AD-A099 043 OFFICE OF NAVAL RESEARCH LONDON (ENGLAND) F/G 14/5

OPTICAL DATA PROCESSING IN EUROPE.(U)

DEC 81 D CASASENT

UNCLASSIFIED ONRL-R-8-80 NL

1 OF 1

AD A
099043

END

DATE FILMED

6-81

DTIC

LEVEL II

ONR LONDON REPORT

R-8-80

(12)

AD A099043

OFFICE OF NAVAL RESEARCH

BRANCH
OFFICE
LONDON
ENGLAND

OPTICAL DATA PROCESSING IN EUROPE

DAVID CASASENT*

31 DECEMBER 1981

*Carnegie Mellon University, Pittsburgh, PA

UNITED STATES OF AMERICA

81 5 18 035

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER R-8-80	2. GOVT ACCESSION NO. AD-A099 043	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) OPTICAL DATA PROCESSING IN EUROPE		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) David Casasent		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Office of Naval Research Branch Office London Box 39 FPO NY 09510		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 31 DE EMBER 1981
		13. NUMBER OF PAGES 19
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Bismuth Silicon Crystal
Optical Data Processing
Optical Signals
Seismic Signal Processing
TITUS Spatial Light Modulators
Wave polarization

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report contains short summaries of some current activities, accomplishments, and problems in France, the Federal Republic of Germany, and the United Kingdom in the field of optical data processing. Both university and industrial research laboratories are included. In all instances, the emphasis is on optical image and signal processing.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

OPTICAL DATA PROCESSING IN EUROPE

I INTRODUCTION

From 30 May - 29 August 1980, I was in residence as a visiting professor at the University of Toulon (Gessy Laboratories). The head of this laboratory is Prof. Georges Bonnet. During this time I worked closely with Guy Lebreton, who had previously spent seven months in my laboratory in the United States. Bonnet and another researcher from Gessy visited my lab in 1979. I was thus quite familiar with most of the personnel at this laboratory as well as their research. Gessy is the major signal and systems laboratory in France. It is also the main laboratory in France for all optical signal processing research. This has been made possible by a recent edict of the DRET (French military funding organization). Gessy works quite closely with government organizations, indus tries and other universities in France and elsewhere in Europe. This report is a summary of Gessy research activities and other similar activities in France, West Germany, and Great Britain in the area of optical data processing. Since my expertise and interest extend beyond optical processing techniques, I also discussed many other data processing problems during my various visits. In all instances, the emphasis was on optical image and signal processing.

Since Gessy is the center for Navy optical signal processing as well as other signal processing systems, this was an ideal central location from which to conduct my survey of optical processing in Europe. Most of the French universities and companies are participating in a research exchange program to unify and direct French research in optical processing; Gessy is an integral part of this effort. Gessy has a contract to survey and report on optical processing research in Europe (this work was originally intended to be part of a joint program with the US Air Force Office of Scientific Research (AFOSR); the status of the US part of this work is not clear at present).

Other major university research labs in France are Laboratoire d' Optique de Besançon, (LOBE [Prof. Vienot]) and the University of Paris (Profs. Lowenthal and Françon). Of the university laboratories I visited in France, LOBE appeared to be doing the most interesting applied optics research work. I was unable to arrange visits to several company facilities (this should be done at a future time). These included Matra in Toulouse (image processing, Dr. Lowitz), Thompson CSF in Paris (signal processing [radar]), and Nice (surface acoustic waves). Because of a shortage of travel funds, I was able to visit only the University College of London (UCL) in Britain; however UCL staff edited a recent special journal issue on signal processing (Proc IEEE 127 F4, Aug 1980) and they are knowledgeable of much of the research taking place in this field throughout the UK.

II FRANCE

1. Gessy Laboratory (University of Toulon) France

Optical signal processing research in Europe is centered at Gessy. Problems being addressed here include optical processing for active sonar and 3-D sonar array processing. Future programs will involve passive sonar and radar processing plus electronic warfare, adaptive phased array antenna processing, etc., applications. This group is also actively engaged in seismic signal processing. At present this research employs conventional signal processing techniques. However, the understanding of wave propagation in the associated media will greatly benefit Gessy's future work in sonar signal processing.

The key element in any optical data processor is the real-time and reusable-input (and quite often matched-spatial-filter) transducer. Much of the French research in optical signal processing employs 2-D spatial light modulators (SLM) rather than acoustooptical transducers. The most notable device is the TITUS electron-beam addressed transducer. Gessy is presently completing research testing and signal processing demonstrations on the PHOTOTITUS SLM. Since this latter device will no longer be commercially available, new work will emphasize the TITUS SLM.

Gessy is also most concerned with the accuracy of an optical signal processing system. This is of major importance (specifically the dynamic range, accuracy of positional data recording, and optical quality of the input transducer) in signal processing, and of lesser importance in image processing. To achieve these goals, improvements are being made in the TITUS to facilitate the use of the device in coherent optical signal processing (specifically, its optical quality, and the the accuracy of its electronic addressing systems are being improved). Tests on this improved SLM for sonar signal processing will be done at LEP (Laboratoire d'Electronique et de Physique Appliqué, Leimel-Bravannes, France) and Gessy in 1981.

A program in surface acoustic wave (SAW) signal processing was also planned to begin at Gessy in late 1980 in conjunction with Thompson CSF. I saw little bulk acousto-optic transducer and system research in Europe (it was only recently that the United States returned to this technology). This is partly because emphasis has been on research and also because electro-optical processing systems can presently be fabricated with presently available acousto-optic components. The BSO (bismuth-silicon oxide) crystal research at Thomson CSF is another major SLM subject that is at the forefront of dynamic holography media work. At Gessy, Lebreton, in particular, will be working with Thomson CSF on optical signal processing applications of this device as a matched spatial filter (MSF) media and as a mixing element for optical correlators during the coming years.

Sonar Array Signal Processing (TITUS SLM). A French Navy-sponsored signal processing program at Gessy to be conducted over the next several years will involve the use of optical signal processing techniques for phased-array data processing for sonar applications. The basic technique is to employ a 2-D SLM and an MSF. Raster recording of multiple Doppler signal replicas is necessary for this system. A key issue to be addressed in this application will be the accurate recording of the data from different detector elements. Specific attention will be given to accurate location of the starting position of the received signals. A preliminary analysis indicates that inaccuracies in the time history record will be of minimal concern if the starting location of the data is accurate. A second key issue in this work will be the phase quality of the SLM. This will require the TITUS device improvements noted under the LEP discussion later. If adequate phase quality is not possible on the SLM, the full processing gain of the received data cannot be achieved.

The immediate phased-array application is sonar. Attention is also being given to nonlinear arrays (US optical signal processing research, to my knowledge, has yet to consider extensively this aspect of optical sonar processing). The TITUS SLM will also be used in this program. Multiplexing is possible in this application because of the slow sonar data rate. Data buffering is a minor preprocessing inconvenience of a sequentially scanned SLM such as TITUS. This problem is not of major concern in this sonar application and the TITUS SLM thus appears adequate. 3-D sonar processing is also possible with this technique. A MSF must now be recorded, however. Several US Navy installations (NOSC and New London Laboratories as well as NRL) expressed interest in such a French system during Lebreton's US visit (once the system exists, the initial research has been conducted, and initial data results have been obtained). I note that this is for active sonar rather than passive sonar (at present).

SNR and Processing Gain of Optical Signal Processors. Initial experiments have been conducted at Gessy using a pseudo-random noise signal with controlled amounts of additive noise. Some of this work was performed over the summer of 1980. It concentrated on accurate data recording and photoreduction. The signal-to-noise ratio (SNR) output obtained for various input SONRs and signal space bandwidth products will be measured for film inputs and later with a TITUS or PHOTO-TITUS SLM. This work will be useful in showing how an optical system with given space bandwidth product and SNR can operate on given input SNR signals and obtain acceptable output signal SNR performance. Such concrete demonstrations and clear descriptions of them are of use in demonstrating what is possible with the large space bandwidth product data available and the real-time and parallel processing possible in an optical signal processing system.

Wave Polarization Studies (Eric de Bazalaire). Gessy personnal have an excellent background in physics. A recent thesis from that lab provided the first full and complete treatment of polarization, birefringence, and dichroic medium effects on wave propagation of signals. This work has many useful applications in signal processing and SLM operation. All results are unfortunately in French and the math is very complex. (After 8 hours of discussion, I understood the idea but not the details.) A complex modified Poincairé sphere model and a new Boule space model were needed and were developed. The Poincairé sphere model can enable treatment of signal and wave propagation including median birefringence

The model was experimentally verified and all new data is thus in rather complex graphical form only.

The technique is useful in the prediction of results of combining parts of totally polarized and unpolarized signals, coherent and partially coherent signals, interference of such signals, etc. It enables one to analyze the phase of elliptically polarized light (it is not in the direction of the electric field vector as many say) and the interference of two elliptically polarized waves that are not orthogonal, not equal in intensity, not propagating in the same direction but are partially coherent. It is clearly impossible to perform analysis of such problems by any other method. Such problems arise as light waves traverse SLMs and in sound wave propagation in the sea and earth (sonar and seismic data).

More specific applications of this analysis method are in electro-optic crystal modulation (a new operating mode for the TITUS SLM is possible based on such an analysis), and in wave propagation in the water (sonar applications) and earth layers (seismology and oil exploration). Application of this analysis technique to such wave propagation studies has resulted in the development of new signal processing methods that employ P (compression) and SH and SV (shear) wave propagation studies. One specific use demonstrated was distinguishing solid and porous earth layers for oil exploration (both media appear the same on a seismic trace unless the shear and compression wave states are properly treated). New directional detectors can be used to provide needed signal processing in this case.

A combined ellipsometer and interferometer was fabricated to allow measurements to be made of absolute path differences as small as 0.001Å in electrically dichroic media such as DKDP (deuterated KDP). This allows one to measure all dichroic and birefringent parameters and media thickness. Another use of this idea is in the measurement of strains in photoelastic materials. Such media are used in building bridge models, etc. on which strain analyses are then conducted. Double exposure holographic interferograms were also produced and a new system using phase conjugate reflection optics and Faraday isolator cells were fabricated and used to separate different multiple fringe patterns present. Recording of elliptical light holograms (in 1 nsec) was also necessary and was achieved in this effort.

<u>TV Feedback</u>. A project in its initial stages at Gessy will use the hybrid optical/digital TV feedback system of A. Lohmann. A CCD detector will be used. Testing of this unit and fabrication of the necessary support electronics to exercise it should yield useful results for optical processor system design and indications of expected performance from optical systems employing such elements. Such work is vitally needed and its documentation for the optics community will be most useful. Details of the feedback system and the algorithm to be used will not be available for a year.

2. LEP

This institute is located in Leimel-Brevannes, France. LEP is a research laboratory of Philips Corporation. Philips is a Dutch company, a fact which has caused it problems in acquiring French military research funding. Philips recently formed RTC (Philips Commercial Company and Philips Industrial Company) as well as SODERN (Sociéte Anonyme d'Etudes et Realisations Nucléaires: this facility fabricates elements and devices, and produces electronics as well as large-screen television displays). RTC and SODERN are French-based. This enables them to obtain French military research funding.

I visited LEP together with Lebreton (Gessy) and M. Lizot (Direction Des Recherches, Etudes et Techniques [DRET]). Present at this meeting were J. Graf, M. Petri and G. Marie of LEP as well as M. Constans and M. Beauzee of RTC and M. Desvignes and M. Frederick of SODERN.

The main purpose of the meeting was to establish future research directions for the PHOTOTITUS and TITUS spatial light modulator (SLM) devices manufactured by this company. Due to the extensive research performed by my US group on the electron-beam-addressed version of this device and because we have the only PHOTOTITUS device in the US, I was included in this meeting.

The structure of LEP has recently been revised. Marie is now in charge of the system division and Petri is in charge of electron gun systems. They are all most interested in pursuing work in signal processing. LEP has also performed much useful recent work in the area of large screen display simulators and image intensified work using micro channel plates. SODERN is presently producing military display systems for the US Air Force and Navy for simulators and cockpit displays. This work is being performed in conjunction with General Electric in the United States. Their work employs the electron-beam-addressed TITUS SLM. The present goals of their program are to increase size from 0.3 to 2 amp/cm^2, to increase crystal size from 28 x 38 mm^2 to 38 x 38 mm^2 and to decrease the grid spacing from 40 to 30 μm. Appendix A describes available systems and applications of this device being pursued by SODERN. Presently available applications and systems include: large screen live displays, air combat simulations, and simulation displays, all in color. (A good contact at SODERN is M. Desvignes, One Avenue Descartes, 94450 Limeil Brevannes.) This company, like most US ones is concerned with a large market availability for any elements and devices they pursue.

TITUS. This SLM is the electron-beam-addressed unit manufactured by LEP/RTC/SODERN. Philips developed a good monochrome display system using this SLM. Then as it was about to be marketed, interest switched and color displays came into demand. A color TITUS unit was built, but it is quite large and bulky as well as expensive. No future work on a color TITUS seems to be in progress. An active program is in progress at RTC as well as at SODERN on the above-mentioned system integration of TITUS into cockpit displays and battle simulators for the US Navy and Air Force.

<u>Coherent TITUS</u>. The noncoherent display market is much larger than the corresponding coherent light modulator market. As a result SODERN (as well as US companies) will require additional government support for research development of the coherent version of this light modulator. (It appears that the noncoherent display market will be able to support interest in a coherent TITUS SLM for several years). The main funds for this research will come from the French Navy at LeBrusc and from DRET. The research work and testing of this device will be performed at Gessy. The immediate application being addressed is active sonar. Work on 3-D sonar arrays as well as range, Doppler, and acceleration displays will also be performed. Future passive sonar processing work is also being discussed as is adaptive array processing. Details on these applications have yet to be formalized. However, Gessy is the key laboratory for this.

<u>TITUS (Ionic Polishing)</u>. Two main improvements in TITUS will be made to allow the use of the device in coherent processing of signals. These are: (1) a more accurate electronic system (to provide very accurate data recording) and (2) better optical quality (a program in ionic polishing is being used to achieve this). This latter area should be of use to many US companies and will also have more applications than merely to improve the TITUS device. Automated crystal polishing is necessary to decrease component costs and improve component reproducibility. Tests of these improved devices will be performed at Gessy with considerable interaction from LEP.

<u>TITUS (Radar and Microchannel Plate Systems)</u>. For present sonar applications presently being considered, signal data rates are such that TITUS is acceptable. Multi-channel multiplexing is suitable for this application. However, for radar applications, 50 MHz bandwidth signals appear possible with TITUS and this is not adequate for most advanced radar applications. System modifications for passive sonar applications of this device will be addressed at a later date. Use of a microchannel plate (LEP has used these for image intensifier devices) on TITUS was also discussed. In an earlier patent LEP considered a microchannel plate electron-beam-addressed light modulator. However, Marie does not feel that the necessary current density can be achieved at the output of the microchannel plate (the DKDP crystal target requires considerably more energy than do other materials). For radar, higher frequencies and bandwidths are necessary. Thus, a micro-channel plate imbedded between the addressing surface and the active electrooptic crystal would have provided improved performance and speed (the electron beam dwell time necessary on each point could thus be reduced and increased speed and bandwidth could be obtained). However, such a solution does not seem realistic.

Gessy will emphasize research on this 2-D SLM for real-time signal processing, both because US signal-processing research is concentrating on acoustooptic devices and because France (LEP) has several 2-D SLM technologies to be exploited. I do not believe that TITUS is of use in radar signal processing because of the bandwidth required, the large associated beam current density needed, and the fact that microchannel plate elements cannot be used to increase electron gain in this transducer.

PHOTOTITUS. Unfortunately, LEP has made a major decision to cease development of this optically addressed SLM. One reason is its limited resolution (this can be overcome by snapshot line addressing). However, for matched spatial filters, far larger resolution (or use of non-MSF and non-correlation processors) is needed. Limited algorithm and architectural work of this type appears to exist in France and Europe. The image addition, subtraction, differentiation, etc. operations possible in 2-D in parallel on this SLM have not been fully exploited. However, the decision has been made. The LEP research team on this device has been disbanded and the photo DKDP SLM is officially no longer available. The major problem with this device is that under high light energy and with excessive use, the silicon photoconductor layer on the unit crystallizes in many cases. This is an irreversible process. No immediate solution to this problem exists. Extensive research would be needed to solve it. For these reasons, I can concur with the decision made by LEP to abandon future manufacture of this SLM. Major attention on SLMs at LEP will henceforth be given to systems using the electron-beam-addressed TITUS SLM.

3. Gessy-ELF.

Recent work by Gessy for ELF (the major French oil company) has been most useful. ELF is centered in Pau. Mr. Henri of ELF visited [illegible] and I later visited him in Pau. He has recognized the need to understand better seismic signal processing (US oil companies have yet to realize this). Future cooperative work by ELF and Gessy may be of considerable use in this application as well as in sonar processing, and may employ optical techniques. In the next year, attention will be given to [illegible] propagation studies in the earth and sea media, to the necessary and [illegible] sible signal processing techniques and to the signal processing [illegible] that can be used. Conventional signal processing rather than optical techniques will be used in this work. Optical techniques may [illegible] after the problem is better defined and the media propagation effects are better understood (and hence the necessary signal processing [illegible] defined). This work should also be useful in sonar signal [illegible] and processing studies.

I visited Henri at Elf Aquitaine in Pau, France. We were [illegible] overall view of the company and a summary of their research, and we [illegible] several siesmic field units and data reduction facilities in operation. Their major concern is near-term results, but they understand and appreciate the need for signal processing. This section of ELF performs interpretations and seismic processing for the company. They use active [illegible] nals, and are considering the use of pseudo random codes. The signal used are low-frequency modulation (LFM) waveforms (10-80 Hz, 10 sec duration, with exponential taper for frequency compensation.) Viewing the collection of this data in the field was most impressive as were discussions with the seismic data analysis group. The team employs an intricate and useful data-collection technique with good field equipment. Three large trucks of special design are used to produce repetitious LFM data. Data collection and filtering is performed on line in a field van unit interfaced to many transducers spaced over the fields being investigated. [illegible]ssy will pursue propagation studies of [illegible] and also of new signal processing techniques over the next few years. Conventional hardward rather than optical processing methods will be used for the foreseeable future.

4. <u>CEFCA</u>

The Cefca Laboratories of the French Navy at Le Pradet have fabricated and used the Vampir Infrared Imaging System. M. Gaussorque is the main point of contact at Cefca, and M. Cohard was also present when I visited this institute in conjunction with the US IR Sensor Team. We saw the French Vampir IR Scanner System in operation. The status of the system and the support image processing used was not clear to me or to the team. Additional reports and discussions on this item may help. As I understand it, the present system scans a 2° x 5° field of view and provides a 144 x 512 x 8 bit image. Fifteen-degree coverage is achieved by three of the above scans. I believe the present system can process one 5° sector of image data on-line (the system evolves at one revolution/second). I don't know how it does 15° or can be extended to 360°. It also is not clear to me what the present processor can really do, which image processing operations are currently on-line, or what is necessary to achieve 360° coverage (72 times the present system capacity).

The basic system employs cooled detectors to obtain information on point emitters in the 3-5 and 8-12 micron IR bands. Its purpose is to detect low-flying missiles (such as the cruise missile) and aircraft. It also works well for locating submarine periscopes, etc. We saw actual data on the use of the system for the above applications as well as for locating the launch of a missile from a ship. This system employs different algorithms to suppress background clutter. Apparently, a 40 M bit/sec processing rate is presently being achieved.

This system is basically a point source detector and the imagery obtained is a by-product. Optical processing has not yet been applied to such point target detection problems either in France or in the United States. There are several possible algorithms and ideas for this, however, no funds have been applied to this application.

At CEFCA, we also discussed the Pyrana system and a French infrared image camera whose data was also shown to us. This system's main feature is its ability to calibrate image data. Its support digital processor performs integration, histogram computations, etc. The present system requires operator (specialist) ,interaction. Its use in future real-time systems is not clear.

(Mr. Claude Bozo conducts electron warfare display and signal processing in the same facility used by CECA).

5. <u>THOMPSON CSF</u>.

I visited this facility at Centre de Richerches, BP10, 91401 Orsey, France. M. Huginard was the host. The main research discussed concerned the BSO transverse work of this company. This work is highlighted in the following line items:

(1) "Theory of Crystal Physics", *Applied Physics Letters*, 29, 591 (1976). I do not believe operation of this device is fully understood; specifically, dichroism, polarization, and optical activity as well as space-charge and the electro-optic effect are all in operation in parallel. Subsequent studies of this device by Gessy may answer this problem. This work may also provide the necessary theory for future applications and use of this device. The work achieved on this transducer up to now is clearly most promising.

(2) "Double Exposure Holographic Interferometry," *Applied Optics*, 16, 1807 (1977). In this work a larger aperture and input data shift was found possible than had been expected. Bragg sensitivity of hologram elements must be studied in this work. The device has limitations: read-out is destructive (30 msec) and its diffraction efficiency is also low (2%). This seems to be due to the maintenance of linearity in the device. The element also appears to have different sensitivities for different spatial frequencies; however, this effect appears to be small. This SLM has good sensitivity at He-Ne wavelength and is thus of use in laser coherent addressing. The band pass spatial frequency response of the device appears to make it useful in matched spatial filtering for optical signal processing. More analysis and study of this application is needed.

(3) "Time Average Holographic Interferrometry," *Applied Optics*, 16, 2796 (1977). This application of this device has major commercial applications and will be further pursued by Thompson CSF.

(4) "Edge Differentiation," *Applied Optics*, 17, 2671 (1978). This application is of use as a preprocessing operation in optical image processing for missile guidance and other applications.

(5) "Polarization Effects," *Applied Optics*, 17, 1851 (1978). The use of polarization in this and other SLMs to decrease noise pattern information has been demonstrated. Much more work in this area is needed. This will be performed by Gessy. The entire issue of polarization studies in thick SLM materials needs additional analysis and quantification.

(6) "Phase Conjugate Applications," *Optics Letters*, 4, 21 (1979), and *Optics Letters*, 5, 102 (1980). These papers discuss a new double-pass system using an output reflection mirror as well as the use of this device for phase conjugate optical filtering.

(7) Holographic Interferrometry. This new commercial application is being pursued at Thompson CSF. The studies will involve the use of this element for testing loudspeakers to see mode structure in them. 1 m^2 objects will be studied using this system. This device works by time integration rather than previous descriptions.

(8) Quadratic Dependence and True Correlation Performance. The photo-conductivity effect in this device is quadratic in light amplitude.

[illegible] electrooptic effect is linear in the amplitude of the spatial charge. [illegible] this device should perform a true correlation as is needed in pattern recognition applications.

(9) Pattern Recognition Correlation. We saw a demonstration of this in a joint transform correlator employing this element as the mixing component. More quantification and analysis of the performance of the resultant system is needed. Gessy will pursue some of this work in its studies of BSO as a MSF and a dynamic holographic medium.

(10) Terminology. The term "nonlinear optics" applies to frequency [illegible] changes and in general these occur at optical frequencies rather [illegible] low frequencies. Thus BSO is not a true nonlinear optical material as was initially stated. It is more properly described as a nonlinear [illegible] medium. A saturable absorber is yet another term used. Dynamic holography requires true nonlinear optics. BSO is not a dynamic holographic material. Such a medium requires fast interaction. BSO actually employs a long integration time, much greater than the mobility time of carriers in the device. This gives BSO potential value as a time integrating element.

[illegible] Liquid Crystal SLM. This new device exists at Thompson CSF. It is [illegible] in structure (much less complex than the associated Hughes liquid [illegible] device). This element uses the BSO mainly as a photoconducting material. A system employing this device has been assembled. Tentative [illegible]ications of this element are as follows: *300 x 300 resolution*, [illegible] contrast ratio, 5 msec response, 50 volt operation required, 5 µJ/cm² [illegible]. Appendix B contains a description and preliminary results [illegible] of the new SLM device.

[illegible] CEPHAG (Centre d'Etude des Phenomes Aleatoires et Geophysiques).

This institute is located in Grenoble and is associated with CNRS. [illegible], CEPHAG did many experiments in the propagation of sonar signals [illegible] long distances. M. Eric Berrayer was the author of a thesis in this [illegible]. The general subject considered was sonar long distance signal trans[illegible] of monotone signals. The signals transmitted were 27 minutes [illegible]. They were emitted from a 200-meter-deep transmitter and received by a submarine at a depth of 100 meters. Monotone sinewave signals were used. The results obtained are summarized below:

(1) Fourier transform harmonics were of course observed from spectral analysis of the received signals.

(2) The Fourier transform spectrum was non symmetric. This implies that the received signals are complex, not real signals.

(3) The signal harmonics had a mean value 15-20 dB below the carrier and an instantaneous value of 3 dB below the carrier.

(4) Only 2-3% of the signal was found to go into the harmonics.

[illegible] the third harmonic was [illegible]

(6) The researchers tried to express the received signal as a deterministic and a random noise signal.

(7) They found a signal broadening of 0.05 Hz measured at the -30 dB point (for a 5.5 minute signal).

(8) They found a small (tenths of seconds) time widening of the received signal.

(9) They observed signal fading also.

(10) They found most statistical correlation between time evolutions of the signal and its harmonic received at one point when there was over 3 Hz separation between the signal harmonics.

(11) These studies helped to model the ocean medium and to determine the needed signal processing for data transmitted in this medium. The studies were also of use in deciding what processing was required for active and passive sonar.

7. ENPG (Engineering National Polytechnic School, Grenoble)

In October 1979, a research program was completed at ENPG. This study was completed with the thesis of M. Jean Paul Henrioux. In this work, the CEPHAG data listed above was used to describe an underwater FSK (Frequency-Shift Keying) code transmission system. A large (3 Hz) separation between frequencies was used. The work was mainly mathematical and statistical analysis. It was not complete, since only 3% of the possible data limit was used. However the researchers did perform experiments also. A time coding (to compensate for fading effects) and frequency coding (to produce SNR [signal-to-noise ratio] gain) were used with nine different time slots (Hamming code) and seven different frequencies (FSK) for each information bit. 50 kM and 100 kM transmission distances were considered. The parameters found best for these two cases were: a carrier frequency of 800 and 500 Hz (both 800 and 500 Hz frequencies were used at the long distance and only 800 Hz at the short distance); code bandwidth of 100 Hz and 50 Hz; bit length of 7.28 and 2.56 sec; a period of 4 sec and 8 sec; a power of 5 W/bit and 100 W/bit for the two corresponding distances.

8. Thompson CSF, Nice

SAW (Surface Acoustic Wave) research is centered at Thompson CSF in Nice. We did not find evidence of any active programs in acousto-optic signal processing work in France. Research within the radar groups of several French companies (e.g. Thompson CSF) should be investigated to asertain the status of acousto-optic signal processing research.

9. Le Brusc, France (Navy Lab)

I visited Laboratoire de Detection Sous-Marin (a lab for sonar detection). Its formal name (acronym) is GERDSM, but it is always simply called Le Brusc. Dr. Lamblu was the host for my visit. I had met several times before with Dr. Henri Mermoz, head of Le Brusc and chief advisor for research in the French Navy. They are most interested in optical signal processing for diverse applications and fund research at several universities.

This lab does most of the French sonar signal studies and fabricates prototype systems. Past projects include: Cormoran (ultra deep towed arrays), Duba (a new towed-array system), airborne systems, and general ASW (Antisubmarine Warfare) work. Development of their systems is done by private industry under LeBrusc contract. This is a key lab as it has charge of the design, study, development and evaluation of future French Navy sonar systems. The lab has other facilities including two lakes elsewhere in France for large system tests, a 6,000-element hydrophone array (Berthe) at Cape Ferrat, and 3 large acoustic tanks at Le Brusc with pressure and temperature control.

I saw their transducer division and we discussed their sound propagation studies, but major interest was on signal processing. Active signals used have included: pure tones, LFM (low-frequency modulation) and hyperbolic (no Doppler problems).

They employ narrow band spectral filtering prior to processing the data. Up to 30 order filters are used in specific cases but 5-6 order filters are the common ones. Beamforming is performed on the received sonar array data. Emphasis is on adaptive processing techniques (adaptive to the spectrum of the noise and input angle, frequency, time, and polarization). They employ the normal covariance matrix inversion algorithm using open-loop optimization (for active systems) and closed-loop optimization (for passive systems). An MSF correlation is then performed with the ability to handle many beams or many Doppler channels in parallel.

I saw data from a recent (Jan. 1980) field test using an *array of sonar arrays* with a 15° beam angle and various separations between a target and a noise source in the water (0°, 7.5°, 15°, etc.). The purpose of the experiment was to measure the effectiveness of various subarray and suboptimal processing algorithms on discriminating the target from the noise source. The basic processing technique used was to process data from "sub" parts of the sensor array to obtain a suboptimal solution W for the adaptive antenna array formula $WS^*=M$, where M is the convariance matrix and S is the steering vector. This subarray processing was used because the data were of such low quality (insufficient number of bits). For these cases, such subarray processing was found to be adequate. Their tests showed that two subarrays were adequate (Input SNR was -20 dB and half beam techniques were used).

The most attractive algorithm (to Le Brusc) at present is to compute the eigenvectors and eigenvalues of the crosspower spectrum matrix of signals from N sensors with M noise sources present ($M<N$). When the N eigenvalues of these matrices are then computed and ordered, it is found that N-M eigenvalues are equal and are the square root of the variance

of the independent noise sources. The other M eigenvalues are larger and equal the eigenvalues of the sources alone. Their corresponding eigenvectors form the basis for direction vectors of a sonar array of arrays. From these eigenvectors and eigenvalues, we can thus obtain the position and spectrum of the M sources.

This latter algorithm can be realized on an optical vector/matrix processor. Le Brusc is presently funding Gessy labs to develop an optical signal processor to perform the cross-correlation operations and other functions. Present post processing (digital) algorithms will require a complex-valued output correlation from the optical system.

10. Laboratoire D'Optique de Besancon (LOBE)

Prof. Vienot is head of this lab group (25030 Besaçon France). His recent research has involved space-time optics and their dualities. This work is continuing. I met with Vienot for one day and reviewed new US optical signal processing research. Vienot found our new general optical processor formulation with general kernel functions to be very good in explaining his space-time optics. He also said that he would recommend that France pursue more applied optics research.

I also met with Dr. Duvernoy for 1 day at LOBE and we discussed his recent basis-function decomposition and synthetic discriminant-function optical-pattern recognition research on statistical optical pattern recognition. Duvernoy has used K-L transforms and chromatic filtering with a hyperspace analysis to do data clustering and classification. His applications include: (1) Handwriting analysis. His new work in this area will involve Kalman filters to predict handwriting changes. It will then detect them when they occur and relate this to changes in the writer's attitude, etc. (Optical Kalman filters have many missile guidance and signal processing applications.) (2) Multisensor image processing. Here a wavelength chromatic basis set is used. Duvernoy noted differences in printed pictures and true natural scenes together with the increased dimensionality of the data when man-made objects were present in the scene (and when blue sky was in the image). He is also building a system with an optical pupil and electronics in a camera to process breast thermograms using his previously described optical/digital system. (3) Electron Perception. Duvernoy is going to build a device that will tell whether input data is of high or low frequency. He will do this using a Fourier transform basis set and simple mean and variance optical filters with noncoherent light. A training set will be used and noise effects of the system analyzed. (4) Analysis of statistical texture and random variable parameters, of Roman ruins. The problem is first to find the statistical parameters of the texture and then design and build the optical system to extract this information.

Dr. La Court at LOBE is continuing his wavelength diversity processing work and has recently used such systems to realize space-variant operations. His new work will be to use space-time optics to benefit from causality effects. The principle is that the temporal impulse response and the pupil shape used are related.

Speckle work, including new wavelength speckle ideas, is being continued to measure machine parts used in missiles. Partial coherence work by Courjeon and Bulabois at LOBE is also being conducted. This work is similar to that of H. Carter (US Navy Research Lab). The purpose of the research is to develop a pupil to place in a coherent optical system to adjust the system's output to make it more able to focus light without the need for coherence and for use with extended sources.

11. Matra

This is the major French company associated with advance missile systems, sensors and electronic warfare. It has many branches.

Matra at BP1, Velizy-Villacoublay 78140 France (phone 946. 96. 00) is the Space Division. They are fabricating the electronic Command and Data Management Subsystem (CDMS) for Spacelab for the joint ESA/NASA program. Matra Optique at 93 Ave. Victor Hugo, BP 209, 92505 Ruiel Maimaison Cedex, France (phone 749, 03, 45) is the optics branch. They make the Traster image recorder system, and the Acotam and Acomat OTF (Optical Transfer Function) measurement systems (the former computes the OTF from the autocorrelation of a wavefront obtained interferometrically, the latter computes the OTF from the Fourier transform or the convolution by a sinusoidal transparency of an object image. I visited the Matra image processing group at Clamart, France, under Dr. G.E. Lowitz. This group and the system described was to be moved to Toulouse France (Matra) in September 1980, with most of the Space Division of Matra.

Lowitz's group has performed much good image processing in the past 3-4 years. This work is well-known in Europe as is Lowitz himself. He is concerned with processing 800 images per day and thus his emphasis has been on dimensionality reduction (otherwise one cannot do the problem). He employs KL transforms to achieve this (a new real-time KL transform hardware system was built to realize this). His next step is based on the philosophy that simple processing techniques must be used to achieve real-time processing. He thus chose a new modified histogram computation technique and has achieved good classification results with it. He notes that the histogram contains much information that is of use in pattern recognition and that histogram computation is easy to realize in hardware (digital).

He first concentrated on reducing the dimensionality of multisensor data (to reduce the uncertainty of the data). A digital hardware real-time fast KL processor achieves this (over 93% of multisensor data is contained in the first two KL eigenvectors). The processing used on this reduced dimensionality data is computation of a modified histogram. He claims that this is the best estimator for radiometry data. His results seem to support the claims made. He has recently shown that analysis of the Fourier transform of the histogram of multisensor data is of use in pattern classification. His recent work has also shown that the Walsh, KL, Sobel and other preprocessing operations yiel quite similar results and thus the simplest one should be used as the preprocessor for histogram computations or their Fourier transforms. This system will now be built and used.

Lowitz seems to be the one who suggested the KL technique to Duvernoy. He also noted that he performed a KL analysis on ship resonances for Dr. Mernoz at Le Brusc and from them could find the ship's dimensions, etc. He performs no optical processing, but others seem to implement his ideas in new and good optical pattern recognition systems.

12. ONERA (Chatillion, France)

Mr. Daure at this company will be making a noncoherent optical processor for adaptive radar for DGRST (Delegation Generale a la Recherche Scientifique et Technique). (Lebreton at Gessy can obtain information on this system.) DRET funding for this work will be transferred to a different DRET group. This company also does work on laser measurements of flow rates using classical systems.

13. University of Rennes, (Prof. Argues)

I spent a day with Prof. Argues. He is a theoretician concerned with decision theory. His work is done for CCETT (television and telecommunications) on satellite transmission and communications problems with no pattern recognition or reconnaissance applications (rather only good image transmission for TV use).

Several of his points seem worth noting here. Argüez considers detection of a signal of known short duration T in continuous wave noise. The time of occurrence of the signal is not known and a limited search bandwidth is assumed. He recommends the use of least square estimation when little is known of the probability laws, and the employment of maximum likelihood estimation when better knowledge is available. He emphasizes that in cases of poor SNR, one must be specific about the problem and he offers the reminder that the same solution does not hold for different problems characterized by poor SNR. He is working on a general methodology to use in different problems. (Work on decision theory in optical processors is needed and hence I include this short note.)

14. LETI

Electroded SLMs were originally developed for displays, page composers, etc. There are indications that they may be adapted for use as non-coherent optical vector-matrix processors. Many manufacturers of such components exist in Europe. LETI (near Grenoble), in work for CNET (telecommunications), has developed a 256 x 256 liquid crystal device only 2 cm x 2 cm. Discussions with researchers who tested this device revealed several problems: field fringing with time (perpendicular alignment liquid crystals would be better), the need for polarized input light, and the small (40 Hz) frequency bandpass (this seems to be the major problems). The device tested had 80 μm cells with 10 μm separation between cells and 16 grey levels. The unit was not sealed. Thompson CSF should be able to produce a better unit (for $5,000 - $10,000). Use of twisted nematic devices or liquid crystals with positive dielectric anistrophy may be best. A homeotropic liquid crystal alignment (normal to the cell walls) yields a stronger and more natural state with less temporal drift than would occur with a cell using liquid crystals with parallel alignment.

Plessey (London) fabricates and sells PLZT (Pb-based Lanthanum-doped Zirconate Titanates) electroded modulators. Linear arrays of 100 elements and wide area (10 mm x 10 mm) cells are commercially available. They are expensive and high resolution does not seem possible, however.

15. CNET (Centre National d'Etudes des Telecommunications)

This is the French national center for the study of telecommunications, under the French government. I visited the branch of CNET in 22301 Lannion, France. My host was Dr. J. LeMezec. His work (roughly translated) is concerned with direction of information and the cooperative exchange of technology (i.e. new technology). This large 1,300-person facility conducts much optics research. They had the first laser in France and several PHOTOTITUS SLM devices. Some holographic memory work lingers on here and some of the people we visited had experience in acoustooptic signal processing. However, major attention is given to fiber-optic work. They are facing the problem of measurement accuracy and standardization issues of fiber-optic system components.

Propagation and radiolink designs are also under extensive study with multipath and frequency selective fading being problems of concern. We also saw the INTELSAT antenna systems and associated processors used for TV and telephone transmissions.

III GERMANY

1. University of Erlangen

The Physikalisches Institut of the University of Erlangen (Erwin-Rommel Strasse 1, D8520 Erlangen) is the center for most of the optical computing in Germany. Prof. Lohmann (head of this lab) is president of the International Commission on Optics and is knowledgeable about most of the optical computing work in Germany. About 20 researchers and post-doctoral students in optics are engaged in a wide variety of optical computing projects with some specific application, but mainly concerned with the development of new ideas.

Research on the TV feedback system first described by Lohmann several years ago is still continuing. Attention has shifted, however, from its use in performing logic function operations to iterative image restoration. This appears to me to be a more practical application. The new work has thus far involved an analysis of different iterative algorithms with attention to the one that is best for the TV feedback system with regard to gain, error sources, etc. Digital simulations of the system have been done and implementation of these theoretical ideas was to begin in the fall of 1980. For many years, this group has worked on image restoration of scenes blurred by light scattering in moving diffuse media. Many algorithms and techniques have been used and compared. Recently, outdoor tests have been performed.

Some adjunct optical operations that are of use as image preprocessing steps for pattern recognition systems have also been completed recently. These include: use of the angular sensitivity of Bragg holograms for high-pass image filtering (this technique performs only 1-D edge enhancement, but the fact that filtering can be done in the image rather than the frequency plane is quite attractive); and a volume hologram laser scanner with high diffraction efficiency and a flexible scan pattern. No future work on these projects is presently planned. A nonredundant pattern recognition technique using multiple synthetic discriminant functions that results in multiple correlation outputs was published in 1979. This system requires fewer filters than other methods because binary-coding of the multiple correlation outputs provides the decision needed. The need to shift the inputs or to align input data exactly is a disadvantage of this scheme, but it provides a good study of basic functions and more important, it is a non-MSF pattern recognition scheme.

Two new projects on which only preliminary data have been obtained are: statistical data analysis by optical processing (present experiments have considered only determining the motility of bacteria by many frame-to-frame correlations); and an optical system to compute histograms (attention is being given only to halftone images, however).

A major new research area will be the use of Wigner distribution functions and their optical realization. These functions are fundamental to many areas such as radiometry and coherence studies. The physical interpretation of the functional displays, and how various optical system transfer functions are describable by simple geometrical changes in the Wigner function display are most interesting. Thus, one major use of this function will be as a general common description of information processing. Applications of the use of this function that are presently being pursued are directed to the production of speech spectrograms optically and to the use of their Wigner function display patterns for recognition of speech patterns and for identification of specific speakers.

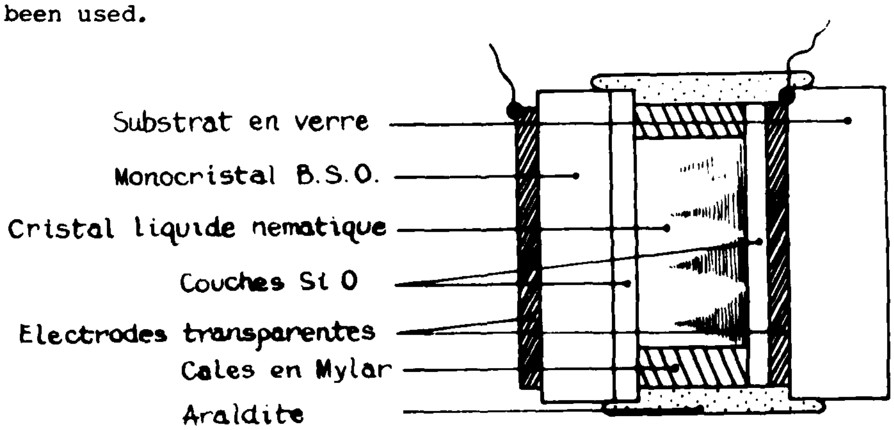
Another major optical processing research application being actively pursued is the use of speckle interferometry and holography to improve the resolution of astronomical telescopes and stellar imagery. The basic concepts and areas are old, but these researchers have achieved results (working with film) that are most interesting to astronomers. The large volume of data to be processed in such cases and the good and useful results that they have thus far obtained were reasons why this application area was chosen. A major portion of the ICO conference in 1981 will address this topic.

Mr. Bartelt of this institute has pioneered much of the present wavelength-coding work in optical processing. The major motivation for this work is the transmission of imagery over fiber-optic lines. They have built a system and demonstrated its use. It seems useful for short trans-

The research of the Electronic and Electrical Engineering Department of UCL is briefly summarized below. The 20 academic staff and 40 students in this department are deeply involved in radar processing and other areas for the UK and NATO. The three groups of special interest here are electromagnetics, physical electronics and systems. The electromagnetics group is concerned with microstrip waveguides, new antenna structures, etc. The physical electronics group is engaged in research on surface acoustic waves and builds acoustooptics (with emphasis on new transducers). They possess a large and extensive support facility with equipment for the production of thin films, ion implantation, plasma etching, and optical waveguide and integrated optics fabrication (emphasis in the latter area is on grating type lens fabrication). Acoustic microscopy for medical and microelectronic applications is another major research topic of this group.

Research in the systems group includes fiber optics for distributed modular radar processors, communications within aircraft, ships, tanks, etc., as well as work on new transducers that can be applied without breaking the fibers. Their work emphasizes the use of multimode fibers and some fiber-optic sensor work.

The majority of my discussions with this group concerned the radar processing, systems and antenna work of Prof. John Forrest and his colleagues. They have recently edited a special issue of *IEEE* on phased array radar (*PROC IEEE* 127 F 4, Aug 1980). Their work on modular radar processor with fiber optic communications is summarized in this issue. Their present interest is in bistable radar for military and other uses. They have also done much antenna work; recent efforts have included circular arrays for null steering and mobile use as well as two antenna systems with wide and narrow (fine resolution) spacings; the two antenna outputs are multiplied or mixed. The addition of a widely spaced antenna array on aircraft or ships can aid in landing or harbor navigation when high resolution is needed. In such cases the normal wide-beam antenna is used for transmission and the adjunct antenna with widely-spaced elements (fine resolution) is used for reception. Optical processing is clearly of use in this case. A project on noise radar is one of the most advanced in this field and one for which acousto-optic time-integration correlation has been used.



STRUCTURE DE LA VALVE OPTIQUE

missions within a shop or building. Use of wavelength as an adjunct parameter in optical processors has also resulted in other new optical processing systems as follows: a new Doppler signal processor (where changes in the wavelength of the light used produces different scaled versions of the input data); new correlation systems where the color of the light is the shift variable that denotes the location of the reference pattern in the input data; texture-coding techniques (in the image and frequency plane) to produce pseudocolor coded imagery; use of wavelength diversity techniques in the nonredundant pattern recognition system noted earlier. In general, more work on 2D to 1D data conversion in these systems is still needed, although use of tilted gratings seems useful in low resolution applications.

2. Other Optics Research in Germany

Six other research groups in Germany that deserve mention are highlighted below.

(a) Siemens Forschungs Laboratorium, (Dr. Rosenberger 8000 Munchen, New Perlach). Research activities include: fiber optics, holographic ID cards and thermo-plastic light modulators.

(b) DFVRL (Dr. F. Lanzel, 8000 Munchen, Oberpfaffen Hafen). Lanzl's research activities in general concern remote sensing. He also did earlier university work on optical TV feedback.

(c) Institut für Nachrichtenticknick der Tu (Prof. H. Platzer, 8000 Munchen, Arcisstrasse). Platzer's research includes a hybrid optical digital system for texture analysis and coded aperture tomography.

(d) Institut für Medizin-Optik der University (Prof. R. Rohler, 8000 Munchen, Barbarastrasse). Rohler's research is in physiological optics. He recently considered CCD detector nonuniformity problems and devised a new signal processor (using physiological optics concepts) to overcome such detector problems. The system is apparently quite like the human eye.

(e) GSF, (Prof. H. Waldelick, 8000 Munchen Neuherbert). Waldelich organizes most German laser conferences. His research is in radiology and pattern recognition in medicine.

(f) Prof. Olaf Bryngdahl of the Physics Department of the University of Essen is completing his new lab. Startup is slow but he has four of Lohmann's students. His interests are in nonredundant pattern recognition, space-variant systems and halftone imagery.

IV UNITED KINGDOM

My 3 months in Europe ended with 3 1/2 days in London where I visited with ONR and AFOSR scientific personnel (Dr. W.J. Condell, Maj. J.W. Bailey and others) and spent one day at University College London (UCL), where I gave a 1-hour seminar summarizing recent US optical signal processing work.

APPENDIX A

ADDRESSES OF SELECTED
EUROPEAN ODP RESEARCHERS

G. Lebreton
Laboratoire Gessy
Université de Toulon
831030 La Garde, France

J.P. Huinard
Thompson CSF
Laboratoire Central de Recherches
Domaine de Corbeville
91401 Orsay France

G. Marie
Laboratoire d'Electronique de Physique
Limeil-Brevannes, France

A. Lohmann
Physikalisches Institut
Universitat Erlangen-Numberg
D 8520 Erlangen
Federal Republic of Germany

J. Vienot
Laboratoire de Physique Generale et Optique
Université de Franche Comte
25030 Besancon cedex, France

J. Forrest
University College
Department of Electronic and Electrical Engineering
London, England

APPENDIX B

TITUS LIGHT VALVE PROJECTION SYSTEM

This new video image projection system is designed for real time reproduction of color data on any type of medium-to large-sized screen.

It is suitable for applications requiring high brightness and image resolution or special features such as slow scan, random access, digital and/or analog inputs. Its high luminous output also makes it suitable for use in normal indoor-light environments.

IMAGE FEATURES

High luminous output: allowed by the separation between the two main functions: *light production and image modulation.*

Memory: between two scans, the image is stored without decay on the crystal target: if scanning is interrupted, the projected image can so be preserved for several minutes. The phenomenon introduces neither lag nor smearing in moving or steady images.

This same property also implies:

- that the image is completely *flicker free;*
- that the image may be locally erased/re-written without change for the other parts, by the use of subrasters.

The video sources can be analog and/or digital.

No raster line structure in uniform illuminance areas: the optical signal is independent of electron beam current intensity.

Random access image writing: The conjunction of the various previous characteristics—memory, independence of beam intensity—affords great versatility in the use of the projector for any type of image.

Compensation of optical distortions: for projection on curved and/or oblique screens.

APPLICATION FIELDS

- simulation for air, sea and land combat, and navigation,
- Situation displays e.g. command centers, operation rooms, firing range supervision,
- real time tele-conference in large rooms,
- large screen live telecast,
- educational displays in scientific, technical or medical fields.

APPENDIX C

Des renseignements complémentaires sur ces études peuvent vous ê tre donnés
Monsieur HOMBROUCK
Laboratoire Central de Recherches de THOMPSON-CSF
Domaine de Corbeville
B.P. n° 10 - 9140J ORSAY
Tél.: 941.82.40

OXYDE DE BISMUTH-SILICIUM/CRISTAL LIQUIDE - BSO/XL

De nouvelles techniques d'enregistrement et de traitement des données ont été mises en oeuvre à la suite du développement de sources de lumière cohérente que sont les lasers. Ces techniques ont bénéficié aussi ce la mise au point de supports photosensibles sur lesquels il est aisé a- inscrire rapidement, en temps réel et en parallèle, es informations existant sous forme optique.

Ay LABORATOIRE CENTRAL DE RECHERCHES de THOMSON-CSF (L.C.R.), les travaux de préparation, de caractérisation et d'optimisation de ces supports ont porté, entre autres, sur une nouvelle classe de matériaux électro-optiques photoconducteurs: les monocristaux d'Oxyde de Bismuth-Silicium (Bi_{12} Si O_2) ou B.S.O.).

La faisabilité de l'enregistrement holographique en temps réel sur ces supports B.S.O. a été démontrée par le L.C.R. au cours des derniers mois.

Le L.C.R. présente à l'Exposition de Physique 1979 une expérience en fonctionnement qui rassemble les résultats de ces travaux ayant conduit à l'élaboration d'une valve optique capable d'assurer la visualisation et la projection sur un écran d'informations introduites sous forme optique par le balayage d'une faisceau laser.

LA VALVE OPTIQUE

Schématiquement, la valve optique est constituée de deux éléments: l'élément photoconducteur et l'élément électro-optique.

DA

FILM

6 –