Parameswaran Hariharan (1926–2015)

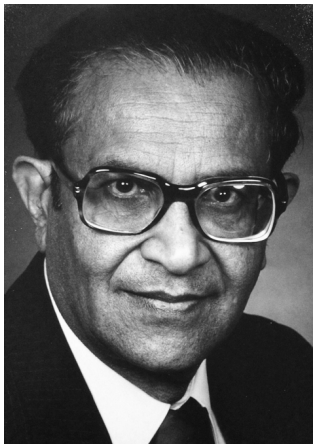
An obituary

Parameswaran Hariharan, known to many of his colleagues and friends as Hari, passed away in Berkeley, California, USA on 26 July 2015. His impact on international optics was profound, especially in the fields of interferometry and holography. Hariharan was born on 26 December 1926 in Madras (now Chennai). He went to school in Madras and then Thiruvananthapuram. He obtained his M Sc degree in physics in 1948 from the University of Travancore. He was a merit scholar and held the first place in the University throughout his collegiate studies. He was awarded the Cullen Memorial Gold Medal, the Boyle Memorial Prize and the Harvey Memorial Prize.

Hariharan joined the National Physical Laboratory (NPL), New Delhi in 1949. Sponsored by the Colombo Plan, he spent three years at the National Research Council (NRC), Ottawa, Canada. Here he published some of his earliest papers in the *Journal of the Optical Society of America*, including one in which he studied the diffracted light emanating from an annulus. Another paper from this time was on the resolving power of photographic emulsions. At the time, NRC not a degree-granting institution. Upon his return to NPL in 1955, K. S. Krishnan, then the Director, agreed to act as his Ph D supervisor. Hariharan put together work done in both Ottawa and New Delhi in a thesis entitled 'Photographic resolving power' and was awarded a Ph D degree by the University of Kerala in 1958. At NPL, he published a series of papers on interferometry, many of them in collaboration with D. Sen.

From 1962 to 1971, Hariharan was Director of the laboratories at Hindustan Photo Films (HPF), Ootacamund. With support from the Managing Director of HPF, M. A. S. Rajan, he carried out research on photographic materials. A paper describing his work was published in *Applied Optics*. It was here that he started working on holography. His research caught the attention of Satish Dhawan who was the Director of the Indian Institute of Science (IISc), Bengaluru, and who had visited HPF in an advisory capacity. Dhawan recruited him as a Senior Professor in IISc, to be based in the Central Instruments and Services Laboratory (CISL). At IISc, his work focused on holography and speckle patterns. Hariharan was elected Fellow of the Indian Academy of Sciences in 1972 and the Indian National Science Academy in 1973.

In the summer of 1972, Hariharan spent three months at the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Sydney, Australia at the invitation of W. H. ('Beattie') Steel, an expert in interferometry. He had fortuitously met Steel in Ottawa in the early 1950s because the Indian and Australian embassies, which were next to each other, had held a joint celebration on 26 January to commemorate both Republic Day and Australia Day. They had



corresponded since then and wanted to do some experiments together. The three months in Sydney were productive for Hariharan, and Steel invited him to return for a year beginning in May 1973. During that stay, Hariharan was offered a permanent position, which he accepted, and spent the remainder of his career in Australia, where he made important contributions to the fields of holography and interferometry.

Hariharan continued to visit scientific institutions in India and to collaborate with Indian scientists, especially after his retirement from CSIRO in 1991. He visited a number of laboratories in India as part of the UNESCO-sponsored TOKTEN (Transfer of Knowledge Through Expatriate Nationals) programme. He was a Jawaharlal Nehru Professor at the University of Hyderabad (1993), and a Visiting Scholar sponsored by the International Centre for Theoretical Physics (ICTP), Trieste, at the Raman Research Institute (RRI), Bengaluru (1996–98) where he collaborated with several scientists. His energy and enthusiasm for work were infectious. His visits to RRI invariably triggered some new experimental activity, either related to the geometric phase or interferometry. For example, one visit resulted in a collaboration with theorists at RRI on four-photon interferometry.

Two of Hariharan's Australian colleagues Bozenko ('Bob') Oreb and Chris Walsh, both of the CSIRO Division of Applied Physics in Lindfield, NSW, Australia, have written in detail about his scientific career in Australia.

As mentioned earlier, Hari came to Australia in 1973 to join the research staff at CSIRO. He had a strong background in classical optics acquired during his periods at NPL and IISc. As Director of the laboratories at HPF, he became an expert in photographic emulsions, which combined with his optical expertise gave him a background perfectly suited to the technically and artistically demanding field of holography. Hari's early contributions included the design of a new three-beam interferometer, the double-passed Fabry–Perot interferometer, and the first practical radial-shear interferometer. This background in interferometry led naturally to his interest in holography. His expertise in processing photographic emulsions (the principal recording medium for the highest quality holograms) led to innovations that dramatically improved the diffraction efficiency and brightness of holograms as well as their stability. The artistic community was quick to recognize the value of his work; he collaborated with artists, including Paula Dawson (http://www.pauladawson.com/), Alexander (http://www.art-alexander.com/), and Margaret Benyon (http://holowiki.nss.rpi.edu/wiki/Margaret_Benyon).

Along with his deep knowledge of classical optics, Hari was an innovative cross-disciplinary thinker. He recognized very early the power of modern electronics and microprocessors in optics, and in 1981, with colleagues at CSIRO, developed a novel holographic exposure control

system which combined the power of modern electronics and clever opto-mechanical devices to enable efficient and accurate holograms to be recorded each time. It was in interferometry, however, where this cross-linking bore the best fruit. The principles of phase-shifting interferometry were in their early stages of development, and Hari worked with his colleagues at CSIRO to develop the hardware needed to shift the phase of the interferometer and the CCD-based detection to record the intensity patterns used by the phase-recovery algorithms. Concurrently with this experimental work, Hari developed more sophisticated algorithms that were less susceptible to phase-shift errors and capable of greater accuracy in phase measurement. The optical workshop at CSIRO was at that time manufacturing optical surfaces whose deviation from form (flat or spherical) was so small that quantitative measurement was increasingly difficult. Hari's innovations in digital interferometry were perfectly timed; with the principle of 'if you can measure it, you can make it', the interferometers designed and built by Hari and his CSIRO colleagues allowed his co-workers to produce optical components and assemblies that in subsequent years found their way into the LIGO interferometer, NASA instruments, optical solar observatories and into industry as reference optics for commercial interferometers.

Hari retired from CSIRO in 1991 as Chief Research Scientist, the Organization's highest scientific rank. He continued his work as an Honorary Research Fellow at CSIRO and an Honorary Visiting Professor at Sydney University. Hari also expanded his circle of research associates and institutions to a number of countries including USA, UK, Japan, India, Mexico and Australia. During the following 20 or so years, Hari continued his prolific innovation and publication programme with the support of his old and new-found associates. His interests broadened as well; for example, he was the first to demonstrate achromatic phase shifting using the geometric phase, and made significant contributions to the study of quantum effects in optical interference.

Hari's lifetime contributions and achievements have spanned an amazing period of more than 60 productive years, during which he published more than 200 journal articles, wrote four highly-regarded books and five major reviews, as well as book chapters and optics articles for non-peer reviewed publications. (For a detailed list of Hari's publications, readers may see the following link: https://scholar.google.com/citations?user=ZxI6kRUAAAAJ&hl=en.)

Hari achieved notable international recognition for his original scientific contributions in interferometry, holography and other areas. These contributions have resulted in a huge impact across the globe and have served as a catalyst to enable countless other researchers to advance the understanding and knowhow in the discipline of optics. Hari has mentored many younger researchers and been an active ambassador and communicator of optics to the international community. Throughout his career he developed a deep understanding and strong capability in optical science and technology by applying his outstanding talent. He embraced a multi-disciplinary approach to develop new concepts and methods by bringing together people from different areas of research. This cross-fertilization of capabilities and ideas resulted in many innovative developments and applications, especially in the area of optical metrology.

Hari had a close association with the Australian Optical Society (AOS). He was the past President of the Society and was awarded the AOS Medal in 1996. Through his close links to the International Commission for Optics (as Vice-President and Treasurer) and SPIE – The International Society for Optical Engineering (Director) he played a major role in bringing the AOS closer to its international peer communities. Hari's awards are too numerous to mention, but possibly those that meant much to him personally were the Gold Medal of SPIE in 2001, SPIE Dennis Gabor Award in 1992, and the Joseph Fraunhofer Award from the Optical Society of America in 1989.

As a colleague, Hari was polite, thoughtful and always willing to share his knowledge. If any of his colleagues had a problem in optics, a half hour spent with Hari was the best way to start down the road to solving it. His presentations were exemplars of clarity: the depth was always appropriate to the level of the audience, the coverage perfect and the timing precise to the second. As a conference speaker, Hari was a Chairman's dream. His books are much the same: concise and clearly written, with not an irrelevant or unnecessary equation to be found. He had an ageless quality to him. Those of us who worked with him for many years, never noticed a change in his personal appearance, his demeanour, or in his scientific insight. He was widely read and had a marvellous sense of humour.

In the latter years of his life Hari moved to the US to be closer to his children and grandchildren. He remarked to one of his CSIRO colleagues that life was 'rocking the grandchildren to sleep, over to the desk to write a paper, back to the grandchildren'. He passed away surrounded by his family, productive to the last.

BOB OREB[1]
CHRIS WALSH[1]
JOSEPH SAMUEL[2,*]

[1]*Commonwealth Scientific and Industrial Research Organization, Australia*
[2]*Raman Research Institute, Bengaluru 560 080, India*
**e-mail: sam@rri.res.in*