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1985

PROCEEDINGS

of the

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SPIE Volume 540

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SOUTHWEST CONFERENCE ON OPTICS

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INTRODUCTION

In 1985 the Los Alamos Conference on Optics, which had been held previously in Los Alamos and Santa Fe, New Mexico, expanded its coverage and moved to Albuquerque as the Southwest Conference on Optics. This was made possible by a broad increase in the Conference sponsorship, which this year included research and educational institutions throughout New Mexico, Colorado, Arizona, Utah, Texas, and old Mexico, as well as SPIE, OSA, and LIA.

Proceedings of the three previous conferences have been published as SPIE Volumes 190 (1979), 288 (1981), and 380 (1983). Because of the increased size of the 1985 conference, the proceedings are being published this year in three volumes: the Proceedings proper; Critical Review of Technology: Radiation Effects in Optical Materials (SPIE 541); and Optical Fabrication and Testing Workshop: Large Optics (SPIE 542). In that portion of the Conference represented by the present volume, about 115 papers were presented, of which the majority were contributed papers given in poster sessions. The texts of most of these papers, both invited and contributed, are included here.

The organization of this volume generally follows that of the Conference, with the papers arranged by the various sessions: General Invited Papers; Optical Components, Materials, and Design; Lasers and Laser Systems; Spectroscopy and Spectroscopic Applications; Applications of Optics; and the Symposium on Optics Along the Rio Grande Research Corridor. There was some rearrangement to provide for a more logical sequence, and the postdeadline papers have been placed in their proper sessions.

It is a pleasure to thank the authors for providing camera-ready text of their contributions, for the most part on time and according to specifications. Each contributed paper has benefitted from two reviews, and thanks are due the reviewers (listed below) who gave generously of their time to help insure the quality of these Proceedings. The prompt and cooperative responses of all these people facilitated rapid publication. I also wish to thank Suzanne Stotlar, Conference Chairman, and the SPIE staff, particularly June Thompson and Kaye Pederson, for their assistance.

It is my hope, and that of every member of the Conference Organizing Committee, that these Proceedings will be useful in summarizing the state of optics research in the southwestern United States, as well as conveying some idea of the excitement felt by those of us fortunate enough to live and work in this region.

R. S. McDowell, Editor
Los Alamos National Laboratory

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OVERVIEW

The Southwest Conference on Optics was held March 4-8, 1985, at the Convention Center in Albuquerque, New Mexico. An outgrowth of the Los Alamos Conferences on Optics ('79, '81, and '83), this meeting brought together over 750 professionals, exhibitors, students, and guests to discuss recent developments in optics, optical technologies, and optical engineering. Enjoying a broad sponsorship from national societies and regional institutions, the contributions of the major laboratories and universities were highlighted. Attendees came from the United States and fifteen foreign countries. Over 150 papers were presented in the Optical Fabrication and Testing Workshop, the Critical Review of Radiation Damage in Optical Materials, and the regular program, 100 in poster format.

The conference also generated money to begin a scholarship fund to support optics-related study by regional students. This fund will be administered by the Albuquerque and Los Alamos sections of the Optical Society of America.

To the sponsors and committee of the conference go my thanks and congratulations. A meeting of this nature requires devotion to detail, endless hours, and great sacrifice, all voluntary. The sponsors, the organizing committee, and the members of the advisory committee are listed elsewhere in this volume. Without them, the Southwest Conference on Optics would not have been possible. Los Alamos National Laboratory and SPIE-- The International Society for Optical Engineering have sponsored the conference since its inception. Joe Yaver, Executive Director of SPIE, has provided his assistance unstintingly. Peter C. LaDelfe, Los Alamos, has served as treasurer since 1978 and taken on many other jobs. After serving on the editorial committee for several years, Robin S. McDowell has edited the '83 and '85 proceedings, no small task.

Having chaired both the Los Alamos and Southwest Conferences on Optics, one of the major rewards of this position has been the opportunity to work with some of the most talented and able members of our field. In technology, in resources, in environment, and in people, the Southwest is an exciting region with broad impact in optics. I hope that future meetings in this area will continue to benefit from the community support we have received.

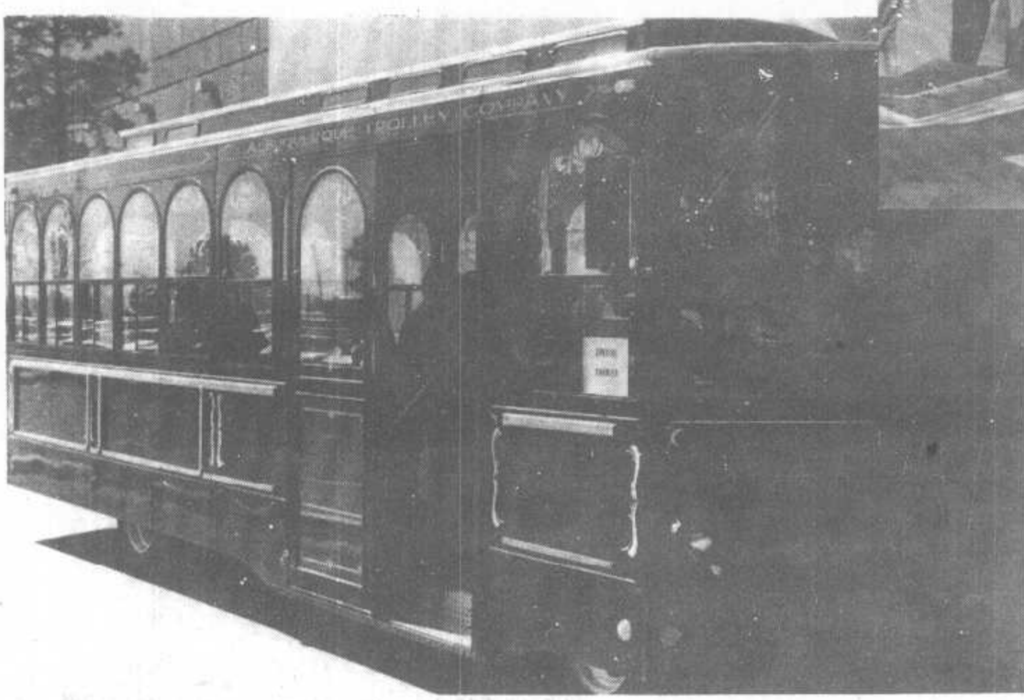
Suzanne C. Stotlar, Chairman
Los Alamos National Laboratory

SCENES FROM THE SOUTHWEST CONFERENCE ON OPTICS

R. Shannon, OSA President

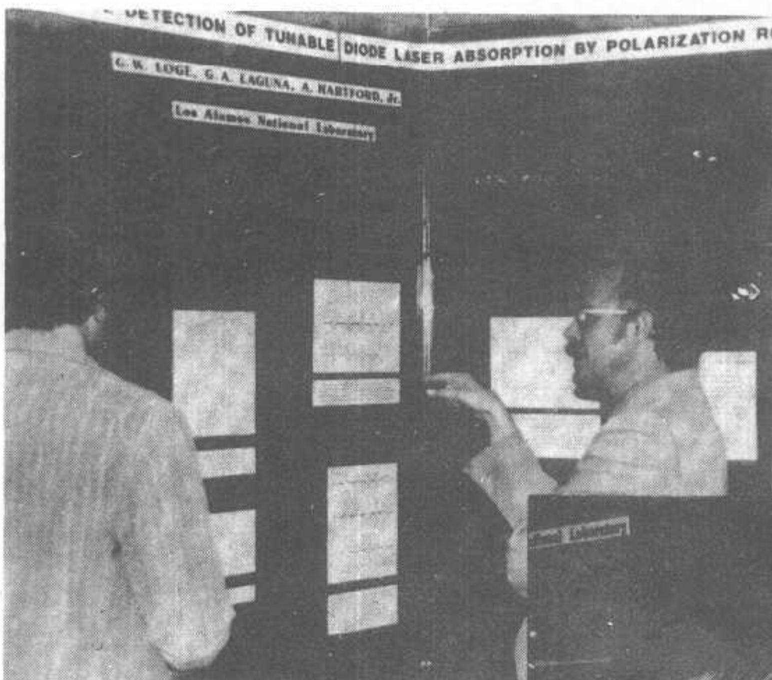
Air Force Weapons Laboratory Tour

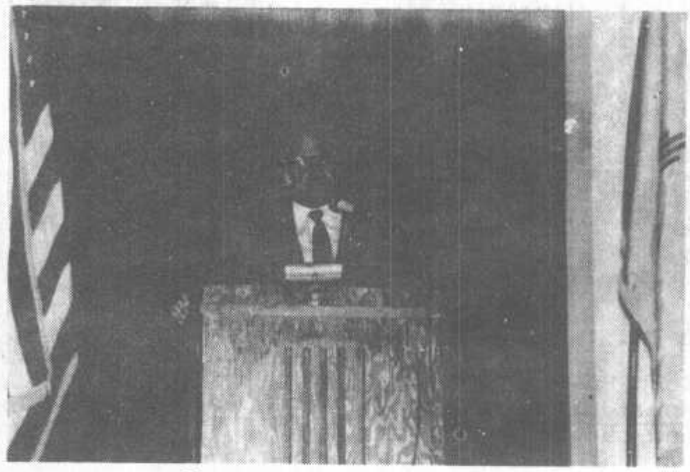
D. Malacara and son, Centro de Investigaciones en Optica



Molly Trolley transported attendees

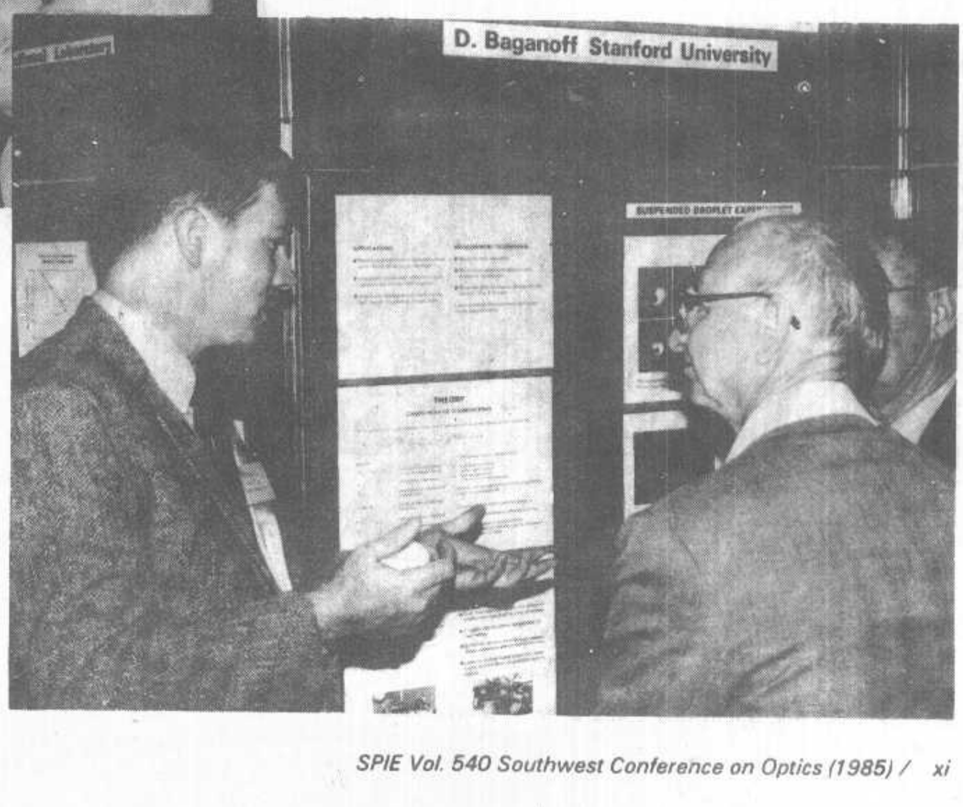
Exhibitor

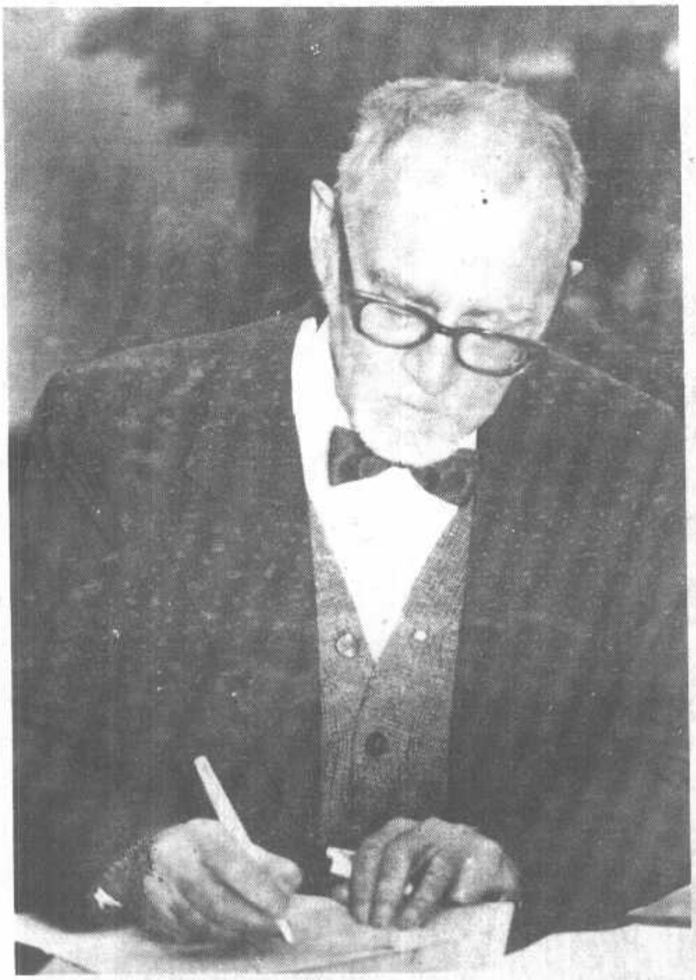




Albuquerque Mayor Harry B. Kinney

Poster presentations

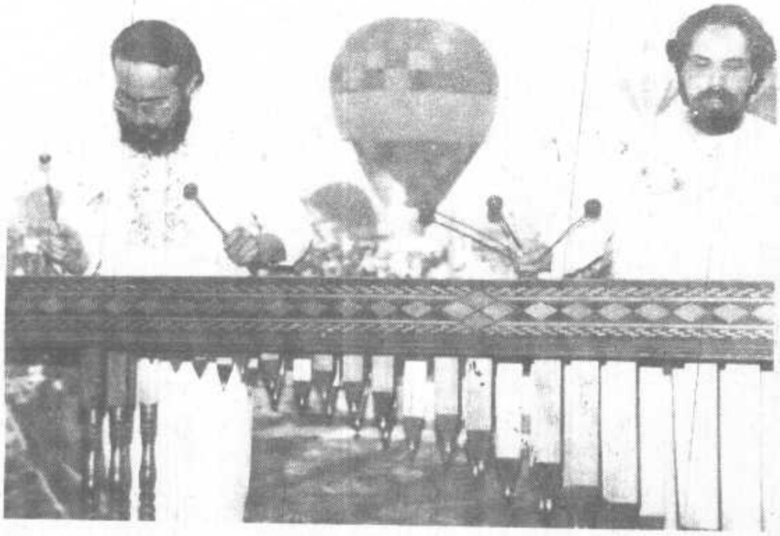




John Howard, Editor of
Applied Optics and Optics News
and banquet speaker

(left to right) Joe Yaver, SPIE Executive Director; S. C. Stotlar, Conference Chairman; and P. C. LaDelfe, Treasurer

Exhibits



New Mexico Marimba Band

S. C. Stotlar,
Conference Chairman

Students visit the exhibits

Art Guenther, AFWL

Session

H. A. Macleod

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Passive optical limiting

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Abstract

We describe a completely passive technique for limiting the power of light beams. The techniques we use are based on optical self-action (self-focusing or defocusing) and nonlinear absorption or a combination of both. These processes are passive and thus require no external mechanism to induce limiting other than the light beam itself.

Introduction

In this paper we report the results of our efforts to develop a nonlinear optical limiter that is completely passive. We present results using a technique by which self-focusing, nonlinear absorption and laser-induced breakdown are used to make the optical power limiter. The basic concept is to use irradiance dependent refraction (self-focusing) and irradiance-dependent absorption to make a passive optical device which has high transmission for low input power, but low transmission for high input power. Results for picosecond pulses and cw input are presented.

Passive optical limiting concept

In this study we used a "tight" focusing arrangement to demonstrate optical limiting. The beam is tightly focused into the nonlinear material and the propagation distance through the cell is large with respect to the Raleigh range, i.e., the depth of focus is small relative to the sample thickness. Irradiance dependent refraction (self-focusing or self-defocusing) and/or irradiance dependent absorption limits the far field fluence. We have previously demonstrated a device based on this concept using nanosecond pulses at 1.06 μm[1] and 10.6 μm[2] and picosecond pulses at 1.06 μm and 0.53 μm.[3,4] The device, which we refer to as an optical power limiter (OPL), is described in detail in reference 3 and is similar to the arrangement used by Bjorkholm et al.[5] to make a bistable device and by Teite et al.[6] to make a power limiter for cw lasers.

In experiments where self-focusing is the dominant nonlinearity we observe catastrophic self-focusing which results in laser-induced breakdown. For materials with negative nonlinear refractive indices, we observe defocusing[8,9,10] and subsequent beam breakup at high input powers.

The fact that the light is focused into the nonlinear material results in an enhancement of the nonlinear processes (self-refraction and/or nonlinear absorption). Many materials exhibit both nonlinear absorption and nonlinear refraction and this arrangement allows for the exploitation of both phenomena.[8] The device response time is dependent on the response time of the nonlinear medium and therefore can be extremely fast, e.g., reorientational self-focusing in CS_2 has a 2 ps response time and materials for which the electronic Kerr effect is the dominant nonlinearity should result in limiting in 10^{-14} seconds. Finally, the device is completely passive.

Results and materials considerations

An example of the limiting behavior of the device described above is shown in Figure 1. For these data the nonlinear material is CS_2. In Figure 1 the device output (D_4) is plotted as a function of the input power for two pulsewidths. The laser wavelength is 0.53 μm, the beam is linearly polarized, and the pulsewidths are 30 and 100 ps (FWHM). Each data point represents the average of five laser firings. Note that the response of the device is linear up to the cutoff power, P_c, of approximately 7 kW and is clamped for higher input powers. There is no apparent pulsewidth dependence shown in Figure 1. This is as expected since the response time for the dominant nonlinearity (the optical Kerr effect) is approximately 2 ps, which is much shorter than pulses used in this experiment. We have shown previously that $P_c=P_2$, the so called second critical power which is related to n_2 by the following relationship[7]

$$P_2 = \frac{3.77\ c\lambda^2}{32\pi^2 n_2}$$

where n_2 is the nonlinear refractive index in esu, λ is the laser wavelength, and c is the speed of light in vacuum. Note that the limiting power scales as the wavelength squared for constant n_2.

By choosing a material with the appropriate n_2 one can adjust the limiting power to the desired value. The fact that liquids having different values of n_2 may be mixed to adjust P_c is a distinct advantage of liquid based optical limiters.[3] An additional advantage is that if optical breakdown of the material occurs, liquids are self-healing. In general it is a simple matter to adjust P_c to a value higher than that shown in Figure 1 since CS_2 has a relatively large n_2 and there are many solvents (e.g., CCl_4 and ethanol) which have very small n_2's. It is quite difficult to decrease the limiting power below that achieved with CS_2. While we and other workers have studied materials which exhibit larger nonlinearities than CS_2 for selected wavelengths and pulsewidths, to our knowledge no other material has the combined large n_2, (1.3×10^{-11} esu) fast response time (2 ps), and broad band response observed in CS_2. In fact CS_2 has a transmission window in the 10.6 µm region and we have recently demonstrated pulsed-power limiting and cw limiting at this wavelength. The pulsed limiting experiments are reported in detail elsewhere in these proceedings and cw results are shown in Figure 2.

The mechanism for the limiting shown in Figure 2 is thermal defocusing. The residual absorption in CS_2 at 10 µm is approximately $0.1\ cm^{-1}$. In this demonstration the beam was focused into a 1 cm thick cell with a 25 cm focal length lens used at f/10. A more optimum geometry, e.g., a tighter focus into the cell, should result in limiting at a lower input than the 0.1 W shown in Figure 2.

Another advantage of using liquids for limiter applications is that they can be used as solvents for other materials that can alter their optical properties.[3] For example, chlorobenzene is a solvent which exhibits a relatively large, fast optical Kerr effect as shown in Figure 3. In Figure 3 the laser wavelength is 530 nm, the beam is circularly polarized, and the pulsewidths are 30 and 100 ps (FWHM). In this case limiting occurs at approximately 35 kW, which may be reasonable for some ps applications, but would be of little use for cw beams. However, a slight amount of mode-locking dye dissolved in the chlorobenzene results in a small amount of broad band absorption. This absorption, in turn, results in thermal defocusing and the resulting limiting is shown in Figure 4. In this case the laser source is a 545 nm, linearly polarized, cw Argon ion laser beam. Limiting is initiated at 3-5 mW and is maintained up to the 2 W maximum output of the laser source used in this experiment. No attempt was made to optimize the thermal defocusing which produced the limiting shown in Figure 4. For example, higher dye concentrations and a tighter beam focus could significantly reduce the limiting power.

Much of our effort is directed toward finding materials which exhibit large nonlinear absorption and/or nonlinear refraction. Three classes of materials which we are currently examining in detail are liquid organics, liquid crystals and intermediate band-gap semiconductors (such as the II-VI materials).[8,9,10] Effective limiting has been demonstrated in the liquid crystal MEBBA, (4-methyl benzylidene 4'-n-butylaniline) for 0.53 µm, ps pulses.[11] The onset of nonlinear transmission in this material occurs at a considerably lower inut power than observed for CS_2 for similar input parameters. The limiting observed in MEBBA and other liquid crystals at 0.53 µm does not have a sharp cutoff power as does CS_2, rather there is a region of continuously changing transmission prior to limiting. This behavior is probably due to nonlinear absorption prior to the onset of catastrophic self-focusing. In fact a two-photon absorption coefficient of 0.6±0.2 cm/GW has been measured for this material.[11]

The mechanism for the observed nonlinearity in MEBBA is not yet understood. We are presently conducting more extensive studies of this material, other Shiff base liquid crystals, and liquid crystal esters. More refined characterization techniques are needed in order to more completely characterize the nonlinear properties of materials for which both nonlinear absorption and nonlinear refraction play an important role. Techniques presently used in our laboratories are described in greater detail elsewhere.[8,9,12]

Summary

The growth of laser applications in a large number of areas, the emergence of optical information processing, and the prospect of optical computing have lead to a need for various types of optical limiters and switches. One such device, the OPL, is the optical equivalent of the Zener diode. We have demonstrated such devices with picosecond response times using various liquids and liquid crystals as the nonlinear optical medium. We have also done studies on optical limiting in solids.[8,9,10] The continued development of materials, such as liquid crystals, with large, fast, broad band nonlinearities is needed to lower the threshold power at which such devices limit or switch off. This development, on the other hand, is paced by research efforts which are directed toward developing a more