In Memory of

Brian M. Hendrickson
(15 February 1944–14 May 1997)

The authors wish to express their regrets at the untimely passing of Brian M. Hendrickson, a staunch advocate and pioneer in the development of photonics technology. Brian was associated with the Air Force Rome Laboratory for 29 years, serving as associate Chief Scientist for Photonics. He received many awards in the field of electrical engineering, including the Harold M. Wright Award for outstanding contributions to the command, control, communication, and intelligence mission of the Air Force. He was recognized by the Institute of Electrical and Electronic Engineers for his engineering excellence. Brian received many honors, including an appointment to Princeton University's Industrial Advisory Board for the University's Advanced Technology Center for Photonics and Optoelectronic Materials.

Brian was a Fellow and member of the Board of Directors for SPIE—The International Society for Optical Engineering. He served SPIE with distinction, dedication, and vigor. His constant presence and participation in numerous SPIE symposia did much to advance the development of photonics.

Most important, to a great many of us Brian was a good friend and an amicable colleague, and we will miss him.

Advancement of Photonics for Space: A Critical Review, edited by Edward W. Taylor,
Proc. of SPIE Vol. 10288 (Vol. CR66), 1028801 · © (1997) 2017 SPIE
CCC code: 0277-786X/17/$18 · doi: 10.1117/12.2285242

Contents

Conference Committee

Conference Chair

Edward W. Taylor, Air Force Research Lab.

Session Chairs

1 Space Environmental Effects on Systems, Components, and Emerging Technologies I
Francis Berghmans, SCK-CEN(Belgium)
Richard F. Carson, Sandia National Laboratories

2 Space Environmental Effects on Systems, Components, and Emerging Technologies II
Marek Osiński, University of New Mexico
Norman S. Kopeika, Ben-Gurion University of the Negev (Israel)

3 Space System Photonics: Applications I
Dilip K. Paul, Tracor Aerospace Electronic Systems, Inc.
Julian P. G. Bristow, Honeywell Technology Center

4 Space System Photonics: Applications II
Timothy D. Cole, Johns Hopkins University
Mario N. Armenise, Politecnico di Bari (Italy)

Preface

The first demonstration of operational fiber optics systems in space (as discussed in CR66-03 by E. W. Taylor) was accomplished during the NASA Long Duration Exposure Facility (LDEF) mission, which extended over the period 1984–1990. This event marked the beginning of an era for accelerating the examination of other potential photonic technologies for space applications. Advances in identifying the influence of space environmental effects on photonics (i.e., optical fiber systems) dominated various SPIE symposia for approximately a decade, beginning in 1985, and continues with the steady emergence of new photonic materials and technologies.

The Photonics for Space Environments (PSE) conferences were a natural outgrowth of these symposia, broadening the symposia topics to include photonic systems for space applications. This Critical Review volume, *Advancement of Photonics for Space* (CR66), is the direct result of four previous SPIE PSE (I–IV) Conferences and Proceedings (1993–96). PSE V was convened concurrently with CR66 at the 1997 SPIE Annual Meeting in San Diego. Within this volume, a group of 15 invited experts present their authoritative overviews of the advances to the technology, including: recent past developments, current status, and projections for future growth and direction. These Critical Review papers are intended to serve as authoritative reference sources for the application of photonics in space environments. Two very broad areas are reviewed within this volume: space environmental effects on systems, components, and emerging technologies, and the application of photonics in spaceborne systems.

The individual reviews examine the effects of radiation, temperature, vibration, and other adverse effects encountered in space by a myriad of emerging and commercially available components and systems, including: micro-electromechanical systems (MEMs), semiconductor vertical cavity surface emitting lasers (VCSELs), optical transceivers, optical detectors, spatial light modulators (SLMs), optically guided wave devices, vertical cavity modulators, optical networks, optical interconnects, high-speed optical processors, holographic data storage, optical communication systems, optical correlators, and space-based remote sensing systems.

Two keynote reviews were presented at this Critical Review conference: "Big benefits from tiny technologies: micro-nanotechnology (MNT) applications in future space systems," and "Optoelectronic processing for space." The first address, presented by H. Helvajian, examined the potential applications of MEMs, MOEMs (MEMs with optics), and quantum effect nanoelectronic devices for both current and future space systems. The authors of this paper optimistically predicted that microengineered devices will "inevitably reduce the size of spacecraft," and "Perhaps the most profound result from this revolution will be that satellites, for some missions, will be mass-produced." The second keynote address, presented by T. M. Turpin, discussed the design criteria and rationale for using optoelectronic processing in space applications such as telecommunications switching and synthetic aperture radar (SAR) processing. Here, the author concluded that "optoelectronic processors are ready for space applications." This argument is supported by the availability of mature key components (such as Bragg cell modulators) and the author's confident reliance on rigorous design studies. To solidify these concepts, the author presented an example of an optoelectonics-based acousto-optic spectrometer (AOS) soon to be launched aboard the Submillimeter Wave Astronomy Satellite (SWAS). A comprehensive overview of key radiation effects research over the past decade focusing on fiber and integrated optics, and acousto optics, and the discussion of very recently (first) reported data regarding proton-induced effects observed in commercially available AlGaAs VCSELs (850 nm) and GaN-based light-emitting diodes is presented in CR66-03 (E. W. Taylor). R. F. Carson et al. (CR66-05) present first data and an in-depth examination of proton-induced responses of VCSEL arrays (780 nm and 850 nm). A comprehensive discussion of the importance of Group III nitrides for space applications is found in CR66-04 (M. Osiński), while a discussion of recently observed electron- and gamma-radiation-induced effects observed in organic and inorganic spatial light modulators is found in CR66-03 and CR66-06 (F. Berghmans et al). Degradation of space photosensors and optics by several radiation environments are reviewed by A. H. Siedle and S. Watts (CR 66-02), including a section reviewing the effects of proton and gamma rays on charge-coupled detectors.

A comprehensive review of the operation, design, and applications of GaAs optical/Si CMOS hybrid-based vertical cavity modulators (VCMs) for space-borne applications such as signal processing, computing, free space optical interconnects, and optical memory storage is presented by J. A. Trezza et al. (CR66-13). The authors conclude that VCM structures and materials are easily tailored to provide amplitude, phase, or direction modulation, and can operate as LEDs or detectors, providing many space-based applications. W. P. Hinkle (CR66-11) presents a thorough review of volume holographic memory technologies, comparing the recent progress in optical storage via photorefractive materials with the traditional computer mass storage methods based on semiconductor and magnetic storage media. D. K. Paul (CR66-12) provides the reader with an extensive overview of advanced SATCOM requirements and presents convincing economic and technical arguments for extensively integrating photonic technologies into communication satellites. The development and space qualification of photonic interconnects appropriate for spaceborne databuses are elegantly overviewed in CR66-12 (J. P. G. Bristow et al.). Among their conclusions, the authors state that databuses can be orbited "with adequate bit error rates in the presence of both long term radiation and single event upsets." The evaluation of a laser altimeter in space environments by T. D. Cole

(CR66-15), advances the arguments for inserting photonics into space systems, as does the presentation by M. S. Gaydeski et al. (CR66-14).

Mideast and European expertise was well-represented in this Critical Review, including contributions from Belgium, England, France, Israel, and Italy. Several European interests in photonic space applications are summarized and extensively discussed in CR66-05. This paper covers a broad spectrum of terrestrially oriented research, development, and applications of photonic devices, and discusses transitioning some of the technology to space applications. An extensive review of free space communications concentrating on the adverse effects of vibration on transmitter pointing direction is presented in CR66-07 (S. Arnon and N. S. Kopeika), while M. N. Armenise and W. Pecorella (CR 66-10) review a wide variety of guided-wave devices that are used in or may be applied to satellite systems.

On behalf of the conference participants, I would like to express our appreciation to the staff of SPIE for their superb support in assembling these Critical Review papers; to SPIE sponsors; and to the general membership for the opportunity to convene this symposium.

Edward W. Taylor