Laser Induced Damage in Optical Materials: 1989
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The Proceedings contain the papers presented at the Twenty-First Symposium on Optical Materials for High-Power Lasers held at the National Institute of Standards and Technology in Boulder, Colorado, on November 1-3, 1989. The Symposium was sponsored jointly by the National Institute of Standards and Technology, the American Society for Testing Materials, the International Society for Optical Engineering, the Defense Advanced Research Project Agency, and the Department of Energy. The Symposium was attended by approximately 200 scientists from the United States, Canada, the United Kingdom, Japan, France, 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 Harold E. Bennett of the Naval Weapons Center, Arthur H. Guenther of the Los Alamos National Laboratory, Lloyd L. Chase of the Lawrence Livermore National Laboratory, Brian E. Newnam of the Los Alamos National Laboratory, and M. J. Soileau of the University of Central Florida. They also served as editors of the proceedings.

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 Twenty-Second Annual Symposium on this topic will be held in Boulder, Colorado, October 24-26, 1990. A concerted effort will be made to ensure closer liaison between the practitioners of high-peak power and high-average power.

The principal topics to be considered as contributed papers in 1990 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 has been our intention to pause and reflect on progress over the past twenty years to the Symposium on Optical Materials for High Power Lasers. It will be our pleasure to present the last (Thin Film, the Second Decade) in 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 comments and criticism from all interested readers relevant to this purpose.

H. E. Bennett, A. H. Guenther, L. L. Chase, B. E. Newnam, and M. J. Soileau, Co-Chairmen
DISCLAIMER

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.

iv
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FOREWORD</strong></td>
<td>iii</td>
</tr>
<tr>
<td>H.E. Bennett, A.H. Guenther, L.L. Chase, B.E. Newnam, and M.J. Soileau</td>
<td></td>
</tr>
<tr>
<td><strong>DISCLAIMER</strong></td>
<td>iv</td>
</tr>
<tr>
<td><strong>SYMPOSIUM WELCOME</strong></td>
<td>xii</td>
</tr>
<tr>
<td>M.J. Soileau</td>
<td></td>
</tr>
<tr>
<td><strong>SEARCH FOR TECHNOLOGY TRANSFER IN HIGH POWER OPTICS</strong></td>
<td>xvi</td>
</tr>
<tr>
<td>C. Martin Stickley</td>
<td></td>
</tr>
<tr>
<td><strong>SUMMARY OF MEETING</strong></td>
<td>1</td>
</tr>
<tr>
<td>H.E. Bennett, L.L. Chase, A.H. Guenther, B.E. Newnam, and M.J. Soileau</td>
<td></td>
</tr>
<tr>
<td>1. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2. Overview</td>
<td>3</td>
</tr>
<tr>
<td>3. Acknowledgments</td>
<td>5</td>
</tr>
<tr>
<td>4. References</td>
<td>6</td>
</tr>
</tbody>
</table>

### 1989 Index - Boulder Damage Symposium

#### Materials and Measurements

- Set of Standard Definitions for Laser Damage in Parameters and Procedures. J.W. Arenberg
- Optical Characterization of Transparent Materials Using Ellipsometry. S.F. Nee and H.E. Bennett
- Microindentation as a Technique for Assessing Subsurface Damage in Optics. R.S. Polvani and C. Evans
Automated Damage Testing Facility for Excimer Laser Optics

K. Mann and H. Gerhardt

39

Expanded Damage Test Facilities at LLNL


47

Laser Damage Database at 1064 nm

F. Rainer, R.P. Gonzales, and A.J. Morgan

58

Damage Measurements on Optical Materials for Use in High-Peak-Power Lasers


74

Laser Induced Damage to Thallium Arsenic Selenide (TAS)


84

Laser Induced Damage in Schott's OG-550 Optical Absorption Glass

T. Whittaker, R. Goedert, and D. Templeton

88

Effects of Laser Damage Processes on Microwave Propagation

R.S. Eng, M.D. Abouzahra, N.W. Harris, D.R. Cohn, and P.P. Woskov

96

Laser Induced Damage to Silicon Photosensor Arrays

Chen-Zhi Zhang, Thierry Benchetrit, Steve E. Watkins, Rodger M. Walser, and Michael F. Becker

115

Sensitive $n_2$ Measurements Using A Single Beam

M. Sheik-Bahae, A.A. Said, T.H. Wei, D.J. Hagen, E.W. Van Stryland, and M.J. Soileau

126
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical Breakdown in Particle Suspension</td>
<td>136</td>
</tr>
<tr>
<td>Kamjou Mansour, M.J. Soileau and E.W. Van Stryland</td>
<td></td>
</tr>
<tr>
<td>Annealing of Induced Damage in Fluoride Glass Components</td>
<td>151</td>
</tr>
<tr>
<td>Osama H. El-Bayoumi, M.J. Suscavage, and L.P. De Rochemont</td>
<td></td>
</tr>
<tr>
<td>The Effect of Laser Annealing on Laser Induced Damage Threshold</td>
<td>164</td>
</tr>
<tr>
<td>N.C. Kerr and D.C. Emmony</td>
<td></td>
</tr>
<tr>
<td>Shockwave Detection, An Efficient Way to Determine Multiple-Pulse Damage Thresholds</td>
<td>180</td>
</tr>
<tr>
<td>S. Petzoldt, A.P. Elg, J. Reif, and E. Matthias</td>
<td></td>
</tr>
<tr>
<td>Application of the Ronchi Ruling Beam Profiling Method to Axially Symmetric Laser Beams</td>
<td>187</td>
</tr>
<tr>
<td>Robert M. O'Connell and Cheng-Hao Chen</td>
<td></td>
</tr>
<tr>
<td>Prediction of Laser Induced Damage by Comparison of Laser Fluence Profile to Damage Spot Radius</td>
<td>200</td>
</tr>
<tr>
<td>R. Goedert, T. Whittaker, and D. Templeton</td>
<td></td>
</tr>
<tr>
<td>IR Laser Beam Profiling Using Quenched Fluorescence</td>
<td>214</td>
</tr>
<tr>
<td>N.C. Kerr, S.E. Clark and D.C. Emmony</td>
<td></td>
</tr>
<tr>
<td>Laser-Induced Failure in Biased Silicon Avalanche Photodiodes</td>
<td>220</td>
</tr>
<tr>
<td>Steve E. Watkins, Chen-Zhi Zhang, Rodger M. Walser, and Michael F. Becker</td>
<td></td>
</tr>
<tr>
<td>SURFACES AND MIRRORS</td>
<td></td>
</tr>
<tr>
<td>The Effect of Subsurface Defects on &quot;Incipient&quot; (Below Threshold)</td>
<td>730</td>
</tr>
<tr>
<td>Laser Damage Nucleation In Fused Silica Optical Flats</td>
<td></td>
</tr>
<tr>
<td>T.J. Magee, C.S. Leung, F.D. Orazio, J.D. Boyer, B.R. Mauro, and V.E. Sanders</td>
<td></td>
</tr>
<tr>
<td>Quantitative Analysis of Surface Trace Metal Contamination on Substrates and Films by TXRF</td>
<td>239</td>
</tr>
<tr>
<td>R. S. Hockett</td>
<td></td>
</tr>
</tbody>
</table>
An Error Analysis of the Wyko TOPO Noncontact Surface Profiler
Van A. Hodgkin

Ultra-Precision Grinding of LHG-8 Laser Glass and Laser Damage Thresholds
Y. Namba, K. Yoshida, H. Yoshida, and S. Nakai

Low Scatter Surfaces on Silicon Carbide
Roger A. Paquin and Matthew B. Magida

Physical Limits on Ultra-High Albedo Diffuse Reflectors
Perry Miles

Optical Damage on SiO₂ Cavity Mirrors Produced by High-Power VUV Laser Irradiation

Damage Assessment and Possible Damage Mechanisms to 1-Meter Diameter Nova Turning Mirrors
G. Edwards, J. Campbell, R. Wolfe, E. Lindsey

Thermal Transport Studies of Optical Coatings, Interfaces and Surfaces by Thermal Diffusion Wave Interferometry
Randall T. Swimm and Gary Wiemokly

Thin Films

Investigation of Thin Films Using Total Internal Reflection Microscopy
F.L. Williams, C.K. Carniglia, B.J. Pond, and W.K. Stowell

Scattering Characterization of Materials in Thin Film Form
C. Amra

Optical Properties and Laser Damage Measurements of Inorganic Polymer Films
Gregory J. Exarhos and Kevin M. Crosby

Interfacial Stability in Optical Coatings
Surface Analytical Methods for the Assessment of Damage in Optical Thin Films
James R. Hoenigman

Laser Conditioning of Optical Thin Films
C.R. Wolfe, M.R. Kozlowski, J.H. Campbell, F. Rainer,
A. J. Morgan, and R. P. Gonzales

Large Area Laser Conditioning of Dielectric Thin Film Mirrors
M.R. Kozlowski, C.R. Wolfe, M.C. Staggs, and J.H. Campbell

Population Distribution of Conditioned Damage Thresholds on AR Coated BK-7 Glass
With Varying Laser Spot Size
D.W. Mordaunt and J.W. Arenberg

Damage Threshold Measurements of Reflective and Transmissive Optics at 130 nm
C.H. Muller, III and C.E. Hamilton

Laser Induced Damage Thresholds of Dielectric Coatings at 193 nm and Correlations to
Optical Constants and Process Parameters
J. Kolbe, H. Müller, H. Schink, H. Welling, and J. Ebert

Angular Dependence of Thin-Film Dielectric Coating Damage Thresholds Revisited
J. D. Boyer, S. R. Foltyn, B. R. Mauro, and V. E. Sanders

Pulse-width Dependence of Optical Coating Damage at 1052 nm

Damage Resistant Optical Coatings Prepared Using High Temperature, Plasma
Chemical-Vapor Deposition
J.H. Campbell, J.L. Emmett, R.M. Brusasco, F. Rainer, R.Th. Kersten,
V. Paquet, and H.W. Etzkorn

A High Temperature, Plasma-Assisted Chemical Vapor Deposition System
R.M. Brusasco, J.A. Britten, C.B. Thorsness, M.S. Scrivener,
W.G. Unites, J.H. Campbell, and W.L. Johnson
The Evolution of Molecular Beam Deposition (MBD) from Laboratory to Production Usage

Investigation and Modelling of Laser Damage Properties of Fabry-Perot Filters
A. McInnes, C.M. MacDonald, D.R. Gibson and A.D. Wilson

High Damage Threshold Al0.0H-Si02 HR Coatings Prepared by the Sol-Gel Process
Ian M. Thomas

1-on-1 and n-on-1 Laser Strength of Binder Aided Zr02 and Zr02-Si02 Reflective Sol-Gel Coatings
H.C. Floch and J.J. Priotton

Structural Modification of D2O/H2O-Dosed CaF2 Optical Thin Films
J.B. Franck

FUNDAMENTAL MECHANISMS

Non-Avalanche Dielectric Breakdown in Wide-Band-Gap Insulators
at DC and Optical Frequencies
P. Braunlich, S.C. Jones, X.A. Shen, R.T. Casper, E. Cartier,
D.J. DiMaria, M.V. Fischetti, and P. Kelly

UV Seeding of IR Laser Induced Damage
N.C. Kerr, S.E. Clark and D.C. Emmony

Measurements of uv Induced Absorption in Dielectric Coatings
M.H. Bakshi, M. Cecere, D.A.G. Deacon, and A.M. Fauchet

The Response of Multilayer Dielectric Coatings to Low Fluence Ultraviolet Light Exposure
V.E. Sanders, J.W. Early, and W. Leamon

Radiation Damage in Single Crystal CsI (Tl) and Polycrystal CsI
O. Barnouin, A. Procoli, H. Chung, and G.H. Miley
Effects of Thermal Conductivity and Index of Refraction Variation on the Inclusion Dominated Model of Laser-Induced Damage
M.Z. Fuka, J.K. McIver, and A.H. Guenther

Theoretical Determination of the Nonlinear Optical Properties of Inorganic Polymers
Steven M. Risser and Kim F. Ferris

Relation Between $n_z$ and Two-Photon Absorption
M. Sheik-Bahae, D.J. Hagan, E.W. Van Stryland, T.H. Wei
A.A. Said, E. Canto, and A. Miller

Photoconductivity of ZnS and ZnSe
B.E. Mason and C.D. Marrs

Formation of a Prefigured Reflecting Surface Topography by Elastic Deformation of the Mirror Substrate. New Concept of Adaptive Optical System
V.V. Apollonov, S.A. Chetkin, E.A. Ivanova, A.M. Prokhorov, G.V. Vdovin

Application of Ultrasonic Capillary Effect in Elements of Power Optics Cooled by Means of a Heat Pipe
V.V. Apollonov, S.A. Chetkin, V.N. Kharchenko, V.N. Motorin, and A.M. Prokhorov

Appendix I. List of Attendees
It is my pleasure and duty to call this year's meeting to order. I was abroad when the final program was put together by my co-chairs and did not learn of this honor until a couple of weeks ago. I had no time to prepare until this weekend, so this will be a bit rough and without the benefit of elegantly prepared slides.

I don't mean to take a stab at my co-chairs, but I must admit that as I began my preparation I couldn't remember a single thing about previous opening remarks by my esteemed colleagues! Did I miss something? Surely these distinguished leaders of national laboratories must have said something profound and prophetic! So I spent part of the day Saturday reviewing the past utterances which have launched this meeting.

It is true that the memory is the second thing to go, because as I read the opening remarks for the past 20 meetings, I found many, profound statements--a few of which are listed below:

This is a quote from the next speaker from 1972:
"It is a pleasure to be here this afternoon."
Martin Stickley, 1972.

"Whatever turns you off." (Alex's definition of damage)
Alex Glass, 1974

"A name which invokes images of people cracking rocks."
Alex Glass, 1976. (In response to Martin Stickley's call for a more positive sounding name for the conference.)

"Our onion unfortunately, exists in Hilbert Space." (Alex borrowing from an ancient philosopher's description that learning is like peeling an onion--each layer exposes another.)

"Who cares?" (Alex on why study damage?)
Alex Glass, 1976.

"It is my annual hope that each year's symposium will be the last." (Alex the failed prophet.)
Alex Glass, 1978.
"The key...is terawatts per megabuck.
Alex Glass, 1978.

"Power Optics." (A supplier of megabucks at the time in comparing laser optics to electronics.)

"Aside from a gain medium, lasers require mirrors." (Insightful words from the great visionary.)

"Progress has been made, but I am confident that in 10 years we will celebrate the 20th and Art and Alex will still be running it!" "...we owe a debt to these 2 young men." (Note the term young.)

To this point I've spared you the profound utterance of my current co-chairs such as:

"Welcome to the Tenth Anniversary Damage Symposium." (Art Guenther gave this greeting at the 11th meeting.)

Then there were profound things said regarding the international participation.

"...countries represented include the British Isles, Canada, England, France, Japan, Scotland, and West Germany:" Brian Newnam, 1980.

"International contributors...have come a long way..."
Hal Bennett, 1985.

It should be clear to all how difficult it is for me since these guys have used up all the good stuff! Further review of these openings presented me with a good outline for my remarks. I will follow the trail blazed by my predecessors:

Outline
1. Welcome participants.
2. Acknowledge sponsorship of NIST, ASTM, and others.
3. Count the papers for this year's meeting and comment on the statistical distribution.
4. Observe that thin films are a major problem.
5. Profound and prophetic statement about the future of the meeting.

I do welcome you to the 20th Anniversary Boulder Damage Symposium. Those of you who are still asleep or partially hung over, may be confused by the fact that last year was our 20th Anniversary celebration. The resolution of this dilemma is the fact that last year was the 20th meeting and this is
the 20th Anniversary (but the 21st meeting). One might say that this meeting is old enough to drink - but you will also note that there is no wine and cheese this year. This situation has resulted from rulings by NIST accountants. In fact, the accountants have made it difficult for us to conduct business as usual, so you can expect further changes next year.

We do want to thank NIST and the ASTM for their continued sponsorship and all the helpful folks at Boulder who make the meeting run smoothly.

There are about 70 papers this year with contributions from 6 countries in addition to the U.S. The talks from abroad constitute 27% of the papers, about the same percentage as from Livermore and Los Alamos. About an equal number of papers come from U.S. aerospace companies (15%) and U.S. universities (16%). About 9% are from DoD labs and the remaining 8% from various other sources.

Our next speaker (Martin Stickley) has suggested on a number of occasions that the name of the conference be changed to something more positive. I want to finish this presentation by noting that there are many positive things being done with phenomena studied by participants in these meetings. Here is a list of a few:

"Spin Offs" of LID Phenomena

1. Laser marking, cutting and drilling of materials.
2. Laser medicine
   a. laser scalpel
   b. laser-induced breakdown for eye treatments and plaque removal.
3. Laser disc storage - the first application of LID to consumer products.
4. Photorefractive information storage, processing, and phase conjugation interconnects.
5. Nonlinear refraction and nonlinear absorption for limiters, switches, and optoelectronic computing.
6. Electro-absorptive switches using UHV manufactured quantum well devices (SEED’s).

So I issue a challenge to us all to keep the name Damage Symposium, but continue to seek positive applications of the phenomena we study. A wise professor once told me that phenomena are neither good or bad—they exist and it’s up to us to find ways to make good things using phenomena given by nature.

Before I left Orlando, I looked into by crystal ball for a glimpse of future laser damage or optical materials problems—here is my short list:

Future Topics for Optical Materials Research

1. Thin films for all applications. Two talks viewing 20 years of thin film work.
2. New laser host and nonlinear optical materials for compact, efficient, tunable and solid state lasers for many old and many new applications.

3. X-ray optics for lasers (remember Harry Winsor said that lasers have mirrors...), and optics for x-ray microscopy and x-ray lithography.


I'm sure that these and other topics will keep optical materials people busy for some time--the only question is where will the funding come from? DoD funding will surely decline as peace is breaking out all over. DOE funding usually finds its way to the national labs--but not much finds its way out. DARPA, under Martin Stickley's leadership, provided much of the spark that lead to modern day materials and much of the research reported at this conference. Materials research tends to be too long-term for present day funding. We need to all do our part in ensuring continued research support for the foundation of the technology food chain--materials research.

Since we don't have an official wine and cheese gathering, I hereby propose that we forgo small gatherings of old friends for dinner, etc. and meet instead at the Dark Horse for an informal, pay as you go, social hour.
SEARCH FOR TECHNOLOGY TRANSFER IN HIGH POWER OPTICS

C. Martin Stickley

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In the late 60's and through the 70's, DARPA supported a broad program to develop optics for use with high power cw CO$_2$ lasers and new laser and nonlinear optical materials. This paper summarizes those efforts and asks anyone who knows in what defense systems these have been used to contact the author.

In the late 1960's and through the 1970's, the Materials Sciences Office (now the Defense Sciences Office) of the Defense Advanced Research Projects Agency (DARPA) funded a broad program to develop optics for high power continuous development of approaches to fabricate large area windows with high transparency (absorption of $10^{-5}$ per cm), optical surface preparation techniques which leave very little residual absorption, and techniques for depositing antireflection as well as reflecting coatings for transparent windows and mirrors. Some development of new laser and nonlinear optical materials was also funded. Approximately $22.9$ M dollars were spent between 1967 and 1978.

The Defense Sciences Office is now searching for examples of where optical parts fabricated using these techniques and the laser and NLO materials have been used in defense systems. While defense uses are of primary importance, NASA and industrial uses are also of interest.

Technologies which may have had the best chance of being utilized include, for windows: casting of fluorides, reactive atmosphere processing of halides, forging of halides, and CdTe growth, distortion and damage studies; for surfaces and coatings: polymers and surface preparation of halides, fluorides, and selenides; for lasers: erbium glass, and holmium and erbium in YLF; for mirrors: beryllium optics; and for laser damage: platinum removal and surface preparation of Owens-Illinois glass, and bulk and surface damage of ruby.

The tables which follow summarize the activities which were supported in each major area. Included are the specific technology developed (e.g. fluoride fusion casting), the contractor, the amount of funding provided, and at the time period where the work was done.

If the reader knows of areas where any of these technologies may have been used in defense systems (as well as for NASA and the commercial sector), please contact the author.
LASER WINDOW MATERIALS

Fluorides
- Fluoride Fusion Casting
  Raytheon 166K 76-77
- Scaling of Fluoride Casting
  Raytheon 790K 74-76

Halides
- Halide Superalloys for High Power Windows
  Raytheon 191K 72-73
- Halide OH Removal
  Hughes Res. Labs 174K 72
- Reactive Atmosphere Processing
  Hughes Res. Labs 215K 76-78
- RAP of KBR
  Hughes Res. Labs 244K 74-76
- Extrusion and Cross-Rolling
  Honeywell 195K 72-73
- Forging of Alkali Halides
  Honeywell 1483K 73-78
- Radiation Hardening
  Oklahoma 113K 72-74
- Press Forging Halides
  NRL 521K 72-75
- RAP of KBR - Characterization
  NRL 80K 76

II-VI Materials
- II-VI Distortion and Damage
  USC 1336K 72-77
- CVD of Cadmium Telluride
  Raytheon 192K 73-75
- CVD of CdTe and GaP
  Raytheon 196K 75-77
- Characterization of II-VI Materials
  MIT 308K 73-76

Chalcogenides
- Oxygen-Free Chalcogenides
  Catholic University 283K 72-74
- Structure-Dependent Absorption
  Texas Instruments 72K 73-74

Other
- Covalent Carbon Window Materials
  UCLA 114K 75-76
- Copper-Leaded CERVIT
  Owens Illinois 27K 76
LASER WINDOW MATERIALS

Measurement Techniques

- Spectroscopy of Halides
  - Cornell 209K 75–76
- Emissivity Facility
  - Block Eng. 250K 73–75
- Multiple Wavelength Calorimetry
  - Alabama 58K 74–76
- Chemical Laser Window Absorption
  - Raytheon 60K 74–75
- CO₂ Laser Window Evaluation
  - AVCO 279K 75–76
- Proof Testing
  - MIT 168K 75–76
- Mechanical Properties
  - MIT 320K 72–75

Theory

- Theory of Coatings and UV Materials
  - Xonics 1342K 72–78

LASER COATINGS AND SURFACES

- Polymer Protective Coatings
  - UC Berkeley 169K 75–77
- Polymer Protective Coatings
  - Rockwell 149K 73–74
- Surface and Coating Technology
  - Hughes Res. Lab 1076K 73–76
- Window Polishing and Characterization
  - NWC 1696K 72–77
- Passive Characterization/HF Coatings
  - NWC 1042K 76–77
- Coating Stress Measurements
  - Perkin Elmer 200K 76–77
- Coating Growth and Stress
  - AFCRL 255K 73–75
- Transparent Abrasives
  - Raytheon 207K 73–75
LASER MATERIALS

- Erbium Glass
  - American Optical 191K 69-71
- Holmium in YLF
  - Sanders Associates 203K 71-73
- Near Visible Laser Materials
  - Sanders Associates 270K 72-75
- Ceramics for Lasers
  - Union Carbide 193K 1977
- Wide Linewidth Materials
  - Texas Instruments 225K 72-73

MIRRORS AND SURFACES

- Beryllium for Optics
  - Perkin Elmer 1434K Prior to 69
- Ion Beam Optical Figuring
  - Kollsman 146K Prior to 69

NONLINEAR OPTICAL MATERIALS

- Cinnabar
  - Tyco 190K 70-71
- Chalcopyrite
  - Stanford 279K 70-74
- High Damage Threshold Materials
  - Isomet 98K 1973
- Chalcogenides
  - Westinghouse 230K 72-75
- IR Laser Components
  - Westinghouse 201K Before 1969
- IR Quantum Counter
  - Purdue
BDM INTERNATIONAL, INC.

DAMAGE TO LASER MATERIALS

Glass
- Laser Glass Damage
  Owens Illinois 616K 69-71
- Glass Surface Treatment
  Owens Illinois 291K 72-73

Ruby
- Bulk and Surface Damage
  Hughes Res. Labs 400K 69-71

Measurement Techniques
- Laser Measurements
  NBS 2369K Prior to 69
- Laser Damage Measurements
  NBS 161K 72-73

Mirrors
- RF Sputtered Metal Mirrors
  Battelle NW 450K 72-73

Research
- Miscellaneous Topics
  Harvard, NWC, USC, AFCRL, Raytheon, Bendix 749K 71-76
LASER WINDOW MATERIALS

Fluorides
- Fluoride Fusion Casting
  Raytheon 166K 76-77
- Scaling of Fluoride Casting
  Raytheon 790K 74-76

Halides
- Halide Superalloys for High Power Windows
  Raytheon 191K 72-73
- Halide OH Removal
  Hughes Res. Labs 174K 72
- Reactive Atmosphere Processing
  Hughes Res. Labs 215K 76-78
- RAP of KBR
  Hughes Res. Labs 244K 74-76
- Extrusion and Cross-Rolling
  Honeywell 195K 72-73
- Forging of Alkali Halides
  Honeywell 1483K 73-78
- Radiation Hardening
  Oklahoma 113K 72-74
- Press Forging Halides
  NRL 521K 72-75
- RAP of KBR – Characterization
  NRL 80K 76

LASER WINDOW MATERIALS

II-VI Materials
- II-VI Distortion and Damage
  USC 1336K 72-77
- CVD of Cadmium Telluride
  Raytheon 192K 73-75
- CVD of CdTe and GaP
  Raytheon 196K 75-77
- Characterization of II-VI Materials
  MIT 308K 73-76

Chalcogenides
- Oxygen-Free Chalcogenides
  Catholic University 283K 72-74
- Structure-Dependent Absorption
  Texas Instruments 72K 73-74

Other
- Covalent Carbon Window Materials
  UCLA 114K 75-76
- Copper-Leaded CERVIT
  Owens Illinois 27K 76
LASER WINDOW MATERIALS

Measurement Techniques

- Spectroscopy of Halides
  - Cornell 209K 75-76
- Emissivity Facility
  - Block Eng. 250K 73-75
- Multiple Wavelength Calorimetry
  - Alabama 58K 74-76
- Chemical Laser Window Absorption
  - Raytheon 60K 74-76
- CO2 Laser Window Evaluation
  - AVCO 279K 75-76
- Proof Testing
  - MIT 168K 75-76
- Mechanical Properties
  - MIT 320K 72-75

Theory

- Theory of Coatings and UV Materials
  - Xonics 1342K 72-78

LASER COATINGS AND SURFACES

- Polymer Protective Coatings
  - UC Berkeley 169K 75-77
- Polymer Protective Coatings
  - Rockwell 149K 73-74
- Surface and Coating Technology
  - Hughes Res. Lab 1076K 73-76
- Window Polishing and Characterization
  - NWC 1696K 72-77
- Passive Characterization/HF Coatings
  - NWC 1042K 76-77
- Coating Stress Measurements
  - Perkin Elmer 200K 76-77
- Coating Growth and Stress
  - AFCRL 255K 73-75
- Transparent Abrasives
  - Raytheon 207K 73-75
LASER MATERIALS

- Erbium Glass
  American Optical 191K 69-71
- Holmium in YLF
  Sanders Associates 203K 71-73
- Near Visible Laser Materials
  Sanders Associates 270K 72-75
- Ceramics for Lasers
  Union Carbide 193K 1977
- Wide Linewidth Materials
  Texas Instruments 225K 72-73

MIRRORS AND SURFACES

- Beryllium for Optics
  Perkin Elmer 1434K Prior to 69
- Ion Beam Optical Figuring
  Kollsman 146K Prior to 69

NONLINEAR OPTICAL MATERIALS

- Cinnabar
  Tyco 190K 70-71
- Chalcopyrite
  Stanford 279K 70-74
- High Damage Threshold Materials
  Isomet 98K 1973
- Chalcogenides
  Westinghouse 230K 72-75
- IR Laser Components
  Westinghouse 201K Before 1969
- IR Quantum Counter
  Purdue
## DAMAGE TO LASER MATERIALS

### Glass
- Laser Glass Damage
  - Owens Illinois 616K 69-71
- Glass Surface Treatment
  - Owens Illinois 291K 72-73

### Ruby
- Bulk and Surface Damage
  - Hughes Res. Labs 400K 69-71

### Measurement Techniques
- Laser Measurements
  - NBS 2369K Prior to 69
- Laser Damage Measurements
  - NBS 161K 72-73

### Mirrors
- RF Sputtered Metal Mirrors
  - Battelle NW 450K 72-73

### Research
- Miscellaneous Topics
  - Harvard, NWC, USC, AFCRL, Raytheon, Bendix 749K 71-76
Laser Induced Damage in Optical Materials: 1989

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ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE)

The Twenty-First Annual Symposium on Optical Materials for High-Power Lasers (Boulder Damage Symposium) was held at the National Institute of Standards and Technology in Boulder, Colorado, November 1-3, 1989. The Symposium was sponsored jointly by the National Institute of Standards and Technology, the American Society for Optical Engineering, the Defense Advanced Research Project Agency, and the Department of Energy. Approximately 200 scientists including representatives of the United Kingdom, France, Japan, Canada, and the Federal Republic of Germany, attended the Symposium. The Symposium was divided into sessions concerning Materials and Measurements, Mirrors and Surfaces, Thin Films, and, finally, Fundamental Mechanisms. As in previous years, the emphasis of the papers presented at the Symposium was directed toward new frontiers and new developments. Particular emphasis was given to materials for high power apparatus. The wavelength range of the prime interest was from 10.6 μm to the uv region. Highlights included surface characterization, thin film substrate boundaries, and advances in fundamental laser-matter threshold interactions and mechanisms. The scaling of damage thresholds with pulse duration, focal area, and wavelength was discussed in detail. Harold E. Bennett of the Naval Weapons Center, Arthur H. Guenther of the Los Alamos National Laboratory, Lloyd L. Chase of the Lawrence Livermore National Laboratory, Brian E. Newnam of the Los Alamos National Laboratory, and M. J. Soileau of the University of Central Florida were co-chairmen of the Symposium. The Twenty-Second Annual Symposium is scheduled for October 24-26, 1990, at the National Institute of Standards and Technology, Boulder, Colorado.

KEY WORDS (8 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)
laser damage; laser interaction; optical components; optical fabrication; optical materials and properties; thin film coatings.

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