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Laser Induced Damage in Optical Materials: 1984

BOULDER DAMAGE SYMPOSIUM

STP 954

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[1]Headquarters and Laboratories at Gaithersburg, MD, unless otherwise noted; mailing address Gaithersburg, MD 20899.
[2]Some divisions within the center are located at Boulder, CO 80303.
[3]Located at Boulder, CO, with some elements at Gaithersburg, MD.

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BOULDER DAMAGE SYMPOSIUM

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FOREWORD

The Proceedings contain the papers presented at the Sixteenth Symposium on Optical Materials for High Power Lasers held at the National Bureau of Standards (NBS) in Boulder, Colorado, on October 15-17, 1984. The Symposium was jointly sponsored by the National Bureau of Standards, the American Society for Testing and Materials, the Office of Naval Research, the Defense Advanced Research Projects Agency, the Department of Energy, and the Air Force Office of Scientific Research. The Symposium was attended by approximately 200 scientists from the United States, the United Kingdom, France, West Germany, and the Netherlands. It was divided into sessions devoted to the following topics: Materials and Measurements, Mirrors and Surfaces, Thin Films, and finally Fundamental Mechanisms. The Symposium Co-Chairmen were Dr. Harold E. Bennett of the Naval Weapons Center, Dr. Arthur H. Guenther of the Air Force Weapons Laboratory, Dr. David Milam of the Lawrence Livermore National Laboratory, and Dr. Brian E. Newnam of the Los Alamos National Laboratory. They also served as editors of this report. Dr. Alexander J. Glass of KMS Fusion acts as Conference Treasurer with Aaron A. Sanders of the National Bureau of Standards as the Conference Coordinator.

The editors assume full responsibility for the summary, conclusions, and recommendations contained in the report and for the summaries of discussion found at the end of each paper. The manuscripts of the papers presented at the Symposium have been prepared by the designated authors, and questions pertaining to their content should be addressed to those authors. The interested reader is referred to the bibliography at the end of the summary article for general references to the literature of laser damage studies. The Seventeenth Annual Symposium on this topic will be held in Boulder, Colorado, from October 28-30, 1985. A concerted effort will be made to ensure closer liaison between the practitioners of high peak-power and the high average-power community.

The principal topics to be considered as contributed papers in 1985 do not differ drastically from those enumerated above. We expect to hear more about improved scaling relations as a function of pulse duration, area, and wavelength, and to see a continuing transfer of information from research activities to industrial practice. New sources at shorter wavelengths continue to be developed, and a corresponding shift in emphasis to short wavelength and repetitively pulsed damage problems is anticipated. Fabrication and test procedures will continue to be developed, particularly in the diamond-turned optics and thin-film areas. Comprehensive modeling studies are, as well, anticipated.

The purpose of these symposia is to exchange information about optical materials for high power lasers. The editors will welcome comment and criticism from all interested readers relevant to this purpose, and particularly relative to our plans for the Seventeenth Annual Symposium.

H. E. Bennett, A. H. Guenther,
D. Milam, and B. E. Newnam
Co-Chairmen

DISCLAIMER

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Symposium Welcome and Perceptions of Future Research

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On behalf of the Symposium Steering Committee of Drs. Harold Bennett, Arthur Guenther, David Milam, and myself, I welcome all of you to the 16th Annual Symposium on Optical Materials for High Power Lasers. Having participated in these Symposia since 1971, I recognize among you a number of persistent old timers as well as many new faces. Obviously, these Symposia are still of great interest to a significant number of scientists in the laser community. For the last several years, we have comprised between 180 and 200 participants and between 40 and 60 papers, as revealed by figure 1, a chart of our experience.

In his opening remarks at last year's Boulder Damage Symposium, Art Guenther reviewed the main themes of laser damage research of the previous 15 years. This year I want to describe my perceptions of the progress needed in the near future. Do you recall the fervor of activity in the late 1960's associated with America's Apollo spacecraft mission? A major concern in those days was the impact of the space environment on the thermal control surfaces such as white reflective paints and second-surface metal mirrors. The potentially dangerous elements of the space environment included solar ultraviolet radiation, electrons and protons in the Van Allen radiation belts, micrometeorites, and the vacuum of space. A number of aerospace companies assembled space effects laboratories, including high-pressure arc lamps, to simulate the ultraviolet portion of the solar radiation and charged-particle simulation chambers. These environmental simulations produced a large amount of very useful data on radiation resistance. Thus, adequately damage-resistant materials were identified or subsequently developed, and the mission to the moon was a resounding success.

Today, similar attention is beginning to be focused on the effects of machine-produced high-energy radiation environments on the window materials and reflective coatings in lasers driven by electron accelerators. Currently, there is much concern about optical elements in the large e-beam-driven excimer lasers for 248 and 351 nm, in particular. Besides having adequate damage resistance for the primary uv laser wavelength, optical coatings must survive the impact of electrons of 100 to >300 kV energies and the resultant x rays. To add further insult, some of the coatings must function in a fluorine gas environment! Laboratory research on coating degradation for e-beam-pumped excimer lasers has been proceeding now for only one or two years.

Recently, another very important accelerator-driven device, the free-electron laser (FEL), has become prominent. Having been associated with the FEL research program at Los Alamos for the last five years, I am very optimistic about its future role in such applications as materials research, industrial chemistry, medical surgery, as well as a potential military tool. Since the first operation of an FEL oscillator at 3.4 μm at Stanford University in 1977 [1], there has been a number of FEL oscillator demonstrations extending from the visible through the sub-millimeter range. Table 1 lists the experimental progress. For more information, the interested reader should consult the review article of Charles Brau [9].

FELs require electron accelerators with energies ranging from a few MeVs for submillimeter waves to 100 to 200 MeV for visible wavelengths. Upon collision with various materials in the accelerator structure, electrons with such energies naturally produce other high-energy radiations, such as x rays, gamma rays, and neutrons. Additionally, the periodic wiggling motion of the electrons traveling through the magnetic undulator (gain region) naturally produces harmonics of the fundamental lasing wavelength. For example, for an FEL lasing at 500 nm, there can be significant power in the harmonics in the extreme-ultraviolet range (<100 nm). The optical elements composing the oscillator cavity and the external directing mirrors cannot be allowed to degrade significantly by any of these radiations.

In the first tests with an infrared (10 μm) FEL oscillator at Los Alamos, electrons caused some permanent damage and x rays caused temporary color centers in the NaCl Brewster windows. The presence of transient absorption was also suspected. With the resulting round-trip losses, the FEL could not reach the lasing threshold. To avoid these losses and attain vigorous lasing, it was necessary to remove the Brewster windows, leaving the cavity mirrors in the vacuum [6,8].

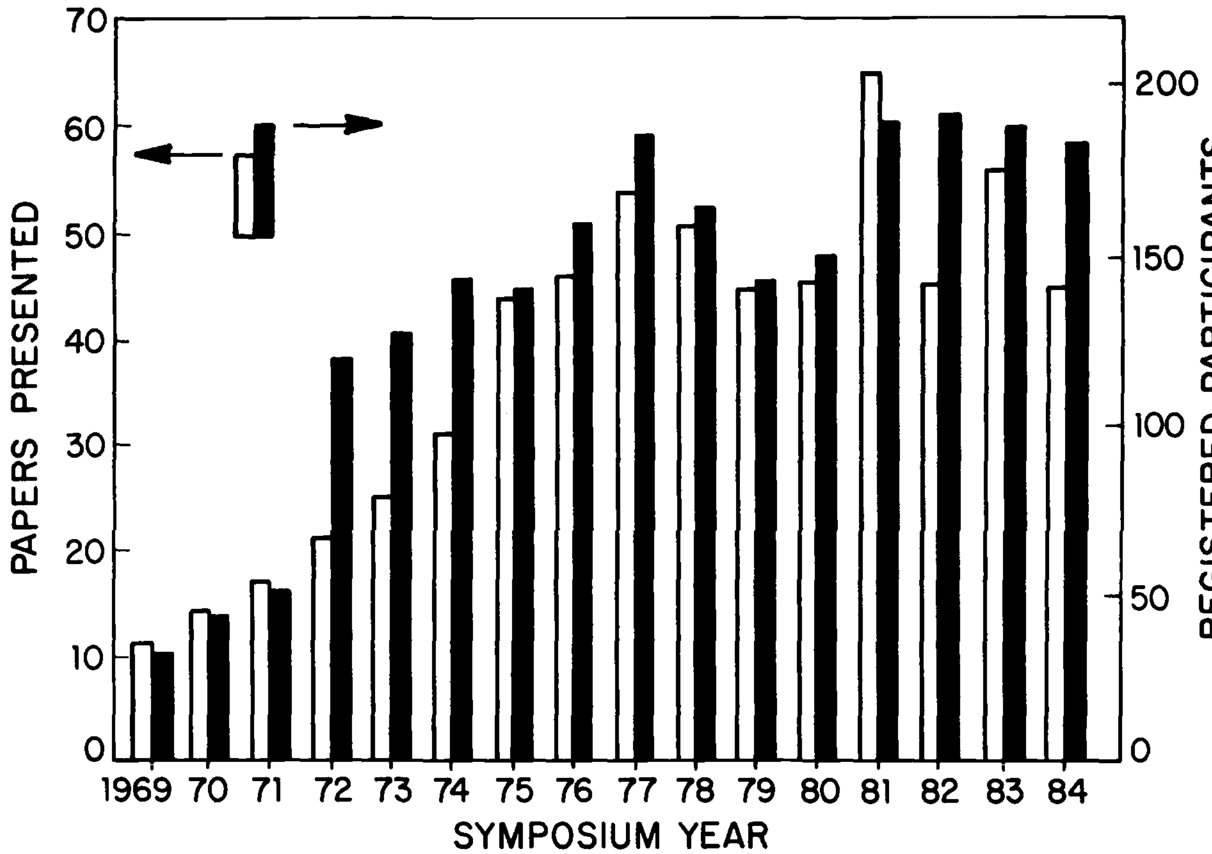

Figure 1. Boulder damage symposium history.

Although radiation-induced degradation of output windows between the laser and atmosphere will still be a concern for powerful, visible-wavelength FELs, the primary future requirement will be for cavity reflectors with reflectances of the order of 99.9% which are not significantly degraded by the multiple environments. We should take note that in the last year FEL researchers at the University of Paris at Orsay have already had to contend with actual degradation of resonator mirror coatings (TiO_2/SiO_2) induced by ~120-nm photons associated with lasing at 640 nm.

The frontier for FELs, as well as for laser oscillators based on harmonic generation and four-wave mixing, is in the VUV and XUV. Attainment of sufficiently high reflectance below 100 nm to permit lasing is a present limitation. However, the recent attainment by Barbee, et al. [10] of over 50% reflectance at near-normal incidence at 17 nm by a Mo/Si multilayer reflector is very encouraging. Such a reflectance over a large enough surface could make an XUV FEL oscillator possible. Who knows? Perhaps one of the topics about which we will hear in future Laser Damage Symposia will be the damage resistance of 100-nm reflectors!

In concluding, I wish to extend our gratitude to the staff of the National Bureau of Standards at Boulder for making these fine facilities available, and for their great assistance in the planning, arrangements, and conduct of our meeting plus their part in preparing the proceedings for publication. These include Dr. Robert Kamper, Chief of NBS-Boulder, Aaron Sanders, Head of the Optical Electronic Metrology Group and the NBS Coordinator of these meetings, and Susie Rivera, Aaron's able administrative assistant who has dealt with almost all facets of these Symposia over the years. Other involved NBS staff are Ann Mannos, Kathy Sherlock, and Shirley Deeg. Pat Whited of the Air Force Weapons Laboratory has also participated in the meeting planning and arrangements.

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Table 1

Summary of Visible and Infrared Free-Electron Laser Oscillators

		Wavelength	Peak Power	Average Power*
1977	Stanford University [1]	3.4 μm	400 kW	5 W
1983 (June)	University of Paris and Stanford University [2]	640 to 655 nm	16 W	5 x 10^{-4} W
1983 (July)	TRW Inc. and Stanford University [3]	1.6 μm	1.2 MW	80 W
1983 (November)	Los Alamos [4]	9 to 11 μm	700 kW	1000 W
1984	Yerevan Phys. Inst. (Armenia) [5]	~40 μm	~6 kW	10 W
1984 (March)	Los Alamos [6]	9 to 11 μm	5 MW	3000 W
1984 (August)	University of California at Santa Barbara [7]	400 μm	~10 kW (est.)	3000 W
1984 (October)	Los Alamos [8]	9 to 35 μm	10 MW	6000 W

*Average over electron macropulse

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