Predhiman Krishan Kaw (1948–2017)

Predhiman Krishan Kaw passed away due to a sudden cardiac arrest on 18 June 2017. An internationally acclaimed plasma physicist, he was the Founder Director of the Institute for Plasma Research (IPR), Gandhinagar, an institute that catapulted India to being one of seven nations building the world's largest fusion experiment: International Thermonuclear Experimental Reactor (ITER) in Cadarache, France.

In his many-splendored career, Kaw played a variety of roles: a great plasma physicist, a powerful motivator, an interpreter with great clarity of thought, a person with deep philosophical and spiritual moorings, a clever and nuanced strategist, and above all a person with a grand vision of the role of India in fusion and plasma physics.

Kaw was born in Kashmir on 15 January 1948, and had an unusual childhood. He was an extraordinary student and a gifted child who was home schooled by his uncles and grandfather. He obtained his Master's degree at the age 16 from MMH College in Ghaziabad. He then joined IIT-Delhi and was awarded the premier institute's first Ph D degree at the age of 18. At IIT he was a research student under M. S. Sodha, who introduced him to plasma physics. After finishing his Ph D at IIT, Delhi, Kaw went to Princeton University, USA initially as a postdoctoral scientist and worked there till 1971 after which he returned to India as an Associate Professor and then a Professor at the Physical Research Laboratory, Ahmedabad. He went back to Princeton in 1975 with the rank of a Professor and eventually returned to India for good in 1982.

Kaw was an outstanding scientist with a broad range of research interests and a prodigious research output spanning 389 papers in international journals. His early work at Princeton during the period 1967–1971 resulted in seminal contributions to nonlinear problems connected with laser–plasma interactions. Notable among these works are: (a) laser-induced parametric instabilities which led to anomalously large absorption as well as back and side-scattering; (b) filamentation of laser light due to ponderomotive forces in a plasma; and (c) relativistic nonlinear effects which have also found application in pulsar radiation phenomena. Most of these results have received confirmation by subsequent experiments and computer simulations. From 1971 to 1975, while he was at PRL, Kaw extended the theory of parametric instabilities to magnetized plasmas. The review articles written by him and some of his collaborators in this period are widely cited and have had a significant impact on the development of intense RF heating in magnetized plasmas and in the interpretation of ionospheric heating experiments at Arecibo. During this period, he also made important contributions to the theory of ionospheric irregularities and even initiated laboratory experiments at PRL to simulate some of the ionospheric phenomena, thereby planting a seed for future experimental plasma physics activities in India.

On his return to Princeton in 1975, Kaw took up research on magnetically confined fusion plasmas and made three pioneering contributions in this area: (a) he showed that the decades old conventional wisdom on the stability of drift waves in sheared geometry (a prime candidate for transport in fusion devices) was incorrect; (b) he demonstrated the existence of a coalescence instability of magnetic islands and showed how model calculations can elucidate complex nonlinear magnetic reconnection phenomena (these ideas have found applications in diverse phenomena like disruption in tokamaks, energy release in solar flares and sub-storm effects in tail regions of magnetosphere); (c) he developed a novel passive approach to current drive in reactor grade plasmas using naturally emitted synchrotron radiation by such plasmas – a technique that can find useful application in future advanced fuel reactors.

In the late seventies and early eighties, he and some of his colleagues at PRL succeeded in persuading the Department of Science and Technology, Govt of India, to set up a major programme of plasma physics at PRL. He returned to India in 1982 to direct this programme, which eventually evolved into the autonomous Institute for Plasma Research. In 1996, the IPR was taken over by the Department of Atomic Energy with a considerable upscaling of the experimental efforts on thermonuclear fusion. Under his leadership and guidance, the Institute made remarkable progress on several fronts: (i) A medium-sized tokamak device called ADITYA was indigenously designed and fabricated. This machine was commissioned in 1989 and has led to some very novel results on intermittency in tokamak edge turbulence. (ii) A large number of basic experiments investigating fundamental processes in plasmas were set up and have led to exciting new physics. (iii) The Institute also successfully developed a number of plasma processing technologies and some of these technologies have been transferred to Indian industries. (iv) The Institute carried out the design/fabrication of an advanced steady-state superconducting tokamak SST–1. This machine was commissioned in 2014 and is one of the few machines of this kind anywhere in the world. (v) The Institute successfully spearheaded India's case for participation in the prestigious ITER experiment and is now the nodal domestic agency managing this participation. (vi) The Institute nurtured and trained a large number of young plasma physicists and technical personnel through its graduate programme and technical training programmes to cater to the rapidly growing R&D activities in the field.

He also continued to actively pursue his research interests in tokamaks but now with an additional incentive of interpreting experimental results from an in-house tokamak ADITYA. In a pioneering effort, he and his colleagues discovered the phenomenon of intermittency in tokamak edge plasma turbulence of ADITYA – a result that spawned a lot of further research in other tokamaks of the world. At this stage Kaw also enlarged his research interests to more

fundamental areas like dynamics of quark–gluon plasmas, equilibria of non-neutral electron clouds and collective effects in dusty plasmas and other strongly coupled systems. In each of these areas he provided new ideas, valuable insights and in many cases strong incentives and frameworks for laboratory experiments. He also continued his investigations on nonlinear phenomena in relativistic light plasma interactions and made important contributions to the theory of envelope solitons and to the physics of anomalous stopping of fast electrons – topics of great interest for laser plasma-based particle acceleration schemes and the fast ignition scheme of laser fusion. He extended activities in these frontier areas of science and technology by forging collaborations with other active research groups within the country and abroad. One fine example is the establishment of collaboration between the theory and simulation activities at IPR with TIFR experiments in the field of laser plasma interactions. This collaboration has led to fundamental insights into issues pertaining to laser energy absorption, magnetic field generation, its evolution and its turbulent characterization in laboratory laser plasma experiments. These ideas are tied up closely with the physics of fast ignition in laser fusion and have also been found relevant to the experiments on Laser Fusion in Osaka.

While the pace of his research work never diminished – he continued to work till the last day of his life – he astonishingly found time to envision, plan, initiate and implement major research and technology development programmes in the country. Apart from developing the national fusion programme, Kaw also made sure that India became an active participant in the international fusion effort. He played a critical role in ensuring that India became a member of the ITER programme. This involved in one part a campaign within the Indian science establishment and concerned ministries to convince them of the importance of fusion technology from a long-term perspective of India's energy security. There was an equally important aspect of convincing the existing ITER partners of India's potential to be an important contributor to the ITER programme. Kaw was the *de facto* leader of the Indian team which participated in the presentation of the formal proposal for Indian membership in ITER and in the negotiations. His persuasive skills were very evident in these meetings. Finally, during the formative years of ITER, Kaw played an important role as Chairman of the ITER STAC, the Science and Technology Advisory Committee of ITER. STAC was the conscience keeper of ITER making sure that there is no compromise in the final scientific and technical objectives of ITER. There is wide appreciation within the ITER system that Kaw did a good job in resolving many complex STAC issues and in helping ITER conform to its technical specifications.

For his outstanding contributions and achievements, Kaw received many honours and awards during his illustrious career starting with the Indian National Science Academy's Young Scientists Award in 1974. In 1985, the Government of India honoured him with the *Padma Shri* and in 1986 he received the S.S. Bhatnagar award. He was a Fellow of all the major science academies in India and also of the American Physical Society. Recently, he was named the 2015 laureate of the Subrahmanyan Chandrasekhar Prize for 'outstanding contributions' in the field of plasma physics by the Association of Asia Pacific Plasma Physics Societies.

Above all, Kaw was a passionate scientist and a great teacher who never tired of promoting the cause of science and spending enormous time mentoring students and younger colleagues. He strongly believed that science should be pursued with complete freedom of thought and implementation. When the IPR buildings were planned, he engaged the architects and some of his colleagues in endless discussions to help incorporate this concept into the design. The wide corridors, the openness to the sky and the surroundings, the oneness with nature and the sense of liberation that they bring are all embodiments of this conviction. Likewise, his office door was always open for anybody to step in and to discuss science with him. As a human being he was extraordinarily kind and gentle with infinite patience particularly for younger colleagues. This coupled with his infectious enthusiasm for research encouraged many students and scientists, not only from within the Institute but also from the Universities and the scientific community abroad to interact with him and collaborate with him in research. Each one of them felt enriched and emotionally touched by his warmth and generosity of spirit. In his more than 50 years of active scientific life, Kaw has not only contributed significantly to the progress of fusion and plasma physics in India and abroad but has also inspired a lot of young minds and touched a great many human lives in an uplifting manner and thus leaves behind an invaluable legacy in science and humanity.

Kaw is survived by his wife (Saroj) and children (Sidharth, Prashant and Puja).

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