

## High Heat Flux Optical Engineering

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Thermal management of high heat load optical systems has attracted renewed interest in the past few years as a direct result of the advent of high-power x-ray beams generated at x-ray synchrotron radiation facilities in the United States, Europe, and Japan. This, incidentally, coincides with a period of reduced interest in high heat load laser mirrors after the concerted and vigorous research and development effort from 1970 to 1990. The synchrotron community is a beneficiary of much of this effort, particularly in the areas of heat transfer, fluid mechanics, materials engineering, fabrication, coating, polishing, and testing and metrology.

While in comparison with laser optics the demand for high-power synchrotron optical components is not substantial, the technical issues are just as much, if not more, challenging. The heat flux absorbed by synchrotron optical components can be as high as  $100 \text{ W/mm}^2$ , exceeding the levels previously encountered.

In this special section of *Optical Engineering*, we have attempted to provide an up-to-date overview of high heat flux optical engineering. While emphasis has been on current issues in x-ray synchrotron optics, the first few papers provide overviews of some of the relevant work conducted principally under the auspices of the high heat load laser mirror programs. These papers provide excellent summaries together with many references on some of the important and relevant work not otherwise referenced or accessible to researchers in high heat load synchrotron optics.

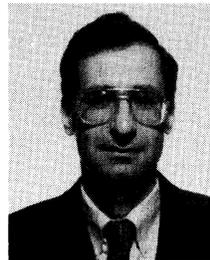
Other papers in this special section cover various aspects of x-ray synchrotron optics including the thermal load of the x-ray beams, specification of x-ray mirrors, mirror designs and facilities in Europe, the United States, and Japan, various cooling techniques for x-ray mirrors and monochromators, and advances in single-crystal and multilayer monochromator designs.

It is hoped that this special section can serve as a single archival source of up-to-date information for engineers and scientists interested or involved in high heat load optics and beamline design and development. We hope that the papers presented here illustrate some of the many technical challenges in high heat flux optics, contribute to a better understanding of current areas of research, and inspire further concerted and multidisciplinary efforts necessary for the development of optical components that allow full utilization of the powerful x-ray beams of the present and near future.

As evident from a number of papers presented here, the trend in thermal management of high heat flux optics is toward designing inherently low distortion devices (such as by placement of the cooling channels to provide balanced thermal

moment), utilization of bendable and possibly adaptive optics, use of enhanced heat transfer techniques (such as microchannel, porous media, or pin-post cooling), application of cryogenic cooling (to exploit the lower thermal expansion and higher thermal conductivity of several important optical materials at low temperatures), and utilization of superior materials (such as silicon and diamond) for optical substrates. On the other hand, if in future years new x-ray sources are developed that provide the necessary tunable, intense, and quasi-monochromatic beams without the additional unwanted background radiation responsible for more than 99% of the thermal load, the task of thermal management will be substantially simplified. Such a turn of events may parallel the development of highly reflecting coatings for laser mirrors, which in part led to reduced interest in high power laser mirrors in the past few years.

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**Ali M. Khounsary** received his BSc degree in nuclear engineering from Queen Mary College, University of London in 1979, and his MS in energy engineering in 1982 and PhD in mechanical engineering in 1987, both from the University of Illinois at Chicago. Since then he has been with the Advanced Photon Source at Argonne National Laboratory and involved in the design and development of various high heat load synchrotron components including

x-ray windows, shutters, monochromators, and mirrors. His main area of interest is thermal management issues in high heat flux components design including enhanced heat transfer techniques, fluid mechanics, materials, thermal and structural analyses, and x-ray optics design, fabrication, and metrology. He chaired the 1992 and 1993 SPIE conferences on High Heat Flux Engineering in San Diego.