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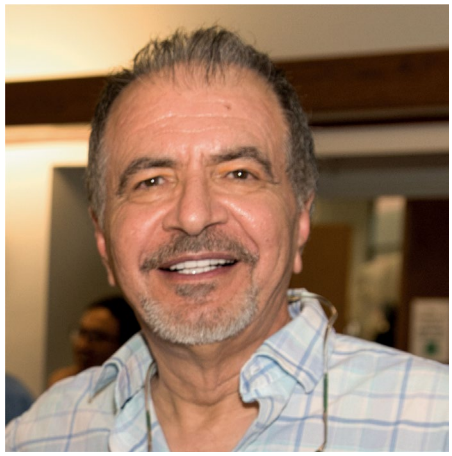
Mansoor Sheik-Bahae (1956–2023)

By Richard Epstein, Denis Seletskiy & Eric Van Stryland

Mansoor Sheik-Bahae, an exceptionally inventive scientist who made important contributions to nonlinear optics, optical refrigeration and laser science, passed away in July 2023, aged 67. He will be cherished for his sharp intellect, good humour, warm heart and the scientific legacy he leaves.



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Mansoor was born in Isfahan, Iran to a large, close family with many accomplished individuals, including doctors, a Sufi guru and world-famous candy makers. One of Mansoor's ancestors was the 17th-century polymath Sheikh Bahā'i, a poet, philosopher, architect, mathematician, and astronomer. Some of his ancestor's brilliance clearly trickled down to Mansoor.

Mansoor came to the US for his undergraduate studies at the Catholic University of America, Washington DC, where he received his BS and MS in electrical engineering. In 1987 he earned his PhD in electrical engineering from the State University of New York (SUNY) at Buffalo for his dissertation on *Picosecond CO_2 Laser Nonlinear Interaction with Semiconductors*. He then joined the Center for Research and Education in Optics and Lasers (CREOL), University of Central Florida, as an Associate Research Professor. In 1994, he became an Assistant Professor at the University of New Mexico (UNM), subsequently advancing to Distinguished Professor, the highest honour UNM awards to its faculty.

Following its inception in 1987, Mansoor joined CREOL along with M. J. Soileau, Eric Van Stryland and David Hagan, with whom he worked closely. Following his arrival, Mansoor was extremely influential in helping build CREOL's reputation as it became the first college in the US devoted to optics and photonics. Among his many contributions was his invention of Z-scan[1], a sensitive and powerful experimental method for characterizing nonlinear optical materials which measures (sign and magnitude) refractive and absorptive nonlinear optical coefficients. In 2012, he and Eric shared the coveted R. W. Wood Prize from Optica (formerly the OSA) for the development of Z-scan and its subsequent uses. Z-scans performed on many different materials allowed the determination of their frequency-dependent nonlinear refractive indices, n_2, and uncovered a universal sign change at frequencies near the bandgap of semiconductors. Using these results, Mansoor elegantly understood that careful application of causality via the Kramers–Kronig relations establishes a universal link between ultrafast nonlinear refraction associated with n_2, and the losses due to two-photon absorption – a connection that was originally considered impossible as these relations are linear. Mansoor's insight was to linearize the problem by looking at nondegenerate nonlinear absorption, that is, two photons of different frequencies[2].

In addition, Z-scan made it possible to measure nonlinear refraction in 2nd-order materials like the popular nonlinear crystal KTP and thus showed that refraction depends on the phase mismatch. This led to the development of the field of cascaded 2nd-order nonlinear optics[3].

In 1995, Mansoor, then at UNM, started collaborating with Richard Epstein at the Los Alamos National Laboratory (LANL) on the topic of optical refrigeration – a solid-state technology that uses lasers and fluorescence to cool a suitable material. While the LANL collaboration is still in place, in recent decades, much of the optical refrigeration work has been carried out at UNM, which has become a world leader in optical refrigeration research. In a ground-breaking demonstration published last year, Mansoor and his co-workers showed that optical refrigeration can cool a load to cryogenic temperatures as low as 125 K (ref. 4).

Optical refrigeration relies on anti-Stokes fluorescence; a laser pumps a suitable material at one frequency and the material fluoresces at a higher average frequency[5]. The energy difference between the pump light and the fluorescence extracts energy from the material, causing it to cool. In practice, implementing the concept of anti-Stokes fluorescent cooling to obtain cryogenic cooling poses many challenges. First, one must find materials that exhibit anti-Stokes fluorescence with high quantum yield and low parasitic absorption of the laser light. With this goal, Mansoor and his team developed ultrasensitive methods for discerning high-performance materials. They identified several candidates with ultrahigh quantum yields, from rare-earth doped glasses and crystals to semiconductors. To the present day, high parasitic absorption has precluded confirmed observation of optical refrigeration in semiconductors, one of Mansoor's unfulfilled dreams.

However, his team did discover that ytterbium-doped yttrium–lithium–fluoride crystals were stellar materials for optical refrigeration[6], quickly becoming the preferred choice for cryogenic cooling in the field. The second practical challenge requires that the optical refrigerator must dispose of the intense fluorescent radiation emitted (near kW cm^{-2}, almost equalling that at the surface of the Sun) without heating the load that is to be cooled. The UNM team designed working optical refrigerator systems, with many optical engineering innovations, from implementing selective coatings that absorb the fluorescence without producing much thermal radiation, to photon recycling concepts. Additionally, the team engineered transparent thermal links that can carry the heat from the load to the cold crystal without being heated by the fluorescence[4,5].

Mansoor's insatiable curiosity and ingenuity piqued his scientific interests in many additional fields. Over the past decade, his research group has made several significant contributions in laser engineering, especially around the issues of heat mitigation in high-power laser designs. For example, Mansoor and his team pioneered a mirrorless semiconductor disk laser[7], thus avoiding thermal degradation issues in high-power lasers due to the parasitic heating in monolithic distributed Bragg mirrors. This invention led to a new field of the membrane external cavity surface emitting laser (MECSEL) and the consequent development of a semiconductor-based sodium GuideStar source for precision terrestrial astronomy[8]. In parallel, Mansoor developed novel semiconductor active mirror concepts to facilitate better thermal management in high-power semiconductor lasers[9].

Guided by Mansoor's theoretical insights on the theory of radiation-balanced lasers (RBLs)[10,11], the UNM group demonstrated novel RBL geometries and first RBL disk lasers[12] while reporting the first cooling in Yb:silica (refs. 13,14) — paving the way toward promising applications of high-precision, high-power fibre laser technology. Mansoor and his team also made important contributions in the field of ultrafast science, from inventions of femtosecond pulse characterization techniques[15–17] to a pioneering demonstration of simultaneous THz and XUV emission from laser-driven plasmas, yielding novel insights into the intrinsic chirp of XUV pulses and strategies for its compensation[18]. Mansoor uncovered theoretical insights into quantum interference and other phenomena in semiconductor laser models[19]. The team also provided key demonstrations of strong plasmon–phonon coupling in solid-state plasmas;[20] high-intensity THz emission from solid-state nanowires, driven by acoustic plasmon modes;[21] a direct observation of Landau damping in solid-state plasmas;[22] novel imaging of THz waves using ultrafast electro-absorption in semiconductors via the Franz–Keldysh effect[23], and Kerr-lens modelocking in a VECSEL[24].

He was always ready to discuss the science you were working on and his feedback was always encouraging. He was driven by doing science while deriving valuable applications for humanity. In his recent collaboration with Jun Ye at NIST, he led a prototype optical refrigeration system that is poised to enable vibration-free cooling of an ultrastable monolithic external cavity to its zero-thermal expansion point, enabling Ye's team to implement some of the most precise tests of fundamental physics using their frequency comb technology. The interplay of science and engineering made Mansoor very happy, and he inspired this passion in his colleagues and students.

He served the professional societies in many capacities, for example as Topical Editor, *Journal of Optical Society of America B*; multiple years as conference chair on laser cooling as well as photonic heat engines for SPIE; programme committee member for Optica-CLEO and IEEE-LEOS, and he was a Fellow of Optica and SPIE and was a senior member of IEEE and nominated this year for Fellow.

The above is a brief summary of some of Mansoor's accomplishments during his career at CREOL and UNM. What is not said is his impact on his colleagues, students at CREOL, UNM and the Optical Science and Engineering programme at UNM, which he helped to establish, becoming its first director. Since his death, we have received countless communications with accounts of how Mansoor affected peoples' lives and careers. These accounts detail much more than just how his science and engineering skills helped them, explaining how his charm, humility, inspiration and kindness set an example for their lives.

As stated at his funeral: "Mansoor was more than his accomplishments; he possessed a beautiful soul and a pure heart. Known for his unwavering generosity and a great sense of humour, he could bring smiles even in the face of adversity. His humble and down-to-earth nature allowed him to effortlessly connect with people of all ages, leaving a lasting impression on those fortunate enough to know him. Mansoor's charisma and charm were contagious, making a cherished presence in every room he entered."

Mansoor is survived by his wife Sherry, his daughter Anahita, his sister Zohreh, and his brothers Rahim and Mahmoud. He will be greatly missed, but he will live on through his publications and through the continuation of his work by many of his students and colleagues.

We, the authors, will miss him terribly.

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