The laser damage meeting: early years

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ABSTRACT

This talk will cover my personal recollections about the early years of lasers and the laser damage situation in the 60s: the persons involved, the lasers used in damage experiments, the companies involved, funding agencies involved, personal interactions in those days, the nature of the papers in 1968, and the unique style of management and conduct of the first and later meetings by Art Guenther and Alex Glass, a co-invited speaker with me at this 50th anniversary meeting.

Keywords: 50th laser damage meeting, early years of laser damage, 50th anniversary conference overview, ASTM, NBS, NIST, laser damage history, 1st laser damage meeting agenda

Good morning! Thanks to all for coming to this 50th anniversary meeting of the Boulder Damage Symposium (BDS). And thanks to MJ Soileau for inviting me.

My talk will focus almost entirely on the 60s, will take us up and into the first Boulder Damage Symposium and will be primarily non-technical. It will mostly cover people and organizations that played a role in the earliest days of lasers related to laser damage (LD).

At the time of the announcement of the laser, I was a lieutenant in the USAF stationed at the Air Force Cambridge Research Laboratory (AFCRL). I was assigned to a communications division and at a division meeting in August 1960, the director asked who wanted to get us into lasers because lasers were to be good for communications, and I raised my hand. This kicked off the effort there to build a ruby laser following Maiman's design (Fig 1). The piece of ruby we used was a small rod which typically was used as a seed onto which a larger ruby crystal is grown via the Verneuil method, but we used it as our first laser rod. (Fig 2). It was about 3mm in diameter and 25 mm long and was heavily doped with 0.5% Cr_2O_3 in an Al_2O_3 lattice. As AFCRL was a research laboratory we had the infrastructure to grow crystals, cut metal, etc. and get experimental things done. We had our first laser operating in Dec 1960, about three months after starting the project.

The R&D part of the Air Force at that time, as it pertained to laser development, was AFCRL for research; Wright Patterson Air Force Base in Dayton, OH for development and the Air Force Weapons Laboratory at Kirtland AFB in Albuquerque for advanced development, especially weapons development. Part of the role of AFCRL as a research laboratory was to support the development labs where possible.

The big guerilla in the US R&D funding world was the Advanced Research Projects Agency (ARPA, later to be called DARPA where the 'D' stands for Defense.) ARPA used funds from their Project Defender – a missile defense program – to begin funding laser R&D in 1960/1961 using the Office of Naval Research as the agent for most of their laser efforts (ARPA had no contracting office at that time). The Strategic Technology Office was the ARPA office that sponsored a number of classified and unclassified programs. As there were only two materials with the potential for high energy and high power lasers, they began funding glass laser development at American Optical Co. in Massachusetts and led by Elias Snitzer (Fig 3) with assistance from Gil Young and Chuck Koester, and at Union

Laser-Induced Damage in Optical Materials 2018: 50th Anniversary Conference, edited by Christopher Wren Carr, Gregory J. Exarhos, Vitaly E. Gruzdev, Detlev Ristau, M.J. Soileau, Proc. of SPIE Vol. 10805, 1080503
 · doi: 10.1117/12.2502567

Carbide of ruby grown by the Czochralski process - a process with the potential for producing higher quality crystals than the Verneuil process. Ruby and neodymium-doped glasses were the only two types of lasers at that time that could store energy in an excited state and produce intense pulses making these appropriate for military applications such as range finding and high peak power weapons.

From 1965 -1971, I was the Chief of the Laser Physics Branch where the laser research was carried out at AFCRL and thus I was the principal interface with other DOD/USAF organizations involved in laser R&D. In this role, I became the agent for ARPA's Materials Sciences Office in optical materials development, and also an agent for WPAFB's laser development efforts especially in new laser technology, such as optical parametric oscillators. I also interfaced with the Air Force Weapons Lab where they were studying, among other things, ruby amplifiers for boosting laser pulse energy.

At this point, let me say a few words about some of the scientists associated with laser damage research in the early 60's.

Undoubtedly one of persons whose research had a huge impact on lasers and led to laser technology that could damage itself was Robert Hellwarth (Fig 4) of the Hughes Research Laboratory where Bob, along with Fred McClung, first demonstrated Q-switching of ruby lasers. This was in 1961. They used a Kerr cell placed within the optical cavity to hold off lasing for a millisecond or so and then activated the Kerr cell to lower the cavity Q and dump the energy stored in the upper lasing state.

One of the first public presentations about laser damage was by Mike Hercher (Fig 5), a graduate student in optics at the University of Rochester's Institute of Optics, who gave a paper summarizing his observations of laser-induced damage in transparent dielectrics at the spring meeting of the OSA in 1964. (Another person named Bruma did also but I did not know him or ever heard of him again.)

The work of Hercher and Bruma was soon followed by a publication in Applied Physics Letters by Hughes Research Laboratory researchers Connie Giuliano and Bob Hellwarth (Fig 6) of their observations of ruby damage. The next chart (Fig 7) is a photo of a sample of Czochralski ruby that Giuliano later used for studies of damage tracks in ruby.

Once Q-switching was reported, it was shown to be possible to Q-switch a glass laser also. I recall that Tony DeMaria (Fig 8) at United Technology was developing high power glass lasers under ARPA/ONR sponsorship and measured the glass damage threshold by determining where, along the length of a one meter long glass amplifier rod, the pulse energy got intense enough to a point where it exceeded the laser damage threshold causing the end of the rod to drop off at the point of damage! So if I had prizes to give out, I'd give first prize to Tony for this real-world way of measuring the damage threshold in glass!

In 1962, the Air Force Weapons Laboratory formed a laser group headed I believe by Art Guenther (Fig 9) who was a captain at that time and who later became a Chief Scientist of the Weapons Lab. One of the able young lieutenants in this group was Pete Avizonis who led efforts to develop high power ruby and glass laser amplifiers.

Given that the AF Weapons Lab was having significant problems with laser damage, I decided that I should initiate efforts within the Laser Physics Branch to tackle laser damage. As a result, I brought in Erlan Bliss. a PhD-level solid state physicist from Case-Western Reserve with an ROTC commitment, and David Milam, a PhD-level graduate of the University of New Mexico, to focus on this new effort. Doing this had a very high payoff as it turns out both, by their very nature, were careful, top-quality scientists (Fig 10) and went on to join in the mid 70s the Lawrence Livermore National Laboratory as major investigators in laser damage.

By the mid-to-late 60s, a number of laser groups in addition to Hughes – for example, Raytheon (Mike Bass) (Fig 11)**,** Lawrence Livermore Laboratory (David Gregg and J E Swain), and Bendix (Peter Braunlich) - were experiencing laser damage.

Erlan Bliss had, by the mid-60s, documented from various publications the complexity of this issue. Laser damage was influenced in particular instances by a large number of variables: temperature, pulse duration, optical pumping conditions, beam diameter, multimode effects, beam focusing, laser wavelength, and details of material growth and preparation. How did researchers communicate during those years to others outside their organization? The ways of doing this in those days were limited compared to the multitude of ways we have today. They included telephone calls, attending meetings of the OSA or the IEEE, and publishing in journals with the primary publication journals at that time being Applied Physics Letters, JOSA A and B, Applied Optics, the Proceedings of the IEEE, and, occasionally, Physical Review Letters.

It became clear that these conventional communicating processes were inadequate, and most important, different laser groups were measuring damage thresholds differently and getting different results.

So it was fairly obvious that a special meeting was needed devoted to exchanging observations and ideas about laser damage. And here is where the genius of Art Guenther and Alex Glass (Figs 12 and 13) came in. As there was international interest in this subject, Art realized that he could not have the US Air Force Weapons Laboratory host such a meeting as foreign visitors – for example from France, England, Russia and other countries - would have resulted in many difficult-to-handle issues for Art and Alex. [As an example, I learned much later that one of the regular Soviet Union attendees and participants was a member of the KGB!]

Art and Alex also had the correct view that proper and permanent documentation of the research results and discussions would be highly desirable, and further that proper measurement techniques – or standards -- needed developing and documenting. Given this, they realized that the American Society for Testing and Materials – ASTM - would be the ideal organization under whose auspices the meeting should be held, and that it would be great if it was held at an organization associated with standards. So Art and Alex proceeded to arrange for the National Bureau of Standards, now called NIST – the National Institute of Standards and Technology - at Boulder, Colorado to host it.

The ASTM charter (Fig 14) stated that the Subcommittee on Lasers and Laser Materials was "*charged with writing specifications for the testing of lasers and laser materials. These specifications must reflect not only the latest information and technology available, but also a perspective which insures that the specification is realistic. By realistic, it is meant that the test must be capable of being performed by the majority of industrial laboratories and, most important, measure a parameter meaningful to both the supplier and consumers."*

As the ASTM goals for the Subcommittee seemed very formidable given the state of knowledge of laser damage at that time, the co-chairmen (Fig 15) restated the goal as: "*The Symposium on Damage to Laser Glass had as its central task to obtain a perspective with regard to damage in laser glass which would aid in the establishment of meaningful damage definitions and test procedures.*

In general, the discussion was restricted to laser glass although other materials were discussed in connection with diagnostic techniques. The co-chairmen of the conference, with much effort, reviewed and summarized the salient points raised by each of the speakers. This, plus the recording and publication of the discussion after each speaker, became unique features of this meeting. Doing this is in contrast to the limited time available for such discussion in meetings held these days. Thus the co-chairmen – Art and Alex - are to be congratulated for the excellent job that they always did when conducting these meetings.

The first Boulder Damage Meeting was held at NBS/NIST on June 20, 1969. Only 10 papers were presented – seven about damage in glass, one about damage in ruby, and the remaining two about damage in other transparent media. The full manuscripts including the discussion at the end were printed and published as ASTM Report 469.

To give you an idea about the variety of topics presented, the following is a list of the titles of the papers, their authors and, in some cases, a few words about the content of the paper:

Edwin Kerr (Fig 16), Perkin Elmer in CT, "Laser Beam Self-Focusing and Glass Damage Caused by Electrostrictively Driven Acoustic Waves". This was a theoretical analysis only, funded by ARPA/STO/ONR

Charles Naiman and Evan Chicklis, of Mithras in Cambridge, Massachusetts, "Applications of Electron Spin Resonances to the Study of Damage in Laser Glass".

Haynes A. Lee and John Myers (Fig 17), Owens Illinois, "Damage Threshold Testing of Laser Glass". Glass laser damage data generally and progress in the development of high damage threshold Owens-Illinois laser glass.

Fred Quelle (Fig 18), Office of Naval Research, Boston, MA, "Self Focusing in Glass". He references work by Zverev of the Soviet Union that stated the damage threshold increased linearly with pulse length

David Edwards, Colorado State University, "Damage and Evidence of Pre-catastrophic Damage in Transparent Solids"

Gil Young and R F Woodcock, of American Optical Co. in Southbridge, MA, "Laser-Induced Damage in Glass". They used amplified stimulated emission to form the damaging pulse – i.e. incoherent radiation

Erlan S Bliss, of the AFCRL, Bedford, MA, "Laser-Damage Mechanisms in Transparent Dielectrics". He surveyed numerous mechanisms and documented his view of their significance in causing damage.

Evan Chicklis, of Mithras, Cambridge, MA., "Non-Destructive Damage Studies of Ruby Laser Rods".

J E Swain, of Lawrence Livermore Laboratory, Livermore, CA., "Surface-Damage Threshold Measurements for Several Laser Glasses". He noted a major increase in surface damage threshold by a combination of chemical etching and the use of barnsite plus on-pitch.

John M. McMahon (Fig 19) , of the US Naval Research Laboratory, Washington, DC. "Glass Laser Materials Testing at the Naval Research Laboratory". He noted the significant difference in laser damage threshold between Owens-Illinois (O-I) and French CGE glass.

Subsequent Laser Damage Meetings grew in scope and popularity. Many more subjects came to be discussed beyond just damage to laser glass, and the format and informality of these meetings led to their great and continuing popularity of the topic of strong optical electric fields interacting with matter of all sorts.

As an example, I departed the AFCRL in 1971 and joined ARPA's Materials Sciences Office where I continued the sponsorship of laser damage studies and broadened the range of ARPA-sponsored studies to include the development of highly transparent optical/infrared materials and coatings for use as windows and mirrors in high power laser systems. In the 70s, this Laser Damage Meeting became the one everyone attended to present research results, learn of others' work in these areas, and greet old friends made at the previous LD meetings.

But still, laser damage continued to be at the heart of this meeting. This is evidenced by MJ Soileau, et al giving an invited review paper in 1988 – the 20th Laser Damage Meeting - on "Laser-induced damage and the role of self-focusing". Their paper gave this summary of the combined papers by Hercher and Bruma (Fig 20) which they presented at the 1964 meeting of the Optical Society of America: in extrinsic laser-induced damage "(1) *linear absorption plays no major role in this type of failure; (2) the damage process is highly nonlinear; (3) electron avalanche breakdown may be initiated by defects or impurities* (note that there is some controversy about this); *and (4) the extrinsic laser-induced damage threshold and morphology depend on spot size."* Interestingly, the Soileau review paper points out that these very early observations of laser damage have held up very well and that much of the research done and presented at the Boulder Damage Symposium since then has been in filling in a lot of the detail and richness not reported in these early papers of the damage phenomena that occur during these high electric field interactions with materials.

Before closing these comments, one might ask, has any of this work ever led to anything of a commercial nature? I suspect that without too much thought, you will realize that it has. See for example, the next chart that shows the commemorative gift at the 30th annual Boulder Damage Symposium held in 1998. (Fig 21). What you see is the result of a laser focused to many tiny spots causing the quartz in that region to melt and then freeze with a different refractive index making it visible to the eye. Probably hundreds of thousands of different objects like this have been produced commercially. And who first showed this could be done but failed to patent it? None other than MJ Soileau and Eric Van Stryland who, at the time, were young faculty at North Texas State in Lubbock, TX. They made these by placing a piece of transparent plastic on a computer-driven stage and created the image of Pluto, Disney's floppy-eared dog, by scanning it repeatedly into and across the path of a pulsed, focused laser beam. When they left Texas and came to Central Florida to create CREOL, some engineering-type folks from nearby Disney came to CREOL seeking projects that CREOL and Disney might undertake together. When they spied the image of Pluto, they knew that was it! (although we never did a project with them.) When MJ is asked about patenting it, he will tell you that he has always found ways to minimize his income, and this is an excellent example as he and Eric never completed the patent process.

One final and beautiful example of this is shown in the last charts. The first one (Fig 22) is the image of George W Bush, the 43rd President of the United States. Note the depth of the image. This creation has an optical property that I cannot explain: when you look at Bush's image from the back (Fig 23 and 24) and from two slightly different angles, it appears you can begin to look around his head! This does not happen with the frontal image and don't ask me why – ask MJ instead!

Thank you for your kind attention, and have an excellent 50th Anniversary Boulder Damage Symposium!

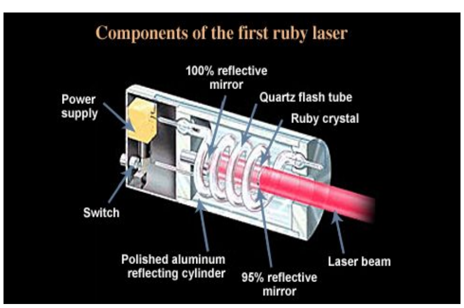

Figure 1 Maiman's ruby laser

Figure 2   Stickley inserting ruby rod with silvered flat ends into laser head

Figure 3   Elias Snitzer, American Optical, developed laser glass and the glass fiber laser

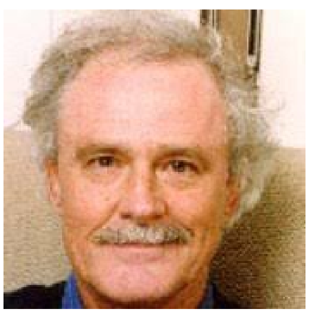

Figure 4   Bob Hellwarth, Hughes Research Lab, inventor of the Q-switched laser

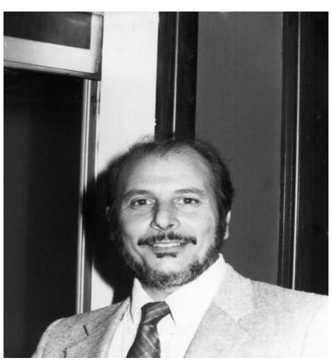

Figure 5   Connie Giuliano, Hughes, with Bob Hellwarth, studied damage in ruby

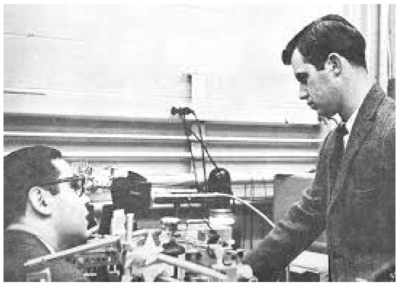

Figure 6 Mike Hercher, U of Rochester, ruby laser dynamics and damage

Figure 7 Ruby sample used by Giuliano to characterize laser damage tracks; 6mm x 6mm x 50mm

Figure 8 Tony DeMaria on right, United Aircraft, glass laser mode locking and damage

Figure 9 Arthur Guenther, Air Force Weapons Lab

Figure 10 Elan Bliss, LLNL, thin person to right of center with white shirt

Figure 11 Mike Bass, Raytheon, damage measurements and theory; surface damage

Figure 12 Art Guenther, AFWL. co-founder of laser damage meeting

Figure 13 Alex Glass, Wayne State, co-founder of laser damage meeting

Materials for Electron Devices and Microelectronics, is charged with writing specifications for the testing of lasers and laser materials. These specifications must reflect not only the latest information and technology available, but also a perspective which insures that the specification is realistic. By realistic, it is meant that the test must be reproducible, capable of being performed by the majority of industrial laboratories, and most important, measure a parameter meaningful to both the supplier and the consumer.

Figure 14 Excerpt from ASTM charge to Lasers & Materials Testing Subcomm.

A one-day Symposium on Damage in Laser Glass was held at the National Bureau of Standards in Boulder, Colo., on 20 June 1969. This meeting had as its main purpose to obtain a perspective with regard to damage in laser glass which would aid in the establishment of meaningful damage definitions and test procedures. Co-Chairmen for the meeting were Alexander J. Glass, Wayne State University, Detroit, Mich., and Arthur H. Guenther, Air Force Weapons Laboratory, Kirtland Air Force Base, N. M. They, together with C. Martin Stickley, Air Force Cambridge Research Center, Hanscomb Field, Mass., and John D. Myers, Chairman, Subcommittee on Lasers and Laser Materials, acted as editors in preparing these conference proceedings.

Figure 15 A less ambitious task was adopted

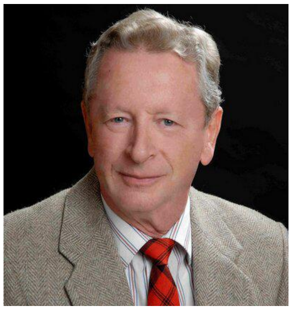

Figure 16 Edwin Kerr, Perkin Elmer, theory of electrostriction of laser beams in transparent dielectrics

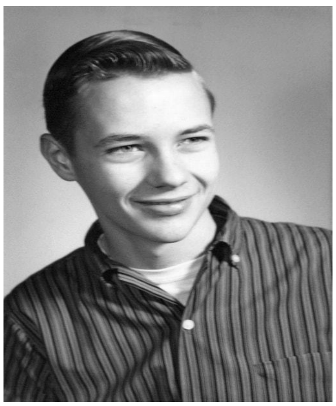

Figure 17 John Myers, Owens-Illinois, laser glass development

Figure 18 Fred Quelle, ONR, self-focusing in glass

Figure 19 John McMahon, NRL, measurement of damage thresholds in O-I and French CGE laser glass

Initial ELID observations by Hercher and Broma presented in 1964 hold up over 25 years

MJ Soileu, et al "Laser-induced damage and the role of self-focusing", presented at the 1988 Boulder Damage Symposium, Boulder, CO

- Linear absorption plays no role in this type of failure
- The damage process is highly nonlinear
- Electron avalanche breakdown may be initiated by defects and/or impurities (there is some controversy about this.)
- The extrinsic laser-induced damage threshold and morphology depend on spot size.

Figure 20

Figure 21 Thirtieth anniversary meeting gift: laser damage in glass

Figure 22   George W Bush, 43rd President of the US; viewed from the front

Figure 23   George W Bush, viewed from the back

Figure 24   George W Bush, viewed from the back but more from one side