterated chains in an undeuterated matrix a contrast of 400 can be obtained, which can be used to concentrate on particular parts of polymers picked out by deuteration. Such experiments assume that there are no other effects of deuteration, but this may not always be completely true. In general the shape of the scattering centers can be obtained; rods, spheres, and laminae can be distinguished from each other. Also, the overall dimensions of polymer chains in solvents can be determined as functions of concentration.

A study of solid silane (SiH_4) in the temperature range from 64 to 88 K was reported by J. Vanderhaeghen, W. Wegener, and S. Hautecler [Studiecentrum voor Kernenergie, Centre d'étude l'Energie Nucléaire (SCK/CEN), Mol/Antwerp, Belgium]. In this temperature range the silane has a plastic phase that is characterized by a high mobility in the molecular motions. They measured the time-of-flight spectra of neutrons scattered incoherently from this phase and separated the spectra into inelastic, quasielastic, and elastic components. By comparing these results with the predictions of various possible models, they were able to conclude that the molecular motion involved instantaneous 120° jumps around threefold axes with an activation energy of approximately 0.2 kcal/mol.

H. Stiller (Jülich, W. Germany) discussed collective motions in molecular crystals. His group has studied methane (CH_4), which also has a plastic phase where the molecules rotate freely and a lower-temperature phase in which those molecules that form a fcc lattice become orientationally fixed. This transition involves a cooperative multipole interaction between the molecules, which can be studied with neutron scattering as the temperature is varied. Stiller demonstrated a simple effective model of the phenomena that could be set on the overhead projector and viewed on the screen. It was a plastic plate on which were mounted a 5 × 5 matrix of rotators separated slightly from each other. To simulate quadrupole interaction the rotators were made of metal tubes with a permanent magnet at each end and a pivot at the center, as illustrated here in a top view.

By spinning all the rotators rapidly by hand and watching them as they slow down, one can see the collective interaction take over as they finally become ordered with alternating north-south and east-west orientations.

The field of electron transport is an extremely broad one covering, as it did here, metals and alloys at high and low temperatures, crystalline and disordered semiconductors, 1- and 2-dimensional materials, and excitons in molecular solids. There was

considerable interest in metallic alloys at high temperatures. J.E. Enderby (Bristol, England) reviewed the experimental information. If the resistivity of lithium alloys is plotted as a function of the concentration of alloying elements, there are large changes. For bismuth and lead there are sharply spiked maxima occurring at compositional ratios corresponding to Li_3Bi and Li_4Pb. For additions of thallium and magnesium the compositional effects are smaller and only broadly peaked. In a similar way there are sharp peaks for Mg-Bi at the Mg_3Bi_2 composition and for Cs-Au at equal atomic concentrations. A number of tellurium alloys also show the same strong composition dependence; these include alloys with Ag, Cu, Ni, and Ga but not with Au.

Studies have been made of the local structure of some of these molten alloys at their maximum resistivity values. Although there is no long-range order in the liquid, the radial-distribution curves show evidence of short-range order. Because there are two atoms in an AB alloy, the assignment of a particular peak in the radial-distribution curve to a specific atom may be difficult. This task is made easier in the case of neutron scattering by the substitution of isotopes of Li, Ag, Cu, and Ni with differing neutron cross sections. The results for Li-Pb and Ag-Te are that the local structure suggests ionic bonding. The results for Ni-Te seem to indicate some more complex mixed bonding phenomena. The overall conclusion is that metal-metal alloys show ionic bonding at the resistivity peaks; for metal-Te alloys the bonding is ionic when there is a large electronegativity difference but is a mixed bonding otherwise.

A theoretical analysis of these phenomena has been made by A. ten Bosch (Berlin, W. Germany). Using a tight-binding-model approach, she was able to show that metallic elements widely separated in the atomic table will change from metallic to ionic and back to metallic bonding as the concentrations vary. At the critical composition there is short-range order with the A atoms surrounded by B atoms and vice versa. At this point also there will essentially be the transfer of a single electronic charge from one atom to the other. Her calculations give distances of nearest neighbors, free energy, density of states, electrical conductivity, and thermoelectric power that are in reasonable agreement with experiment.

A novel experimental method for obtaining high-temperature data on metals was described by V. Seydel (Kiel, W. Germany). He uses an exploding-wire technique with a risetime to the boiling point of about 1 μsec. The time resolution of the measuring system is better than 8 nsec. With the rapid heating no correction is needed for the effect of surface tension on wire geometry in the molten state. Also the chemical and thermal interactions with the surroundings are neglible, and so the method has some distinct advantages over slower heating in the high-temperature region. Ni, Fe, Co, and Pd showed less than a 2% variation in resistivity from the standard values. Seydel also obtains good values of the heat of fusion. He has recently begun to study the optical emissivity of his samples at high temperatures as an additional parameter.

Two papers on $LiNbO_3$ were of special interest. R. Orlowski (Philips Laboratories, Hamburg, W. Germany) discussed the effect of applying an electric field to the material and illuminating it. If the light is in the near-ultraviolet region, appreciable photoconductivity is produced, and the freed electrons go from the illuminated regions to the dark regions, where space-charge fields build up. When the $LiNbO_3$ is used as a medium to record volume holograms, this space charge modulates the refractive index through the electro-optic effect. Using 350-nm light and oxidized crystals, Orlowski observed high storage efficiency and low conductivity with storage times of at least a year.

With illumination in the visible region, $LiNbO_3$ shows even more unusual phenomena, which were described by E. Krätzig, also of the Philips Laboratories in Hamburg. No external field is applied to the crystal. However, illumination activates a photovoltaic effect that results in open-circuit voltages as high as 100 kV/cm. The maximum photovoltaic effect occurs for illumination at about 400 nm and is strongly dependent on the amount of iron present as an impurity in the crystal; 0.1% of Fe_2O_3 seems to produce the largest effect. Both Fe^{2+} and Fe^{3+} ions are present in the crystal. Krätzig suggests that the visible

absorption is due to Fe^{2+} ions that are photoionized by light. The resulting electron is trapped by Fe^{3+} ions. Finally, it has been determined that the anisotropic charge transport that gives rise to the photovoltaic effect is determined by the excitation process rather than by trapping effects. The suggestion is made that the Fe^{2+}-ion site is asymmetric with respect to the Nb ions around it, and so photoelectron emission is in a particular lattice direction. This photovoltaic effect leads to changes in refractive index that again can be used to store holograms (cf. next *ESN* article).

As mentioned above, the attendance at the meeting was a disappointment, and it gave rise to a considerable amount of discussion concerning the role of the Condensed Matter Division of the European Physical Society and what to do about future meetings. It was also the time for a new head of the Division to take charge. M. Balkanski of the University of Paris had been chosen, and he approached these problems with strongly held views about their solution. He would like to have a yearly meeting of the Division with all six of its sections represented each year. Balkanski hopes for a meeting with 1,000 people in attendance. His model is the March meeting of the American Physical Society, which is the Mecca for American solid-state physicists. In spite of the confusion, a dozen parallel sessions, and the ten-minute talks of the March meeting, its virtues and drawing power remain—everyone will be there, the latest in all relevant fields will appear, and it is the best way to see and be seen. In Europe the situation is more complex. Each country has its own well attended solid-state meeting which serves as meeting place and job shop. It is unlikely that these will be supplanted. Balkanski hopes to have the Condensed Matter Division Conference in conjunction with these national meetings rotating, say, among France, Germany, and the UK. If that turns out not to be possible, he may try to pull a meeting together himself in Paris. His hope is that the European community will come to be aware of its own strengths and make better use of them. It is now common, for instance, for European post-doctoral scientists to spend a year or two in the US. In many cases equal opportunity and training are available elsewhere on the Continent but may not be known to the student or his advisor.

There was no consensus that Balkanski's plan would work. The tightness of travel funds is a difficulty. Some felt that if this new meeting were to succeed as suggested by Balkanski it would be at the expense of the established national meetings. In the years ahead it should be instructive to see how this "Common Market" approach works in solid-state physics. (Clifford C. Klick)

NEW MATERIALS FOR HIGH-SPEED VOLUME HOLOGRAMS

The Thomson-CSF Central Research Laboratory (LCR) is situated in a quiet wooded area on the Corbeville estate near Orsay, a suburb of Paris. Thompson-Brandt and Thomson-CSF form a group of companies that is heavily involved in electronics products. Thomson-CSF expends one-quarter of its sales on R&D and employs several thousand research people for R&D activities. The LCR has 450 research people and about 500 development people.

The mission of LCR is threefold:

(1) To conduct basic and advanced research to pave the way for the long-term future,

(2) To conduct studies according to a prearranged plan and to organize the transfer of results to applied research or development work carried out in other divisions, and

(3) To render special services to the Group.

The purpose of my visit was to see the work of Dr. François Micheron, head of videodisc work. Micheron has a group of six people conducting fundamental material research related to the storage and retrieval of information by optical methods. He has a fairly free hand to determine the direction and amount of effort devoted to various research projects.

Most of my discussion with Micheron's group concerned holographic memories. For several years there has been considerable interest in finding a practical way to store and

retrieve information optically in a three-dimensional storage medium. The reason for this interest is that, in principle, the storage density could be as high as $1/\lambda^3$ or about 10^{12} bits/cm^3 for an average wavelength λ of 0.6 μm. All other storage media, such as discrete memory elements, ferromagnetic cores, and semiconductors, fall short of this mark by several orders of magnitude.

Research in this area is important for continued development of the videodisc system, one of Thomson-CSF's commercial products that uses optical recording and readout of video information on a flexible plastic disc rotating at 1500 rpm. This system now uses direct recording of a carrier frequency modulated by the video signal, but holographic recording may be incorporated in future systems.

Micheron and his assistant, Dr. J.P. Huignard, described their work on sensitive hologram storage in crystals. This work was started in 1973 and now they feel that they have found the ideal material—$Bi_{12}SiO_{20}$ (BSO) or $Bi_{12}GeO_{20}$ (BGO). In these materials, photons are absorbed and generate electrons which diffuse or drift under the influence of an electric field and are eventually trapped.

Projection of an image or hologram onto the materials thus produces a nonuniform charge distribution which produces a space-charge field resulting in a modulation of the refractive index via the electro-optic effect. The production of volume-phase holograms in $LiNbO_3$ was demonstrated by earlier workers. The photosensitivity, however, was about three orders of magnitude below that of photographic plates. The use of $LiNbO_3$ doped with Fe^{2+} or other ions increased the sensitivity, but it still remained at a level of about 200 mJ/cm^2 at a wavelength of 5145 Å. Micheron and his colleagues have found that with their new materials they can achieve a photosensitivity comparable with that of a photographic plate—200 μJ/cm^2 with BSO. The diffusion and drift lengths (for an applied electric field of 10 kV/cm) in these crystals are 0.5 μm and 10 μm, respectively. Since these lengths are comparable with or larger than holographic fringe spacings, good photosensitivity can be reached. If the drift length is smaller than the fringe spacing, space-charge overlap occurs and the sensitivity is reduced. That is the situation with $LiNbO_3$ (cf. pp. 353-4).

In practice an external electric field up to 9 kV/cm is applied during the exposure and then removed. This field causes the diffraction efficiency to increase tremendously over that without the field. No fatigue is observed, and the storage time in darkness is about 30 hours. Hologram recording is performed with an argon laser (wavelength 5145 Å), and good image reconstruction is observed from out-of-focus Fourier holograms. In these experiments, readout is done at the same wavelength as the writing; hence erasure occurs during readout. Nondestructive readout can be performed with longer-wavelength radiation but image distortion then occurs.

Although it had been shown earlier by von der Linde that $K(Ta,Nb)O_3$ (KTN) crystals also can achieve high photosensitivity, BSO and BGO can be made in larger sizes and have better optical quality. Micheron claims that he is now able to reconstruct volume holograms with images surpassing those produced by photographic plates. He feels that real-time interferometry is an important application for these holograms. For example, strain analyses of turbine blades or any other high-speed object could be carried out in real time by using a holographic interferometric technique. In general, however, Micheron believes that he is well ahead of the applications people in his research on volume holograms.

Micheron's group is conducting high-quality research and has been active in several other aspects of optical information storage which are described in a chapter entitled "Optical Systems and Photosensitive Materials for Information Storage," by J.P. Huignard, F. Micheron, and E. Spitz, in a book edited by B.O. Seraphin, *Optical Properties of Solids: New Developments*, published by the North-Holland Publishing Company in 1976. (Vern Smiley)

ONRL REPORTS

See the back of this issue for abstracts of current reports.

PHOTOEMISSION ELECTRON MICROSCOPY—A RENAISSANCE?

Electron microscopes have become so prevalent that liaison scientists usually spend little time viewing them during a tour through a laboratory generally presented to them. This was not the case for me on a visit to the University of Leeds, where Professor J. Nutting, head of the Department of Metallurgy, enthusiastically exhibited his Department's newest electron microscope and photographs taken with its use. The reason for this particular attention is that the Leeds microscope is unique in Britain and there are few like it in the world. It is a photoemission electron microscope.

Photoemission electron microscopy (PEEM) is so new, and the results I observed at Leeds were so impressive that I have looked somewhat closely at PEEM. A short description is presented here; a more complete account will appear as an ONRL Technical Report.

PEEM is not new in concept, having been described in 1933. Technical difficulties delayed the development of a practical instrument until the late 1960s, however.

Emission electron microscopy is based on the emission of electrons from the samples under observation. In the earliest developments, electrons were generated by thermionic emission; this required that the sample be heated to elevated temperatures in order to obtain a sufficient exoelectron current. The present-day photoemission microscope, too, uses thermionic emission at high temperatures but produces electron emission at less elevated temperatures by bathing the sample in a heavy flux of photons. Accordingly, the photoemission microscope's optics closely resemble those of the metallurgical microscope. In the latter, the light reflected from the object is collected and focused for observation by a set of glass lenses. In the emission microscope, electrons emanating from the sample are collected and focused by magnetic lenses. Herein lies a fundamental distinction between the electron emission microscopes and transmission and scanning electron microscopes. In the latter two cases, the electrons that are accelerated through the microscope column originate from a heated filament or a separate emission cathode. Consequently, in the emission microscope, the sample is mounted "at the top" (i.e., at high negative potential); in the other two electron microscopes, the sample is at ground potential. Its external physical appearance, with its array of appendages (e.g., vacuum equipment) identify the emission microscope as a close cousin of other electron microscopes.

Figure 1 shows a schematic view of the photoemission microscope. The specimen holder (1) supports the sample (4) whose surface is to be imaged. Ultraviolet light from four high-pressure mercury-vapor lamps (3) is reflected from the highly polished anode plate (5) onto the sample surface. Emitted electrons are accelerated in a static field along a 5-mm path through 40 kV. The electrons then pass through the anode aperature into a three-stage magnet column and finally onto a fluorescent viewing screen (9).

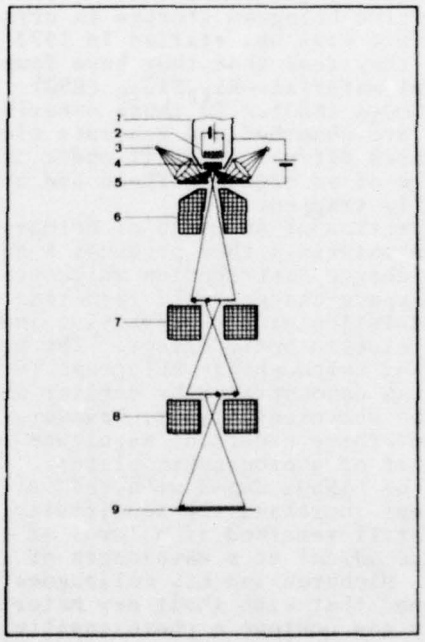

Fig. 1. Schematic diagram of the photoemission electron microscope. 1. Specimen holder. 2. Specimen heating stage. 3. UV lamps. 4. Sample. 5. Pierced anode. 6. Objective lens. 7. Intermediate lens. 8. Projector lens. 9. Fluorescence screen and camera.

A camera is situated below this screen. Magnifications are variable between 10^2 and 10^4; the resolution varies between 150 Å and 300 Å, depending on the specimen material. At temperatures above about 1,000°C, thermionic emission begins, and the uv light sources may be switched off. The combination of photo- and thermionic emission allows a continuous study of materials in the range from room temperature to 2,000°C.

The PEEM located at the University of Leeds was produced by Balzers (Liechtenstein). As of the end of 1975, their "Metioscope KE3" microscopes were located in: Neuchâtel, Zurich, Liechtenstein, Tübingen, Karlsruhe, Aachen, Münster, Grenoble, Leeds, São Paulo, and Moscow. In the Metioscope, a sample is loaded by tilting the holder into a position from which it can be lowered into a vacuum lock. Further rotation allows the surface to be cleaned by bombardment with a stream of argon ions. A motorized cross table allows any location in a 3-mm × 3-mm area on the specimen to be examined. During operation a vacuum of the order of 10^{-7} Torr is maintained by use of a conventional oil-diffusion and rotary pumping system in conjunction with a liquid-nitrogen cold trap. Two types of specimen-heating methods are employed. Radiation is used for slow heating and cooling of 12-mm-diam. cylindrical specimens in the range from room temperature to 1,200°C. An electron beam is used for rapid heating of 1-mm-diam. specimens in the range from room temperature to 2,000°C and also for heating tensile specimens in the range from room temperature to 1,200°C.

The intensity distribution in a photoemission micrograph is determined by three main contrast phenomena: relief (topographical) contrast due to different inclinations of various surface elements with respect to the optic axis, grain contrast due to variations of the materials' work functions as functions of lattice orientation, and material contrast due to variations in work functions between materials. The latter two contrasts are particularly well developed in PEEM since the intensity of emitted electrons depends strongly on photon energy. Thus the choice of particular photon-energy bands, which generally lie in the spectrum of mercury-arc lamps, offers the opportunity of clearly distinguishing different materials or crystallographic orientations. In fact, the situation is complicated by surface contaminants, which frequently provide contrast enhancement.

Relief contrast, in which scanning electron microscopy (SEM) excels, is the most difficult one for PEEM. Such contrast comes from the deflection of electrons by the variation in the electric field near a material's surface. However, distortions in electric fields are common, leading to images that may not be entirely faithful. Apparently relief microscopy is the proper domain of SEM; in material and grain contrast, PEEM should excel.

Photoelectrons originate from depths of about 100 Å in metals to 500 Å in nonmetals. The same is true in SEM when secondary electrons are used for relief-contrast studies. In materials and grain contrast, SEM uses backscattered electrons as well as secondary electrons, and so an appreciably deeper depth is probed (2,000 Å to 2 μm). Consequently, PEEM lends itself very well to sample examinations in which flat polished surfaces are employed. It offers the unique capability of producing images of surfaces with material contrast and submicroscopic resolutions down to a few hundred Å.

The aforementioned advantages of PEEM, together with the ability to produce surface micrographs suitable for automated high-resolution quantitative structure analysis, form the basis for its use in metallurgical and mineralogical investigations. Four examples of micrographs taken with PEEM are shown in Figs. 2-5. Figure 2 shows a micrograph of white cast iron. The cementite phase (dark) is etched, whereas the white needles of martensite in the austenite regions are unetched. The figure shows both true material contrast and orientation (structure) contrast. Figure 3 is a micrograph of a deformed beryllium-bronze without chemical etching. Note the slip lines and the deformation twins. Figure 4 is a micrograph of a cemented carbide with three different carbides embedded in a cobalt matrix. Most of the grains here are too small to be investigated via an electron-beam microprobe, the standard chemical-analysis microscope technique. However, with suitable markings on the sample, microprobe analysis can be made and matched against PEEM to yield submicroscopic chemical

surface analysis. Finally, Fig. 5 shows an oxidized nickel surface. The oxidation was carried out *in situ* at an oxygen pressure of 10^{-4} Torr.

Fig. 2. Micrograph of deformed beryllium-bronze. Slip lines and deformation twins appear on the polished unetched surface. The approximate figure dimensions are 50 μm × 70 μm.

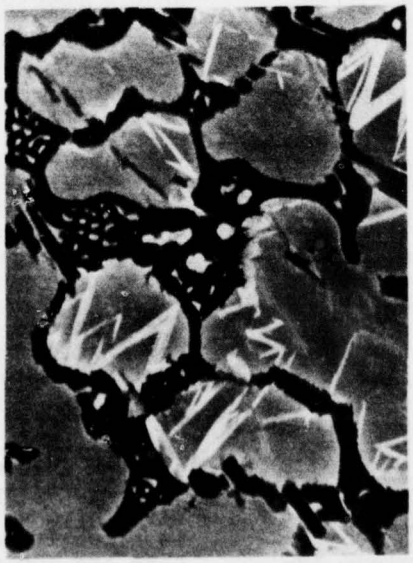

Fig. 3. Micrograph of white cast-iron. Cementite (dark), martensite (white), and austenite (gray) phases are visible. The approximate figure dimensions are 85 μm × 120 μm.

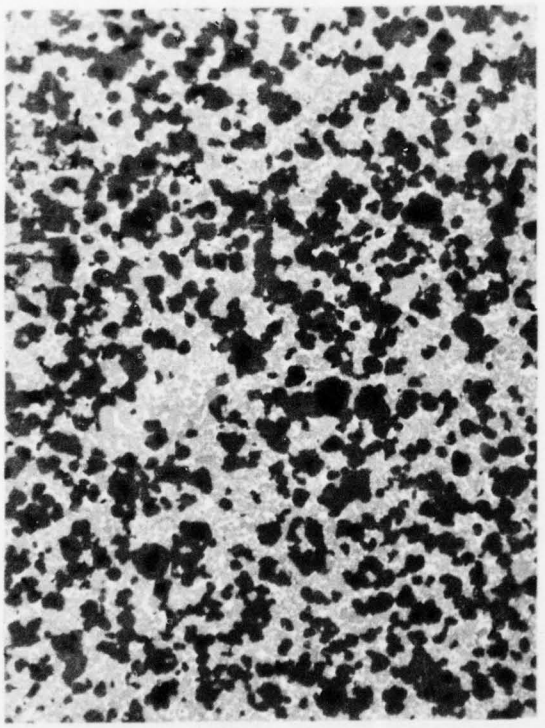

Fig. 4. Micrograph of a cemented carbide structure, with three distinct types of carbide particles embedded in a cobalt matrix. The sample had been mechanically polished. The approximate figure dimensions are 85 μm × 120 μm.

Fig. 5. Micrograph of an oxidized nickel surface. The oxidation was carried out at 900°C. The approximate figure dimensions are 600 μm × 800 μm.

There is, of course, substantially more information that an investigator will require before rushing to his phone to place an order for a PEEM, and some of these may be answered in the more expanded discussion in a forthcoming ONR Technical Report. However, it is clearly appropriate to present one further datum—the cost. Balzers' price for their KE3 is approximately one million Swiss francs (about $400,000). (A. Sosin)

ONRL REPORTS

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ELECTRON MICROSCOPES AND MICROPROBE ANALYZERS IN THE WONDERFUL WORLD OF COLOR

If a picture, presumably black-and-white, is worth a thousand words, what's the value of a colored picture? Color display is the latest contribution to scanning electron microscopes (SEM) and electron-probe microanalyzers (EPMA), coming from Israel, in a joint development effort between Prof. David Brandon (Technion, Haifa) and Elscint Ltd. (Haifa).

Color display has already appeared in video displays in other fields, particularly in medicine (ONRL Report C-13-76). See the cover of *Science* (Vol. 194, 24 Dec. 1976) for a display of signal amplitudes, via color, of a nuclear-magnetic-resonance probe of a tumor, and *ESN* 31-4:142 for a description of color-display development at Cambridge University. The addition of color display for SEMs and EPMAs is, nevertheless, notable in itself and is unique in some ways.

A convenient starting point for describing the Israeli color display is the generation of x-rays by the impact of electrons upon a possibly inhomogeneous target (i.e., sample). The x-ray photons are sorted by dispersive spectrometers to yield a dot-by-dot image in color showing the elemental composition. More precise quantitative elemental analysis calls for focusing the electron beam on specific points and counting the number of emitted photons or sweeping along a fixed line, giving single point counts and summed line counts, respectively. This is an on-line procedure, requiring substantial operator involvement, and it suffers from inaccuracies due to contamination problems and inherent instabilities of the system.

The Israeli element-concentration display and processor (ECDP) continually stores the x-ray data in a 2-dimensional 96 × 96 × 8-bit memory block, addressed according to the position of the electron beam. A statistically significant display of the data can then be generated. The image can be stored either in the ECDP memory or on tape for off-microscope study, releasing the microscope for other uses.

The intensity of the x-rays may be scaled before storage to provide elemental-concentration maps with a dynamic range of 1:256, and these can be transferred to a magnetic-tape cassette with provision for up to 38 maps. Further processing allows display through 8 shades of grey or 8 colors. As equal concentration levels may be coded with the same color, isoconcentration maps may be generated by eliminating the other colors. Maps of two different elements, each one coded with a different color, may be superimposed and the overlapping regions coded with a still different color. If desired, the data may be filtered to provide a smoothed mapping of concentrations. Other features include single-cell readout, two-channel simultaneous analysis and display, etc.

The effects of this enhanced data-processing latitude are most impressive. The black-and-white "foggy patterns" that tempt the imagination but leave much doubt are replaced by easily visualized contours. Comparisons of alternative displays, featuring patterns of different colors to bring out different elemental-composition contours, are extremely helpful. A vast number of microscopic investigations of materials should profit from such color display. (A. Sosin)

LASERS IN CHEMISTRY—A CONFERENCE

A conference on Lasers In Chemistry was held at the Royal Institution in London, 31 May-2 June 1977. The conference was international in character, with 14 countries represented by 253 participants. It was opened with a few welcoming remarks by Professor Sir George Porter, Nobel Laureate and Director of the Royal Institution. The 2½-day conference was divided into 8 sessions: Raman and other scattering, pollution and combustion, diatomic spectroscopy, isotope separation, infrared photochemistry, laser techniques, polyatomic spectroscopy, and short-pulsed techniques. The format of the meeting was somewhat unusual. Several invited speakers gave lengthy presentations while the authors of contributed papers had a maximum of 5 minutes to summarize their findings and answer a few questions.

I was not present for three of the sessions, but have included some

information on them from the conference digest, which contained the complete papers.

Raman and Other Scattering. J.P. Taran (Office National d'Etude et de Recherches Aérospatiales-ONERA) gave an invited paper on coherent anti-Stokes Raman spectroscopy (CARS). This is a technique which has been known for several years, but its application to spectroscopy is relatively new. Taran described the basic principle—that CARS makes use of a nonlinear interaction between two laser beams focused onto the same small volume in a medium. When the difference in frequency between the two lasers is equal to a vibrational Raman resonance in the medium's molecules, a beam of coherent light (CARS radiation) is emitted with a frequency ν_3 such that $2\nu_1 = \nu_2 - \nu_3$, where ν_1 and ν_2 are the two laser frequencies and ν_3 the CARS frequency. As the technique is used in practice, ν_1 is obtained from a fixed-frequency laser and ν_2 from a tunable laser, usually a dye laser. As ν_2 is tuned, ν_3 also varies and the anti-Stokes Raman spectrum is obtained.

CARS emission is coherent and can be collimated whereas spontaneous Raman emission is emitted into 4π steradians in the same manner as Rayleigh scattering. Therefore, nearly all the CARS radiation can be collected, resulting in a relatively high received intensity and discrimination against fluorescent and thermal background radiation. The intensity of CARS radiation is nonlinearly dependent on the molecular number density whereas spontaneous Raman emission is a linear effect. Therefore, the relative sensitivity of the CARS technique is dependent on the density. In one example the CARS signal was six orders of magnitude larger than the spontaneous Raman signal. An interesting possibility exists in generating an entire spectrum as opposed to a single line with one laser pulse by using a broadband dye laser as one of the pumping sources.

Two other nonlinear effects may occur as the result of illumination of a material with intense monochromatic light of a single frequency. Scattered radiation appears at $2\nu_0$ and $2\nu_0 \pm \nu_1$, where ν_0 is the frequency of the incident radiation and ν_1 is the frequency associated with a transition between two energy levels. The effects are termed *hyper-Rayleigh* and *hyper-Raman*, respectively. According to D.A. Long *et al* (Univ. of Bradford, Bradford, West Yorkshire) a Q-switched ruby-laser pulse with a flux of 10^{-13} W/cm^2 typically produces 10^{17} hyper-Rayleigh photons, but only 0.01 to 10 Stokes hyper-Raman photons. Long *et al* applied the technique to a single crystal of NH_4Cl which undergoes an order-disorder phase transition at 242.3 K. He made measurements first at 306 K on a crystal that had been kept at room temperature for 12 months before the experiment. He then cooled the crystal below the transition temperature to 230 K and allowed it to warm up again to 306 K over a period of 9 hours. The hyper-Rayleigh scattering intensity was 100 times larger for the second measurement than it was for the first one. The hyper-Rayleigh scattering was thus shown to be a good indicator of residual order in certain crystals. Further study is necessary to determine whether hyper-Raman emission will be a useful tool.

Three papers were presented on the use of laser-beat spectroscopy to study the surfaces of liquids. Basically the principle consists of beating laser light, scattered from thermally driven fluctuations at the liquid surface, with unscattered laser radiation at the cathode of a nonlinear detector to produce a beat-frequency spectrum. According to G. Bird (Southampton Univ., UK) these microscopic surface waves, called *ripplons*, have frequencies in the range 0-100 kHz and amplitudes less than 5 nm. A study of the autocorrelation function, which is the Fourier transform of the power spectrum, for different scattering angles provides a measurement of viscosity in a very thin layer.

Pollution and Combustion. Five papers were presented, of which four described some form of remote monitoring of pollutants in the atmosphere and the fifth a Raman method for remote measurement of temperature in a gas-air flame.

S. Sutton [Central Electricity Research Laboratories, Central Electricity Generating Board (CERL, CEGB), Leatherhead, UK] described a collaborative program between CERL and Marchwood Engineering Laboratories (MEL CEGB); the team has developed a differential lidar (optical radar) system for remote detection of pollutants. The scheme

uses an idea first proposed by R. Schotland (Univ. of Arizona, Tucson) in 1964 in which two laser pulses at two wavelengths are propagated nearly simultaneously through the atmosphere. One wavelength coincides with an absorption line in a particular pollutant gas, the other with an atmospheric window. A receiver collects the radiation backscattered from aerosols at both wavelengths as a function of time. From the two backscattered signals it is possible to deduce the concentration of the pollutant gas as a function of range. The group is using a frequency-doubled dye laser operating near 3000 Å to measure SO_2 concentration in a power-plant plume. Concentrations of SO_2 at the 0.1-ppm level were measured from a distance of 600 m.

Two other papers were presented on the same method; one was given by C.J. Koh *et al* (Univ. of Hull, UK) and the other by D.J. Brassington (CERL). The former paper describes an infrared system based on a 10.6-μm CO_2 laser. An interesting feature of this work is the use of a heterodyne receiver. Brassington's paper described the performance of a differential lidar system employing a tunable parametric oscillator which covers the wavelength region from 1.4 to 4.2 μm. The sensitivity claimed is 100 ppb of CO at 1-km range with 150-m range resolution.

Isotope Separation. A paper by M. Stuke and F.P. Schäfer (Max-Planck Institut für Biophysikalische Chemie, Göttingen) discussed a method of enrichment of chlorine isotopes by selective photoaddition of ICl to acetylene. They selectively excited $I^{37}Cl$ to an electronic-excited state below the dissociation limit. The excited molecules react strongly with certain scavengers like acetylene to yield $C_2H_2I^{37}Cl$. An enrichment factor of 48 for ^{37}Cl was obtained from a natural mixture of ICl after 10 minutes of irradiation of a 150-mliter volume at a power level of 50 mW.

Infrared Photochemistry. J. Wolfrum (Max-Planck Institut für Strömungsforschung Göttingen) talked about single-photon-selective infrared photochemistry. He and his colleagues used a pulsed HCl laser to selectively excite $H^{35}Cl$ vibrationally. For example, for the first time, measurements were made on the nonreactive and reactive channels

$$^{37}Cl + H^{35}Cl(v=1) \longrightarrow {}^{37}Cl + H^{35}Cl(v=0)$$

and

$$^{37}Cl + H^{35}Cl(v=1) \longrightarrow H^{37}Cl(v=0) + {}^{35}Cl.$$

Isotopic enrichment of $H^{37}Cl$ was produced in the final mixture.

Laser Techniques. Various kinds of lasers and laser techniques were discussed. B.K. Deka and P.E. Dyer (Univ. of Hull, UK) have developed a tunable, high-radiance (10^{12} W/cm^{2}sr) hydrogen-fluoride/deuterium-fluoride (HF or DF) laser suitable for dissociation or other studies in the 2.6- to 3.0-μm region for HF and 3.6- to 4.0-μm region for DF. The lasing medium was formed in low-pressure mixtures of SF_6 and H_2 or D_2. An important feature of the system was a planoconvex unstable resonator.

Initial experiments were performed on absorbing gases in which visible luminescence was produced. As yet the origin of this emission is unknown, but similar results in experiments with intense 10.6-μm radiation are thought to arise from dissociation products produced after high vibrational excitation of the absorbing molecule.

R.G. Harrison *et al* (Heriot-Watt Univ., Edinburgh) claim to have produced an optically pumped NH_3 laser with an efficiency of 15-20%—the highest efficiency reported for an optically pumped laser. A peak power of 1 MW is produced at a wavelength of 12.8 μm. The optical pump is a transverse-excited atmospheric-pressure (TEA) CO_2 laser operating at a wavelength of 9.29 μm. Possible applications include the pumping of spin-flip Raman lasers.

P.K. Schenck (National Bureau of Standards, Washington, DC) reported a new tool—the optogalvanic effect. This effect is an electrical signal produced at the electrodes of a gas-discharge tube or two electrodes in a flame when the gas or flame is irradiated by a laser operating in resonance with an electronic transition of some atomic species present. This technique is free from the problems associated with more conventional optical methods where extraneous scattered excitation light and broadband emission from the discharge or flame contribute noise to the detection scheme. Applications include: identification and determination of concentration of atomic

species, a convenient and inexpensive method for laser wavelength and linewidth calibrations, and a convenient source of signals to lock lasers to various atomic transitions.

Polyatomic Spectroscopy. Most of the papers concerned recent spectroscopic methods employing lasers. These include two-photon absorption spectroscopy, which provides information on symmetry-forbidden transitions in electronically excited states, and level-crossing spectroscopy, which is free of Doppler broadening and can be used to resolve hyperfine structure.

Three papers on the spectroscopy of polyatomic molecules were given in which the optoacoustic effect was used as a tool. This effect has been known for several years and has been used by a few investigators. The sensitivity has been increased, and the method is becoming more popular. In this technique a chopped, narrowband tunable laser beam is passed through a cell containing a gas under investigation and a microphone. When the laser is tuned to an absorption line of some species, a fluctuating pressure change is produced which is detected by the microphone. Identification of species and concentrations are two applications.

D.A. Haner *et al* (School of Chemistry, Univ. of Bristol, UK) used the optoacoustic technique with a tunable dye laser to study forbidden transitions in unstable sulfur compounds. Colles described his work with this technique to make high-resolution measurements of the spectra of nitrosomethane and trifluoronitrosomethane and, additionally, the spectroscopic detection and high-resolution analysis of low photoproduct concentrations of nitrosomethane during the photolysis of nitromethane.

Short-Pulse Techniques. Everyone's concept of a short pulse is different. Things are even more confusing now that fractional-psec pulses are being produced. The session chairman wisely grouped the papers into two categories—the first, "μsec and nsec work" and the second, "psec investigations."

D. Phillips (Univ. of Southampton, UK) described his work and that of his colleagues on the simultaneous use of time and spectrally resolved emission curves. They excited aromatic molecules in the vapor state with 2573-Å radiation from a pulsed, frequency-doubled Ar laser. Time-resolved spectra with time windows varying from 100 psec to 80 μsec in width and, in effect, from 0 to ∞ in delay were obtained. Evidence of two or more emitting states was clearly obtained.

Porter himself gave an invited review paper in which he summarized psec techniques applied to chemical kinetic studies. Porter pointed out that laser-flash photolysis is the only available method for studies involving times shorter than 1 nsec. The source for such studies is usually a mode-locked laser. Because the lifetimes of some states in organic molecules are extremely short, very short pulses must be used. A lower limit exists for usefulness of short pulses for chemical studies at about one femtosecond (10^{-15} sec) where the uncertainty energy is of the same order of magnitude as bond energies (see *ESN* 29-7:294). The record so far in flash-photolysis work is 2.1 psec.

The conference covered the area of lasers in chemistry comprehensively. Several papers were, however, somewhat far afield from chemical applications. (Vern Smiley)

MATHEMATICAL SCIENCES

THE CONTRIBUTION OF J.H. WILKINSON TO NUMERICAL ANALYSIS—A GIANT STEP BACKWARD

In ceremonies at Buckingham Palace on 31 May the Duke of Edinburgh, Prince Philip, presented Dr. J.H. Wilkinson a Diploma of Honorary Fellowship in the Institute for Mathematics and Its Applications (IMA). Three other well-known British applied mathematicians were also present for the occasion honoring Wilkinson—Sir James Lighthill, Sir Hermann Bondi, and Prof. T. Brooke Benjamin.

Wilkinson, who was elected a Fellow of the Royal Society in 1969, is best known for his work on the analysis of error in the solution of large numbers of simultaneous linear algebraic equations. His books on the subject include *Rounding Errors in Algebraic Processes* and the comprehensive volume

entitled *The Algebraic Eigenvalue Problem*. At the Buckingham Palace ceremonies, Sir James outlined Wilkinson's contributions, referring to him as one of the heroes of the great revolution that has taken place during the 25-year reign of Queen Elizabeth II—the computer revolution. Lighthill made the point that the major contribution that the computer has made to engineering, science, and industry is the ability to analyze very large, complex systems quantitatively, taking into account the mutual interactions among hundreds or thousands of different elements of the systems. Before Wilkinson's work, virtually nothing was known about the propagation of the numerical round-off errors that occur at each step in the immensely long chain of arithmetic operations required to solve a system of many hundreds of simultaneous algebraic equations. Hence, at the end of the long calculation, it was virtually impossible to conclude anything about the accuracy of the computed solution. To quote Lighthill, "Jim broke away completely from the previously existing approaches towards calculating how rounding errors might accumulate. He replaced them by one completely new piece of philosophy, and then founded on it a vast library of effective, fast, reliable methods for obtaining solutions with acceptably small errors. The new philosophical idea was backward error analysis. When a computer takes a question and produces finally an answer to it (or, more strictly, an approximate answer), backward error analysis means finding just how small a change in the numbers appearing in the question would have sufficed to make that answer the exact answer!"

Among Wilkinson's other numerous scientific distinctions, in 1970 he received both the John von Neumann Award of the Society for Industrial and Applied Mathematics (SIAM) and the A.M. Turing Award of the Association for Computing Machinery (ACM). He is the only person to have received both these awards. In 1973 he was elected a Distinguished Fellow of the British Computer Society and in 1974 achieved the rare distinction of being elected an Honorary Foreign Member of the American Academy of Arts and Sciences.

At the age of 15, Wilkinson received a "major open scholarship" to Trinity College, Cambridge, where in his first two years he was elected most outstanding student in the entire University. By the age of 19, he had graduated with first-class honors and a distinction in the infamously difficult Part III of the Mathematical Tripos. Since 1946, he has been with the National Physical Laboratory (NPL), Teddington, Middlesex, where he received several posts of distinction, called "Individual Merit" posts. In 1974 he was appointed Chief Scientific Officer of NPL.

The award ceremonies at Buckingham Palace were limited to a very small group of invited guests. Later, on 6 July, the IMA sponsored a one-day symposium at the Royal Society in London entitled "The Contribution of Dr. J.H. Wilkinson to Numerical Analysis." The symposium featured four technical presentations on various facets of error analysis, in addition to commemorative personal reflections by two of his closest colleagues, Prof. Leslie Fox of Oxford and Prof. C.W. Clenshaw of the University of Lancaster. Wilkinson himself spoke on "A Case History of a Problem in Numerical Analysis." The symposium attracted 130 participants from throughout British industry, government, and the universities. In addition, there were about a dozen people from Canada and the US, and a few from Europe.

On a personal level, Jim Wilkinson is regarded by all who know him as warm and witty, and always good company. Amusing stories, many perhaps apocryphal, about Wilkinson are legion. One concerns an occasion on which he and the Archbishop of Canterbury were seated together at High Table in one of the Cambridge colleges. When the Archbishop asked about his field of scholarship, Wilkinson replied that he worked for Her Majesty's Government in the area of error analysis. "I see," said the Archbishop, "I do exactly the same thing for the Church, but we call it sin."

At present, Wilkinson is on leave from NPL and is spending the first semester of this academic year in the Computer Science Department at Stanford University. (William J. Gordon)

GETTING THINGS INTO FOCUS IN NORWAY— ACOUSTIC-WAVE AND WATER-WAVE RESEARCH

The focusing of waves is the common denominator of several fascinating research projects being carried out by a small group of applied mathematicians and experimental physicists at the Central Institute for Industrial Research (CIIR) in Oslo, Norway. These projects range from acoustic and infrared photography to an investigation of the possibility and practicality of focusing water waves.

My host at the CIIR was Dr. Even Mehlum, who shares the supervisory responsibility for these and other projects with the research group's administrative head, Dr. Stefan Ljunggren.

To those familiar with computer-aided ship design, Mehlum is well known as the chief architect of Norway's ship-design system called AUTOKON. The Central Institute's research and development program in computer-aided ship design began in the late 1960s with sponsorship from the Aker group of shipyards. The mathematical theory and practical computer algorithms upon which Autokon is based were developed by Mehlum and his collaborators over a period of several years. In 1974, rights to the marketing and maintenance of the system were transferred to Shipping Research Services (SRS), an Oslo-based consulting organization providing professional services to the shipbuilding, offshore, aerospace, and automotive industries. SRS operates world wide with more than a dozen offices in the US alone, the main one of which is at 205 S. Whiting Street, Alexandria, Va. 22304. Although a group at CIIR continues to develop and refine Autokon in conjunction with SRS, the fundamental mathematical research work is complete and Mehlum himself is no longer involved with the project.

The first of the three wave-focusing projects that I will describe is what the CIIR group refers to as the "acoustic camera." This research is aimed at developing equipment for visual imaging of underwater objects via acoustic illumination and reflection. The basic problem, which is to design a lens that can focus acoustic waves, was addressed as early as the 1930s but failed because the lens was in the shape of a conventional double-convex optical lens. As Mehlum explained, the geometry of such a refractive lens produces inevitable resonances at those places where the lens thickness is an integral multiple of the acoustic wavelength. Many attempts have been made to overcome the resonance problem, and some acoustic lenses are commercially available that are used with a pulsed source.

In contrast to these earlier attempts, the CIIR lens is a flat disk into the surface of which a series of Fresnel-type diffraction zones are photoetched to produce the focusing effect. The calculation of the positioning and depth of etching of the zones is based upon Mehlum's own analysis of the wave equation for sound in a given acoustic medium and a lens of known acoustic properties. Although he would not elaborate on the details of the analysis, he stressed that the major breakthrough enabling the construction of an acoustic lens that will focus at a given image distance all points within a certain target volume was the mathematical formulation and computational solution of a highly nonlinear optimization problem involving integration over both the target and image ranges. At the core of this optimization problem resides the wave equation for acoustic transmission through the lens material and the surrounding media. The classical methods of Fourier and Fraunhofer are based upon far-field approximations that are valid only for a very small viewing angle and result in lenses with f numbers of about 200. The CIIR lenses, whose fringe patterns are computed by asymptotic expansion of near-field approximations, have f numbers close to 1.

The CIIR group has carried out preliminary tests on a prototype acoustic lens designed according to Mehlum's specifications and appears to have obtained excellent results. A lens was demonstrated about 1 m in diameter and 50 mm thick. It focused sound from a source about 4 mm in diameter at a distance of 2 m to a remarkably clear image at an equivalent distance from the lens, the image being explored by a small probe hydrophone and displayed on a paper recorder. The lens has an energy-transmission efficiency of 85%, with only 15% of the incident energy lost by absorption or reflection. Experiments are now underway to investigate lens aberrations.

Application of the underlying mathematical theory developed by Mehlum is not restricted to the design of acoustic lenses for use in "acoustic photography." Indeed, it has already

been applied to the experimental design of lenses for electromagnetic waves in the infrared spectrum. The types of infrared lenses now commercially available are very expensive and are limited to about a 200 mm diameter. For about $1,000, CIIR constructed an experimental infrared lens that more than rivaled the focusing ability of a $20,000 germanium lens. It seems possible to construct infrared lenses of the CIIR type with apertures of up to 2 m without significant energy absorption. Moreover, since the lenses are basically flat disks with interference zones etched on the faces, it seems possible to mass-produce such lenses cheaply by means of pressing machines such as those used to produce phonograph records. Although all refractive lenses suffer from chromatic aberration, this can be largely compensated for by the use of filters. Of course, such problems do not occur if the energy source is monochromatic. An unspecified Norwegian company is about to take over this infrared project from the CIIR in order to develop the concept further and it is hoped, to begin to market such lenses.

Mehlum is enthusiastic about the further development and refinement of refractive lenses and cameras. He and his coworkers envision applications to a host of situations in which one would like to "see" through nontransparent media. For instance, one industrial group in Norway is already engaged in the further development of the CIIR work for the purpose of viewing chemical reactions taking place within ovens. Medical and other applications concerned with nondestructive testing and noninvasive observation also come quickly to mind.

Having had such success with the focusing of acoustic and electromagnetic waves, why not try to focus water waves? Why not, indeed! With funding from the Royal Norwegian Council for Scientific and Industrial Research, this is precisely what Mehlum and a group of experimentalists at Trondheim are attempting to do. Mehlum claims that the problem of designing a "water lens" is mathematically of the same sort as for the acoustic lens but is more complicated because of the wide frequency and angular spectra, the dispersivity of water waves, etc. In spite of the complications, he has managed to demonstrate in theory that water waves can, in fact, be focused. In an energy-conscious world, the ability to concentrate (and extract?) wave energy is an exciting prospect.

It was only this year that the experimental program in a ship-model tank at Trondheim began and, although it's too soon for definite conclusions, the early indications are very encouraging. For more than two years before this, Mehlum and his associates had been working on the theory and computer simulation of the water lens. In brief, the lens consists of a string of buoyant obstacles that are anchored to the bottom and float slightly beneath the surface of the water. The purpose of these obstacles is to retard and increase the amplitude of a wave as it passes over top. The theory is that a collection of such anchored, underwater buoys, if strategically placed off a coastline, will produce sufficient relative retardation along the length of the wavefront as to cause the wavefront to distort and thereby focus.

The much-publicized "Salter ducks" extract wave energy by bobbing up and down as the wave passes by. In other words, they capture energy from a very distributed source. The Norwegian idea is to concentrate the wave energy first and then to attempt to extract it.

If Mehlum's theory actually works out in practice, the water lens will create quite a splash.
(William J. Gordon)

MECHANICS

PHYSICAL CHEMISTRY AND HYDRODYNAMICS—THE LEVICH 60TH-BIRTHDAY CONFERENCE

A Conference entitled "Physical Chemistry and Hydrodynamics," on the occasion of the 60th Birthday of Veniamin G. Levich, who first identified this important interdisciplinary field, was held on 11-13 July at Somerville College of Oxford University. The Conference sponsors included 18 Nobel laureates in addition to other dignitaries in science and technology. Levich was prevented from being present at this testimonial occasion by the government of the Soviet Union, which refused to grant his request for a visa

to attend the Conference. Nevertheless, his review paper "Physicochemical Hydrodynamics" was read to the international audience by Professor G.K. Batchelor (Dept. of Applied Maths. and Theor. Physics, Univ. of Cambridge).

Veniamin Levich, a student of Lev Landau, is one of the most distinguished of Soviet scientists and a member of the Soviet Academy of Sciences. He, however, incurred the displeasure of the government when in 1972 he asked for an exit visa in order to emigrate to Israel; almost immediately his university chair evaporated, thus leaving him without a post. Cut off from his laboratory, former colleagues, and students, he is now trying to write a new book on physicochemical hydrodynamics and is waiting for the day when he will be allowed to leave.

In order for the reactants in a chemical process to come into intimate contact with each other on the atomic or molecular level, it is generally necessary for at least one of them to be in a fluid state. For the continuation of the reaction not to be blocked by the reaction products, some fluid-flow field must be present. It is clear, therefore, that the reaction and the flow field interact with each other; the study of this interaction was identified as the discipline of physicochemical hydrodynamics by Levich in the early 1950s.

The various classes of physicochemical hydrodynamic problems involve solid, liquid, and gas phases with interfaces between all possible combinations of phases. An interesting device invented by Levich is the rotating-disk electrode; in this device, a disk electrode rotates in its plane about its symmetry axis while immersed in a liquid electrolyte. The laminar boundary layer formed in the flow field is of constant thickness; thus diffusion processes are similar all over the surface of the disk. (The same situation prevails at a rotationally symmetric stagnation point, as was pointed out by Batchelor.) When the flow is turbulent, transport is enhanced and turbulent diffusion scale lengths are therefore much greater than corresponding laminar ones. Thus, the physicochemical hydrodynamicist must concern himself with reactions taking place at the surfaces of bubbles, droplets, thin films, and at the interface of two fluid streams. A dramatic example of an application of this discipline is the ablating, reacting nose-shield of a reentering space capsule.

The meeting, comprising some 60 papers, was run in two parallel sessions and was organized about six topics, namely, physical transport, interface mechanics, interspersed phases, chemical hydrodynamics, electrochemistry, and physics. A considerable percentage of the papers were concerned with turbulent mixing and diffusion. Some papers treated thermal convection and others studied reacting particles and droplets in flames. Experiments using laser anemometry were described; the particle and droplet sizes and their velocities could be evaluated, and changes in these quantities could allow reaction rates to be inferred. The effect of capillarity in inducing fluid motion was described. An interesting example of a useful effect of capillarity is in the centrifugal casting of soft contact lenses, where the optical surfaces are formed by the interaction of surface tension and the acceleration field while the lens material cures. Turbulent entrainment of particles, diffusion of particles in turbulent flow fields, and diffusion of particles in convective flow fields were the subjects of various papers.

A considerable part of the meeting was devoted to the rotating-disk electrode, including the basic theory and applications to the study of reaction kinetics, convective diffusion, chemical vapor deposition, and corrosion processes.

A number of papers were concerned with rheological fluids (fluids with mixed liquid and solid properties), and a very informative lecture was presented on the hydrodynamics of liquid crystals. A liquid crystal is an ordered fluid phase in which the elongated molecules constituting the crystal are locally aligned in a preferred direction. In the nematic phase, there is no ordering of the centroids of the molecule, whereas in the smectic phase the centroids lie in parallel regularly spaced planes normal to the direction of orientation of the molecules. The preferred orientation of molecules, which can be aligned by a magnetic field, results in an anisotropic viscosity. The deviation of the viscosity in the smectic phase from the isotropic viscosity of the unordered state is greater than that of the nematic phase.

The viscoelastic behavior and the general behavior of the nematic phase in simple shearing and alternating flows were described, as well as various hydrodynamic instabilities and the onset of turbulence in this very interesting medium, the study of which is called nematohydrodynamics.

A paper on the physics of ice-lens formation and ice heaving described the accumulation of ice by diffusion of moisture through a porous medium to an ice nucleus. The drive causing the diffusion is, the difference in chemical potential between the liquid and solid phases. And so, when spring arrives, it is observed that the former billiard-table smoothness (?) of last summer's lawn is now replaced with lumps and bumps caused by ice-lens formation (if one is lucky) or moles (if one is not so fortunate). Rolling easily takes care of the former.

In all, the meeting was a successful and kaleidoscopic presentation of a broad and varied subject. The Conference organizer, Prof. D.B. Spalding (*Dept. of Mechanical Engineering*, Imperial College, London) deserves special commendation for his tireless efforts in insuring the Conference's success. (Martin Lessen)

THE BERLIN SYMPOSIUM ON TURBULENCE

The latest in a series of meetings dealing with turbulence, transition, and/or drag reduction was held in Berlin, 1-5 August at the Hermann-Föttinger Institut für Thermo- und Fluiddynamik of the Technical University of Berlin. The Symposium on Turbulence was sponsored by the Technical University, the Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt, the Deutsche Forschungsgemeinschaft, and the Deutscher Akademischer Austauschdienst. The conference chairman was Prof. H. Fiedler (Technical Univ. of Berlin) with Prof. L.S.G. Kovasznay (Johns Hopkins Univ. and recently of ONR-Tokyo) as scientific advisor.

The program of the meeting was divided into sessions in the areas of structure, stability, theoretical analysis and modeling, transport, noise, a general catch-all, and a final discussion period.

The papers concerning the structure of turbulence were reports of experimental observations of unbounded jet and shearing-layer (two-stream interface) flows as well as boundary-layer flows over walls. In the unbounded flows, investigations of the effect of initial conditions, such as the initial thickness of the shearing layer or a disturbance at the trailing edge of the structure separating the two streams, indicated a marked influence on the near-field properties of the mixing layer. However, it seemed that the far field (downstream) returned asymptotically to the classical similarity solution, which is independent of the initial conditions. Organized structures consisting of a moving row of vortices with their axes perpendicular to the flow direction were found in turbulent jets and shearing layers, and a discussion of the "pairing" or "coalescing" of these vortices as they proceed downstream followed. It is unfortunate that the coalescing of these vortices to form larger ones with larger spacing as they move downstream, was first called pairing; an examination of many incidents of coalescing indicates that the vortices may combine even in a noninteger manner. Thus, 1.7 old vortices may combine to form one new one, and the remaining 0.3 may combine with 2.4 others. Also, when coalescense occurs, the trace lines demarcating the vortices show practically no activity, and so it seems that only the dead or dying remains of the previous generation of vortices combine to form the next generation. Indeed, a mechanism for the evolution of the large-scale structure in terms of a marginal instability of the mean flow field was advanced.

The papers and discussion of wall-bounded shear-flow turbulence structure dealt with an even more difficult problem than the unbounded-shear-flow case. The reason is that the unbounded shear flows are everywhere "bursting," while the bounded shear flows consist of bursts embedded in nonbursting regions. A "burst" can be considered to be a high-frequency, large-amplitude self-excited disturbance associated with an inflection point in the velocity profile. An unbounded shearing flow has an inflected velocity profile throughout the flow field while a boundary-layer flow may not have such a profile at all. If, however, the

boundary layer is unstable in the sense that a self-excited traveling-wave-like disturbance grows within it, the combination of the wave and the average flow may produce local regions spaced one disturbance wavelength apart where the velocity profile has an inflection point and is susceptible to bursting. What has been described is a two-dimensional phenomenon; the actual bursting, however, is three-dimensional. And so, many experiments have been performed in order to observe the occurrence and appearance of turbulent bursts. The now popular technique of "conditional sampling" uses the signature from a burst to trigger detailed data acquisition from a battery of probes. Smoke and other flow visualization schemes are used to try to picture the bursts. In a paper reported at the Meeting, a turbulent spot induced by a spark was studied as it developed within a turbulent boundary layer; the relation between such a spot and a naturally occurring burst, however, was not clear.

An interesting paper by G.L. Brown (Univ. of Adelaide, Australia) presented theory and supporting experimental observations of a secondary Görtler (H. Görtler, Freiburg i.B., Germany) instability in unstable boundary-layer flow. The Görtler instability is associated with a curved flow having such a velocity distribution that the flow elements at two different radii tend to interchange. A traveling-wave disturbance so distorts an otherwise parallel boundary-layer flow that a Görtler (interchange) instability develops at points in the boundary layer spaced a wavelength apart. The vortices developing from the instability have their axes aligned with the flow. Though such vortices may modify a burst, their net effect on the average flow properties may not be great. A paper by P.O.A.L. Davies (Southampton Univ., UK) demonstrated ring-vortex formation in the near field of a jet and then showed an azimuthally periodic structure in the ring vortex; such a structure may indeed be related to the Görtler secondary instability.

A number of papers dealt with various schemes for calculating turbulent flows. A common feature of these "closure" models is that parameters in the resulting equations are fitted to data from a "canonical" experiment related to the class of flows being modeled, and then it is found that the tuned "closure" model adequately "predicts" the flow characteristics of the class. Of course, the equations and constants so obtained will not work for an unrelated class of flows; it is therefore clear that little more fundamental than curve fitting is involved in the whole procedure. A paper by A. Barcilon (ONR, London), T.E. Butler (Univ. of Rochester, NY), and me, however, involved the theory of hydrodynamic stability in predicting the characteristics of a turbulent shearing layer in the atmosphere without recourse to fitting any parameters to data.

In the area of transport, the turbulent transport of heat in jets, wakes, and shearing layers was reported. The transports of momentum and heat proceed differently in a turbulent flow; momentum can be transported by turbulent fluctuations through the mechanism of a Reynolds stress (similar to a stress tensor in a gas with random particle motion) whereas turbulent heat transport occurs only when there is wave breaking. Since the wave-breaking zone in a turbulent flow is narrower than the region where turbulent fluctuations occur, the thermal-change width of a turbulent shearing layer is narrower than the momentum-change width.

It was noted that, whereas the researchers in the structure of turbulence were, by and large, very hesitant to relate their observations to hydrodynamic stability theory, some of the investigators of noise from turbulent jets were not at all inhibited in this regard and furthermore pointed out the relationship. Sound radiation from a jet is most pronounced when the phase velocity of the instability wave of the jet is supersonic relative to the flow outside the jet; the disturbance waves then have conical wavefronts and radiate their energy out to infinity (Čerenkov radiation).

The meeting was largely comprised of a reworking of various aspects of shearing layers (interest in which dates back at least to Kelvin and Helmholtz), the gathering of additional data by conditional sampling, the tail end of the present phase of jet-noise reasearch, and a further massaging of "closure" (data-fitting) schemes. Despite the fact that there existed a paucity of new ideas, a number of authors presented more than one paper; in fact, one author presented four!

Some of the session chairmen did not help matters by allowing authors to overrun allotted times. The scarcity of new ideas suggests that the field could benefit from fewer meetings and better planning of research. (Martin Lessen)

PHYSICAL SCIENCES

THE 1977 DUMAND SUMMER WORKSHOP, MOSCOW

The 1977 Deep Underwater Muon and Neutrino Detection (DUMAND) Summer Workshop was held under the sponsorship and at the invitation of the Soviet Academy of Sciences. Directly following the Neutrino-77 conference at Elbrus, which ended 25 June, it started on a Sunday to avoid delaying the participants who attended both meetings.

The DUMAND project is not yet an officially established one; it has not as yet the blessing of a funding agency, nor does it as yet boast an annual budget. It is a collaboration of high-energy, cosmic-ray, and theoretical physicists, astrophysicists, astronomers, acousticians, computer scientists, geophysicists, oceanographers, ocean engineers, and other assorted enthusiasts—all captivated by a simple but audacious objective: to use the ocean as a gigantic neutrino detector. The aims are to observe and study cosmic-ray neutrinos (and muons) at energies far above those available from any present or foreseeable accelerator—those neutrinos (and muons) that arise from the interactions of the primary cosmic-ray protons (and heavier nuclei) in the earth's atmosphere, as well as those that impinge upon us directly from extraterrestrial sources. The latter have hitherto not been observed. The detection of the low-energy neutrino bursts that accompany gravitational stellar collapse is also one of its aims, but that has been temporarily shelved until someone devises a less expensive detection procedure for neutrinos in the 20-MeV region than any now known to us.

Such studies would extend our knowledge of the "weak interaction," the sole mechanism of interaction between neutrinos and the rest of the universe, and they would vastly extend the infant science of neutrino astronomy. One might hope to detect neutrino fluxes from the galactic center, from point sources like expanding supernova shells, and perhaps from remote galaxies whose neutrinos date from an early epoch in which the sources may have been much brighter.

Why the ocean? Because detectors of enormous mass are needed to detect the feeble current of neutrinos, which interact with matter so weakly that on the average they may, if their energies are in the right range, readily penetrate the earth, or even a star, without undergoing a single interaction. The ocean alone offers the requisite mass. Two modes of detection appear possible. The more certain, but probably the more expensive, is optical detection: photomultipliers pick up the Čerenkov light that is generated in transparent media by highly relativistic particles—in this case the secondaries produced by the neutrino interaction. This is a standard laboratory method and is well developed and well understood.

Less certain, but possibly less expensive, is the acoustic method, in which the sound produced by the neutrino interaction is picked up by an array of sensitive hydrophones. The sound originates from the pressure pulse generated when the energy of the neutrino, divided among many secondaries, is converted into heat as the particles are brought to rest. This method, first suggested by G. Askarian (Lebedev Institute, Moscow) in the fifties, has been shown to work in the laboratory, but further studies are still necessary to ascertain how well it will work in the ocean at the energies of interest. Its principal advantage is that sound is attenuated in the ocean far less rapidly than light; thus the detectors may be farther apart and fewer in number. Early work on these problems is summarized in the *Proceedings of the DUMAND 1976 Summer Workshop*, published by DUMAND, Fermilab, Batavia, Illinois 60510.

Atmospherically generated neutrinos are accompanied by highly penetrating charged muons, whose intensity at sea-level is relatively high. To avoid the interference such particles would produce, it is necessary to go to a considerable depth in the ocean; about

5 to 6 km is desirable. Thus the problem for DUMAND engineers is to design an experimental apparatus in which thousands of sensors, distributed through a volume of perhaps 1 to 100 km^3 of ocean, can be accurately located with respect to each other and will operate continuously, reliably, and smoothly for many years, returning their data to shore by submarine cable as they are accumulated.

The Moscow venue of the conference emphasized the serious and sustained interest of the Soviet scientists, which has been manifest from the beginning of the project about four years ago. In the year following the 1976 DUMAND workshop in Honolulu, experimental and organizational progress has been far more rapid, and the 1977 Conference provided an opportunity for meeting to discuss progress and formulate plans. The DUMAND meeting was held at the Lebedev Institute in Moscow; the arrangements were supervised by Prof. G.T. Zatsepin, and the organization of the conference was in the capable hands of Dr. V.S. Berezinsky (both of the Lebedev Institute).

Two previous workshops, in 1975 and 1976, had been concerned with establishing the conceptual feasibility of both the physical measurements and the ocean engineering. With last year's suggestion of acoustic detection, the economics of the project began to look far more favorable, and the notion of detectors of 10^9 tons (1 km^3) or even more, began to appear realistic, and even conservative. This year's Workshop was concerned with establishing more clearly the possible extraterrestrial sources of ultra-high-energy (UHE) neutrinos and their probable intensities, and in reviewing the progress to date on acoustic detection, both in the USSR and in the US. Total attendance was approximately 25-30, of whom eight were US physicists. Soviet participants included A.I. Alikhanian, B. Pontecorvo, A.E. Chudakov, V.S. Berezinsky, G.T. Zatsepin, Rosenthal, L.M. Ozernoi, B.L. Ioffe, G. Askarian, B. Dolgoshein, A.I. Petrukhin, and V.D. Volovik, the latter reporting on his pioneering work on the acoustic detection of particle beams.

The agenda of the three-day meeting, which was conducted on an informal basis (and mostly in English), was varied to suit the interests and needs of the participants and to follow the directions in which the frequently animated discussions led. On the first day Prof. F. Reines (Univ. of California, Irvine) described the history of the DUMAND project and its present status; Zatsepin (Lebedev Institute and Univ. of Moscow) reviewed the cosmic-ray properties that determine the conditions for the proposed detection schemes and discussed what might be learned; and Prof. D.N. Schramm (Univ. of Chicago) discussed the astrophysical aspects, particularly with regard to estimating the anticipated high-energy extraterrestrial neutrino flux.

The uncertainties in these estimates amount to several orders of magnitude, and so predictions range from highly pessimistic (no observable signal) to highly optimistic (many high-energy events).

On the second morning I opened the program with a description of the design of a four-stage prototype 10^9-ton combined optical and acoustic detector. This description elicited the objection that the acoustic threshold of detection (which the Soviet scientists place at about 10^{15} eV, at least ten times the value favored in the US) would be too high for the acoustic detectors to be useful on so small a detector; the event rates would be too low. This was followed by discussions by Ozernoi and by Berezinsky on the probable sources and intensities of extraterrestrial neutrinos. Berezinsky concluded that with a detector of 3×10^{11} tons (300 km^3) even a pessimistic estimate of the intensity of neutrinos of 10^{15} eV and above leads to an observed event rate of 10/yr or more.

Prof. L. Sulak (Harvard) discussed the expected signature of high-energy neutrino interactions and the instrumentation required to extract the maximum information from them. Strong objections were raised to the analysis; there was skepticism concerning the optimistic conclusion reached, that a kinematic analysis comparable with that of accelerator experiments is possible. The point was (and is) not resolved.

Berezinsky then discussed experiments to look for resonant production of W bosons (intermediate vector bosons postulated as the carrier of the weak interaction). The reaction would be $\bar{\nu}_e + e^- \rightarrow W^- \rightarrow$ anything. The expected mass of the W is about 70 GeV in the Weinberg form of gauge theory, but it might be much heavier. Ioffe commented that the experiment might possibly

determine the mass; he also thought it important (as suggested also by D. Cline) to look for the Higgs boson, a postulated scalar boson necessary in gauge theory.

P. Kotzer (Seattle) gave a short description of a proposed experiment to attempt to observe neutrino oscillations by using an optical detector in the ocean near Seattle and a neutrino beam produced at Fermilab pointing in that direction. Neutrino oscillations are fluctuations in intensity that might be observed if a coherent beam contains neutrinos of two different types whose rest masses are slightly different and which can transform into each other.

The third and last day of the meeting was devoted mainly to discussions of acoustic-detection possibilities. First B. Dolgoshein (Moscow Physical Engineering Institute) gave a review of the subject and detailed the results of new Monte Carlo calculations, using the MARS program at Serpukhov to determine the shower distribution from very high-energy hadronic cascades and the resultant acoustic radiation pattern. The acoustic pattern is not symmetrical about the plane through the maximum of the cascade that is normal to the shower axis. It rises more sharply on the side toward the origin (the upstream side) and falls off more slowly on the downstream side. Hence, with sufficiently accurate observation of the acoustic pattern, the sense of motion of the incident particle along the cascade axis can be inferred. Other new results include the prediction of a considerable, though rapidly absorbed, acoustic radiation flux in the 100- to 200-kHz band. The direction of the shower can readily be determined to 10 mrad or better.

V.D. Volovik (Univ. of Kharkov) described the acoustic-research experiments that have been going on there for several years (since 1971) and which, although published, had been unknown to the DUMAND group. He believes that the mechanism of sound production by particle beams is not purely thermoacoustic but includes bubble or microbubble formation. The theoretical analysis predicts that, as the pressure in the liquid increases beyond 200 atm, the bubble-formation contribution vanishes; at the pressures to be encountered in DUMAND (500-600 atm) the effect becomes purely thermoacoustic except that dissolved gases, if present, can contribute too.

L. Sulak (Harvard) then presented the results of DUMAND experiments at Brookhaven and Harvard using proton beams at 150-200 MeV and at 32 GeV. There are some discrepancies between the results of Sulak and Volovik, particularly concerning the temperature and pressure dependences, which are not yet reconciled.

Dr. John Learned (Univ. of California, Irvine) presented a new exposition of the theory of thermoacoustic pressure pulses produced by particle beams. It uses a Fourier-transform approach into the time domain rather than the frequency domain; it will shortly be published. Comments were made that it needed more detailed accounting of absorptive and dispersive effects.

Finally, Prof. A. Parvulescu (Inst. of Geophysics, Hawaii) discussed a few observations on an alternative site for DUMAND, to the west of the island of Hawaii. He presented some actual spectral analyses of hydrophone recordings made at Barking Sands, Kauai, to show the existence of signals, probably due to porpoises, which in waveform, at least, appear remarkably similar to those to be expected from a nuclear cascade. (They could be distinguished by their radiation patterns, since the cascade signal is confined to a narrow disc.)

The meeting closed with expressions of thanks to the organizers and of hopes for continued and closer cooperation in the future. There are no plans for publishing the proceedings of the Workshop. (Arthur Roberts, Fermilab, Batavia, Illinois)

HIGH-POWER LASERS AND APPLICATIONS—A CONFERENCE AT MUNICH

The Fourth Colloquium on Electroni Transition Lasers was held in Munich on 20-22 June under the sponsorship of the Deutsche Forschungsgemeinschaft, the US Air Force through the Office of Scientific Research (AFOSR) and the European Office of Aerospace Research and Development (EOARD), and the US Army European Research Office (USARSG). The Laser 77 Opto-Electronik Congress and Trade Fair with equipment displays and a technical seminar was in progress

simultaneously at the Congress Center. One had a considerable choice as to what kind of laser information to partake of at any given time. More than 130 participants from 11 countries were in attendance and about 40 papers were presented. The conference was not divided into categorized sessions; however, the majority of papers seemed to fall into one of the following four categories: new laser developments, chemical lasers, excimer lasers, and specific high-power lasers. Several review papers were presented that summarized work on various high-power laser systems and related topics such as spectroscopic methods. The papers will be published in book form by Springer-Verlag. I will concentrate on describing a few of the results that are relatively recent.

Dye lasers are continually being improved, extended in wavelength, and increased in power or energy, and new applications are being found. Professor F.P. Schäfer (Max-Planck Institut für Biophysikalische Chemie, Göttingen, Germany) summarized two areas of dye-laser research: vapor-phase dye lasers and high-average-power liquid-phase dye lasers. Present dye lasers will not operate in the uv below about 3220 Å because solvents absorb there. The hope is that vapor-state dyes capable of "lasing" can be developed for the uv. At present p-bis[2-(5-phenyloazolyl)] benzene (POPOP), p-terphenyl, and three other compounds have been made to "lase" in the vapor state. Temperatures above 300°C are necessary to achieve concentrations high enough ($>10^{-4}$ mole/liter) to achieve laser action. Schäfer stated that electron-beam excitation of vapor-phase dyes would be ideal and is being pursued, but success seems to be elusive.

Schäfer described the high-power liquid-dye laser work going on in his laboratory. Recently he has achieved the impressive figure of 109-W average power from a flashlamp-pumped dye at a 50-Hz repetition rate. He said it should be possible to reach an average power of 1 kW.

K.D. Foster (Defense Research Establishment Valcatier, Courcelette, Quebec, Canada) reported on an HCl cw chemical laser that operates over the wavelength range from 3.6 to 4 μm. Foster and his colleagues obtained a power of 13 W with a chemical efficiency of 11.4%—the most efficient, purely chemical cw laser reported to date.

R.W. Field reported on his successful work with an optically pumped cw I_2 laser that operates on more than 100 electronic transitions between 5,700 and 13,400 Å. Only one other molecular system, Na_2, has been made to produce cw laser action on electronic transitions. Field believes this system has the potential for high efficiency, but loss mechanisms, as yet not understood, degrade the performance.

One of the problems associated with achieving high-average power from xenon- and krypton-halide lasers has been the expense of replacing the xenon and krypton, which rapidly become contaminated. C.P. Christensen (Department of Electrical Engineering, USC) described a cryogenic gas-recycling system that permits him to operate his laser at a pulse rate of 200 Hz and an average output power of 52 mW.

Excimer laser systems other than those using rare-gas-halide molecules have been the subject of recent searches. J.H. Parks (Avco Everett Research Laboratory, Inc.) reported on his success with HgCl at a wavelength of 5576 Å. Excitation was by electron beam, and the efficiency was 0.8%, which is comparable with that of ArF lasers.

The subject of high-power IR lasers has received intense interest for many years since it first was demonstrated that the CO_2 laser at 10.6 μm could operate at very high power levels in both the cw and pulsed modes. L.E. Wilson [Air Force Weapons Laboratory (AFW), Albuquerque, New Mexico] reviewed the details of HF and DF chemical lasers. The Air Force device uses C_2H_2 or C_2H_4 as fuels (or similar deuterated compounds for the DF laser), F_2 or NF_3 as oxidizers, and He as a diluent. An important modification of the nozzle system is the addition of trip holes which provide turbulent mixing. In this way the power output is increased by 80%. Continuous output powers of 8-9 kW have been reached.

Several papers were presented on the atomic-iodine laser. A summary of the latest work was presented and its potential for laser fusion was discussed (see *ESN* 31-9:375).

Threshold currents of 40-50 A are required for rare-gas uv ion-lasers; therefore, it is difficult to reach

high-power levels. G.J. Collins (Department of Electrical Engineering, Colorado State Univ., Ft. Collins, Colorado) has achieved uv metal-ion-laser action with thresholds as low as 2 A. In addition he has extended cw laser action to 2200 Å—1000 Å lower than any other system. Collins has investigated Cu II, Ag II, and Au II (the spectroscopists' notation for Cu^+, Ag^+, and Au^+) in hollow-cathode discharges in rare gases. An oven is not required as the metal ions are sputtered into the discharge from the cathode.

Attempts to achieve high pulse-energy, low beam-divergence, and tunable, narrow linewidth simultaneously from dye lasers have generally been unsuccessful. I.J. Bigio (Department of Electronics, The Weizmann Institute, Rehovot, Israel) gave an excellent paper in which he described his work on a coaxial flashlamp-pumped dye laser using an unstable resonator and injection locking with a cw dye laser. He has obtained nearly diffraction-limited pulses of one joule with a linewidth of less than 15 MHz.

Until recently transverse-excited atmospheric-pressure (TEA) CO lasers have not produced very energetic pulses. W.E. Schmid [Projectgruppe für Laserforschung der Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V., (PFL) Garching, Germany] has made a 50-fold improvement over previous systems by slightly cooling the gas and adding a substance to help in preionization. Schmid obtains 5 J in a 50-μsec pulse with an efficiency of 2% from an active volume of only 1.25 liter. The laser oscillated on as many as 18 P-branch transitions and with as much as 30% of the energy in a single line when intracavity selection was used. At operating temperatures below -20°C the discharge becomes unstable. The electrodes use a sliding-spark arrangement and are fabricated by using a copper mesh embedded in plastic.

H.R. Lüthi and W. Seelig, researchers at the Institute of Applied Physics, University of Berne, have built cw argon- and krypton-ion lasers using anodized Al segments. Their lasers are capable of 175-W cw on the basic Ar lines; however, in this case they were reporting the power output of the uv lines of Ar III (Ar^{++}) and Kr III (Kr^{++}). In the argon system they can obtain 61 W at 352 and 364 nm; 17 W at 336, 334, and 333 nm; 3.8 W at 300, 302, and 305 nm; and 0.4 W at 275 nm. In the krypton system they obtained 19 W on the 356- and 351-nm transitions and 4.5 W on the 312-, 324-, and 337-nm transitions. For every line studied the output power increased without saturation up to the available discharge current, 480 A. The system has a discharge length of 1.7 m and an overall efficiency of 0.03% at 351 nm.

Professor D.J. Bradley of Imperial College, London, discussed advances in electron-beam-pumped rare-gas laser systems. He attributes recent advances to a new electron-beam source, which pumps his Xe laser at 10 pulses per second. The Xe laser produces 12-mJ pulses of 10-nsec duration in the 1700-1755 Å range. The third harmonic at 570 Å has been produced from these pulses, and he is attempting to obtain the fifth harmonic at 340 Å. He also intends to use the new source to excite the rare-gas halide systems.

Dr. Y. Haas of the Hebrew University of Jerusalem is studying the oxetane family of compounds as possible laser media. These molecules decompose on heating and leave their products in excited states. He dissociated tetramethyldioxetane into two acetone molecules [$(CH_3)_4C_2O_2 \rightarrow 2(CH_3)_2CO$] and observed the chemiluminescence produced from them in the 10-μm region. Further studies of the kinetics of this process and of the decomposition of other members of the family are being undertaken.

Dr. J. Wolfrum of the Max-Planck Institut für Strömungsforschung, Göttingen, discussed IR-radiation-induced reactions of the form $AB + C \rightarrow A + BC$. One reaction of interest in this category involves ground-state CN and atomic oxygen to produce CO in an excited state. Dr. S. Fischer of the Technical University of Munich described his attempts to predict the energy distributions of the products of the foregoing generalized reactions and compared his calculations with experimental results. His predictions include the vibrational, translational, and electronic excitation of the products.

This conference covered the area of high-power lasers comprehensively in accordance with the title. In doing so the coverage has gone somewhat beyond the area of electronic-transition lasers, which was the original topic

of this series of conferences. Dr. K. Kompa (PFL), one of the conference organizers, said that the next meeting in the series may specialize in short-wavelength lasers. Atlanta, Georgia is being considered for the conference site in order to coincide with the Tenth International Quantum Electronics Conference. [Vern Smiley and MAJ. James H. Gorrell, Jr. (EOARD)]

ONE-TERAWATT IODINE LASER—ASTERIX III

A previous article (*ESN* 29-6:280) described Asterix III, which was under construction at the time at the Max-Planck Institut für Plasmaphysik in Garching, FRG. This iodine-laser development is now carried out at the same location, but by the Projectgruppe für Laserforschung der Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V. under the direction of Dr. S. Witkowski.

The characteristics of the iodine laser were described by Dr. K. Hohla, Dr. K.J. Witte, and other staff members in two papers at the Conference on High Power Lasers and Applications in Munich, 20-22 June, 1977 (see this *ESN* issue, p. 372), and also during a visit to their laboratory after the Conference. Last fall the system reached the terawatt (10^{12} W) power level: 500 J in 500 psec. The laser consists of an oscillator with four amplifier stages. The last amplifier uses 64 flashlamps and is 10 m long. The maximum pulse rate is 1 pulse every 8 minutes, and the overall efficiency of the laser is 0.15%. Witte feels that the iodine system could be scaled to the 10- to 100-kJ energy range.

This laser has a very high single-pass gain, about 10^9 to 10^{10}, for the entire system. Consequently pre-pulsing can be a problem. Recently, pre-lasing outputs have been reduced from 50 mJ to 1 mJ. This has been accomplished by introducing a saturable absorber cell of iodine which adds an attenuation of 30-40 dB to low-level signals. Furthermore, Faraday rotators are used to decouple the second stage from the third and the third from the fourth. The I_2 cell is heated to a temperature of 800°C, which causes the molecules to dissociate into ground-state atoms and results in a large absorption until the intensity reaches a few J/cm^2, which is a high enough level to saturate the laser transition and thereby cause the cell to become transparent.

At present there are only three laser systems available for fusion experiments. They are CO_2, Nd-glass, and iodine. An iodine system is the least expensive to construct and the medium is easily replaced. However, its low efficiency is a definite limitation compared with the other two systems.

The iodine laser operates at a wavelength of 1.3152 μm on a forbidden atomic transition from the first electronic excited state to the ground state after photodissociation of the molecule. The pulsewidth is narrowed by increasing the linewidth. A buffer gas such as CO_2, C_3F_7, or Ar is added to the system to produce collision-broadening of the rather narrow laser transition. The most effective broadening—by a factor of as much as 10—is produced by CO_2.

According to Hohla, a pulse width of 100 psec now seems optimum for fusion work. He feels the best method is active mode-locking. Another interesting method is the use of optical breakdown in a N_2 cell, which chops off the tail of a longer pulse. However, other processes in breakdown are not yet thoroughly understood. The use of a hot I_2 cell, previously described as a pre-pulse limiter, also sharpens the leading edge of a pulse. Hohla described the use of a Pockels cell to shorten the pulse, which is then passed through a hot I_2 cell. Pulses of 200-psec duration are generally obtained in this manner; however, pulses as short as 60 psec have been observed. Mode-locked operation at 500 psec is generally used for present work.

When a high-power laser is used with a target, additional precautions are necessary to prevent optical feedback to the laser that can reduce its output power and also damage optical components. Witte stated that the results of 15 shots from Asterix III with a target indicate that the power can be brought to the same level as without the target. The effect of the target on the spectrum of backscattered radiation helps reduce feedback problems. The exit pulse arriving at the target through a final focusing lens has a

spectral bandwidth of about 0.1 Å. Witte and Dr. K. Eidmann described results of a spectral analysis of the total backscattered radiation. The spectrum was a "spike" 3 Å wide sitting on a pedestal about 15 Å wide. Additionally, some energy appears at $2\omega_L$, $3\omega_L/2$, and $5\omega_L/4$, where ω_L is the laser frequency. In other words, much of the backscattered energy is shifted in wavelength beyond the linewidth of the laser transition and therefore does not cause a problem.

A smaller iodine laser, Plasterix, is located in a room below Asterix III. This laser is the same as Asterix III without a final amplifier. A beam (30 J at 1 nsec) from Plasterix is brought up by mirrors to the same target chamber as is used for the Asterix III experiments.

Further target-interaction experiments are planned for later this year. (Vern Smiley)

SEEING THROUGH FOG AND BETTER IMAGES AT ERLANGEN

The Physikalisches Institut der Universität Erlangen-Nürnberg is located in Erlangen, FRG, a rather small town close to Nürnberg in Franconia. The purpose of my trip there was to discuss image processing and related topics with Prof. Dr. Adolf W. Lohmann.

Prior to returning to Germany in 1972, Lohmann worked in the US at IBM in San Jose and later was a professor at the Applied Physics and Information Sciences Department of the University of California at San Diego (UCSD). He has been an innovative contributor to his field of optics for many years.

According to Lohmann the University is composed of 12 Fachbereiche (Schools) under the University President. Mathematics and Physics is one of these. Each School is divided into Fachgruppen such as Physics, Mathematics, etc. Lohmann has the chair in Applied Optics, which is one of five chairs in the Physikalisches Institut (Experimental Physics Institute), a part of the Physics Fachgruppe.

Lohmann's group consists of fourteen people including an assistant professor, acting assistant professors, research assistants, and MS and PhD students. About 80% of the research effort in applied optics is in the area of image processing. Within that framework there are projects on hybrid image-processing (the combined use of optical methods with TV and other electronic techniques), holography, and image-forming through turbulent media.

One experimental project that could be of potential benefit to the Navy and other agencies is concerned with real-time seeing through moving fog. In 1973 Lohmann and C.A. Schuman [*Opt. Commun.* 7, 93 (1973)] reported their investigations on the use of holography through fog. Their technique, however, suffered from a time-delay necessitated by the photographic development of the hologram plate. H. Schmalfuss, a graduate research assistant, has now extended this technique to real time by replacing the photographic development with an electronic method incorporating a closed-circuit TV system. An image-plane hologram is stored temporarily on the cathode of a TV tube. The hologram is then reconstructed electronically at TV speed and displayed on a monitor.

This technique works only in the presence of moving fog or other scattering medium but is ineffective in a stationary medium. A block diagram of the experimental arrangement is given in Fig. 1.

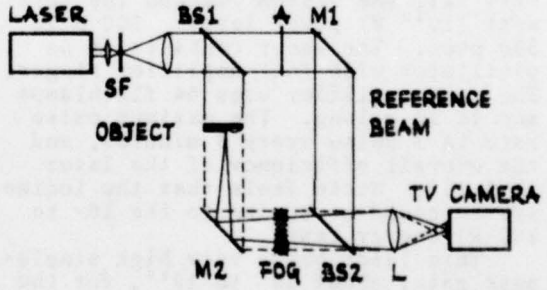


Fig. 1a. Optical recording setup. SF is a spatial filter, A an attenuator, BS1, BS2 are beamsplitters, M1, M2 are mirrors, and L is the imaging lens.

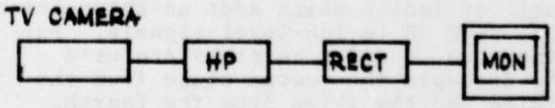


Fig. 1b. Electronic reconstruction setup. HP is the high-pass filter, RECT the rectifier, and MON the monitor.

A Doppler shift is associated with laser light scattered from moving fog drops. If the Doppler shift is sufficiently large, the scattered light will not interfere with the unscattered image-light nor with the reference-beam light. Hence the scattered light can be separated from the unscattered light. A necessary condition on fog velocity in order that the separation of scattered and unscattered light can occur is:

$$v \geq \frac{\lambda z M}{\tau \, \delta x} ,$$

where v is the fog velocity, λ is the wavelength of the laser, z is the object-to-fog distance, M the image magnification, τ the exposure (or integration) time, and δx the resolution limit of the recording system.

The mathematical expression for the intensity distribution across the TV camera tube contains six terms, only one of which carries the unscattered-image information. Some of the other terms disappear if the velocity condition above is met; the rest fluctuate slowly and are eliminated by an electronic high-pass filter.

Initial experiments have been made in the laboratory with artificial fog, simulated by a thin sheet of foam rubber containing particles having radii equal to about 10 wavelengths of the laser light. I saw movies made of the laboratory experiments in which the image recovery was very impressive. Future plans call for experiments in natural fog and further development of the theory.

Lohmann and Dr. G. Häusler showed me another project with important practical applications to medical, biological, and other fields. They have developed a hybrid system for real-time increase in the depth of focus of an ordinary incoherent optical system. A microscope produces a poor image when the object has depth—a result of the extremely small depth of field of the optical system. In order to see different depths, one must refocus the device on different object planes. Lohmann and Häusler attach a TV system to the microscope and move the object back and forth rapidly. The electrical signals are then processed. A combination of high-pass filtering, which preserves the high-spatial frequencies, and signal integration is used to produce an image signal that contains in-focus information over a much larger depth. The processed image is then displayed on a monitor.

G.P. Weigelt described his projects on speckle interferometry, photography, and masking techniques that have been carried out under Lohmann's guidance. Speckles are formed when laser light strikes any rough surface and are caused by the surface acting like a random diffraction grating. In general they are not desirable as they result in nonuniform illumination. However, they can be put to practical use. Speckles are also observed in telescope images when the light passes through an inhomogeneous medium such as a turbulent atmosphere. Earlier work by this group was concerned with modifications of a method developed by A. Labeyrie, who used speckle interferometry to increase the resolving power of telescopes.

The image of a star in a large telescope is a disk containing a large number of random speckles, each of which is about the size of the Airy disk (the diffraction-limited spot that would be present in a perfect optical system with no turbulent atmosphere present). The limiting size of the image disk is about 1 sec of arc. For the 200-inch telescope at Palomar, the speckle size corresponding to the Airy disk is about 0.02 sec of arc. Labeyrie showed that the resolving power of telescopes can be increased by taking a large number of photographs of the image with a spectral bandwidth of about 250 Å at exposure times short enough to freeze the speckle pattern. Each speckle photograph was optically Fourier transformed and all transforms were superposed on a photographic film, thus forming the average power spectrum. This power spectrum had considerably improved resolution over an individual photograph. However, the power spectrum rather than an image was obtained.

A new technique for reconstructing real images from astronomical speckle photographs was described by Weigelt. This method is useful for a limited number of objects, including double stars and objects such as galactic nuclei or moons of planets where two parts are present, one of which is unresolvable and the other is resolvable but small. The technique requires three steps of image processing of an original set of speckle photographs.

Weigelt has demonstrated that the scheme works in the laboratory with a simulated turbulent atmosphere. He will now continue the experiments with real telescope images. Another interesting project, with medical applications, is a technique employing holographic interferometry to make strain analyses of thigh bones to which a prosthetic hip joint has been added. A real-time hologram of the bone when pressure is applied is compared with a previously made hologram of the bone not under pressure. When pressure is applied to the joint, differences in deformation between the prosthesis and bone show up clearly as interference patterns. In this way new prosthetic hip joints can be studied and evaluated.

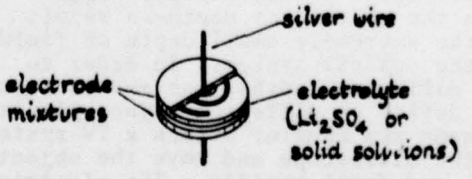
Lohmann has a good group of active and talented assistants and students and a well-equipped laboratory. One can expect that they will continue to produce high-quality contributions in applied optics. (Vern Smiley)

SOME PHYSICS RESEARCH AT CHALMERS INSTITUTE OF TECHNOLOGY

The Physics Department at the Chalmers Institute of Technology is the largest Physics Department in Sweden, in part because its faculty provides physics instruction for the nearby University of Gothenberg as well. My visit was at the invitation of Professor Arnold Lundén, who had, incidentally, just finished a term as head of the Department, which is one of five in the School of Engineering Physics. The research program in experimental physics covers a very wide area, from nuclear physics to surface physics; of particular interest to me were Lundén's own researches on solid-state electrolytes, the surface physics studies by Stig Andersson and P.O. Nilsson, and some aspects of the operation of the Materials Science Center affiliated with the Department.

Lundén's interest in solid electrolytes arose from his involvement many years ago in research on electromigration in molten salts, undertaken with the aim of isotope enrichment of nuclear fuels. These investigations got him interested in the basic aspects of diffusion, conductivity, and related properties of molten salts, leading into studies of these phenomena in solids. For some years Lundén's main interest has been lithium sulfate and its various solid solutions with other alkali sulfates and sulfates of divalent cations (Ca^{++}, Mg^{++}, Zn^{++}). These salts are good ionic conductors, and as such are of interest for solid-state batteries in competition with systems involving beta-alumina and the silver-iodide/alkali-iodide double salts. In contrast to the latter two types of solid electrolytes, in which only monovalent ions have high mobility, both mono- and divalent cations are highly mobile in the lithium sulfate salts. These salts are thus useful with a variety of active metal anodes (such as calcium, magnesium, or zinc), the electrolyte being a solid solution of the corresponding lithium-divalent-metal sulfate, and the cathode being an oxidizing agent such as manganese dioxide.

Experimental cells as shown in the accompanying figure were formed by pressing layers of powder in a steel die. The electrode layers also contained the electrolyte powder and often had graphite admixed to give both ionic and electronic conductivity. Flat spirals of silver wire were used as the current leads. When operated in the temperature range 350-750°C, these cells, which weigh a few grams, generate voltages from 1.2 to 2.6 volts, and have internal resistances of the order of 1 to 1000 ohms with electrolyte thicknesses of 1 to 4 mm in 20 mm-diameter cells. The highest power density of 400 W/kg was obtained from a cell with a Li_2SO_4-$MgSO_4$ electrolyte, a Mg anode, and a MnO_2 cathode, operated at 745°C. The open-circuit cell voltage was 2.3 volts, and it delivered 1.35 volts on discharge across a 2-ohm resistor. The theoretcal energy density of the cell was 1170 Wh/kg.



Cell with incorporated current collectors of silver wire.

It appears that for primary batteries, at least, the sulfate-based cells are competitive with other high-temperature alternatives (see *ESN* 31-6:219). More complicated cells, such as one using a complex lithium-silver-magnesium iodo-sulfate as an electrolyte with a silver anode and an iodine cathode, can operate at room temperature.

Before exploring their applications in batteries, Lundén and his associates studied the physical properties of the lithium-sulfate-based salts for many years and made measurements of their thermal expansion, thermoelectricity, thermal diffusion, electromigration, and mechanical properties. X-ray studies in the literature had shown that the sulfate ions in lithium sulfate form a face-centered-cubic or pseudocubic lattice in which both tetrahedral and octahedral positions are available for cations. This results in a large excess of vacant cation sites, which is a rough explanation of the high cation-mobility and electrical conductivity. An oversimplified description of these salts is that they are "half liquid and half solid." X-ray diffraction patterns of lithium sulfate and similar salts show a surprisingly small number (only 3-4) of sharp lines. Leif Nilsson has undertaken a neutron-diffraction study of lithium sulfate at the Institut Laue-Langevin (ILL) in Grenoble; a preliminary account of his results should appear soon in letter form and will provide additional insight into the structure of these salts.

Stig Andersson carries out a very extensive and enthusiastic surface-physics program based on combined electron-energy-loss spectroscopy and low-energy electron diffraction (EELS-LEED) studies. Andersson has designed a particularly precise EELS equipment which is briefly described in *Solid State Communications* 20, 229 (1976), but the full details of its design have not yet been published. The energy resolution of his EELS spectrometer is 0.7%, and when operated at primary electron energies in the range 1-2 eV it yields a resolution of 7-14 meV.

Andersson has concentrated on nickel as a substrate and has studied the adsorption of Na, K, O and CO on the (100) face of Ni. He has done a very thorough job of studying the structure and vibrational excitations of CO adsorbed on the Ni(100) surface, as well as investigating the mechanism of the catalytic action of Ni surfaces on the disproportionation reaction: $2CO \rightarrow C + CO_2$. In his most recent paper [*Solid State Communications* 21, 75 (1975)] Andersson has proposed that there are two configurations in which CO is bonded to the Ni. One of these is linear, with the C bonded to the Ni and the CO molecule standing out perpendicular to the Ni(100) surface. In the second configuration the CO molecule is bridge-bonded to two nearest-neighbor Ni atoms; i.e., there is a bond between the C atom and two adjacent Ni atoms, and the CO molecule is oriented perpendicular to the surface as in the previous case. In the first configuration the bonding is very much the same as that in nickel carbonyl, $Ni(CO)_4$.

Andersson's more recent (unpublished) theoretical study of the LEED intensity measurements in this system in cooperation with J.B. Pendry (Daresbury Laboratory, Cheshire, UK) has modified the first model. The Ni-C and C-O distances in the adsorbed layer, derived from the theory, were 1.80 and 0.95 Å, respectively. The first distance is in agreement with the Ni-C distance in nickel carbonyl, but the C-O distance in the carbonyl is 1.15 Å rather than 0.95 Å. It is considered highly unlikely that the C-O bond could be compressed so much simply because of adsorption of the CO molecule. The authors therefore propose that, instead of being perpendicular to the Ni(100) surface, the CO molecule is tilted at an angle of about 34° with respect to the surface normal; the actual C-O bond length in the adsorbed molecule would then be close to the 1.15-Å value found in $Ni(CO)_4$, but its projection in the direction perpendicular to the Ni(100) surface would be 0.95 Å.

Andersson and collaborators from the University of Aarhus, Denmark (B.I. Lundqvist and J.K. Nørskov), have also studied the mechanisms of the catalytic action of nickel surfaces on the disproportionation reaction: $2CO \rightarrow C + CO_2$. They propose that the role of the surface is to circumvent the symmetry restrictions that exist for the corresponding gas-phase reaction. A paper on this subject will be given at the Seventh International Vacuum Congress and Third International Conference on Solid Surfaces, in Vienna, 1977.

Andersson has also studied the structure of an adsorbed surface of O on Ni(100) as well as the vibrational excitations of such a surface. He has also investigated the effects that a preadsorbed saturated chemisorption layer of hydrogen on Ni has on the structure of the subsequently adsorbed CO molecule. Preadsorption of H eliminates the linear bond described previously and favors the "bridge" bond of the CO to two Ni atoms. This latter work is also to be presented at the Vienna Conference in 1977, whereas the work on the oxygen adsorption is given in the 1976 *Solid State Communications* article cited above.

P.O. Nilsson and his colleagues have been carrying out a variety of studies using x-ray photoelectron spectroscopy: the band structures of V_3Si and copper, and the chemisorption of CO on copper. In a paper on the last-named subject, to be given at the Fifth International Conference on Vacuum UV Radiation Physics, Montpellier, in September 1977, angle-resolved ultraviolet photoelectron-spectroscopy studies of CO adsorbed on Cu(111) show that the CO is in a tilted orientation with respect to the normal to the copper surface, reminiscent of the tilting of the CO molecule on Ni(100) observed by Andersson.

Closely connected with the Physics Department is the Materials Science Center. One of the features of the Center is a secondary-ion microanalyzer (SIM), an IMS 300 made by Cameca of France, the only one of its kind in Scandinavia. It is used as an analytical service instrument in interdisciplinary materials research. The SIM can perform a three-dimensional elemental analysis of layers from 50 Å to 20 μm below the surface of solid specimens. It operates by eroding the surface through sputtering, mass-spectrometrically analyzing the secondary ions ejected by the sputtering, and then performing mass-resolved ion-optical imaging. A. Lodding and L. Lundkvist, the two people who preside over the instrument, have done a great deal of work on Ga diffusion in Si_3N_4 films, on nonmetal impurities in metals (generally steels), and the distribution of fluorine and other elements in apatites of biological interest, particularly in teeth. Much of their work is done in response to outside interest and sponsorship.

Finally, there is a well-equipped laser laboratory under Morgan Gustafsson, abundantly provided with a variety of US-made lasers. In addition to a program of basic studies, the group is concerned with pollution monitoring by laser-optical techniques and is involved in collaborating with groups that operate field equipment. (James H. Schulman)

ACOUSTICS AT TRONDHEIM

In a recent article in these pages entitled "Norwegian Offshore Technology—Small is Beautiful" (*ESN* 31-3:119), Nunn and McKendrick provided a valuable overview of the noteworthy concentration of expertise in the Trondheim area available for application in the offshore-engineering field. They have indicated the central position of the Norwegian Institute of Technology (Norges Tekniske Høgskole, NTH), part of the University of Trondheim, in this concentration. Further, they have pointed out the role of the OTTER (Offshore Technology Testing and Research) group in bringing the needs of industry to the attention of NTH and as a means of integrating the activities of three principal independent research and development activities: the Foundation for Scientific and Industrial Research at the University of Trondheim (Selskapet for Industriell og Teknisk Forskning, SINTEF), the Norwegian Ship Research Institute (Norges Skipsforskningsinstitutt, NSFI), and the River and Harbor Laboratory (Vassdrags- og Havnelaboratoriet, VHL).

Acoustic research at Trondheim centers in the Electronics Research Laboratory of NTH (Elektronikklaboratoriet ved NTH, ELAB), which is affiliated with SINTEF and is also an affiliated member of the OTTER group. ELAB's main objective is to carry out R&D in the fields of electronics and acoustics, and to strengthen and stimulate scientific and technical activity at NTH. It works in close cooperation with the Department of Electrical Engineering of NTH, and facilities and scientific equipment are to a large extent shared. The university staff contributes to the ELAB research activities both as scientific supervisors and as research

participants, while members of the ELAB staff contribute in the university's educational arena.

ELAB has a total staff (excluding short-term employees) of about 120, of whom 80 are scientists and engineers. Its funding (NKr 11.4 million in 1976, approximately $2.5 million) comes largely from industrial and government contracts, which provide about 65% of the total. An additional 30% is from the Royal Norwegian Council for Scientific and Industrial Research (Norges Teknisk-Naturvitenskapelige Forskningsråd, NTNF) for research initiated by the laboratory, but this is largely on a matching basis against industrial contracts. Less than 5% is provided, via SINTEF, from NTNF as "basic" funding.

The Acoustics Division of ELAB—with sections for electroacoustics, environmental acoustics, and acoustic measurements—constitutes the Laboratory of Acoustics (Akustisk Laboratorium), and is under the scientific supervision of Prof. A. Krokstad of NTH. The laboratory performs in the Norwegian structure a role similar to that played in Denmark by the Acoustical Laboratory of the Technical University of Denmark (Danmarks Tekniske Højskole) at Lyngby (Prof. F. Ingerslev). This includes the provision of facilities and expertise in airborne noise measurement, and in the architectural, environmental, and room-acoustic areas, which can be utilized in the preparation of national specifications and positions. The facilities are completely automated and all routine measurements are computer programmed and processed.

In addition to more routine measurements and studies, ongoing projects include (i) development of a computer model for the investigation of room acoustics, which has been applied to the investigation of a number of existing concert halls, many simple room shapes, and in consultation work on room acoustics; (ii) studies of road-traffic noise including computer-model simulation; and (iii) SAMSIN, a highly flexible computer-controlled system for speech-transmission-channel simulation and testing for the Norwegian Telecommunication Administration.

These projects and the laboratory facilities reflect a high level of application of electronic and computer technology to a wide range of acoustic problems. The diversity of current interests is further indicated by two other activities: first, the building of a new large anechoic chamber for investigation of the noise of large, heavy machinery, and, second, study of the origin of noise-induced hearing loss. In the work on hearing loss the correlation between various measures of industrial noise and basilar-membrane displacements (measured by the Mössbauer technique and calculated from a transmission-network model of the inner ear) has been studied. It suggests that noise-induced hearing loss is possibly due to mechanical stimulation and destruction of hair cells caused by movement of the basilar membrane (Kringlebotn *et al*, Contributed Paper H.5, 9th Int. Cong. on Acoustics, Madrid 1977).

Acoustics at ELAB is by no means limited to the Laboratory of Acoustics. A section within the Telecommunications Division is almost exclusively concerned with underwater-acoustic applications. This section, which is also under the scientific supervision of Krokstad, is led by Dr. J.M. Hovem, who about three years ago returned to Trondheim after completing a tour of duty at NATO's SACLANT Anti-Submarine Warfare Research Centre, La Spezia, Italy, where he worked on underwater acoustic-propagation problems. Hovem has recently been appointed a *dosent*, (asst. professor) for underwater acoustics in the University and is giving a course in this subject to electrical engineering students.

Recent and ongoing activities within this section include work in the following areas: parametric sonar in which operation of the source is based on a nonlinear acoustic effect, in conjunction with and supported by SIMRAD A/S (Horten), underwater-navigation instrumentation for a small underwater vehicle for the Continental Shelf Institute (Institutt for Kontinentalsokkelundersøkelser, IKU), shipboard propeller noise with the NSFI, underwater acoustic classification of fish with the Marine Research Institute (Havforskninginstitutt), and consultation assistance to the Norwegian Petroleum Directorate and the IKU on underwater site inspection. Throughout Hovem has encouraged his section to work closely with other national institutions, and all tasks are essentially joint efforts.

In the fish-classification work emphasis is on resonance phenomena and

study of target strength as a function of frequency, species, size, and depth. For this work a downward-looking sonar system is being constructed capable of operating over the frequency range 1 to 4 kHz. It will be installed this summer on a raft in protected water to look at the acoustic returns from caged individual fish. It will subsequently be used to study echoes from fish schools. The primary interest in these studies is that they may provide information helpful in the conduct of fish-population surveys. Current surveys, as, for example, the international (UK, USSR, Norway) catlin surveys in northern waters, rely on conventional single-frequency echo-sounder information, aided by echo-integration techniques, and supported by fish sampling.

The group's parametric-sonar work is part of a research effort in which SIMRAD A/S and the Department of Physics of the University of Bergen also participate. An initial experimental sonar was designed primarily for high-resolution subbottom profiling. The difference-frequency output of the acoustic source of this system, which was driven at frequencies near 38 kHz, could be varied between 1 and 7 kHz and had a beamwidth of 5 to 10°. The source, housed in a towed body, was intended to be towed about 100 m above the bottom, while a trailing ten-meter-long 40-element array was used for reception. Early tests in Oslo Fjord, off Horten, gave acoustic returns from as deep as 40 m below the bottom. Parallel to the ELAB work, Halvor Hobaek at Bergen has, since the mid-1960s, conducted both theoretical and experimental research on parametric acoustic transmitting arrays and has recently surveyed the theoretical and experimental work in this field (Univ. of Bergen, Dept. of Physics Report No. 99, Feb. 1977). With M. Vestruheim, now at the University of Texas, Hobaek has paid particular attention to the properties of the near field. His survey highlights particular topics of the near-field behavior for further study.

A. Lövik of Hovem's group is working closely with the Ship Model Tank of the NSFI on ship noise and particularly on propeller cavitation noise. He and J. Vassenden of that facility have demonstrated the practicality of using the Institute's large cavitation tunnel for measuring the cavitation noise from a model propeller mounted in its test section. Measurements on model propellers in this facility have been compared with full-scale radiated-noise measurements (made in open water with the ship passing a measuring hydrophone and also by a hydrophone placed on the hull near the propeller) to evaluate a procedure they have developed for scaling the level and frequency of a propeller noise spectrum. Initial noise measurements have been made on a four-bladed 2.55-m-diameter propeller for a 950-ton ocean research vessel operating over a range of speeds, both with the propeller as originally designed and again as redesigned to reduce radiated noise. This work has shown good agreement between spectra predicted from the model measurements and full-scale observations. It and the scaling technique were reported in September 1977 in a paper given at the Institution of Mechanical Engineers' Conference on Scaling for Performance Prediction in Rotodynamic Machines at the University of Stirling, Scotland.

In the navigation area Hovem's section has worked closely with and for the IKU on instrumentation for precision underwater topographic surveying, which has been installed on the remotely controlled unmanned underwater vehicle SNURRE. Included in this instrumentation package are a long-baseline acoustic navigation system using bottomed transponders, depth measurement, an echo sounder for distance above the bottom, a computer interface, and processing and display equipment. The high noise level of SNURRE presented difficulties in reception of navigation-system acoustic signals on the vehicle itself, and it has been necessary to modify the initial navigation system so that return signals are sent back to the surface command vessel rather than to the SNURRE. Transmission to SNURRE from the command vessel is then via the control cable (Torsen *et al* "Instrumentation of an underwater vehicle for high-precision topographic surveys," *Proc. of Symposium on Automation in Offshore Oil Field Operation, Bergen, June 1976*, pp. 273-277, North Holland Pub. Co., 1976).

The diversity of acoustic projects underway at ELAB, with its close connection with the electrical engineering department of the university, is undoubtedly of considerable value in the central training role of the university.

In this connection it is worthy of note that NTH is the training school for engineers in Norway. The acoustic R&D activity at ELAB and, particularly, that of the Hovem's "underwater" section strongly reflect the growing response to, interest in, and application of acoustic techniques and knowledge in the offshore-engineering marine-technology area. In total the Trondheim effort ably complements the efforts of other Norwegian institutions with strong capabilities in the underwater-acoustics field, such as those of the Underwater Division of the Norwegian Defense Research Establishment and the commercial capability at SIMRAD A/S. (A.W. Pryce)

PSYCHOLOGICAL SCIENCES

THE HUMAN FACTORS GROUP AT THE ROYAL AIRCRAFT ESTABLISHMENT

The Flight Systems Department of the Royal Aircraft Establishment (RAE) at Farnborough has a small but vigorous Human Factors Group of experimental psychologists under the stewardship of Dr. R.G. Cumming, an MD. The atmosphere of installations like Farnborough is a mix of aircraft design and development and applied research, and the Human Factors Group performs on all these dimensions. They provide consulting services to aircraft designers and users, and they do laboratory research on aviation-related topics.

An aircraft pilot's task is one of heavy workload, and when the heavy workload is combined with high working speed we have a work-stress situation that impresses everyone, including the pilots. The pilot's task is particularly heavy on the visual side because he must scan both the instrument panel and the external world almost continuously, and it is easy for the gaze to be in the wrong place. A design challenge is arranging the cockpit for the efficient processing of visual information. Various research approaches have been taken over the years. Distributing some of the visual events over other sense modalities, as well as instrument design and arrangement for easy visual processing, have been investigated. None of these approaches has touched the time-sharing of the external world with the cockpit panel, which is the most demanding visual requirement of all.

In recent years we have had interesting attempts to ease this problem. One is the head-up display, where flight instrument and weapons information are projected transparently at eye level onto the windshield so that they can be easily time-shared with the outside world. Another is the helmet-mounted display (HMD), where a miniature cathode-ray tube (CRT) (about 25 mm in diameter) is mounted over one eye. Flight or weapons data can be shown on the CRT and shared with the scene of the outside world viewed by the unencumbered eye. Or, the HMD can show the outside world via low-light television or infrared, and the unencumbered eye can process the instrument panel. No matter which way the equipment is arranged, eye movements are reduced and the efficiency of visual scanning is increased.

All of this seems a neat answer to an old problem, but Dr. John Laycock of the Human Factors Group has been working on the HMD in a simulated situation, and he finds that it introduces binocular rivalry where different scenes to the two eyes do not blend but oscillate in a confusing fashion and compete for attention. Binocular rivalry is complex. Among the variables that have been found to determine such rivalry are luminance, color, and image complexity; iris control for brightness and lens accommodation for focus cannot occur independently for the two eyes (AGARD Report No. 642, 1975). Binocular rivalry is worst when images in the two eyes are perceptually complex, such as the instrument panel for the unencumbered eye and a low-light television display from the HMD, and is least when the HMD is presenting a perceptually simple display such as a weapon-aiming reticle. Laycock may be on the track of a solution, however, because in his own extensive experience with the simulated set-up, he has observed that practice can bring binocular rivalry under control. Through perceptual learning he can "will" an image for one of the eyes in or out of attention. This solution is yet to be documented experimentally, and

Laycock said that the cure, if it is one, may have detrimental side effects. The act of willing an image in or out of attention takes a considerable amount of time; it is far from instantaneous. Is the central switching time longer than for the peripheral eye movements that we seek to minimize? Perceptual learning may be a general solution to binocular rivalry but, if it is not, all the variables for binocular rivalry will then have to be brought into delicate balance for all conditions and all pilots in order to make the HMD operationally useful. If the balance cannot be achieved, the HMD will be restricted to simple symbology, but then there are other ways of presenting simple symbology that do not have the behavioral complications of the HMD (e.g., the head-up display). Other problems, which have human-factors ramifications that may be solvable by engineering ingenuity, are the HMD's weight on the head and neck and the danger that it might pose during cockpit ejection.

Dr. Alan Buffett is investigating perceptual problems of flight also. Low-light TV or infrared used for night flying has a single sensor for image collection and a single cathode-ray-tube display in the cockpit. Such an arrangement provides a view of the outside world, but it is a monocular one that sacrifices the component of depth perception coming from binocular disparity (place a pencil on the edge of your desk and try flicking it off with your finger with one eye closed if you don't believe that two eyes are better than one for depth perception). A pilot needs all the depth cues he can get, particularly when he is flying high speed and low level at night and must find targets and navigation checkpoints. Of course, there are other depth cues, such as size in which more distant objects are smaller, but depth information from retinal disparity is primary, and a pilot would be comforted to have it. Buffett believes that the answer may lie in a stereo-TV system in the aircraft, where there would be two well-separated external cameras and a binocular cockpit viewer. His laboratory research compared one-camera TV, stereo TV, and unaided binocular vision as ways of viewing a scene for which depth judgments were required. So far he finds that stereo TV is better than one-camera TV but not as good as unaided eyes. Buffett has various refinements in mind, and he is continuing with other experiments. Buffett's researches, like Laycock's, are good examples of the complementary interplay between behavior and engineering design. (Jack A. Adams)

AIRCREW TRAINING RESEARCH AT SCIENCE 3 (RAF)

According to their organization chart, the British Royal Air Force has a considerable amount of its psychological research housed under Science 3, a personnel and research unit located in the London area. They conduct studies and make recommendations to the RAF management on such topics as personnel selection, aircrew training, flight safety, recruitment, and air traffic control. Science 3 is under the direction of K.W. Tilley.

One can only guess how much the world has invested in flight simulators for the training of aircrews. Certainly the investment is over a billion dollars, with the US military and commercial airlines having a share worth several hundred million dollars. The investment will be accelerating rapidly in the next few years because the cost of aircraft and the energy to run them is becoming so great that more and more aircrew training will be diverted to the simulator. Aircrews will not care for this trend very much because they like to fly (as good aircrews must), but economic forces will undoubtedly press for less training time in the air and more in the simulator whether aircrews like it or not. It is unlikely that the simulator will replace the aircraft (although in principle there is no reason why not), but there is little doubt that it will play a stronger role in aircrew training than ever before.

A distressing thing about flight simulators is that most are developed and used without ever having their training value assessed, and so we have little idea of the training worth of our billion-plus investment. An accepted method of assessment is the transfer-of-training experiment that measures the degree to which skills

learned in the simulator transfer to the aircraft. This experiment has two standard forms: (1) measurement of transfer for the simulator as it is designed and as it is used under standard conditions in the flight-training curriculum, and (2) measurement of transfer to assess features of simulator design or methods of its use in the curriculum. In (1) we ask the straightforward question of whether the simulator is doing a training job or not, and in (2) we might ask, say, whether a visual display for the presentation of landing cues, or whether a doubling of the amount of training time in the simulator, will increase transfer of training. The value of experiments like these is obvious, and we can only surmise that the reason they are not routinely run is that they are expensive and time-consuming. They involve simulators that are instrumented for aircrew proficiency measurement, instrumented aircraft, a large research staff, and a good supply of test personnel (who can be expensive if they are operational aircrews) to serve as experimental subjects.

It is particularly gratifying, therefore, to find that Science 3 is well down the research road on a major transfer-of-training experiment for the Phantom F-4 simulator. The study is in the spirit of how best to use the simulator because it compares a standard amount of training (30 hours) that is established in the flight-training curriculum with an augmented amount (47.5 hours). Six Phantom aircraft were fitted with flight-data recording equipment for 20 continuous variables and 15 discrete variables for the recording of aircrew proficiency. The simulator was correspondingly instrumented. The study was initiated and directed through major stages by Graham Shepherd, but he transferred to the Research Branch of the RAF in Northwood, London, and so the wrap-up is in the hands of John Anderson and his colleagues at Science 3. The experiment is in the data-analysis stage.

Anderson reports that a preliminary review of the findings suggests that increasing the amount of simulator training makes little difference in the proficiency of aircraft control, but it does increase proficiency in procedural activity, which is mostly discrete acts associated with the radar and fire-control system. These findings make sense. Aircrews encounter the Phantom at advanced stages of training, and by that time they have had hundreds of hours of flight training in other aircraft. Even though they are trainees they nevertheless are experienced in aircraft control, and so a few hours more or less in a flight simulator should not make much difference for proficiency in flight control. On the other hand, the radar and fire-control systems of the Phantom are new to aircrews. There is plenty of need for training in new subsystems, and so extra time in the simulator is beneficial.

The Nimrod is a maritime patrol aircraft that is a derivative of the Comet airliner, and Science 3 has done a training study on its behalf. Among Nimrod's functions are submarine hunting and killing. Its aircrew can be divided into the "front end" and the "back end," with the front end being the standard crew positions for flight control and navigation, and the back end having a number of crew positions directly dedicated to the details of search and destroy. The Nimrod has a simulator for the crew of the back end, called the Maritime Crew Trainer, and a study on how best to use it has been conducted by Alan Parfitt. Like the Phantom simulator study, the experiment is about training methods, but in this instance there is no transfer to the aircraft. The study is concerned entirely with aircrew behavior changes in the simulator, and so it is assumed that the best training conditions in the simulator produce the best transfer to the aircraft. Transfer of training to the aircraft is assumed, which is less than desirable, but the request of Nimrod aircraft for research purposes would have been a request with a foreordained negative response (it is not news to researchers that operational activities come first in the military).

Parfitt divided 12 operational aircrews into 3 groups of 4 crews, and they were given either 1, 2, or 3 simulator sessions a month for 6 months. A session was a 6-hour mission. Each group was further subdivided into 2 subgroups of 2 crews. A subgroup was given either a routine debriefing after a mission or an intensive debriefing in which the mission was criticized in detail, mistakes were pointed out, and recommendations were made about correct actions. An assessment crew,

relying mostly on rating scales, measured the performance of each crew throughout each session. The results were that the amount of simulator training had an uneven effect on crew performance, benefiting some activities and not others. The interactions between crew members were among the skills benefited; interactions are, after all, learnable skills, just like individual operator skills. Findings such as these show training-program managers how to use simulators effectively by giving training emphasis to those skills in which operational aircrews are known to be deficient. In addition, Parfitt found that better performance was associated with the intensive debriefing. These findings have now been incorporated in the Nimrod's training routines. (Jack A. Adams)

A MENTAL TEST FOR ALL SEASONS

Psychometrics, or mental testing as some would say, has a hard-headed empirical tradition of objective tests and statistics. Tests have been devised that measure such human abilities as perceptual, verbal, and reasoning, and batteries of them are weighted in different ways to predict success in training. Both the British Royal Air Force and US Air Force use batteries of ability tests in the selection of candidates for flying school. Mistakes in prediction are made (the correlation between test battery and success in training is not perfect), but they are far fewer than successes and so the tests are practically useful.

With the empirical traditions of psychometrics, it is surprising to find RAF psychologists (in a research unit of the RAF called Science 3), who monitor the testing of aircrews, evaluating a test whose origins are personality theory, projective techniques, and psychoanalysis—domains where there is ordinarily far less objectivity than psychometricians demand. This test is the Defense Mechanism Test (DMT) devised by Professor U. Kragh at the University of Lund, Sweden. The test is a projective one whose items are ambiguous stimuli that are subject to various interpretations. The Rorschach ink blot is an example of a projective test, and its stimuli are not only ambiguous but objectively meaningless. Whatever meaning an ink blot has lies in the perceptions of the observer, which are the source of its alleged value. By contrast, the DMT stimuli are ambiguous and objectively meaningful but are still capable of imposed meaning. For example, a sober-looking woman might be shown standing over a cat. Is she going to feed it? Speak fondly to it? Kill it? The subject of the DMT is asked to draw rough sketches and write brief descriptions of what he infers from the ambiguous stimuli. His responses are scored to yield an index of defense mechanisms, or the degree to which the subject mounts mental defenses against threats to his ego.

What do defense mechanisms have to do with flying? The idea is that the maintenance of defense mechanisms requires considerable psychic energy, leaving fewer mental resources to cope with the stresses of flying. All of this would strike the typical psychometrician in the armed forces as imaginative nonsense. Heads were turned, however, by the impressive performance which T. Neuman, a Swedish psychologist, reported for the DMT at the 1975 meeting of the Western European Association of Aviation Psychologists. Not only was there excellent prediction of failure in flying schools of the Swedish Air Force, but there was the prediction of accident behavior as well (the air forces and airlines of the world would dearly love to screen and ground their accident-prone pilots). The prediction of accident behavior by means of a personality test implies that accident-proneness is a dimension of personality that can be identified and measured, but there are many psychologists who do not believe it. True, some people have more accidents than others, but when accident opportunity (the exposure factor) is considered, and when random factors are taken into account (by chance, A can have more accidents than B), there is little left that can be ascribed to a systematic dimension of personality, it is argued. The RAF psychologists of Science 3, in the spirit of skepticism that motivates the replication of any visible research, are running their own evaluation of the DMT. It will be a while before their findings on the prediction of

flying success are available, and even longer before their findings on accident behavior are in hand.
(Jack A. Adams)

NEWS & NOTES

FORTHCOMING MEETINGS

A Summer School of Theoretical Physics on Ill-Condensed Matter will be held at Les Houches in the French Alps from 3 July to 18 August 1978. Seminars will be given on the physics of disordered systems: percolation and localization, glasses and spin glasses, alloys and liquids, and polymers. An introduction to the physics of defects, solitons, and instabilities will be included in the program. The Summer School is sponsored by the University of Grenoble and the NATO Advanced Study Institutes Program.

The organizers are R. Balian, R. Maynard, and G. Toulouse; further information can be obtained by writing to the Ecole d'Eté de Physique Théorique, 74310, Les Houches, France.

PERSONAL

Sir Hermann Bondi is moving from the UK Defence Ministry to take over the position of Chief Scientist in the Department of Energy vacated by Dr. Walter Marshall.

Prof. H. Charnock, Director of the Institute of Oceanographic Sciences, has been appointed to the Chair of Physical Oceanography at Southampton University from 1 February 1978. He held the chair from 1966 to 1971.

Dr. Joseph Duffy, Reader in Mechanical Engineering at Liverpool Polytechnic, has been appointed Professor of Mechanical Engineering at Rensselaer Polytechnic Institute, Troy, New York, for three years.

The award of a knighthood was given to Prof. F.C. Frank, a Henry Overton Wills Professor of Physics and Director of the H.H. Wills Physics Laboratory, University of Bristol, since 1969, and a founding member of the Polymer Physics Group of the Institute of Physics, London. He has published many articles dealing with dielectrics and with the physics of solids, in particular crystal dislocations, crystal growth, mechanical properties of polymers, and the mechanics of the earth's crust.

Another founding member of the Polymer Physics Group, Prof. Manfred Gordon, has been awarded the Jaroslav-Heyrovsky Gold Medal of the Czechoslovak Academy of Sciences. Gordon is Professor of Chemistry at the University of Essex in Colchester with interest in polymer science.

Dr. Peter G. Lowe, Lecturer in Engineering at Cambridge University and director of studies in engineering at Clare College, has been appointed to a Chair of Structural Engineering within the Department of Civil Engineering at Strathclyde University, Glasgow.

Dr. Tim Gray, Senior Lecturer and Deputy Director of Environmental Biology at the University of Liverpool, has been appointed to the Chair of Biology at the University of Essex.

Prof. E.W.J. Mitchell, Professor of Physics at Reading University, has been appointed Dr. Lee's Professor of Experimental Philosophy at Oxford University from 1 October 1978. He succeeds Prof. Brebis Bleaney, who is relinquishing the professorship and the headship of the Clarendon Laboratory to concentrate on research.

Prof. R.N. Pryor, Professor of Mining at the Royal School of Mines, London, and Head of the Department of Mining and Mineral Technology, has become President-Elect of the Institution of Mining and Metallurgy. He will assume the presidency in June 1978.

Professor W.E. Spear of the Carnegie Laboratory of Physics at the University of Dundee was the first recipient of a new prize—the Hewlett-Packard Award. It was presented to him on 28 July 1977 at the Conference on Electron Transport and Molecular Solids held at Leeds University. The

presentation was made by Dr. W.J. Merz, Chairman of the Condensed Matter Division of the European Physical Society. The award was for Professor Spear's pioneering work in developing methods for doping amorphous semiconductors.

Dr. D.J. Waddington, Senior Lecturer in Chemistry at the University of York, has been appointed to the Chair of Chemical Education.

OBITUARIES

Lord Adrian, Nobel Laureate, Chancellor of the University of Cambridge, 1968-75, Vice-Chancellor, 1957-59, and for many years Professor of Physiology and Master of Trinity College in the University, died on 1 September at the age of 87. In 1975 he was chosen to be the first Chancellor of Leicester University.

E.D. Adrian was an outstanding British physiologist and his work was devoted throughout to the central problems of neurophysiology. His EEG investigations formed the basis of, and provided the stimulus for, much of the research on this subject throughout the world. He extended Keith Lucas' experiments and analyses to the more complex phenomena of sensation and later to the central nervous system. This work proved to be a natural complement to that of Sir Charles Sherrington, many of whose deductions, obtained before the days of modern electrical recording and display, Adrian was able to make directly evident by sight and sound. Adrian and Sherrington shared the Nobel Prize in 1932.

Adrian received the Royal and the Copley Medals of the Royal Society, honorary doctorates from many universities, honorary membership in foreign societies, and was an editor of *The Journal of Physiology*. In 1955 he was elevated to the peerage.

Sir Harry Garner, who was Chief Scientist to the Ministry of Supply from 1949 to 1953, died on 8 August at the age of 85. He entered government service soon after WWI and held a number of posts in the scientific departments of the Air Ministry. He became Senior Scientific Officer at the Royal Aircraft Establishment in 1927 and was Chief Technical Officer at the Marine Aircraft Research Establishment at Felixstowe, also becoming Principal Director, Scientific Research (Air).

The death has been announced of Professor Sir Frederic Williams, aged 66. Prof. Williams' name will always be linked with electronic computers and in particular the "Williams tube," which applied the charge-storage property of a cathode-ray tube for computer memory and was used in parallel banks in all of the fast machines of the late 1940s and early 1950s. During WWII Williams worked at the Telecommunications Research Establishment (now incorporated into the Royal Signals and Radar Establishment), where he played a large part in the development of primary and secondary radar. It was then that he had the idea behind the cathode-ray-tube digital storage. After the war he worked at the University of Manchester, where he was responsible for one of the first stored-program digital computers. The team he assembled at Manchester carried on with the computer work which resulted in Manchester University's becoming a leader in this field.

Sir Frederic was a greatly respected figure in the university world; he was awarded Honorary Doctorates by Durham, Wales, and Sussex, and he was elected to fellowship of the Royal Society in 1950. Among the honors that he received were the Hughes Medal (of the Royal Society) and the first Benjamin Franklin Medal (of the Royal Society of Arts). In his own University he had held office as a Pro-Vice-Chancellor and as Dean of the Faculty of Science and of the Faculty of Music. He received a knighthood in 1976.

ONRL REPORTS

R-6-77 EFFICIENCIES OF VARIOUS METHODS FOR SOLAR CONVERSION by W.G. Soper

Three methods are examined for converting solar energy to electricity or shaft work: heat engines, thermal decomposition of water to produce H_2, and solar cells. Maximum efficiencies of conversion are found to lie between 20% and 50%. For most applications, the heat engine is superior to the water-splitting process.

R-7-77 PRELIMINARY DESCRIPTION AND SPECIFICATIONS FOR A DANISH COASTAL MARINE DATA COLLECTION SYSTEM by J.P. Simpson

To an increasing extent Denmark is faced with a series of problems linked with the safe navigation of large and deep draft ships through the Danish waters. This is particularly important in the narrow and shallow fairways of the Baltic approaches where the waters have a transient nature because of their position between the fresh Baltic and the saline Kattegat. Instantaneous sea level, sea state, current, sound speed, ice probability and buoyancy are among the factors to be considered when navigating the Danish straits. The Royal Danish Administration of Navigation and Hydrography has undertaken the job of developing a system to measure or compute these parameters, providing "real-time' oceanographic data to transiting ships.

R-8-77 ACUTE RHABDOMYOLYSIS FROM EATING QUAIL by J.B. Bateman

Acute rhabdomyolysis results from susceptible persons eating quail during the migrating season. The etiology is unknown. Muscular exercise is an important precipitating factor. In this paper the literature on this and related rhabdomyolytic and hemolytic syndromes is reviewed, ranging from biblical times to the present day. It seems likely that the responsible agent present in the quail is of dietary origin and that susceptibility to poisoning in man is based upon an inherited biochemical defect. In view of the importance and seriousness of acute exertional rhabdomyolysis among military personnel, all types of rhabdomyolytic illness are thought to be worthy of close attention.

C-5-77 DIRECT SATELLITE BROADCASTING by N.M. Blachman

The Symposium on Direct Satellite Broadcasting (DSB), held in Dublin 23-25 May 1977, included 17 papers discussing the potentialities and problems of this new medium, which is to bring television to private homes via either 1-meter paraboloid dishes or larger community antenna. This Symposium follows up the World Administrative Radio Conference of early 1977, which assigned frequencies for DSB in the 12-GHz band. Although intended primarily to rally support for DSB, the Symposium also included discussions

C-5-77 (cont'd)

of previous DSB work, planned experiments, technical specifications, cost comparisons, programming aspects, and difficulties, many of which remain to be resolved.

C-8-77

COLLOQUIUM ON OPTICAL FIBER CABLE, INSTITUTION OF ELECTRICAL ENGINEERS (UK) by D.A. Hart

This report presents short summaries of papers presented at a colloquium on optical fibers held in London on 17 May 1977. Topics include propagation, cable manufacture, strength, testing and installation of optical fiber cables.

C-9-77

INCOMAT 1977—INTERNATIONAL CONFERENCE MARTENSITIC TRANSFORMATIONS, KIEV, USSR, 16-19 MAY 1977 by J. Perkins

The third conference on martensitic transformations was held in Kiev in May 1977. This report presents a review of oral presentations made at the conference, generally in Russian, which provided a unique opportunity to learn of the extent of the Russian work in the field. Topics treated at this conference covered many aspects of martensitic transformations: morphology of transformation; thermodynamics and kinetics of transformation; impact of lattice stability; wave propagation of nucleation; crystallography and structures; effects of deformation, dislocations, and stacking faults; shape-memory effects; and effects of stresses and strains.