1980 Topical Meeting on Infrared Lasers

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The 1980 Topical Meeting on Infrared Lasers was held December 3-5 at the University of Southern California, Los Angeles, California. Approximately 100 people registered for the meeting, 43 papers were presented, and there were two panel discussions. The meeting was supported by the U.S. Army Research Office, the U.S. Department of Energy, the National Science Foundation, and the U.S. Office of Naval Research.

NEW LASERS

The purpose of the meeting was to direct attention specifically toward the development of lasers for the IR rather than to applications. Although there are many kinds of lasers, only a few of these satisfy criteria that make them useful for a wide range of applications. These difficulties become especially apparent when there is a need for a powerful, easily operated, monochromatic, workbench device at a new wavelength, such as 15 or 20 μm, even though such a device exists at 10 μm. Although it has been a cliche to say that the laser is a solution looking for a problem, this is largely inaccurate simply because lasers that are useful for a wide range of applications exist only within a few spectral regions. Thus there is a need for new approaches to the research and development of infrared lasers, and the meeting provided a forum for comparing a wide range of technology and approaches.

The technical program chairperson was Curt Wittig. There were sessions on optically pumped lasers (organized by Paul D. Coleman), nonlinear and parametric processes (organized by Robert Byer), diverse new lasers (organized by Harold Fetterman with Aram Mooradian acting as chairperson), chemical and molecular lasers (organized by C. Randy Jones), and iodine lasers (organized by Arthur Guenther). Panel discussions included one on future basic laser research organized by C. Paul Christensen and a panel on chemical and molecular lasers organized by C. R. Jones.

PAPERS REVIEWED

A brief review of some of the papers is presented below. Summaries of the papers may be found in the technical digest (*Topical Meeting on Infrared Lasers Technical Digest*, available from IR Laser Meeting, Department of Electrical Engineering, University of Southern California, Los Angeles, Calif. 90007).

Current work on free-electron lasers—particularly with application to the near- and mid-IR regions—was discussed by Charles Brau of Los Alamos Scientific Laboratory and Todd Smith of Stanford University. Brau presented a review of fundamentals for the varied technical audience and discussed current technical problems as well as applications to laser photochemistry. Smith reviewed current work at Stanford and discussed technical problems related to the linear accelerator technology, currently an important device limitation.

Peter Sorokin of IBM presented an application of a new method for obtaining time-resolved single-shot broadband infrared absorption spectra. Sorokin and co-workers Ph. Avouris, D. S. Bethune, J. R. Lankard, and A. J. Schell-Sorokin generated broadband, intense, ~10-nsec IR radiation by Raman scattering with a broadband

Cadmium selenide OPO used at Los Alamos Scientific Laboratory for 16-μm generation. The OPO is pumped by an HF laser. The work was reported by Robert Wenzel and George Arnold.

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dye laser in Rb vapor. The IR radiation was passed through an absorption cell, and the absorption spectrum was observed by upconverting the IR using four-wave mixing in another metal-vapor cell. Several specific examples were presented, including a transient temperature measurement of the decomposition reaction $2NH_3 \rightarrow H_2 + 3N_2$.

Robert Byer of Stanford reviewed tunable IR generation by three- and four-wave interactions and stimulated Raman scattering, comparing efficiency, power levels, thresholds, and current applications of each. Byer also discussed his current work on the development of coherent spectroscopy with results including spectra of CH_4 obtained using an optical parametric oscillator (OPO) and providing 0.08-cm^{-1} resolution. The use of intracavity étalons for OPO's was discussed by Robert Wenzel of Los Alamos.

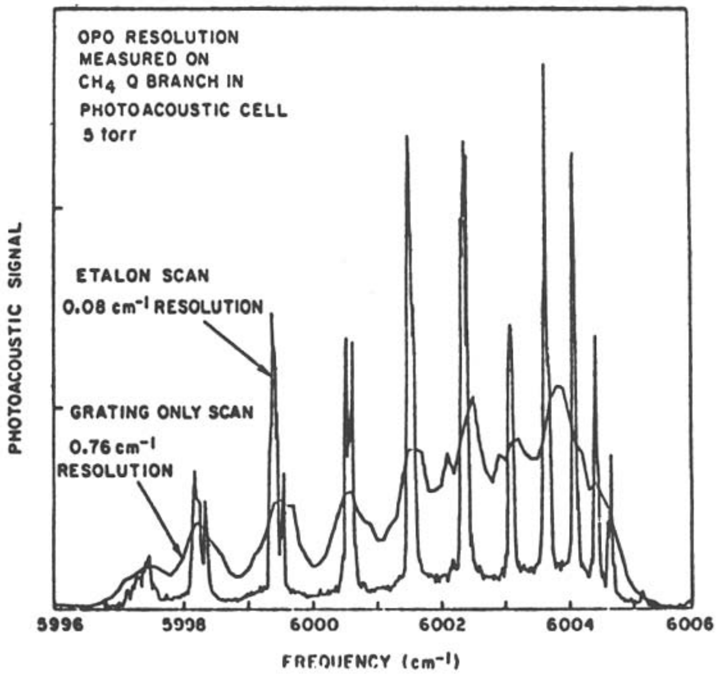
Work on stimulated Raman scattering by CO_2 (10 μm) in H_2 was reported by Paul Rabinowitz and co-workers of Exxon and by John Carlsten and Norman Kurnit of Los Alamos. Rabinowitz described a method of enhancing efficient high-energy output and pulse autosynchronization using new multiple-pass-cell methods.

Recent developments in several optically pumped solid-state lasers were presented. Irwin Schneider of the Naval Research Laboratory reported tunable cw laser output at power levels 5–10 mW beyond 2 μm from a Nd:YAG-pumped (150-mW input-power) lithium $(F_2^+)_A$ center in a KCl host. Schneider also reported room-temperature lifetimes of lithium $(F_2^+)_A$ centers of several weeks.

The application of color-center lasers to high-resolution spectroscopic devices was reported by J. V. V. Kasper of the University of California at Los Angeles and co-workers C. R. Pollock and Frank L. Tittel of Rice University.

Another tunable solid-state laser, the alexandrite ($BeAl_2O_4$:Cr^{3+}) laser, was described by J. C. Walling of Allied Chemical Corporation. Pulsed output of 5 nsec with energy >500 mJ at 6 Hz and tunability between 700 and 800 nm was reported.

R. G. Eckardt and Leon Esterowitz of the Naval Research Laboratory ob-



Grating-only (0.76-cm^{-1} resolution) and grating-plus-étalon (0.08-cm^{-1} resolution) photoacoustic spectral scans of the CH_4 overtone Q-branch spectrum at 5-Torr pressure, taken using a computer-controlled $LiNbO_3$ OPO at Stanford University by Martin Endemann and Robert Byer. The OPO has a 4500-cm^{-1} tuning range.

tained optically pumped output at six wavelengths in Ho- and Er-doped $LiYF_4$ from 0.7 to 3.9 μm using a frequency-doubled tunable neodymium-activated lanthanum beryllate (Nd:BEL) laser pump. Tunability of the Nd:BEL laser was achieved by use of an innovative intracavity birefringent filter technique.

Aram Mooradian presented a paper written with Peter Moulton describing work on Nd:YAG-pumped transition-metal ion lasers at Lincoln Laboratories. Recent results included cw tunable near-IR power levels greater than 1 W in the TEM_{00} mode and 100-psec, 250-MHz pulsed output. A precise measurement of the Nd:YAG 1.06-μm stimulated-emission cross section ($8.1 \pm 0.8 \times 10^{19}$ cm^2) was reported by Milton Birnbaum and co-workers.

Various new optically pumped gas lasers were described in the session organized by Paul D. Coleman. 180-mW cw output at 153 μm from $^{15}NH_3$ was achieved, using a 19-W $^{13}C^{16}O_2$ pump, by C. R. Pidgeon *et al.* of Heriot-Watt University and was described in a paper presented by S. D. Smith. Smith also described gain-peak shifts resulting from shift in a two-photon resonance that was due to a third field.

Len Nelson and co-workers of Math Sciences Northwest and C. R. Jones of Los Alamos reported a four-level system in CO_2-pumped NH_3 wherein mid-IR laser output is correlated with far-IR laser output. A theoretical analysis of the system has been made by C. W. Patterson of Los Alamos.

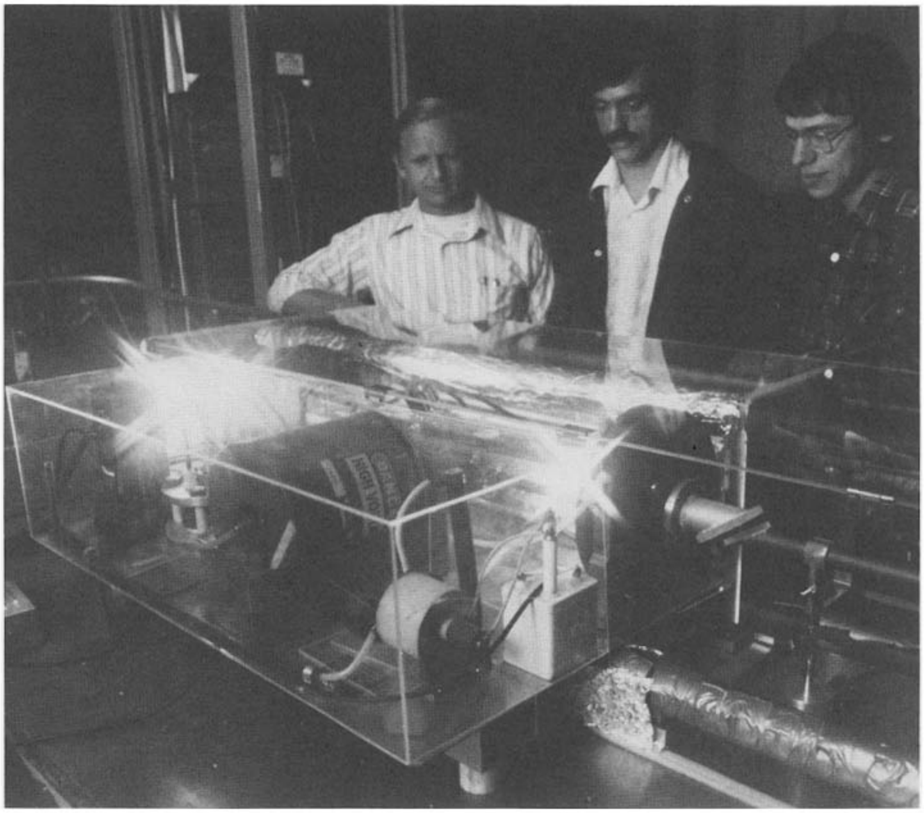
Pulsed output using CO_2 as a pump was reported in C_2D_2 near 500 cm^{-1} with energies up to 380 mJ by H. N. Rutt of Culham and in CH_3CCH around 625 cm^{-1} by T. A. Fischer and C. Wittig of the University of Southern California. Continuous-wave output using CO_2 as a pump was obtained in SO_2 by A. R. Calloway and E. J. Danielewicz of the Aerospace Corporation and on 38 lines in CD_2F_2 by Elza C. C. Vasconcellos of Campinas, Brazil, and F. R. Petersen and K. M. Evenson of the National Bureau of Standards.

A discussion of techniques for studying the role of collisions in optically pumped lasers between active molecules including CH_3F and CH_3OH and buffer gases was presented by N. M. Lawandy of NASA. Lawandy was able to observe collisional narrowing and determine collision cross sections for SF_6 (4.65×10^{-14} cm^2) and CS_2 (5.30×10^{-14} cm^2) with CH_3F. In another paper written with D. W. Robinson, Lawandy reported superfluorescent output from flash-pumped H_2O. Experimental work on ring resonators for OPL systems was discussed by D. L. Brower, W. A. Peebles, D. Umstadter, and Norman Luhman of UCLA. These authors reported efficient operation of a ring resonator in D_2O at 285 μm with a pulsed (80-nsec) CO_2 pump.

A cw ring system with a He-Xe discharge amplifier was studied by N. Takahashi and Hideya Gamo of the University of California at Irvine, who presented a theoretical analysis of intensity fluctuation near threshold along with experimental measurements. In another area, infrared bistability in InSb correlated to large changes in susceptibility near band-gap resonance around 5 μm was reported by S. D. Smith and D. A. B. Miller of Heriot-Watt University.

Single-mode operation of 0.5-J pulsed CO_2 laser using an intracavity absorbing gas was reported by R. A. Dougal and coauthors. Single-mode power was typically 70% of multimode output. Lyle Taylor of Westinghouse presented a paper on two 14-μm oscillators in CO_2 employing a conventional amplifier and a second paper with coworkers W. H. Kasner, D. W. Feddman, and D. R. Shure on a 16-μm ($020 \rightarrow 010$) CO_2 TE laser. Power output up to 20 mJ per pulse in a cooled system was reported. Artemio Scalabrin, C. H. Brito Cruz, and H. L. Fragnito of Campinas, Brazil, reported on a heliumless CO_2 system. Such a system is especially important in Brazil because of the expense and lack of production facilities for helium. Uniform discharges up to 400 Torr were achieved by using a preionization technique. A study of powerful chemical-laser-beam quality gain-related effects was reported by George Valley of Hughes Aircraft Company.

Considerable interest was shown in the session devoted to the iodine laser. Discussion of oxygen–iodine energy-transfer-related problems was presented by William McDermott and R. F. Shea of the U.S. Air Force Weapons Laboratory, R. F. Heidner of the Aerospace



Single-longitudinal-mode TEA CO_2 laser used at Texas Tech University to obtain narrow-linewidth, high-power output with precision and accuracy comparable with that of a narrow-band-diode laser. Left to right, Martin Gundersen, Terry Yocom, and Roger Dougal.

Corporation, H. V. Lilenfeld *et al.* of McDonnell Douglas, and O. C. Sandall *et al.* of Rockwell International. A summary of current work on a flash-lamp-excited iodine system being investigated for the French laser-fusion effort was presented by D. Friart of the Centre d'Etudes de Limeil. The paper listed five coauthors from the Centre and three from the Laboratoires de Marcoussis. One novel feature of the system was the placement of flashlamps within the gain region of a large amplifier.

Papers on HF and DF systems were presented by S. T. Amimoto and co-workers from the Aerospace Corporation, G. W. Holleman and H. Injeyan of Hughes Aircraft, and R. C. Brown and co-workers from Michigan State University. Leroy Wilson of the Air Force Weapons Laboratory presented a review of cw DF chemical-laser problems.

INFRARED-LASER PANEL

Two panel discussions addressed problems in laser research. One panel was entitled "The Status and Future Directions of Chemical and Molecular Infrared Lasers." It was organized by Randy Jones of Los Alamos; Terrill Cool of Cornell University was the chairperson. Panel members included Robert Center, Peter Clark, Anthony De Maria, Steve Dymokos, Doyle McClure, Stuart Searle, Wayne Solomon, Walter Warren, and Leroy Wilson. Most of the panel members were from the aerospace industry, although two were from military agencies and the moderator was from a university.

The discussion was begun with a brief description from each panelist on the research and development his institution is pursuing in IR lasers. Each emphasized where his institution seemed to be going in this area. Some time was devoted to those areas that the panel thought needed support from basic research.

Some areas of applications are the following: far-IR lasers are a new and fruitful field of technology that is not well developed but that will be supported by new applications. Currently FIR devices are used for scientific applications including plasma diagnostics for the development of Tokomak and other plasma devices. Industrial applications that are developing for FIR lasers include inspection, quality control, and diagnostics of plastic and polyethylene materials used for electrical insulation and other applications.

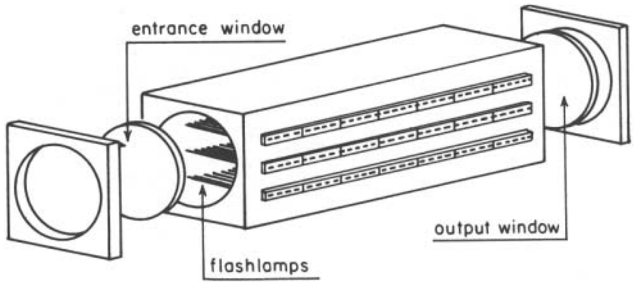
In the area of the CO_2 laser, applications include materials working, military range finders and target designators, lidar, wind monitors and remote atmospheric detection, and safety applications for low-flying helicopters. Radio-frequency excitation of waveguide CO_2 lasers to reduce contamination from electrodes and increase lifetime is being actively studied, along with processing technology for waveguide laser materials.

Chemical and combustion-driven processes for U.S. Department of Defense lasers is an area of engineering, physics, and chemistry research. Lasers such as HF and DF are being actively studied.

Current applications were reviewed in an effort to suggest which types of applications are likely to merit further research and development during the next five years. Several examples were discussed that illustrate the substantial significance that the discovery of new laser sources and technology has had on military, commercial, and scientific applications of lasers. A continuing need was seen for fundamental research directed toward the achievement of laser operation at wavelengths, power levels, and energies not now available. Emphasis on lower-cost laser sources should lead to more-extensive commercial use of lasers. Defense-supported research was cited as being most influential in the achievement of present-day laser capabilities, but need was seen for additional sources of funding for more-general development of laser technology for commercial and scientific applications.

BASIC-RESEARCH PANEL

The second panel was entitled "The Future of Basic Laser Research" and was organized by C. Paul Christensen of the Engineering Division of the National Science Foundation. Panel members included Paul D. Coleman, Bob D. Guenther, Abraham Herzberg, Paul Kelley, Howard Schlossberg, and Todd Smith. There are many areas in which new lasers are required, and some of the areas discussed included spectroscopy, communications, high-power applications, and laser photochemistry.



Flashlamp-pumped iodine amplifier envisaged as part of an eight-beam laser structure at Laboratoires de Marcoussis in France. Flashlamps are in the gain medium.

The development of new laser devices will be followed by many new and unforeseen applications, as S. Desmond Smith noted. Increased development of new devices should be pursued in areas in which progress is feasible, recognizing that many applications will be found for a useful device.

The solution to a laser problem is often contingent on solving more than one ancillary technological problem. This point was discussed by Art Guenther of the Air Force Weapons Laboratory. Thus many problems, including power conditioning, reliability, efficiency, and utility, must be addressed in the development of a useful device. It is easy to neglect these problems, concentrating only on one aspect; yet each of these areas is just as essential for applications as a proof-of-principle demonstration of lasing.

Support of basic laser research in universities by non-mission-oriented agencies is very low, particularly when compared with support for large single-goal projects involving lasers. A valuable national resource that is especially applicable to these many separate problems requires more support because the solution of these problems will provide the foundation for future technology.

Finally, the current job market is a particularly sensitive issue. The university and government agencies are experiencing tremendous difficulties in recruiting needed manpower and are for the present unable to compete adequately with the drain of personnel at all levels to industrial positions.

SUMMARY

During the last few years impressive results have been achieved in several areas. Important new developments include the Raman-shifted CO_2 devices, the optically pumped near-IR solid-state lasers, the new optically pumped gas lasers, the iodine lasers, and the new generation of spectroscopic laser devices. The research and development of new IR lasers is incorporating many different approaches, from existing submillimeter technology to quantum electronics and approaches that are also being employed in the visible and ultraviolet. Perhaps the current state of the art might be compared to the development of color television 20 years after the discovery of Hertzian waves.

It has become apparent that in order to achieve a new laser that is useful, a broad variety of problems must be addressed. The problem of IR laser development remains challenging and complex; however, on the basis of results presented at the meeting, the following may be concluded: a larger amount of research support should be directed toward funding of the smaller, varied projects—projects that lead to important results such as these. It is because the results are so varied, and yet each important in itself, that they contribute to the foundation of future technology.

It is a pleasure to acknowledge the work of the program committee in organizing the meeting. The efforts of Curt Wittig as technical program chairperson and of Robert Byer, Paul Christensen, Terry Cool, Anthony DeMaria, Harold Fetterman, Art Guenther, Randy Jones, Paul Kelley, and Jarus Quinn and the Optical Society office were especially appreciated.