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Conference on optical scattering standards

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Abstract

This paper is a report on a conference, Standards for Scattering from Optical Surfaces, that was held February 6 and 7, 1979, at the National Bureau of Standards in Boulder, Colorado. Approximately 50 scientists attended and heard a dozen invited papers and a panel discussion. The visitors agreed, among other things, that national physical standards are needed. There was also general agreement that NBS should consider providing measurement services (such as well characterized surfaces) based on a state-of-the-art facility for precision scattering measurements and calibrations.

Introduction and Conclusions

Optical scattering from polished transmitting and reflecting surfaces is a problem that has been nagging for a long time. Recently, I organized and the National Bureau of Standards sponsored a conference, part of whose purpose was to determine the nature and seriousness of the problem and to evaluate the need for new methods and national standards for attacking it.

Approximately 50 scientists from all over the country attended and listened to about a dozen invited papers and a panel discussion. In addition, audience participation during the day-and-a-half conference was high; we took this to be an indication of the depth of the problem.

During the panel discussion and in private talks with my colleagues and me, the visitors agreed on several points.

1. Laser gyros and certain other systems need exceptionally high quality optics to minimize the effects of scattering.

2. Lack of standards causes significant costs because of the need to overspecify and overdesign systems.

3. National standards are necessary to specify the character of optical surfaces in the uv, visible, and ir spectral regions.

4. NBS could provide national standards and calibration services and measurement assurance programs based on those standards.

In addition, the participants agreed that no single standard could possibly satisfy every need. Partly for this reason, there was mixed feeling as to whether or not NBS should also develop inexpensive instrumentation or techniques. There was, however, general agreement that NBS would need a state-of-the-art facility for precision scattering measurements and calibrations.

Invited Presentations *

I invited John Stover (Rockwell International) to present an overview paper. He described the general scattering problem and argued that the results of any scattering measurement must be accompanied by a rather detailed description of the experimental parameters, including especially angular limits or their equivalent. His case was echoed in a later paper by Eugene L. Church (U.S. Army ARRADCOM), who showed that scattering measurements were meaningful only within the range of angles that corresponded to the meaningful spatial frequency spectrum of surface irregularities.

Harold E. Bennett (Michelson Laboratories) discussed total integrated scatter (TIS), or total scatter into a hemisphere. He showed how TIS measurements often correlated well with theory and contended that TIS was one good candidate for a standard because a single number could be used to characterize a surface. Norman Thomas (Optical Coating Laboratory, Inc.) showed a scatterometer that measured the light scattered into a 28° (full angle)

* These summaries are mine and have not been reviewed by the authors or panelists.

cone centered about the specular beam. With this instrument, he said, OCLI has developed multilayer mirrors whose surface roughness is a fraction of a nanometer.

Jean M. Bennett (Michelson Laboratories) described angular scattering measurements and theory. She distinguished among micro-irregularities, scratches and digs, and dust particles and showed that there was a need to explain theoretically measurements of the latter two classes.

John P. Rahn (Michelson Laboratories) discussed the design, calibration and use of a system designed to measure angular scatter from laser gyroscope mirrors. Kent Stowell (Air Force Avionics Laboratory) likewise described an existing system and showed early results of scattering measurements.

William L. Gamble and John Stettler (U.S. Army MIRADCOM) described a telescopic system for measuring scattered radiation from a variety of targets; they discussed the design of the low scatter telescope and the search for suitable low scatter materials such as the backwall of the room in which the measurements were to be made. Robert Breault (University of Arizona) similarly described problems encountered in designing and constructing low scatter optical systems; he particularly asked for data on the scattering properties of various absorbers such as those used inside lens and mirror enclosures.

Stephen R. Scheele (Hughes Aircraft) showed the need for low scatter optics in infrared space sensors, for example, so they will not be blinded by the bright horizon. He described a system that would measure angular scattering at several wavelengths and from 0.5° to 70°.

James Harvey (University of Dayton Research Institute) noted that scattered radiation is, in general, skewed as a function of angle, in a sense because of the sin θ term that appears in the grating equation. He therefore argued that surface scattering data should be presented as a graph of radiance (not power) as a function of direction cosine and plotted in a log-log format. When data are presented in this way, many curves derived from a single sample coalesce into a single curve.

William L. Wolfe (University of Arizona) simply asked NBS to develop three Lambertian scattering standards, one each for the uv, visible and ir portions of the spectrum. In later discussion, many participants agreed that the standards need only be stable and reproducible; possibly weak gratings on a hard substrate would be adequate.

Harry Corey (Union Carbide) spoke about using optical scatter to measure the approximate, arithmetic average roughness of samples prepared for a purpose other than optical.

The panel discussion saw at least a dozen audience members participate as well. I have synthesized most of the results of this discussion in the Introduction and below. The panel members were Aaron A. Sanders (NBS), Chairman; Jean Bennett, Church, Stover, and Philip L. Jessen (Kaman Sciences Corporation).

Summary

In concluding remarks, I pointed out that we had learned that different workers with different tasks will have differing needs and perspectives. TIS (or scattering into a cone) is the easiest parameter to measure, and it results in a single number. However, certain applications may require measurement of scattered light as a function of angle; this could include a more or less complete specification of bidirectional reflectance or simply a measurement of scattered power at one or a few angles. Both TIS and single angle scatter may be useful when comparing samples prepared by similar processes, even in cases where they do not produce quantitative descriptions. In other applications, light that is scattered directly back along the beam may be important. And finally, cosmetic standards are probably necessary both as standards of workmanship and for specifying certain kinds of lenses, mirrors and, more specifically, reticles.

Thus, there is not (and probably cannot be) agreement as to the means to specify optical surface quality. Based in part on the papers presented at the Conference and on the panel discussion, I conclude that the candidates are those shown in Table 1. None will satisfy every need; possibly the whole set will not satisfy every need.

TABLE 1

WHAT TO SPECIFY?

1. Total Integrated Scatter (or scatter into a wide cone).
2. Scatter at one angle (or a few), or into a narrow cone about the specular direction.
3. Bidirectional reflectance or scattered power as a function of angle.
4. RMS or arithmetic average roughness. (Less useful in optics than specification of scattered power or radiance.)
5. Cosmetic standards (such as Scratch and Dig Standards or ASTM F 532-77T).