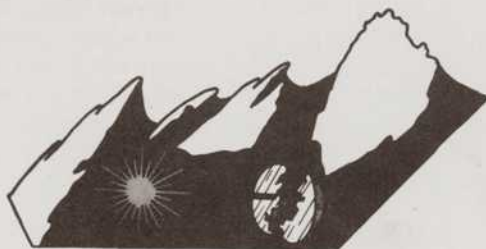




NBS SPECIAL PUBLICATION **638**

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

# Laser Induced Damage in Optical Materials: 1981



*BOULDER DAMAGE SYMPOSIUM*



STP 799

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# Laser Induced Damage In Optical Materials: 1981

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## Foreword

The Proceedings contain the papers presented at the Thirteenth Symposium on Optical Materials for High Power Lasers held at the National Bureau of Standards (NBS) in Boulder, Colorado, on November 17-18, 1981. 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, Japan, France, West Germany, the Peoples Republic of China, Sweden, and the USSR. 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 Fourteenth Annual Symposium on this topic will be held in Boulder, Colorado, from November 15-17, 1982. 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 1982 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.

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 Fourteenth Annual Symposium.

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

#### Disclaimer

Certain papers contributed to this publication have been prepared by other than NBS authors. These papers have not been reviewed or edited by NBS; therefore, the National Bureau of Standards accepts no responsibility for comments or recommendations contained therein.

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 Bureau of Standards, nor does it imply that the equipment, instruments, or materials identified are necessarily the best available for the purpose.

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SYMPOSIUM WELCOME  
Harold E. Bennett  
Naval Weapons Center  
China Lake, California 93555

Welcome to the Thirteenth Annual Symposium on Optical Materials for High Power Lasers, familiarly known as the Boulder Damage Symposium. To the uninitiated the expression "Boulder Damage" connotes the damage one can do with boulders, hence the more descriptive official name "Optical Materials for High Power Lasers." In some cases, however, the two ideas may not be too far apart. Figure 1 shows a 10-cm or 4-inch diameter laser doubler for the Livermore National Laboratory Argus laser after it was radiated by mistake with a 500-joule pulse rather than a 50-joule pulse. The results are similar to those which would have been observed if it had been hit by a boulder, and are clear evidence to those of us who are used to examining small damage sites under a microscope that laser damage phenomena do indeed scale.

Pictures like this are the spectacular part of our business, but we are only successful when nothing happens to the optical components during laser irradiation. To meet this goal, a wide number of unspectacular and usually unrelated specialties must be employed. Surface physics, multilayer film technology, materials technology, optical design, crystal growth, metallurgy, optical finishing technology, infrared and restrahten spectroscopy, solid state physics and chemistry, and laser technology are a few examples of the wide range of fields which have been applied to produce the fairly spectacular advances in laser damage threshold which have been achieved over the past decade or so. Our subject is clearly at the boundaries between conventional fields of science rather than in the mainstream of any one of them, and anyone who expects our work to be mainly running lasers and blowing up samples is simply naive.

In another sense, however, we are establishing a new field of optics. Several years ago at this symposium Major Harry Winsor, now at the Air Force Office of Scientific Research, pointed this out and suggested the name "power optics" in analogy with the handling of electrical power which at low frequencies has long been a part of electrical engineering. Previous to the advent of high powered lasers the field of optics was almost entirely concerned with what might be called signal optics, the handling of small signals, maximizing signal-to-noise ratio, etc. Radio and microwave technology is the analogous specialty in the field of electrical engineering. This symposium was set up to attack the problem of power optics and has always been the primary forum for advances in this new field of optics. It is now in its 13th year, and, although the hope was once expressed that all the power optics problems would be solved by now, I see no more evidence that will occur than that the field of power engineering at electrical frequencies will disappear.

Through the years the number of papers given at this symposium and the number of people attending it have both grown, as seen in figure 2. This year we will have 63 papers presented, the most ever, and about the maximum which can be given in a two-day meeting without going to double sessions. The meeting has also become international in scope, and we would like to warmly welcome the participants from overseas who are with us now. In addition to the Japanese and the many countries in Western Europe which are represented, we have a delegation from the Soviet Union with us today and also one from mainland China. We welcome you and are happy to prove again that science has no national boundaries.

A lot of basic information has been reported at this conference over the years, and even the old timers are having difficulty remembering where it is in the Proceedings. We therefore all owe a special debt of gratitude to the Air Force Weapons Laboratory Library which has now assembled an index

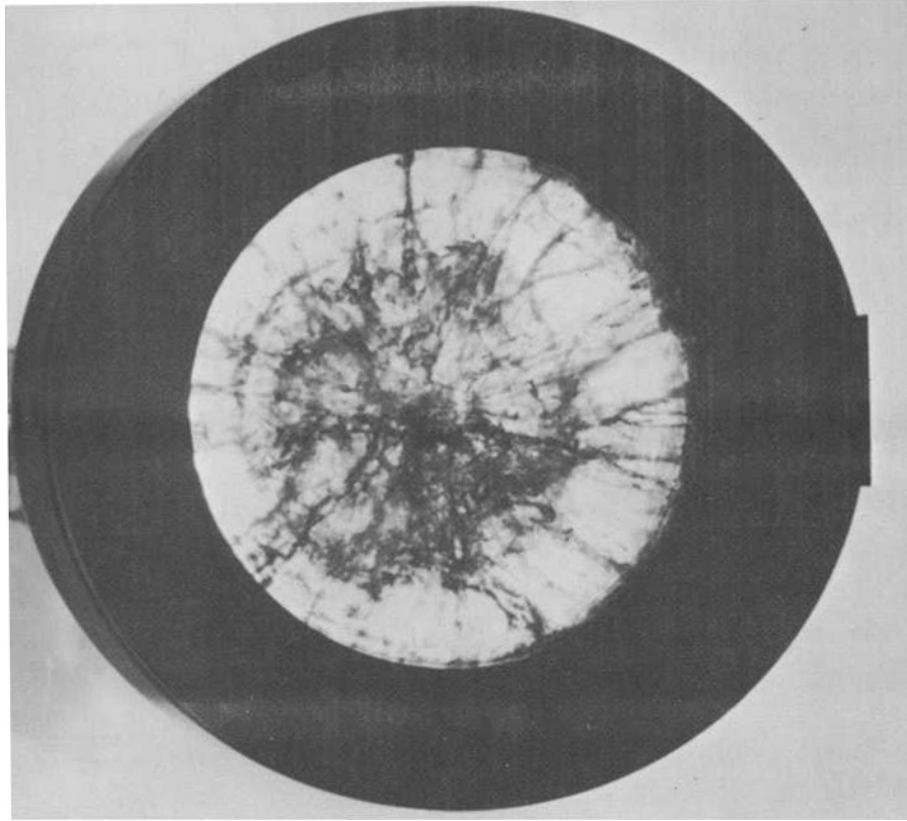


FIGURE 1. Component damage in the Argus Laser

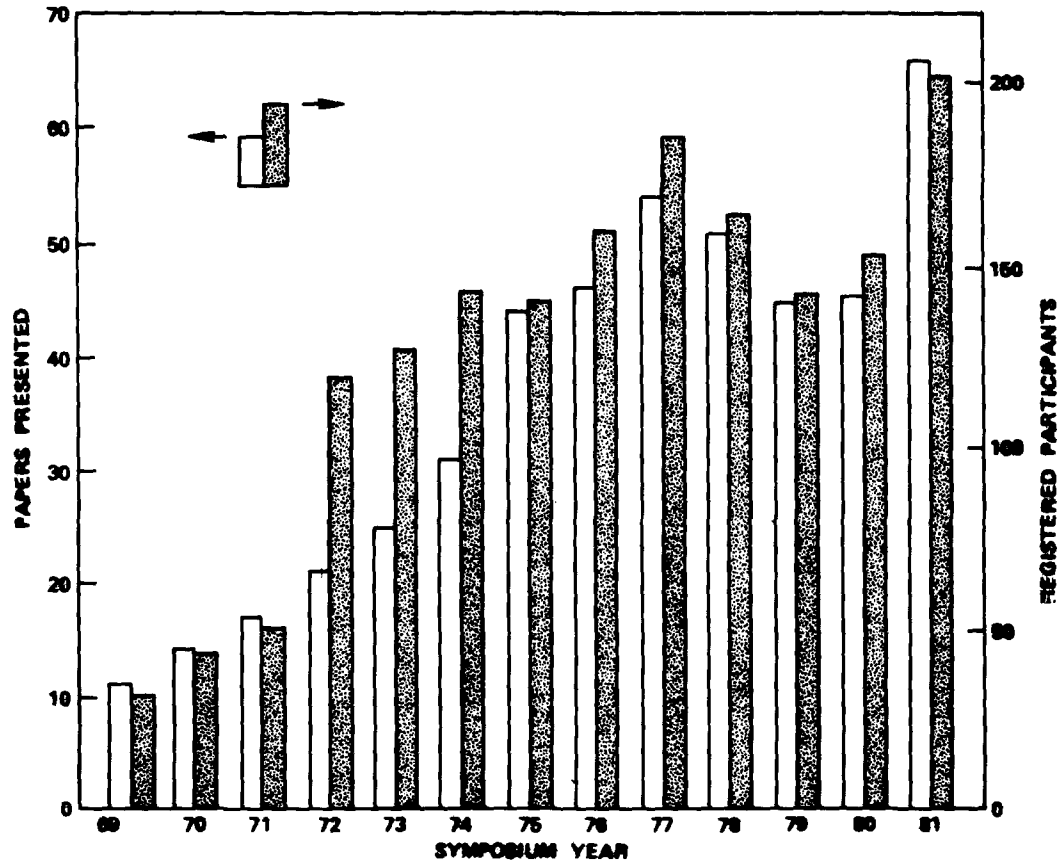


FIGURE 2. A history of the Boulder Damage Symposium

of the Symposia proceedings for the last 10 years. It includes listings by author, co-author, title, subject and key words as well as a compilation of all the published abstracts for the first 10 years. The index will be distributed to all participants of this meeting and also to those who attended the Tenth Annual Meeting but are not present today. A second index is planned by the Library to cover the following five years. It is expected to be equal in size to the initial ten-year index, which indicates how interest in the subject of power optics has grown.

A word about our poster papers. There are 22 poster papers presented on each day. Authors are to be at their poster boards during the morning poster break and again during the afternoon break. To help the audience, a rapporteur will report at the end of each morning's session on the poster papers for that day. The afternoon break is then available for members of the audience to see those papers they missed during the morning break. We are proud of the contribution our poster papers make to the symposium and are encouraged that authors often request that their papers be given as posters rather than as an oral presentation.

We are pleased to report a new addition to our management team. Dave Milam from Lawrence Livermore National Laboratory has joined Art Guenther, Brian Newnam, and myself as a full fledged member of the Steering Committee for the Symposium. Alex Glass, who with Art Guenther was responsible for initiating this Symposium and whose name is a household word to participants in the field, will remain as Treasurer of the organization. Aaron Sanders of the National Bureau of Standards in Boulder has taken the responsibility for developing funding for the symposium and will also coordinate the Bureau's support for its activities. We welcome him to the team.

Special thanks are due to Susie A. Rivera, Aaron's secretary, for acting as a focal point for the Symposium Proceedings and for handling many of the innumerable details which make the symposium possible. Thanks are also due to the others at the registration desk and especially to Pat Whited, Art Guenther's secretary, for her efficient help in making the symposium run smoothly.

Let me conclude by thanking our professional sponsor, the American Society for Testing and Materials, and our financial sponsors, the National Bureau of Standards, the Air Force Office of Scientific Research, the Office of Naval Research, the Department of Energy through both Livermore and Los Alamos National Laboratories, and the Defense Advanced Research Projects Agency for making this meeting possible. They and we hope that you will find the next two days both pleasant and valuable to your work in power optics.

## Boulder Damage Symposium 1981

### ASTM Welcome

John A. Detrio  
University of Dayton  
Dayton, Ohio 45469

Welcome to the Thirteenth Annual Boulder Damage Symposium. Maintaining the quality and high standards of technical excellence and the timely presentation of new results is indeed a difficult challenge to the participants and one that Art Guenther, Alex Glass, Hal Bennett, Brian Newnam, and Dave Milam have faced, and they have met the challenge successfully. In spite of the maturity of the laser damage field, this conference continues to provide an effective international forum for the interchange of data and ideas on laser induced damage.

There was talk a few years ago that interest was waning, the laser damage issues were dead or at least put to rest, and that not much new would be uncovered. This first midlife crisis occurred after about the seventh year. If the folk wisdom concerning changes in life directions every seven years is correct, then our second passage is fast approaching.

As with individuals whose character is strengthened by adjusting and successfully making these passages, this conference has changed its character in an evolutionary way over the years and should successfully take up the future challenges. Where will these challenges lie? Where will the pursuit of fundamental questions of laser interactions lead? No one knows for certain, but just as certainly there are still unresolved questions and issues which are being uncovered as shorter laser wavelengths are used, as pulse durations are shortened, and as power levels increase.

Many practical issues have already been identified but not solved. Multiple irradiation damage effects, the influence of contamination and its control, improved surface preparation, coating deposition, and cleaning are examples of important but seemingly mundane issues. The study of these problems will provide new insights and lead to improved components and lasers and to a better understanding of materials and laser interactions.

The experimental efforts will stimulate theoretical analysis and improvements in diagnostics. Many improvements in materials purification and analysis have benefited from, or been driven by, the needs of lasers and designers or by the desire to increase the laser damage resistance of optical components.

As long as the Boulder Damage Symposium serves the international community of scientists concerned with laser damage, the American Society for Testing and Materials will continue to support these meetings.

Last year I challenged the attendees to consider working on Laser Damage Standards. This year I have emphasized a different challenge, but one consistent with the second role that ASTM fulfills - to share knowledge and to stimulate the pursuit of knowledge.

On behalf of ASTM, WELCOME TO THE THIRTEENTH ANNUAL BOULDER DAMAGE SYMPOSIUM.

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