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LASER RESEARCH IN IRELAND, GERMANY, AND AUSTRIA

RICHARD S. HUGHES

19 DECEMBER 1980

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(14)

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
6-6-80	AD-A098	573
4. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED
6 Laser Research in Ireland, Germany and Austria		9 Technical Repts.
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s)
10 Richard S. Hughes		
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT TASK AREA & WORK UNIT NUMBERS
U.S. Office of Naval Research London Branch Office Box 39, FPO NY 09510		
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE
		19 December 1980
		13. NUMBER OF PAGES
		8
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)		
Aerosol Scattering Boron Nitride Waveguide Lasers Electro-optics Laser Neurosurgery Nd Lasers Picosecond Spectroscopy		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		
This review contains short summaries of Electro-optics Research and comments on the activities observed. The discussions include the research programs, key personnel, trends, and general observations. The review is essentially complete for Ireland and partially complete for Germany and Austria.		

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LASER RESEARCH IN IRELAND, GERMANY AND AUSTRIA

I. Northern Ireland

Institution: The Queen's University of Belfast
Division: Dept. of Pure and Applied Physics

Key Personnel: Ian Duncan (Host), J.C. Earnshaw, P.N. Clough, C.L.S. Lewis, T. Morrow, and C.J. Latimer.

Comments: The student enrollment is dropping at Queen's and as the research budget is tied to enrollment, the research budget is shrinking. The outlook of those with whom I visited, was not very optimistic with respect to the near-term research environment.

Ciaran L.S. Lewis is doing interesting work with Nd laser systems. The main system can operate with one of three oscillators having pulse widths of 10 ps (glass); 25, 50, 100, or 200 ps (YAG); or 30 ns (YAG). There are two preamplifier stages and three amplifiers. The maximum output energy is close to 7 J. This is a one-beam system and has been used to generate plasmas from flat plates. A two-beam system is under development so that they can perform absorptive, time resolved x-ray spectroscopic experiments. The results obtained by Lewis and others working in this laboratory are fed into the Rutherford Lab's laser/fusion program. One example of this is "X-ray Streak-Camera Study of the dynamics of Laser-Imploded Microballoon," M.H. Key, et al., *Appl. Phys. Lett.* 34, 550 (1979).

Peter N. Clough is using laser excited fluorescence to get a handle on chemical reaction dynamics (angles, translational and internal energies) resulting from crossed molecular/atomic beam experiments. Clough has been developing tunable lasers since 1974 and he has focused on the 250 to 320 nm region. He has a argon-ion laser (low) pumped dye laser which is tuned with a prism and one uncoated etalon. The dye laser is frequency doubled with ADP and has a final output of 30-40 microwatts and a linewidth of about 0.001 nm. Using this laser he has studied the vibrational distribution of CS formed in the reaction $O + CS_2 \rightarrow CS + SO$.

Tom Morrow started working on dye lasers in 1969 and has developed coaxial flashlamp pumped dye lasers. Most recently he has used an N₂ laser flash photolysis system to monitor transient triplet state absorption of a number of scintillators in solution and in the vapor phase.

I would classify the following investigators as laser users as opposed to Lewis and Clough, who have been quite deeply involved in laser development. John C. Earnshaw has used argon-ion lasers in a study of capillary wave propagation in lipid membranes (photon correlation spectroscopy) and he has studied cellular dynamics using laser (He-Ne) doppler microscopy. Calin J. Latimer is using an e-beam and an N₂ laser pumped dye laser to produce highly excited atoms. He is determining the radiation lifetimes and transition probabilities of atoms in high Rydberg states.

II. The Republic of Ireland

Institution: University College, Dublin, (UCD)

Division: Department of Experimental Physics

Key Personnel: Denis L. Weaire, Sean O'Connor, P.K. Carroll and J.A. Scott.

Comments: UCD is one of the three campuses of the National University of Ireland; the others are located at Cork and Galway (discussed below). Weaire, who is the acting chairman, is trying to improve the department's financial position. He said that because of the recent economic growth, etc., fewer young people are emigrating and that more than 25% of the population is under 25 years of age. Enrollment is up and several high technology companies have moved into the country, e.g., MOSTECH and National Semiconductors. The general impression I received throughout the Republic of Ireland was one of optimism regarding the future of the R&D environment. UCD had planned to develop an electro-optics group in the near future, however, with Prof. Dan Bradley's move to Trinity College (discussed below), I believe this plan has been abandoned. Weaire moved to UCD from Heriot-Watt University and he plans to continue working on the theoretical aspects of amorphous semiconductors. He may get into atomic spectroscopy in the future. One of his main objectives is to develop a center for computational physics at UCD—this would be the only such facility in Ireland.

The Department of Experimental Physics is heavily involved in atomic and molecular spectroscopy and a wide variety of spectrographs are available. This department is world renowned for its aerosol scattering work (Nolan, et al.), and I talked briefly with J.A. (Tony) Scott. Scott was responsible for solving the problems in General Electric's smoke alarm. I did not meet H.W. Sidebottom, but I was told that he is using a flashlamp-pumped frequency-doubled dye laser to study the effects of triplet state quenchers. (This work may be a duplication (in some ways at least) of the work done much earlier by Dave Gregg at Lawrence Livermore Lab.)

John O'Conner has demonstrated the use in absorption spectroscopy of the continuum (35 to 200A) obtained by laser irradiation of the elements from samarium by ytterbium. A Q-switched ($\Delta t \sim 25$ ns) ruby laser having a peak power of 200 MW was used in this work. They are developing a Nd oscillator and double-pass amplifier from which they expect to obtain 10 GW peak power.

Institution: Trinity College (Univ. of Dublin)

Division: Department of Physics

Key Personnel: Daniel O'Connell, Brian Henderson (after 1980), Daniel Bradley (after Oct. 1980), E.C. Finch, and J.M.D. Coey.

Comments: Perhaps the most interesting news regarding electro-optics and the Republic of Ireland is the move of Prof. Dan Bradley from Imperial College, London, to Trinity. This move was most unexpected and even though he undoubtedly will build up a strong EO program at Trinity, his peers seem to be unaware of

any specifics. Bradley was formerly the chairman at Queen's University, Belfast, and he held a chair at Imperial College immediately prior to this move. He is a recognized leader in EO in the UK and his move to the Republic of Ireland will certainly add stature to their EO "image".

D.C. O'Connell was my host and his research and that of J.M.D. Coey were reviewed. O'Connell is investigating F-centers (oxygen vacancy) in additively colored MgO samples with F-center densities as high as 10^{19} cm^{-3} were prepared by heating to 1800°C in a 100 atmosphere Mg vapor. An N_2 laser (450 kW, 10 ns) was used to determine lifetimes (F_2 -center, F-center and green band) and the photoluminescence resulting from excitation at 351.1 nm has recently been reported. He has very recently observed photochromism in gallium doped MgO—a change in the emission band upon excitation and a reversion upon illumination with red light.

Coey has studied the magnetic properties of amorphous solids, i.e., solids having no crystalline atomic lattice, and a review of this topic which he presented while working at the IBM T.J. Watson Research Center has been published (*J. Appl. Phys.* 49, 1646 [1978]).

Institution: University College, Cork
Division: Department of Electrical Engineering

Key Personnel: M.C. Sexton, Sean L. Prunty.

Comments: Sexton and Prunty are developing far infrared (FIR) lasers to be used in the diagnostics of fusion research devices—to determine ion and electron temperatures of hot plasmas via Thomson scattering. They have developed and are improving boron nitride cw CO_2 waveguide lasers as pumps for D_2O lasers. In less than one year Prunty built an impressive CO_2 and FIR capability. This rapid progress was facilitated by their collaborative work with the UK Atomic Energy Authority (UKAEA), Culham Laboratory (D.E. Evans). Prunty works closely with UKAEA and Sexton consults for (conducts experiments at, etc.) the Department de Physique des Plasma et de al Fusion Contrôles, Association EURATOM—C.E.A. Fotenay-aux Roses, France.

Institution: University College, Galway
Division: Department of Experimental Physics

Key Personnel: George F. (Frank) Imbush, Phillip W. Walton, and T.J. Glynn.

Comments: There is very little research in EO at UCG. That which is conducted is described below and the department program in optical spectroscopy is also reviewed.

Frank Imbush, who was one of Art Schawlow's first two graduate students at Stanford, has maintained the high degree of enthusiasm for research typical of most graduate students. He is studying the luminescence characteristics of pure and doped solids (e.g., MnF_2 and MnF_2 doped with Eu^3 and Er^3 in order to

get a handle on nonradiative processes and excitation transfer among ions. Among the "tools" available are: argon-ion, nitrogen and dye lasers; Jarrel Ash (1 meter), Chromatix (1 meter) and Spex Double Monochromator (0.85 meter).

Philip Walton is in charge of applied physics & electronics, a new program within the Department of Experimental Physics. He is the principal investigator for an effort in ionography. This work, which is supported by the US National Institute of Health (NIH) has the objective of developing a technique of optically projecting x-ray images. They have demonstrated the ability to optically project x-ray images from within a sealed gaseous ionography chamber. Resolutions of up to 10 line-pairs per mm have been obtained with a 5 mR (50kVP) exposure.

III. Federal Republic of Germany

Institution: Projektgruppe für Laserforschung der Max-Planck-Gesellschaft für Förderung der Wissenschaften eV (Project Group for Laser Research, Max-Planck Society for the Advancement of Science), D8046 Garching bei München

Key Personnel: Herbert Walther, S. Witkowski and K.L. Kompa.

Comments: The following comments apply to the two Max-Planck laboratories.

The financial support of these laboratories is obtained from the Federal Government, the provinces of Germany, private industry (e.g., IBM), and patent royalties. Max-Planck Institutes (MPI) are established in the following manner. The Max-Planck Society establishes a Max-Planck Group for a 5-year trial period. If at (or near) the end of this trial period a need for continued work in the particular field exists and the Group has been productive, etc., the society votes to establish an institute. The Project Group for Laser Research has recently been voted to become the Max-Planck Institute for Quantum Optics.

The following are general, but in my opinion important, observations regarding the Max-Planck Institutes/Groups. (1) These laboratories are exceedingly well funded and are well equipped with the latest in instrumentation, etc. (2) They are undermanned. (3) Even though some thorough research is conducted at the Max-Planck Institutes/Groups, there appears to be some "headline" work without the desired followup research. (4) There is a continual flow of scientists into and out of the Max-Planck Institutes and even "permanent" members don't stay permanently. The next step after the MPI is often either a full professorship or the leadership of an industrial research laboratory.

The Project Group for Laser Research (mentioned above), with approximately 50 scientists, was started in January 1976 and was expected to become officially the Max-Planck Institute of Quantum Optics by early 1981. Witkowski, a plasma physicist, was responsible for the group's laser/plasma interactions. It was projected that about 30% of the new Institute's work would be "applied research." At present, the group's support (around \$10 M) is about 50/50 federal/provincial.

The group is composed of three subgroups: Laser/Plasma led by Witkowski, Laser Chemistry headed by Kompa, and Laser Spectroscopy under Walther. One of the major accomplishments of Witkowski's subgroup was the development of the Asterix III laser system which is now used routinely for laser/plasma studies. The Asterix III system is a photochemical gas laser using iodine as the active medium; it operates on the ($^2P_{1/2} - ^2P_{3/2}$) transition of atomic iodine at 1.315 microns. The system, an oscillator and 4 amplifiers, is in essence a collection of 5 quartz tubes and 92 flashlamps. The dimensions, output characteristics, etc., of the 4th amplifier are rather impressive; active length/diameter 740/15.5 cm; maximum energy stored, 288 kJ; number of flashlamps, 64; energy added to the beam, approximately 300 J; output when used as an oscillator, 1000 J. The system is capable of delivering slightly over 1 TW in 280 ps and can be fired once every 10 minutes (They routinely get off around 20 shots/day). The system overall efficiency is 0.08%.

Kompa's subgroup is involved in laser isotope separation, laser photochemistry and uv laser development. The last mainly involves excimer lasers. This group has the capability of both determining candidate laser materials (fluorescent quantum yields, etc.) and testing for laser action. M. Diegelmann, who worked here until recently, discovered the IF laser operating at 491 nm. In December 1979 Hohla, Diegelmann, and Kompa reported on two new uv laser materials: ClF and F₂.

In addition to his leadership role at the Max-Planck Group, Walther chairs the Physics Section of the University of Munich. His subgroup is concentrating its efforts in 3 areas: using lasers to investigate simple chemical reactions, studying the fundamental processes in charge transfer reactions and the spectroscopy of excimers. He recently coauthored a paper on a laser-induced fluorescence study of the reactions of F atoms with CHI and CFI. The following paper titles give a fair representation of the nature of this subgroup's work. "Sub-Doppler Spectroscopy of BO_2 from Backscattering," "Laser Excited Fluorescence of the Vibronic States of BO_2 ," "Quantum Beats Observed in Photoionization," and "Vibrational Energy Transfer in Ethylene and Ethylene-Benzene Mixtures."

Institution: Max-Planck Institut für Festkörperforschung (Max-Planck Institute for Solid-State Research) Heisenbergstrasse 1, D-7000 Stuttgart 80, FRG

Key Personnel: Ernst O. Gobel, Fritz von der Linde, and Friedrich Drissler.

Comments: This solid-state physics institute is about 10 years old and is considered to be the "Bell Lab" of Germany. The institute has 8 departments (2 chemistry, 3 theoretical physics and 3 experimental physics) each with approximately 30 members (~20 scientists and ~10 technicians). Each department has a director and 2 or 3 "permanent" members—the remainder are either PhD students or researchers with 2-year contracts.

As was observed at MPI, Garching, the laboratory is short on manpower (30-40% of their scientific staff are foreigners.)

A few comments on some of their projects follow.

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F. Drissler is one of seven people working in the area of photobiology. He is using enhanced anti-stokes Raman scattering in a study of living cells of chlorella pyrenoidosa, a green monocellular alga. His spectra are recorded with a 5 cm^{-1} resolution using argon-ion laser excitation, a 1-meter double monochromator and photon counting detection. He planned to publish in 1980 on the discovery of phase transitions in this alga which occur during warming up to 230K and 261K.

E. Gobel recently came to MPI from the University of Stuttgart. He is interested in determining the longitudinal mode behavior of GaAs, GaAlAs and InAsP/InP lasers. While at the University of Stuttgart (1979) he published on an elegant technique for measuring the optical gain spectra of such double heterostructure devices. He is now concentrating on two areas:

(1) Time resolved recombination radiation in GaAs ($10^{17} - 10^{18}$ carriers/cm³) resulting from two photon absorption. He plans to use pulsed lasers and an electronic streak camera with a time resolution of 1 ps in this efforts.

(2) Measuring the absorption (absorption edge) at various delays after laser excitation to get a measure of electron density and temperature as well as the relaxation time.

J. Kuhl is responsible for picosecond spectroscopy and he has developed two laser systems for this work:

(1) Pulsed: frequency doubled mode-locked Nd:YAG. Used with an optical parametric oscillator, this yields 20 ps pulses with signal wavelengths from 0.6 to 0.9 micrometers and idler wavelengths of 1.15 to 2.5 micrometers. Nd:YAG laser produces 10 to 100 pulses/s with a pulse width of 25 to 30 ps.

(2) Picosecond and subpicosecond (as short as 0.35 ps) pulse generation in synchronously pumped mode-locked cw dye lasers. With this system they have been able to study the lifetime of excitations directly—in contrast to their determination from linewidth data.

F. Keilmann has been involved in a wide variety of investigations including the following: ultrafast nonradiative relaxation in p-germanium (using a CO₂ laser); piezoelectric excitation of coherent THz acoustic phonons (using HCN and H₂O lasers); measurements of subpicosecond relaxation using tunable-laser-induced grating dip (used 2 CO₂ lasers); development of a cavity-dumped mode-locked TEA CO₂ laser; and the study of microwave resonances in living cells.

IV. Austria

Institution: Neurochirurgischen Klinik, Universitat Graz, Graz (Neurosurgical Clinic, University of Graz)

Key Personnel: Prof. Fritz Heppner (group leader), Dr. Peter Ascher, Dr. Rainer Oberbauer.

Comments: Heppner and his colleagues, Ascher and Oberbauer, are Europe's leaders in laser neurosurgery. Ascher, in conjunction with Sharplan Inc. (an Israeli manufacturer of laser medical equipment) started CO₂ laser neurosurgery in 1976. Laser surgery of both the brain and spinal cord is now considered routine by this group. The primary reasons for using laser neurosurgery are the reduced damage (immediate-absence of physical contact, and delayed-due to the absence of bleeding after surgery) and reduced bleeding during this type of surgery (increased visual capability).

The primary procedures include benign tumor vaporization, removal of vascular abnormalities, pain treatment, and the vaporization of suspect areas on tumor beds.

This group is working closely with Sharplan in the development of improved CO₂ laser systems for surgery. The present systems produce up to 50 W in a 1 mm diameter spot (at the focus). They plan to produce a more sharply focused (much less than 1 mm) beam in the future.

The group's work is excellent, morale is high and financial support is a mix of "federal" and "county" funds.

Institution: Institut für Physikalische Electronic, Technische Universität Wien (Institute for Electronic Physics, Technical University of Vienna)

Key Personnel: Prof. Ernst Bonek (group leader), Dr. Walter R. Leeb, Prof. A.J. Schmidt and Dr. E. Wintner.

Comments: I visited two groups: Communications Engineering headed by Bonek and Quantum Electronic and Laser Techniques headed by Schmidt.

The first group is involved in the development of lasers (i.e., building lasers) and the modification of purchased lasers to provide for the desired output characteristics. The emphasis of their work is on the latter. Leeb, who works for Bonek, built Europe's first waveguide CO₂ laser; he has also built a number of cw CO₂ lasers. He is currently working on a CdTe (0.8 mm x 0.8 mm x 10 cm) modulator to be used with one of the group's CO₂ lasers. This project is funded by the European Space Agency (ESA) and the objective is to modulate up to 1 GHz. Leeb has published a number of papers on intracavity modulation techniques for CO₂ lasers since 1977. Leeb is also involved (both in his laboratory and for Siemens A G, Research Labs) in optical fiber gyroscopes. He coauthored 2 papers in *Applied Optics* in 1979 on this topic.

Bonek has published a number of papers in the last 6 years on intracavity millimeterwave modulation of CO₂ lasers (using GaAs), ir laser sideband observation in GeH₄ and CD₄, and, most recently, on direct-frequency-reading ir spectroscopy.

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I visited Wintner of the Quantum Electronic and Laser Techniques Group. This group has developed N_2 lasers and has used them to pump dye lasers. They have also developed techniques for tuning and pulse shortening these N_2 pumped dye lasers. In late 1979 they reported on a dye laser pulse width of 0.03 nsec using a pump pulse modulation technique. In 1978 they published on a variation of Hersch Pilloff's 2-simultaneous-wavelength dye laser. While the work of this group is good, I feel that it is not pushing the state-of-the-art to the extent that Bonek's group is.

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