AD-A129 442   FREE ELECTRON LASER RESEARCH IN EUROPE(U) OFFICE OF   1/1
NAVAL RESEARCH LONDON (ENGLAND) J R NEIGHBOURS
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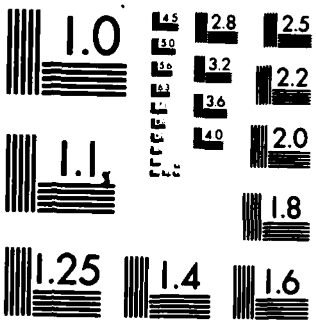

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FREE ELECTRON LASER RESEARCH IN EUROPE

J.R. NEIGHBOURS

3 MARCH 1983

UNITED STATES OF AMERICA

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER R-3-83	2. GOVT ACCESSION NO. AD-A129442	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Free Electron Laser Research in Europe		5. TYPE OF REPORT & PERIOD COVERED Technical
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J.R. Neighbours		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US 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 3 March 1983
		13. NUMBER OF PAGES 12
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)

Free electron laser	Relativistic electron beam
Gain	Undulator
Stimulated emission	Wiggler magnet
Spontaneous emission	Microwaves

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

This report describes the activity in free electron laser research in France, Israel, Italy, and the United Kingdom. In addition, the report lists key scientists and their recent works.

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CONTENTS

FREE ELECTRON LASER RESEARCH IN EUROPE

1 INTRODUCTION

This report provides an overview of the status of free electron laser (FEL) research in Europe as of early 1982. Most of the material was obtained during discussions with scientists at the sites listed. The report is arranged alphabetically by country, and gives laboratory addresses, principal scientists, and short descriptions of research.

2 FRANCE

Laboratoire de Physique des Milieux Ionises (PMI)

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L. Vallier
K.L. Felch
W.D. Jones

Recent Publications

K.L. Felch et al., "Collective Free-Electron Laser Studies," *IEEE J. Quant. Elect.*, QE-17 (1981), 1354.

M. Gazaix et al., *Interaction Between a Thin Polyethylene Target and a Relativistic Electron Beam*, p 473.

K. Felch, L. Vallier, and J.M. Buzzi, *Collective Free-Electron Laser in Resonant Pump Conditions: Experiment and Theory*, p 231.

K. Felch et al., *Experimental Studies of the Quality of Intense Magnetized Electron Beams Used for Microwave Generation*, p 971.

H.J. Doucet, ed., *Proceedings of Fourth International Topical Conference on High-Power Electron and Ion-Beam Research and Technology*, (Available from Laboratoire de Physique des Milieux Ionises, Ecole Polytechnique, 91128 Palaiseau, France).

K. Felch and L. Vallier, "Calibration of a Millimeter Microwave Grating Spectrometer," (To be published in *Rev. Sci. Instrum.*).

Summary

This relatively small group devoted to studying the FEL in the collective regime is headed by Prof. Doucet. Buzzi and Vallier are permanent staff; Felch was a postdoctoral associate who has since left the Ecole Polytechnique. Jones is an American visitor from the University of South Florida who has collaborated extensively with Doucet.

The group is studying the FEL in the special situation of resonance (Raman) effects in a magnetic field. The approach is to elucidate the basic physical effects that are important in a single pass of the electron beam--not necessarily to develop a working FEL.

Traditionally, Raman scattering is described as the process occurring when light passing through a medium undergoes a change in frequency (inelastic scattering) and a random alteration of phase. In an FEL, relativistic electrons pass through a wiggler magnet which has a periodic transverse field. When the electron beam is considered, the field of the wiggler magnet is equivalent to a high powered electromagnetic wave propagating in the opposite direction. The FEL laser radiation is that which is Raman back-scattered by the electron beam.

An intense relativistic electron beam can propagate in vacuum only with a longitudinal guiding magnetic field B_z to prevent spreading of the beam. Interaction of the transverse component of the electron velocity with the longitudinal magnetic field induces cyclotron-type motion of the electrons in addition to translation so that the electrons follow helical paths. When the electron motion induced by the wiggler is of the same period as that of the cyclotron motion, a resonance may occur.

In experiments at the PMI, a weak helical field was used as the wiggler, along with longitudinal guiding fields of 16 to 20 kG. A PULSERAD 110A electron beam generator provided a 20-ns, 1-MeV, 15-kA electron pulse in a foil-less diode. The annular beam propagated in a 2-m drift tube that had a teflon window at the end for transmission of microwave radiation. The resulting radiation was analyzed using a microwave grating spectrometer built at the PMI; the device was tunable between 50 and 350 GHz.

Although only a very small (20 G on axis) helical pump field was needed to initiate microwave emission, no emission was observed for zero pump field. The emission occurred when the resonance condition was fulfilled and was broadband over the range of the spectrometer. At low pump fields the microwave power was strongly dependent on the pump field, but it tended to saturate at higher values. Details of the experiments, the results of which are not completely understood, are given in the publications cited earlier.

The results might depend on beam quality, beam duration, or the position of the beam with respect to the helical field axis. Plans at the PMI are to produce an intense beam in which the limit on beam quality (energy spread) is from space charge. A patent for a device to achieve this goal has been filed. Other plans are to investigate the regime of very intense magnetic fields. Doucet has a patent on a device to produce intense, short period, transverse magnetic fields by putting a screw thread on the inside of the slit copper cylinders used to concentrate the magnetic field in a pulsed solenoid. Using pulses between 10 and 100 μs in duration, Doucet expects to obtain longitudinal fields of 100 to 200 kG and transverse fields of 10 to 20 kG. He believes that a thread pitch as small as 0.1 mm can be used; below this value, the skin depth will begin to affect operation of the device.

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D.A.G. Deacon
K.E. Robinson
Y. Farge
Y. Petroff

Recent Publications

C. Bazin et al., "First Results of a Superconducting Undulator on the ACO Storage Ring," *Journ. Physique-Lett.*, 41 (1980), L547.

D.A.G. Deacon et al., "Gain Measurement on the ACO Storage Ring," (L.U.R.E. Report, March 1981; to be published in *Proc. 1981 Particle Accel. Conf. IEEE Transactions in Nuclear Science*).

Summary

This is a joint project between Stanford and the L.U.R.E. group of the Universite Paris-Sud. Madey, Deacon, and Robinson are from Stanford; Farge and Petroff, who is nominally in charge, are from L.U.R.E. Much of the actual experimental work has been done by Deacon, who came to L.U.R.E. in early 1980 and will remain there at least until the end of 1982.

The ACO storage ring is a 22-m-circumference machine designed to operate in the range between the injection energy of 240 MeV and the maximum energy of 540 MeV. With a stored current of 100 mA, the machine has alternate curved and straight sections and fourfold symmetry with a maximum length of 1.3 m in a straight section. The radio frequency (RF) drive frequency is 27.2 mHz. The average radius of the machine is $22/2\pi = 3.50$ m, and the actual radius of bending in the bending magnets is 1.1 m. Used primarily for synchrotron radiation research in the ultraviolet, the machine has three beam lines for that work alone. The remaining straight section is available for FEL experiments. This section was modified to accommodate an undulator and was equipped for input and exit ports suitable for visible radiation.

For FEL experiments, the energy must be lowered to 150 MeV; in the process, the beam current drops from the injection current of 150 MeV per bunch to 40 MeV per bunch. To have reasonably stable operation at 150 MeV, an old set of hand-controlled sextapole magnets was added. Because of a poor vacuum in the machine, the beam's lifetime is rather short. And given the time required to lower the undulator after stable operation has been achieved, the actual current available for use in FEL experiments is degraded to approximately 10 mA.

In early 1981 a superconducting undulator began operating. The device had 23 periods of 4-cm wavelengths (total length equaling 92 cm) and could produce a 4.6 kG magnetic field on the axis of the electron beam. After injection into the storage ring, the electron beam oscillates in the plane of the electron orbit. To provide adequate space for these radial oscillations, the vacuum chamber in the undulator section was an inverted "T" shape, with the crosspiece of the T outside the region of the pole faces. The inverted T-shaped vacuum chamber was connected to ACO at both ends with flexible stainless hose.

When the electron beam was injected, the undulator magnet and the undulator fastened to it were raised to allow the electrons to oscillate in the crosspiece of the T. After the oscillations had damped out so that the electron radius was essentially constant, the undulator magnet was lowered so that the electron beam passed between the pole faces of the undulator. Also during the damping of the oscillations, the energy of the machine was reduced to 150 MeV.

For relativistic electrons passing through a periodic electromagnetic structure, the fundamental wavelength of emitted radiation is given by

$$(1) \quad \lambda = \lambda_0/2\gamma^2(1+K^2/2+\gamma^2\theta^2)$$

for electrons traveling parallel to the axis of a planar undulator. In equation (1), $\gamma = E/m_0c^2$, E is the electron energy, m_0c^2 is its rest mass energy (0.511 MeV), and λ_0 is the period of the undulator. The magnet parameter K is given by

$$(2)\quad K = eB_0\lambda_0/2\pi m_0 c = \psi_0$$
$$= 0.0934 B_0\lambda_0,$$

where B_0 is the maximum magnetic field on the trajectory, e and m_0 are the charge and mass of the electron, c is speed of light (B_0 is expressed in tesla and λ_0 in mm), Θ is the angle of observation to the z axis, and ψ is the maximum angle between the velocity of the particle and the z axis.

The emission of light by the undulator was observed for several sets of parameters. For an electron energy of 150 MeV and a maximum undulator field of 3.2 kG (K = 1.20), the wavelength predicted by equation (1) in the forward direction ($\Theta = 0$) is 399 nm. As was expected, the experimental spectral distribution was very similar to a $(\sin x/x)^2$ distribution in intensity with the wavelength of the principal maximum at 402 nm. A color picture of the radiation falling on a white screen is roughly twofold symmetric, with a progression of colors from blue to red as the angle Θ increases.

At higher energies (E = 240 MeV and K = 1.58), black regions are observed in the vertical plane perpendicular to the direction of color spreading. (The vertical plane is the plane of oscillation of the electrons as a result of their passage through the undulator.) The bands correspond to the direction $\pm\Theta = 1$ (in a pseudo-rest frame traveling in the undulator with the mean longitudinal electron speed), and move closer together as the energy is increased. The directions are the transverse vertical ones where no emission is to be expected because the electrons are oscillating along these directions.

Gain in the visible region of the spectrum was also measured. A linearly polarized continuous wave (CW) argon laser operating at either 488 or 514.5 nm was adjusted so the optical path overlapped the electron path. The laser was focused to a waist in the center of the undulator, and a part of the laser beam was amplified each time a stored electron bunch passed through the undulator. Because of the small gain expected to be associated with the small current in the storage ring, synchronous detection was used at either 13.6 or 27.3 MHz.

The measured gain curves were distorted because of the short (about 9-minute) lifetime of the electron current, and the maximum gain was quite small. At 488 nm the largest measured gain was 4.3×10^{-4}, with a beam current of 9.6 mA per bunch and a dimensionless magnet parameter of k = 1.49. The data are rather scattered but indicate an increase of gain with beam current up to about 40 mA per bunch. With further increase in beam current, the gain decreases somewhat. Experiments were also performed at a magnet parameter of K = 1.72; the gain values measured were less than those observed at K = 1.49.

Shortly after the preliminary measurements had been completed, the superconducting undulator magnet failed during an experiment on lengthening of the electron bunches. The failure was so extensive that it was decided not to repair the magnet. Instead, a new three-section undulator using permanent magnets is being built. The new undulator will have 18 sections of 8-cm spacing and will give 3.5-kG peak field on axis. The middle section is removable so that optical klystron experiments also can be performed.

3 ISRAEL

Hebrew Univ.

Racah Institute of Physics
The Hebrew Univ. of Jerusalem
Jerusalem, Israel

Principal Scientists

F. Dothan
L. Friedland
A. Ludmirski
A. Fruchtman

Recent Publications

Ira B. Bernstein and J.L. Hirschfield, "Amplification on a Relativistic Electron Beam in a Spatially Periodic Transverse Magnetic Field," *Phys. Rev.*, 20A (1979), 1661.

L. Friedland and J.L. Hirschfield, "Free Electron Laser With a Strong Magnetic Field," *Phys. Rev. Lett.*, 44 (1980), 1456.

P. Avivi, F. Dothan, A. Fruchtman, A. Ludmirsky, and J.L. Hirshfield, "Experimental Study of Electron Orbit Stability in a FEL Magnetic Wiggler," *Bull. Am. Phys. Soc.*, 25 (1980), 910.

L. Friedland, "Electron Beam Dynamics in the Free Electron Laser With a Guide Magnetic Field," *Bull. Am. Phys. Soc.*, 25 (1980), 911.

J.L. Hirshfield, I.B. Bernstein, and L. Friedland, "Theory of the Free Electron Laser in Combined Helical Pump and Axial Guide Fields," *Bull. Am. Phys. Soc.*, 25 (1980), 911.

Summary

Hebrew Univ. is involved in a 3-year project devoted to gaining an understanding of the basic physical mechanisms of gain in the FEL. The project in theory and experiment is being done in cooperation with Yale Univ., and is sponsored by the US-Israel Bi-National Science Fund. Dothan and J.L. Hirshfield (Yale Univ.) are principal investigators. Freidland is a theorist recently returned from a visit to Yale.

A Febetron electron accelerator is in use, along with a 4-kG axial magnetic field and a pulsed wiggler magnet in the form of a double helix of 36-mm pitch. With the guiding field set at a constant value, the wiggler is pulsed to give a relatively small field (20 G). As the wiggler field decays, a stability condition is reached in which the electron follows helical paths determined by a series of slit experiments. In tests up to an energy of 20 keV, the stability regime is found to be that predicted by Friedland's calculations of the single particle regime. The currents in the tests are small enough that operation is thought to be in that regime.

In the combined fields, improved gain is predicted when a "resonance condition" between the helixal trajectories and the transverse magnetic field is obtained. Future experiments will investigate this possibility; in addition, the work will be extended to increased electron energy and current.

The 1979 paper by Bernstein and Hirshfield deals with calculations of the dispersion relation and gain of an FEL that has a cold relativistic electron beam interacting with a helical magnetic field. The work has been extended by Fruchtman and Hirshfield to a beam with a finite energy spread. The calculations predict a reduction in amplification as a result of phase mixing and no enhancement of gain due to wave-particle coupling.

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Principal Scientists

A. Gover
P. Dvorkis
S. Ruschin

Recent Publications

A. Gover and A. Yariv, "Collective and Single-Electron Interactions of Electron Beams With Electromagnetic Waves, and Free Electron Lasers," *Appl. Phys.*, 16 (1978), 121-138.

A. Gover and Z. Livni, "Operation Regimes of Cerenkov-Smith-Purcell Free Electron Lasers and T.W. Amplifiers," *Opt. Comm.*, 26 (1978), 375-380.

A. Gover and A. Yarviv, "Collective and Single Electron Interactions and Cerenkov-Smith-Purcell Free Electron Lasers., in *Novel Sources of Coherent Radiation*, ed., S.F. Jacobs, M. Sargent, and M.O. Scully (Reading, MA: Addison Wesley, 1978), pp 197-240.

A. Gover, "An Analysis of Stimulated Longitudinal Electrostatic Bremsstrahlung in a Free-Electron Laser Structure," *Appl. Phys.*, 23 (1980), 295-298.

A. Gover and P. Sprangle, "'Exact' Low Grain Formulation of the Free Electron Laser--Including Transverse Velocity Spread and Wiggler Incoherence," NRL Memorandum Report 4221 (15 September 1980).

A. Gover, "Predicted Effect of Mode Cooperation and White Light Lasing in Warm-Beam Free-Electron Lasers," *Opts. Lett.*, 5 (1980), 525-527.

A. Gover, C.M. Tang, and P. Sprangle, "Feasibility of DC to Visible High Power Conversion Employing a Stimulated Compton Free Electron Laser with a CO_2 Laser Pump and Axial Electric Field" (submitted to *Journ. Appl. Phys.*).

A. Gover and P. Sprangle, "United Theory of Magnetic Bremsstrahlung, Electrostatic Bremsstrahlung, Compton-Raman Scattering and Cerenkov-Smith-Purcell Free Electron Lasers," *IEEE Journ. Quant. Elect.*, QE-17 (1981), 1196.

Summary

A senior lecturer in the Electrical Engineering Department, A. Gover is a well-known theorist who, in addition to his work at Tel Aviv Univ., often collaborates with P. Sprangle at NRL. Dvorkis and Ruschin are experimentalists; Ruschin joined the group in late 1980 after a postdoctoral appointment at Cornell Univ.

Experiments on the Smith-Purcell effect are in progress. A sheet of 50-kV electrons passing near a 600-line/mm grating is used to produce infrared rather than visible radiation. The experimental arrangement will allow a study of the effects of varying the distance between the electrons and the periodic electrostatic structure of the grating. The work is being done by Dvorkis for a PhD thesis.

Gover and Ruschin have proposed a study of the nonlinear mechanism of electron beam trapping in the ponderomotive potential of two oppositely propagating electromagnetic waves. In the proposed experiment, the electromagnetic waves will be intense beams from transversely excited CO_2 lasers. An electric field applied axially along the electron beam will be used to separate the trapped electrons from the untrapped ones and thereby allow measurements of trapping efficiency and bunching. Although stimulated emission of infrared radiation is expected, the study is to concentrate on the laser beam-electron interaction using measurements of the energy distribution of the electron beam.

The experiment is claimed to be simple, relatively inexpensive, and able to provide information on trapping efficiency and saturation characteristics.

4 ITALY

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Principal Scientists

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G. Dattoli
A. Marino

Recent Publications

G. Dattoli, A. Marino, and A. Renieri, "A Multimode Small Signal Analysis of the Single Pass Free Electron Laser," *Opt. Comm.*, 35 (1980), 407.

G. Dattoli and A. Renieri, "Storage Ring Operation of the Free Electron Laser: The Oscillator," *Nuov Cimento*, 59B (1980), 1.

G. Dattoli, A. Marino, and A. Renieri, *The FEL-Microtron Activity at the C.N.E.N. Frascati Center*, C.N.E.N. Frascati Report 80.42/cc (October 1980).

G. Dattoli, A. Marino, and A. Renieri, *Beam Quality Limitations to the Single Pass FEL Dynamics*, C.N.E.N. Frascati Report 81.9/cc (January 1981).

G. Dattoli, E. Fiorentino, T. Letardi, A. Marino, and A. Renieri, *Progress in the FEL Project at the C.N.E.N. Frascati Center*, C.N.E.N. Frascati Report 81.10/cc (February 1981).

"Theory of the Free Electron Laser," Proc. of the course *Physics and Technology of Free Electron Lasers*, ed., A.N. Chester, S. Martellucci, and A. Renieri (Erice, 1980, to be published).

Summary

Renieri and Dattoli are theorists who have published work on FELs in refereed journals and in the proceedings of various conferences and schools. Marino is an experimentalist formerly engaged in nuclear physics. The FEL experimental project under the leadership of Renieri was funded by the Italian National Research Council in November 1980. Equipment is being assembled in a partitioned 60-ft x 20-ft space in the building formerly devoted to the synchrotron, which was dismantled in 1975. The experiment on the construction of a single-pass FEL is planned to proceed in three steps: measurement of spontaneous emission, achievement of gain, and achievement of lasing action.

Initially the source for the electron beam will be a microtron (sometimes called an electron cyclotron) that was on hand. The machine accelerates electrons, which are confined in a constant magnetic field, by passing them through an RF-driven cavity. The microtron was originally a 12-MeV, 60-mA machine with the electrons injected from outside the cavity (Wernholm injection); modification to injection from within the cavity (Kapitza injection) has increased the electron beam energy to 20 MeV. The characteristics of the machine are given in Table 1. Operating with a 2-MW S-band magnetron driving the cavity, the electron beam power is about 700.

The wiggler magnet used is constructed of $SmCo_5$ permanent magnets arranged in 40 periods of 5 cm. Including transition sections, the wiggler's overall length is ∿2.25 m. In the 2.4-cm gap, the peak field strength is about 3 kG.

The system was expected to be ready for experimentation by the end of 1981. Radiation will be near λ = 30 μm and is expected to be detected with commercial bolometers. The first two stages of the experiment will use the magnetron-driven cavity. For lasting action, more power is needed. To achieve higher electron energy, it is planned to replace the magnetron with a high power klystron and to substitute a new, larger microtron magnet.

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R. Barbini
G. Vignola

Recent Publications

R. Barbini and G. Vignola, *LELA: A Free Electron Laser Experiment in ADONE*, (Laboratori Nazionali di Frascati Report LNF-8/12, 10 March 1980).

R. Barbini, et al., *The LELA Undulator* (Laboratori Nazionali di Frascati, Report LNF-80/62, 9 December 1980).

Table 1

Frascati Microtron Parameters

Operating frequency	3 GHz (S band)
Pulse duration	2 to 4 μs
Electron bunch duration	∿20 ps
Electron bunch separation	∿300 ps
Emittance	3 mm mrad
Energy	12 MeV Wernholm injection 20 MeV Kapitza injection
Energy spread	0.12%
Average current (@ 20 MeV)	35 mA
Peak current (@ 20 MeV)	650 mA

Summary

Until 1978, the 1.5-GeV electron storage ring ADONE operated at the laboratory was used mainly for high energy physics colliding beam experiments. Now the ring is used for nuclear physics, synchrotron radiation research, and, with the installation of a wiggler magnet, FEL research. Tazzari is the director of the accelerator division. Barbini and Vignola, the scientists principally concerned with the FEL experiment, intend to replace one of the 12 straight sections of ADONE with a wiggler magnet. The project is called LELA, for Libre (Free) Electron Laser in Adone.

"In order to avoid all unnecessary technical complications," Barbini and Vignola have chosen to operate in the visible region and use magnetic fields obtainable by standard magnet technology. The energy of the electrons in the storage ring can be varied between 500 and 1500 MeV, and within that range the highest possible electron energy was chosen to achieve the highest possible peak current. The spontaneous radiation wavelength, λ, is given by equation (3).

$$(3) \quad \lambda = \lambda_o/2\gamma^2 \; (1 + K^2/2 + \gamma^2\theta^2)$$

The magnet parameter K is given by equation (4), in terms of the maximum magnetic field on the trajectory. If the magnetic field varies in a cosine-like manner, the magnet is approximately

$$(4) \quad K = 6.6 \; B_o\lambda_o ,$$

where B_o is the peak magnetic field expressed in units of kilogauss and λ_o is in meters. In addition to producing spontaneous radiation in the visible region, the magnet was designed to have the maximum number of magnetic periods contained in the replacement section 2.5-m long.

With the spontaneous radiation wavelength fixed in the visible and at a convenient laser line, the magnet strength, magnet spacing, and electron beam energy can be varied to achieve the desired wavelength. To maximize the number of magnetic periods in the wiggler and to allow operation at highest possible beam energy, parameters listed in Table 2 were selected.

The design for the wiggler has 20 periods of 11.6 cm for a total length of 232 cm. The wiggler is to be manufactured by a commercial firm near Rome and was scheduled for delivery in May 1981. A complete description is in Barbini's report, *The LELA Undulator*, and a shorter version is to be published in *Nuclear Instruments and Methods*.

Table 2 also gives the length of the optical cavity, which will be an extension of the straight section of the ring occupied by the wiggler. In the FEL experiments, ADONE will be operated with three electron bunches; the optical cavity length will be adjusted to one-half the distance between bunches. Thus, a single photon bunch will travel inside the optical cavity and will meet one of the electron bunches once every round trip.

The radiation wavelength listed in Table 2 is the same as that from an Ar laser, and the experiments to be carried out will use that radiation. A Coherent Optics CR-10 Ar laser has been purchased, and the necessary optics have been ordered.

ADONE was scheduled to be down for 3 or 4 months during the summer of 1981, when a new 51.4-MHz RF system, a new computer, and new ports for synchrotron radiation studies, as well

Table 2

Operating Parameters

Wiggler period	λ_o = 11.6 cm
Number of periods	N = 20
Wiggler length	L_w = 2.32 m
Root-mean-square magnetic field on axis	3153 G
Electron energy	E = 610 MeV
Radiation wavelength	λ = 5145 angstroms
Optical cavity length	L = 17.5 m

as the LELA section, were to be installed.

With ADONE again operating, the zeroth experiment was to be the measurement of the radiation spectrum in the forward direction and the rationalization of the measurements with the values predicted by equation (3). A similar experiment has been performed on ADONE using a different magnet; there was an unexpected result for the shape and width of the spectrum. The effects may be the result of rather large systematic errors; the results obtained with the new system are expected to clarify the reasons for the discrepancies.

Further work will be on gain. An experiment to verify the relation of gain as a function of current was expected to be run at the end of 1981. A second gain experiment, scheduled for 1982, was to monitor with a high speed photodiode the dynamics of a single bunch of electrons passing through the wiggler. Finally, a lasing action experiment using an optical cavity will be done. The three experiments are expected to take 2 years.

5 UNITED KINGDOM

Principal Scientists and Their Institutions

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Summary

A new proposal for a combined university-Daresbury Laboratory FEL experiment was submitted to the

Table 3

Expected Operating Parameters

Energy	30 to 100 MeV
Average pulse current	250 mA
Useful pulse length	8.5 s
Repetition rate	100 Hz
Peak bunch current	10 A
Bunch length with ECS (50 MeV)	60 ps
Energy spread	±0.1%
Emittance expected (50 MeV)	2 mm mrad

UK's Science and Engineering Research Council. The proposal differs from previous unsuccessful ones from the Daresbury Laboratory. The emphasis is on the experimental investigation of FEL physics at 10 instead of 120 μm, and cooperation between Heriot-Watt Univ. the Univ. of Glasgow, and Daresbury Laboratory is called for.

The proposal is to perform an FEL experiment with the large linac, which has been operated since 1967 by the Department of Natural Philosophy of the Univ. of Glasgow. The machine is at the Kelvin Laboratory, a part of the National Engineering Laboratory at East Kilbride, about 10 miles from the university. After mid-1982, when the nuclear structure program of experiments is scheduled to terminate, the linac was to be available for use as a dedicated electron source for the FEL experiments.

M. Poole and G. Saxon are research scientists connected with the storage ring and sychrotron radiation source (SRS) project at Daresbury Laboratory. The wiggler magnet is to be built at Daresbury under the direction of Poole. J. Reid is professor of physics at the Univ. of Glasgow and is in charge of the Kelvin Laboratory; R. Owers is the manager of the accelerator, which was built by M. Kelliher. S.D. Smith is professor o physics at Heriot-Watt Univ. an is in overall charge of the join FEL project; C. Pidgeon is als on the staff and will help Smit in the design and procurement o the optics.

The linac can operate a repetition rates of 250 Hz an energies up to 160 MeV. It i not expected that energies ove 100 MeV will be needed, but larg current is desirable. Consequently the repetition rate wil be held to 100 Hz. As electro beam quality affects the performance of an FEL, plans were t modify the linac by installing new electron gun, focusing coils and pulse forming network fo changing the pulse length. Th present energy compression syste (ECS) will still be used. Th expected operating parameters ar shown in Table 3.

Initial experiments ar planned at a wavelength of 10 μm with the linac operating at 5 MeV. This requires a wiggle magnet of 8-cm period and 2.7-k field, which is in reach of conventional electromagnet technology The proposed planar wiggler magne will have 62 periods of 8 cm t give a total length of 5 m. Th magnet is to be of uniform perio not tapered, and to have a 2.5-cm aperture. Calculations indicate that such parameters can be achieved with water-cooled coils dissipating 25 kW.

An undulator magnet composed of rare earth-cobolt permanent magnets is now being built by Poole for use on the SRS. Based on the experience gained from the project, the wiggler for 10-μm operation may be changed to a permanent magnet wiggler--depending on the relative costs. For experiments planned in the 1- to 5-μm range, a permanent magnet wiggler will be needed.

Operation at 10 μm is expected to be in a high gain regime. A standard confocal or semi-confocal optical cavity will have the usual mirrors used for CO_2 lasers. Brewster windows of ZnSe are to be used to allow the optical radiation to enter and exit the evacuated gain path through the electron beam. Gain measurements will be made using a small CW CO_2 laser.