line radiation behavior was consistent with the multihundred electron-volt electron temperatures measured with Thomson scattering. Doppler T_i values increased during strong $n = 2$ kink activity, to values as high as 1 keV. The detailed design of a new plasma gun and flux conserver suitable for the CTX programmatic goal was presented, as well as positive results from a high-explosive-driven dome inversion experiment.

The mechanical helicity injection experiment HESS was explained. In this scheme, a high-explosive driven cylindrical wall generates helicity by driving an initial solenoidal magnetic field into twisted grooves in a concentric opposing wall.

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SUMMARY OF THE 21st DAMAGE SYMPOSIUM ON OPTICAL MATERIALS FOR HIGH POWER LASERS, BOULDER, COLORADO, NOVEMBER 1–3, 1989

The symposium was held at the National Institute of Standard and Technology (NIST) at the foot of the Rocky Mountains in Boulder, Colorado. The conference was attended by 188 scientists, 32 from foreign countries. Some Chinese and Russian scientists were expected, but did not come due to the political situation in their countries. A strong participation from the defense and aerospace industries was observed.

Thirty-three oral papers and 28 posters were presented. The oral presentations were divided into four broad categories:

1. materials and measurements
2. surfaces and mirrors
3. thin films
4. fundamental mechanisms.

The study of radiation damage in optical materials is a very broad field in which investigations can be performed in various ways. Contrary to other fields of physics, no comprehensive physical theory has yet emerged to explain and predict the damage in optical materials due to high-intensity radiation. Systematic methods to harden materials have not appeared. Only "recipes" that work in one case but not in another are known to harden the films or materials against the effects of radiation.

A few welcoming words by M. J. Soileau (University of Central Florida) reminded the participants of the wide scope of the conference, which was to be reflected in the diversity of the presentations. This is due to the wide applicability of lasers (industry, medicine, computers, information, optoelectronics). As Soileau noted, future topics in optical materials research are at least as wide in scope and include thin films, new lasers and nonlinear optics, X-ray optics for lasers and for X-ray lithography, etc.

A long review of the 20-yr-old Boulder Damage Symposium was presented by L. L. Chase [Lawrence Livermore National Laboratory (LLNL)]. Chase outlined 20 yr of achievement, whether in the improved optical properties of materials in the visible and infrared ranges or in improved manufacturing techniques. He also analyzed the various ways to study damage in materials (identification of damage and experimental setups for damage testing). As the following speaker, J. Arenberg (TRW), mentioned, there is effectively a great need for standards in commerce, engineering, and science, and this need is particularly strong in optical damage analysis.

The first category of oral presentations started with various talks on measurement methods for linear and nonlinear indexes of refraction and for assessing damage in optics, as well as the investigation of laser damage on silicon arrays. A very important talk on dielectric breakdown in SiO_2 was presented by P. Braunlich (Washington State University), who stated that laser-induced breakdown was not attributable to impact ionization avalanche, as had been thought for many years. In that case, he concluded, experimental data accumulated over a period of many years have to be thrown away.

The second part of the conference was devoted to surfaces and mirrors. Only four talks were presented, one of which examined in particular the polishability of reaction-bonded silicon carbide. That material was shown to be a viable laser mirror material that can be polished to <10 Å root-mean-square (rms) and <5 Å rms when a silicon coating is applied.

The third part, devoted to thin films, was the most important of the conference by the number of papers. Review sessions of the early years of thin film research (1969 to 1979) by A. Guenther and of the later years (1980 to 1988) by B. Newnam, both from the Los Alamos National Laboratory, were presented and gave the audience a summary of the progress made during those years. They were followed by various talks on laser damage in thin films and on various methods of thin film deposition and optical damage analysis.

Preconditioning of thin films was shown in the past to increase the damage threshold and is considered an essential method of achieving that goal. One can, for example, use laser irradiation at subthreshold fluences [C. R. Wolf et al. (LLNL)], which can increase the threshold by a factor of 2 to 3 over that of the preconditioned film. This enhancement was shown to be permanent. A study on the heat resistant coating of the NOVA laser system showed small conditioning effects of these films. Experiments on small samples showed a laser damage threshold of $\sim$30 to 45 J/cm^2. Various talks followed, especially on plasma chemical vapor deposition (CVD) of thin films. Considering, for example, the cost of NOVA's mirrors ($50 000 each), this study is an important one. Plasma CVD coatings have the highest threshold of any optical coatings, comparable to that of superpolished Corning fused silica (50 to 60 J/cm^2).

The fourth part of the conference was devoted to the study of fundamental mechanisms. Damage in silicon was found to be caused, in the ultraviolet (UV) range, by photoionization and electron avalanche. On the contrary, damage in the infrared is due to thermal effects and to the creation of defects. A similar investigation on quartz showed the cause, in the UV, to be photoionization, and, in the infrared, thermal effects.

Three poster sessions were held during the breaks. They all revolved around various experimental setups used in laser damage studies, damage threshold determination and prediction, laser effects on materials, etc. Lawrence Livermore National Laboratory, for example, is actively engaged in laser damage research and presented some of the facilities available for studies in that area. This laboratory owns ten laser systems devoted to optical damage studies only. These systems cover a wide range of parameters (1064 nm and higher harmonics, from 10 Hz to single shot, 1 to 100 ns full-width at half-maximum and from 10 to >70 J/cm^2).

Due to the very wide scope of the conference, the variety of experimental methods, and the lack of physical theories and modeling of radiation damage, an impression of heterogeneity was given throughout the conference. The field of study is obviously very broad, and contributions can be made from any branch of physics. All talks were given in NIST's big amphitheater. An evening of "decontraction" was provided at a local cafe-theater with a feature performance of the musical, *Singing in the Rain*.

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