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Laser Induced Damage in Optical Materials: 1987

BOULDER DAMAGE SYMPOSIUM

ASTM

STP 1038

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- Reactor Radiation

[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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NOTE: As of 23 August 1988, the National Bureau of Standards (NBS) became the National Institute of Standards and Technology (NIST) when President Reagan signed into law the Omnibus Trade and Competitiveness Act.

BOULDER DAMAGE SYMPOSIUM

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Foreword

The Proceedings contain the papers presented at the Nineteenth Symposium on Optical Materials for High-Power Lasers held at the National Institute of Standards and Technology in Boulder, Colorado, on October 26-28, 1987. The Symposium was jointly sponsored by the National Institute of Standards and Technology, 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 over 190 scientists from the United States, Canada, the United Kingdom, India, Japan, France, Taiwan, and the Federal Republic of Germany. 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, Dr. Brian E. Newnam of the Los Alamos National Laboratory, and Dr. M. J. Soileau of the University of Central Florida. They also served as editors of this report.

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 Twentieth Annual Symposium on this topic will be held in Boulder, Colorado, October 26-28, 1988. 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 1988 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. It is our intention to pause and reflect on progress over the past twenty years of the Symposium on Optical Materials for High Power Lasers. It will be our pleasure to present a comprehensive array of tutorial lectures by distinguished workers in the field of laser induced damage in optical materials.

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 our Gala Twentieth Annual Symposium.

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

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Certain papers contributed to this publication have been prepared by non-NIST authors. These papers have not been reviewed or edited by NIST; therefore, the National Institute of Standards and Technology accepts no responsibility for their accuracy, nor for their comments or recommendations.

Certain commercial equipment, instruments, and materials are identified in this publication in order to explain the experimental procedure adequately. Such identification in no way implies approval, recommendation, or endorsement by the National Institute of Standards and Technology, nor does it imply that the equipment, instruments, or materials identified are necessarily the best available for the purpose.

CONTENTS

Surfaces and Mirrors

Thin Films

Fundamental Mechanisms

OPENING COMMENTS - 19TH ANNUAL DAMAGE SYMPOSIUM

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The chairmen of the 1987 Boulder Damage Conference wish first to acknowledge continued support by the National Institute of Standards and Technology. Access to NIST facilities and contributions by individuals in that organization have provided a stable and comfortable environment during this series of 19 conferences. For the 1987 meeting, we had the assistance of Bob Kamper, Director, NIST Boulder, of Aaron Sanders, Leader of the Optical Electronic Metrology Group, and of an administrative staff: Susie Rivera, Edit Haakinson, and Ann Mannos. Major contributions to the organization and operation of the conference were again made by Pat Whited of the Air Force Weapons Laboratory.

This year we will have 73 papers presented by authors from 15 countries. As in previous years, the majority of the authors are affiliated with either a university or a commercial organization, while the remainder are affiliated with a national laboratory.

As has become typical, the topic most often discussed will be damage in thin films. This effort has consumed 30 to 55 percent of our effort in each year since 1977. Including the papers at this conference, we have heard 265 reports of studies related to some aspect of the production of damage resistant films. Sixteen different processes for making films have been investigated. Conservatively estimated, execution of this work required at least 100 man years. Since many participated without sharing authorship, the total effort expended was probably much greater than the conservative estimate.

Progress is apparent. Films made by several processes are better than they were 20 years ago, and our industrial facilities can now coat substrate with diameter exceeding 1 m. Films with higher density, lower stress, and lower scatter have been produced by several ion-assisted technologies. Solution-deposited silica antireflection coatings have excellent damage resistance. We have learned much about making coatings for both ultraviolet and infrared applications. Other examples of progress could be cited.

However, with few exceptions, progress has been incremental and many questions remain unanswered. The fundamental mechanism for damage in films is still a subject of debate. Large coaters do not produce films with quality equal to those that have been made in smaller research machines. And, after having studied 15 competing processes, we still rely heavily on a technique that was available 20 years ago, electron-beam evaporation.

Considering the magnitude of our past effort and the number of unresolved issues, it is possible without being overly cynical to question whether these issues can be resolved by a larger but similar effort. Note that I do not question whether progress is possible; past effort did produce a few exceptional optical coatings with thresholds 2-5 times larger than thresholds of commercially available films. We have not reached a fundamental limit.

It is more difficult to suggest what else should be done than it is to cite unresolved issues. Without pretending to know the specific steps that should be taken, I would comment on two general topics. The first is my growing concern that we have not established an adequate flow of real information from research into production. The hypothesis underlying much of our research is that information obtained through the relatively inexpensive study of small samples made in small research machines can be transferred to improve large coatings made in production machines. However, large coatings do not have thresholds as large as those frequently reported in studies of small samples. When sliced into the black and white version, this implies either that research concepts have been evaluated by production groups and found to be ineffective, or that research concepts have not been evaluated. If the former is true, is it because the research data are wrong, or do fundamental differences in large and small coaters prevent transfer of information? If the results are not being evaluated, is this caused simply by the press of production schedules and the large cost of doing research in large machines? Some rather blunt comment by our production community, which could be made without divulging the detailed proprietary aspects of coating production, would be of great value.

The second general concern is the now elderly problem of identifying the defects responsible for coating damage. Work done between 1972 and 1974 indicated that damage to coatings is initiated in very small volumes. The few exceptions are instances where spatially averaged absorption is important -- in coatings used in the far UV or far IR or those used in lasers operating at high average power. Much effort has been spent in the study of these defects, but their basic nature remains a mystery. My belief is that nonstoichiometric subvolumes are the defects which most often determine the damage resistance. However, I reach this conclusion through a rather circuitous argument and cannot prove that it is correct. Other candidates are impurities from the substrate itself, from compounds used in polishing or cleaning of the substrate, or from the coating chamber, or film imperfections such as pinholes, grain boundaries, or local areas of poor adhesion. Lacking identification of the limiting defect, we are left with the two general routes we have so far followed -- the somewhat random search for a coating process that makes perfect films, or the somewhat random tuning of existing coating processes. Since our search pattern would be narrowed by that ability to remove even some of the contenders from the list, identification of limiting defects is the most important issue before us.

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