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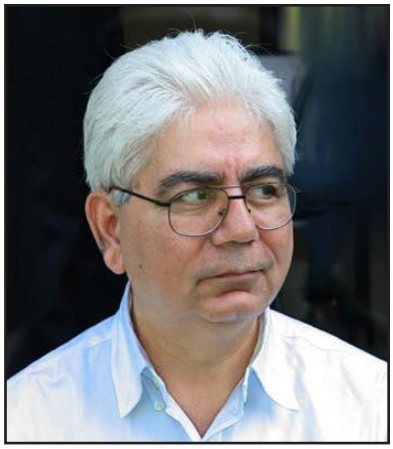

Prof P K Kaw

*Guest Editors : Ramesh Narayanan & Satyananda Kar*

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# Predhiman Kaw: The Father of India's Nuclear Fusion Program

Amita Das
*Department of Physics,*
*Indian Institute of Technology Delhi, Hauz Khas, New Delhi-110 016, India*

Dedicated to Prof P K Kaw

This article offers a glimpse into the remarkable life of Professor Predhiman Kaw, highlighting his scientific contributions and visionary leadership in pioneering India's nuclear fusion program. His journey through life is truly inspiring, serving as a beacon for present and future generations.

Professor Predhiman Kaw, a world-renowned plasma physicist, played a pioneering role in India's Nuclear Fusion Program. As the founding Director of the Institute for Plasma Research (IPR), he provided visionary leadership that significantly advanced fusion research in the country. Under his guidance, IPR made remarkable strides in plasma physics and fusion technology, ultimately leading to India becoming a full partner in the International Thermonuclear Experimental Reactor (ITER) project—a global initiative to demonstrate the scientific and technological feasibility of nuclear fusion energy for peaceful use.

Born in Srinagar, Professor Kaw's early life was shaped by historical and political circumstances. His family, recognizing the growing instability for Kashmiri Pandits in the valley, relocated to Delhi soon after partition. In Delhi, he and other children in the family, including his elder brother and cousins, were home-schooled by their father, grandfather, and uncles. Despite never attending formal school, he displayed extraordinary intellect and, at just 10 years old, cleared the board examinations, making him eligible for college. However, age restrictions in Delhi's colleges prevented his admission, prompting his family to send him to Srinagar for further studies, where he lived with his maternal grandfather.

This period in Srinagar was profoundly meaningful for Professor Kaw. It was here that he first connected with his homeland and the essence of Kashmiriyat—a cultural and spiritual heritage he fondly recalled throughout his life. The region, once a revered center of learning in ancient India, resonated deeply with his intellectual pursuits. His journey, marked by exceptional scholastic achievements, seemed a fitting continuation of Kashmir's legacy as a beacon of knowledge and wisdom.

After completing his Intermediate studies in Science in Kashmir, Professor Kaw pursued his B.Sc. and M.Sc. at MMH College, Ghaziabad, which was affiliated with Agra University at the time. During this period, he commuted daily from Delhi to Ghaziabad to attend classes. Later, Professor Kaw fondly recalled his college days and the inspiring mentorship of his professors - Prof. Chandra Bhushan, Prof. Agarwal, and Prof. Singh—who guided the first M.Sc. batch at the college with great enthusiasm. He shared these memories in an interview with Gauhar Raza on Rajya Sabha TV's Eureka. Demonstrating exceptional academic brilliance, Professor Kaw completed his M.Sc. at the remarkable age of 16, graduating as the top-ranked student and gold medalist at Agra University. Although his family had hoped he would join the civil

*Corresponding author*
*e mail:amita@iitd.ac.in* (Amita Das)

services, he was too young at the time to appear for the examination. Determined to make the most of the intervening years, he enrolled at IIT Delhi for a Ph.D. under the guidance of Professor M.S. Sodha—laying the foundation for his groundbreaking contributions to plasma physics and fusion research

Professor Kaw's time at IIT Delhi deepened his passion for physics to such an extent that he abandoned his initial plan of appearing for the civil services examination after his Ph.D. Instead, he chose to dedicate his career to scientific research. This decision led him to Princeton University, where he joined Professor Dawson's research group. Between 1967 and 1971, he spent four years at Princeton, initially as a research staff member and later as an Assistant Professor. During this period, he worked on a wide range of topics in plasma physics, collaborating with and learning from some of the leading physicists of the time. His work at Princeton laid the foundation for his future contributions to the field and paved the way for his pioneering role in India's nuclear fusion research.

## Young Predhiman

Predhiman Kaw's scientific career soared at Princeton. He investigated a wide range of issues related to the propagation and absorption of laser light in plasmas—which are critical questions even now for understanding the mechanisms of inertial confinement fusion. In addition, his research extended to topics such as parametric instabilities of ion cyclotron waves, surface waves in plasma half-space, and ion plasma surface waves. Known for his rigorous and quantitatively precise approach, Kaw often found himself fascinated by Professor Dawson's ability to derive intuitive approximations from detailed calculations. Dawson's insights, despite their simplicity, frequently captured the essence of complex plasma phenomena with remarkable accuracy—something that deeply influenced Kaw's perspective on theoretical physics.

Young Predhiman quickly made an impression at Princeton with his brilliance, dynamism, and boundless enthusiasm. His remarkable energy earned him the nickname "Indian Fireball". This was narrated by Peter Mulser to the author of this article. While Predhiman had been a child prodigy, what set him apart was not just his intellect but also his maturity. He was fully aware of his exceptional abilities, yet he carried no ego—handling his gifts with a natural ease. The recognition he received only fuelled his drive to excel, yet he remained a humble and grounded individual at heart.

At the time (and even today) the United States was/is often seen as a dreamland. Many Indians who spent time there return with altered accents or an exaggerated admiration for the country. However, despite arriving in the U.S. at a young and tender age, Predhiman remained unaffected by these cultural shifts. He never adopted an American accent and continued speaking English at his usual rapid pace, something Americans often found unusual. Upon returning to India, he remained the same unassuming person, seamlessly adapting back to his roots. It was remarkable that, even at such a young age, he possessed the maturity to navigate social pressures with effortless grace.

During his time at Princeton, Dr Vikram Sarabhai extended an invitation to Predhiman Kaw, offering him a faculty position at the Physical Research Laboratory (PRL) in Ahmedabad. Sarabhai had a grand vision for establishing fusion research in India, and Predhiman seemed like the perfect candidate to spearhead this effort. Upon meeting him for the first time in US, Sarabhai was struck by Predhiman's youthful charm and is said to have remarked, "*Professor Kaw you are just a boy*." However, after engaging in a conversation with him, he was so impressed by Predhiman's intellect, depth of knowledge, and also sensing his natural leadership abilities, that he offered him not only a faculty position but also appointed him as the head of the plasma research group at PRL. True to his commitment to advancing scientific research in India, Predhiman returned in 1971 to take on this pivotal role, laying the foundation for the country's future in fusion energy. However, Sarabhai's untimely death in December 1971 was a significant setback for India's fusion program. Despite this, Predhiman continued his work at PRL until mid-1975, contributing extensively to plasma physics research and mentoring numerous students and colleagues.

During these four years at PRL, he collaborated with several researchers on a range of theoretical and experimental studies. This period saw him author a review article on parametric instabilities for Advances in Plasma Physics. He also carried out theoretical studies on wave propagation effects on electrojet instabilities in space plasmas with his student P Chaturvedi. Additionally, along with Chaturvedi and Ivanov (a visiting researcher at PRL), he explored electromagnetic effects on equatorial electrojet instabilities. As the Area Chairman of the Plasma Physics Group, Predhiman organized experimental studies on electrojet instabilities in collaboration with P I John, Y C Saxena, and Satyaprakash. He also teamed up with Abhijit Sen, A K Sundaram, and students like Parvez Guzdar to investigate random density fluctuations in the growth of parametric instabilities, along with other key issues such as ballooning modes and parametric drift waves.

Predhiman's passion for physics was so intense that he often became completely engrossed in discussions, oblivious to the passage of time. It was a common sight—just before lunchtime, he would excitedly walk into a colleague's office, eager to share his latest calculations. What began as a quick discussion would seamlessly stretch through lunch, with others too captivated (or too polite) to interrupt. It is said that Prof. Sundaram, having fallen victim to this lunchtime ventures one too many times, developed a rather strategic survival tactic—he started sneaking out of his office a little earlier than usual to avoid getting caught in one of Predhiman's marathon discussions. Rumor has it that on some days, Sundaram's most complex calculation was not about plasma physics, but rather the precise timing needed to escape before Predhiman appeared at his door! The team Predhiman worked closely with during his time at PRL—Abhijit Sen, P I John, Y C Saxena, and A K Sundaram—eventually became the core group that played a pivotal role in advancing India's fusion program in the years to come.

During this period, Predhiman also spent time visiting various laboratories and institutes abroad, leading to several fruitful collaborations. He had a standing invitation at UCLA, where he would spend about a month each year. It was during this time that he co-authored the famous six-author paper on parametric instabilities [1], collaborating with Y C Lee (his former postdoctoral researcher at Princeton) and Jim Drake. Additionally, he worked on filamentation and trapping instabilities with George Schmidt, although this particular work was never published.

Predhiman also spent about three months in Japan working with Nishikawa's group, where he contributed to research on envelope solitons in inhomogeneous plasmas, as well as two-dimensional and three-dimensional envelope solitons with exponential nonlinearity. He further explored BGK modes for wave-wave interactions using the kinetic wave equation. He also attended a six-week workshop on lasers at the ICTP in Trieste, organized by Rosenbluth and Sagdeev. During this time, he collaborated with Rosenbluth and Roscoe White on parametric instabilities in inhomogeneous plasmas.

Professor Kaw decided to return to Princeton in 1975. However, his four-year tenure at PRL from 1971 to 1975 had fostered a vibrant and rigorous research environment, reinforcing his belief that high-quality scientific work could be accomplished in India with the right manpower and financial support. Although he moved back to Princeton, he remained deeply committed to the vision of developing an indigenous research group in plasma science, with fusion research at its forefront.

## From Professor in Princeton to founding Director of the Institute for Plasma Research

While his second time at Princeton, Kaw frequently discussed with his Indian colleagues ways to revitalize fusion research in India. These discussions took place at his residence, conference venues, or wherever they happened to meet. At the time, around 8–9 Indian scientists were working in the U.S., all keenly aware of the active Plasma Physics group at PRL. They envisioned collaborating to develop a robust research program.

Eventually, Kaw and some of his former colleagues at PRL devised a comprehensive Plasma Physics Programme (PPP) aimed at advancing studies on magnetically confined high-temperature plasmas in

India. He successfully persuaded the Department of Science and Technology (DST), Government of India, to establish the program at PRL. Kaw remained at Princeton until 1982, after which he returned to India to lead the DST-sponsored Plasma Physics Programme at PRL.

Initially, a group of six to seven scientists from the U S, along with a similar number from PRL, joined the Plasma Physics Programme (PPP). However, within a few years, all those who had returned from the U.S.—except Kaw—moved back, as their families struggled to adapt to life in India. In this context, the contribution of Mrs. Saroj Kaw, Professor Kaw's wife, deserves special recognition. A highly successful paediatrician in the U.S., she made the significant decision to leave her thriving career and return to India with her husband. Despite the challenges of transitioning to a different environment, she embraced the change wholeheartedly, without regret.

Eventually, the program was left in the hands of Kaw and the PRL team. However, within just four years (1982–1986), the group expanded significantly, growing to approximately 75 researchers working across various domains of plasma physics. During this period, a new facility—the Beta Lab—was constructed at PRL specifically to support the Plasma Physics Programme (PPP). The lab quickly evolved into a vibrant center for cutting-edge research in plasma science. At its core was a device called BETA, an acronym for Basic Experiments in Toroidal Assembly, which enabled a wide range of experimental investigations. Numerous important studies were carried out using this device, many of which are discussed in detail in an article by P. I. John [2].

In this period, Kaw extended the theory of parametric instabilities to magnetized plasmas. His review articles from this era remain widely referenced, having significantly influenced the development of intense Radio frequency heating in magnetized plasmas and the interpretation of ionospheric heating experiments. Additionally, he made crucial contributions to the theory of ionospheric irregularities in the equatorial electrojet.

The Plasma Physics Programme (PPP) continued to flourish and, by the mid-1980s, evolved into an independent institute under the Department of Science and Technology (DST). This new entity was named the Institute for Plasma Research (IPR) and was established on the western banks of the Sabarmati River in Gandhinagar, the capital of Gujarat, India. Professor Kaw became the founding Director of the Institute.

The growth and direction of any research institute are often shaped by the vision and interests of its leadership. As directors change, so too can the priorities and focus areas of the institution. In this regard, the Institute for Plasma Research (IPR) was particularly fortunate to have Prof P K Kaw as its founding Director for nearly three decades—a tenure that is exceptional, and perhaps unparalleled, in the Indian scientific context.

What truly set Prof Kaw apart was his inclusive and expansive view of science. He never drew boundaries between his own interests and other emerging areas. His intellectual curiosity was both deep and wide-ranging, allowing him to nurture and support a broad spectrum of research—from fundamental theoretical work to cutting-edge technology development. Equally notable was his adept use of the institutional autonomy granted to IPR. Under his visionary leadership, the Institute, despite its modest size and limited resources in the early years, accomplished an impressive array of scientific and technological milestones. His legacy laid a strong, interdisciplinary foundation for IPR.

Prof Kaw maintained an extraordinary balance between his administrative duties and scientific pursuits throughout his tenure as Director. It was truly remarkable how effortlessly he navigated both worlds. His office setup itself reflected this dual commitment. He had three adjacent rooms: the central one, occupied by his personal assistant, served as the gateway to the two side rooms—one dedicated to academic discussions and the other to administrative meetings. This physical arrangement mirrored the mental discipline with which he compartmentalized his responsibilities.

Though he had broadly designated his mornings and evenings for scientific engagement and reserved the afternoons for administrative matters, real life rarely respected such schedules. Urgent issues, unexpected visitors, or assertive staff members often interrupted his academic time. Yet, he never kept anyone waiting. He would momentarily pause the scientific discussion, promptly handle the administrative matter with characteristic efficiency, and then return—often resuming the scientific conversation exactly where he had left off. We, his colleagues and collaborators, often found ourselves drifting off-topic in his brief absence, only to be astonished when he rejoined and steered us right back with pinpoint precision. His ability to seamlessly switch between administrative and scientific modes was nothing short of awe-inspiring, leaving all who worked with him deeply impressed by his clarity of thought and unwavering focus.

Despite serving as the founding Director of the Plasma Physics Programme and later the Institute for Plasma Research (IPR) for nearly three decades, Prof. Kaw remained a remarkably humble and unassuming individual. One incident stands out vividly in my memory. We were staying at a guest house during a visit, and Prof. Kaw had left early the next morning. While we were checking out, the person at the reception asked about him. When we told him that Prof. Kaw was our Director, he was genuinely surprised. He remarked, "He is such a simple person! I have often placed him on the 7th floor." (The guest house had nine floors, with the higher floors offering more spacious and premium accommodations meant for senior dignitaries.) "Unlike directors from other institutes," the receptionist continued, "he never once objected or demanded a higher floor."

It is both humbling and poignant that someone who led a premier national scientific institution with such integrity and humility could leave behind a legacy so deeply rooted in simplicity. Prof. Kaw set a powerful example—not through grand gestures, but through everyday actions that spoke volumes about his character. In contrast, one cannot help but notice the subtle displays of status that have crept into institutional culture—even within the same walls he once led. It is not uncommon today to see individuals having staff prepare their offices in advance, switching on the air conditioning so the room is perfectly cooled before their arrival. Prof Kaw, on the other hand, would carry his own bag to his room and personally switch on the lights, fan, and air conditioner—no fuss, no airs. His actions reminded us that true stature is not defined by position or privilege, but by humility, respect for others, and the quiet dignity with which one carries oneself.

In open scientific discussions at the Institute, Prof Kaw often played the role of a devil's advocate—deliberately siding with the weaker argument. He would then challenge the seemingly stronger side, which was often confident in having thoroughly addressed all aspects, with a series of incisive and probing questions. These interrogations would continue until the stronger side had completely exhausted its defenses and was compelled to return with a fresh round of focused investigations.

This approach was both intellectually stimulating and, at times, quite amusing. To the casual observers, it often appeared as though the stronger side was in the wrong—simply because they were being rigorously questioned by Prof Kaw. Such was the weight of his presence and the respect he commanded. Naturally, stories of these exchanges would circulate throughout the Institute, adding to the lore in a way that was as entertaining as it was inspiring.

As a colleague, he was someone with whom one could engage in open and thoughtful discussions on virtually any area of physics. His critiques were always insightful, often identifying subtle yet important issues. If one could address his questions and concerns satisfactorily, it was almost certain that they would be well-prepared to respond to any reasonable queries raised by a referee anywhere in the world.

Prof Kaw was an exceptional teacher who shared a unique and enduring bond with his students. He always found time—not just for his own students, but for anyone, within the Institute or beyond, who wished to discuss physics. His door and mind were always open. He had an extraordinary ability to instantly recognize the strengths and promises in people, and he knew exactly when and how to offer support. He

encouraged independent thinking while remaining a steadfast source of guidance and reassurance whenever it was needed.

Prof Kaw never dismissed any idea outright—especially those from younger researchers. Instead, he would always try to find something worthwhile in it. Often, he would unearth a deeper meaning, saying, "Perhaps what he/she means is this," and proceed to reveal an insight so profound that even the promoter would not have thought. It would leave me in awe. More than once, I found myself marveling at how he could extract depth from what I had thought were simple or even half-baked ideas.

As someone who has worked with students myself, I know how tricky it can be to revise a student's draft—especially without offending them. I have even seen students complain to Prof Kaw when their manuscript drafts were entirely rewritten by other collaborators. But Prof Kaw had a remarkable way of handling such situations. With the touch of a master artist refining a child's raw sketch, he would take what initially seemed fragmented or unclear and transform it into something meaningful and elegant. Watching him do this—often with drafts I had assumed to be beyond repair—left a lasting impression on me. It was both humbling and deeply motivating to witness such intellectual generosity and finesse first-hand.

It is equally important to recognize that, though a theoretician by training, he not only directed but made notable contributions to a technology-intensive field—providing clarity that shaped key decisions and offered original ideas of lasting significance.

## Aditya, SST1 and ITER participation

IPR embarked on a technologically ambitious path, with fusion research as its cornerstone. This vision materialized through the successful development and operation of advanced tokamak machines like Aditya and SST-1, which significantly strengthened the country's technological base. Building on the foundational work with the BETA device, the program progressed to designing more complex tokamaks capable of magnetically confining plasma for fusion experiments. These efforts not only demonstrated indigenous expertise in high-end technologies but also paved the way for India's entry as a full partner in the prestigious international fusion initiative, ITER.

The first Tokamak developed under the program was named Aditya, a word that means "Sun" in Hindi—symbolic of its focus on the goal towards harnessing fusion energy. Aditya was the first indigenously designed and built Tokamak machine in India, marking a significant milestone in the country's fusion research efforts. It is a medium-sized device, featuring a major radius of approximately 0.75 meters and a minor radius of 0.25 meters.

The plasma within Aditya is confined using a magnetic field of around 1.2 Tesla, generated by current-carrying coils. Notably, these coils are resistive, as opposed to the superconducting coils used in more advanced Tokamaks. Despite being relatively modest in scale, the device contributed significantly to the development of diagnostics, plasma control, and confinement studies in India. It provided an experimental platform to investigate key aspects of Tokamak physics—such as plasma instabilities, impurity transport, edge turbulence, and offered critical training ground for generations of Indian plasma physicists and engineers.

Aditya was among the earliest fusion devices to report the phenomenon of intermittency in plasma turbulence. These observations demonstrated that plasma transport in the edge region is not a smooth, diffusive process but rather occurs in bursts—characterized by sporadic, large-amplitude transport events. This insight contributed to the evolving understanding of turbulent transport in magnetically confined plasmas, where intermittent structures such as blobs and filaments play a critical role. This machine has been contributing to scientific research for more than three decades now. It has now been upgraded to Aditya - U with improved magnetic field systems, upgraded diagnostics etc,.

The Steady State Superconducting Tokamak (SST-1) was conceptualized in the mid 1990s at IPR. At the time when the SST-1 project received government approval, IPR underwent a significant transition—from being an autonomous institute under the Department of Science and Technology (DST) to becoming an autonomous institute under the Department of Atomic Energy (DAE). SST1 marked a significant advancement by incorporating superconducting magnets to enable steady-state plasma operation. SST-1 became operational in late 2013, achieving plasma discharges with currents exceeding 100 kA and durations over 300 milliseconds at a central magnetic field of approximately 1.5 Tesla. After initial commissioning in 2013 and system enhancements through 2015, SST-1 began producing consistent plasma. Its operational progress and early scientific results were showcased at the 26th IAEA Fusion Energy Conference in Kyoto in 2016, officially establishing it as an active experimental platform in global fusion research.

The scientific and technological capabilities demonstrated through the successful development of Aditya and SST-1 were instrumental in positioning India as a full partner in the prestigious international collaboration, ITER (International Thermonuclear Experimental Reactor). ITER aims to achieve key milestones in fusion energy research, including the realization of a self-sustaining fusion reaction—known as a 'burning plasma'—the production of 500 MW of fusion power, and the demonstration of integrated operation of technologies essential for future fusion reactors.

Table 1 illustrates the progressive advancement in key technological domains—such as vacuum volume, magnetic systems, RF heating, cryogenics, cryoline distribution, and control instrumentation—from India's Aditya tokamak to SST-1, ITER, and finally toward reactor-scale fusion devices. This progression highlights not only the escalating complexity of fusion infrastructure, but also the significant strides made in indigenous capabilities that align with global benchmarks. Each successive platform serves as a vital stepping stone in developing the sophisticated technologies essential for realizing commercially viable fusion energy. (* Non – superconducting Copper coils)

Table 1. The progressive advancement in key technological domains

| **Technologies** | **Aditya** | **SST1** | **ITER** | **Reactor** |
|---|---|---|---|---|
| **Vacuum Base Pr $10^{-8}$ Torr** | Volume ~ $Mt^3$ | ~ 10 $Mt^3$ | ~ 1000 $Mt^3$ | ~ 10000 $Mt^3$ |
| **Power Engg** | MegaWatt (MW) class | ~ 10 MW class | ~ 100 MW class | Few 100 MW class |
| **Magnets** | Copper, size ~ 0.5 Mt, Mjoule (*) | SC, size ~2 Mt ~ 10 MJoule | SC, ~10 Mt ~ GJoule | SC, ~10 Mt ~ 10 GJoule |
| **RF and neutral beam power** | MW | ~ 10 MW | ~ 100 MW | ~ 100 MW |
| **Cryogenic plant** | NA | ~1.5 kW (Liq. He) | ~80 kW (Liq. He) | ~100 kW (Liq. He) |
| **Cryogenic distribution lines** | NA | 100s of meters | Several Kilo-meters | Several 10s of Kilometers |
| **Instrumentation and control** | milli-second, milli-meter order displacement 100 kAmps over 100s of micro-second | milli-seconds, milli-meter displacement 100 kAmps over 100 micro-second | milli-second, millimeter displacement Mega-Amps current in milli-seconds | Milli-second, milli-meter order displacement Mega-Amps in milli-second |

Throughout his career, Professor Kaw consistently made a passionate appeal to both national and international communities on the critical importance of fusion power and its role in humanity's future. He not only authored thought-provoking articles [3] on this theme but also articulated his vision through influential

lectures. A defining moment in this advocacy came when he delivered the prestigious Artsimovich Memorial Lecture at the 14th IAEA Conference on Plasma Physics and Controlled Fusion in Würzburg, Germany, in 1992. Titled "Fusion Power, Who Needs It?", the lecture offered a visionary perspective on the promise of fusion energy in addressing the world's growing energy demands. In his address, Professor Kaw emphasized the need for global collaboration in advancing fusion research, observing how a once-fragmented community was beginning to unify around a shared purpose. He noted that the question—"Fusion Power, Who Needs It?"—was acquiring renewed urgency, as the world increasingly recognized the necessity of sustainable energy solutions.

This lecture stands as a seminal contribution to the discourse on fusion energy, encapsulating Professor Kaw's deep foresight, scientific conviction, and unwavering commitment to the pursuit of a cleaner and more equitable energy future.

## Other Areas: Support and Collaboration

Beyond his pioneering work in fusion, Professor Kaw had a broad spectrum of scientific interests and was known for his collaborative spirit. He engaged with several research groups both in India and abroad, contributing to a diverse range of topics. His collaborations spanned from studying quark-gluon plasma with Professor Parikh at PRL to exploring the physics of anomalous electron energy stopping in laser fusion targets. Notably, his work in the latter area involved close interaction with experimental groups at TIFR Mumbai (Professor G Ravindra Kumar's group) and ILE Osaka (Professor K A Tanaka's group), which proved to be particularly impactful [4-6].

When Indian scientists proposed the idea of hosting one of the LIGO detectors in India, as part of the global gravitational wave observatory network, they sought Professor Kaw's support. He immediately recognized the scientific significance of this mega-science project. The addition of an Indian detector was crucial—it would dramatically improve the network's ability to localize gravitational wave sources across the sky. Professor Kaw not only lent his administrative backing but also took a deep scientific interest in the endeavor. He foresaw how the expertise developed at IPR, particularly in maintaining high vacuum systems for tokamaks, could be leveraged to support the vacuum infrastructure needed for LIGO's long arms. His involvement extended far beyond oversight—he actively engaged in understanding the complex scientific challenges posed by the project. I recall a series of talks which were organized at IPR, where it was a treat to hear experts like Professor Sanjeev Dhurandhar, Professor Bala Iyer, and Professor C.S. Unnikrishnan delve into the technical intricacies of the project.

It is important to note that this was around the year 2012 or so, prior to the first detection of gravitational waves—a time when the field was still preparing for its defining moment. Professor Kaw, then Director of IPR, could often be seen with the iconic book Gravitation by Misner, Thorne, and Wheeler on his desk. He would leaf through it whenever he found a moment, and frequently, our interactions with him those days would transform into engaging discussions in this area. Even after his retirement, Professor Kaw remained committed to the LIGO-India initiative. As Mrs Kaw fondly recalls, he would get up at 4 a.m. and begin his work on the project, writing reports or preparing documents etc.,—his dedication unwavering. His contributions remain a testament to his deep-rooted passion for science and his relentless pursuit of collaborative excellence.

There is an important reflection that we, as members of the scientific community, must keep in mind. Whenever a particular group or research area receives substantial support from the government, it should be a moment of collective celebration. Such successes are not isolated victories—they represent opportunities to strengthen the case for increased investment in science as a whole, something we all aspire to. Voices of scientifically incorrect and irrelevant skepticism or division risk undermining this broader vision. Instead, it is far more constructive to view these achievements as pathways that can open doors for others. Equally

important is the responsibility of those who receive such support—to maintain a broad, inclusive perspective on science. A truly curious and committed scientific mind does not draw rigid boundaries between "our work, our area" and "their work, their area." Professor Kaw exemplified this spirit. His ability to support and appreciate scientific endeavors beyond his own domain reminds us that generosity of intellect and openness to collaboration are as vital to progress as individual brilliance.

## Glimpse of my personal recollections

I first met Professor Kaw during my job interview at the Institute for Plasma Research. He was the founder Director of the Institute. At that time, I was in the final stages of writing my thesis on condensed matter physics, focusing on disordered systems. During my presentation, he asked sharp and insightful questions that not only challenged me but also provided valuable perspectives on my research. What stood out most was that he did not make me feel as if I was being interviewed – instead, it felt like an engaging scientific discussion. His depth of understanding and keen interest left a lasting impression. When I was offered the position, I eagerly looked forward to work with him and anticipated an exciting new chapter in my career.

It was truly a remarkable journey—an opportunity I will always cherish. I learned so much simply by observing him. Over the years, I had the privilege of working on a wide range of topics with him. Our first collaborative paper focused on the instability of elliptical vortex cores in electron clouds. Together, we explored several fundamental aspects of plasma physics, including fast electron time-scale phenomena using the Electron Magnetohydrodynamic (EMHD) model, current- and beam-driven instabilities, anomalous electron transport and energy dissipation, as well as magnetic field generation and turbulence in laser-plasma interactions. It was a pure, unfiltered joy to do science alongside him. Our collaboration continued until his passing in 2017.

In December 2018, seeking to be closer to family, I left IPR and joined his alma mater—the Department of Physics at IIT Delhi. Since then, I am happy to develop niche research directions along with my students and post docs here, particularly in novel schemes of laser energy absorption. One such direction makes use of strong magnetic fields to influence energy transfer from laser directly to heavier ion species [7]. It has led to an entirely new domain of research on laser interacting with magnetized plasmas. Particularly interesting observations on enhanced and efficient harmonic generation, laser focussing etc, domain of Electromagnetic wave transparency were uncovered, some of which are yet to be published [8]. Another unique mechanism identified by me involves work on mass-limited micro-globular plasma targets. These compact systems, characterized by their curved geometry, are becoming increasingly important for miniaturized and energy-efficient applications. Their structure facilitates recurrent collisions amidst bulk and surface waves and consequent wave breaking, resulting in episodic energy absorption surges, efficient thermalization, and absorption levels that surpass those of traditional planar targets [9].

I take particular pride in these studies. Laser energy absorption in plasmas remains a fundamental challenge in high-intensity laser–matter interactions in the context of applications such as laser fusion. This topic has driven decades of research and continues to inspire the long-standing Anomalous Absorption conference series, which was initiated by Predhiman Kaw and William Kruer in 1971 in Princeton and it is now approaching its 53rd edition in 2025.

At IIT Delhi, I also got the opportunity to explore research in several interdisciplinary areas. Notably, I collaborated with exceptionally insightful and generous Professor V Ravishankar on collective effects in Yang-Mills systems—an area I had previously only encountered in passing during collaborative discussions between Professor Kaw and Professor Parikh from PRL. We have studied streaming instabilities in the context of YM fluids and identified new modes. Interestingly we also identified a mode that propagates

without getting affected by the medium [10]. Recently, we have provides experimental methods for the first time to resolve the outstanding Wu Yang ambiguity for an important class of gauge potentials [11].

Somewhere deep within, I often feel as though Professor Kaw is watching over me from the cosmos, gently blessing my small yet sincere efforts—*my Gilhari Prayas*, as it is called in the Ramayana—much like the little squirrel who humbly contributed to Lord Rama's great mission.

## Awards and Recognition

Professor Kaw received a number of prestigious accolades during his illustrious career. Among them were the Padma Shri—India's fourth highest civilian honor—and the Shanti Swarup Bhatnagar Award, both reflecting his remarkable contributions to science. He was conferred the Distinguished Alumni award by the Indian Institute of Technology Delhi. Recognition continued well beyond his retirement. In 2016, he was awarded the S. Chandrasekhar Prize by the Division of Plasma Physics, Association of Asia Pacific Physical Societies (DPP-AAPPS). As part of this honor, Professor Kaw was invited to author a review article tracing the history and challenges of nonlinear laser plasma interaction research for the journal *Review of Modern Plasma Physics*. In a quietly moving conclusion to this chapter of his scholarly life, he submitted the final proofs of the article on what turned out to be the very last day of his visit to IPR—an act that seemed destined, as though the arc of his lifelong devotion to science was always meant to culminate in that singular, meaningful moment [12].

In an interview with Gauhar Raza on the Rajya Sabha TV program Eureka, Professor Kaw fondly reminisced about receiving the Young Scientist Award from the Indian National Science Academy (INSA) back in 1974. He was just 26 at the time—young, enthusiastic, and absolutely thrilled. As he put it, that award had a special place in his heart because it came at a very young age and inspired him to excel further.

And speaking of trophies, there are a few light-hearted stories attached to some of these honors. One particularly memorable moment came when he was awarded the Padma Shri in the same year (1985) as Bollywood icons Naseeruddin Shah and Smita Patil. Professor Kaw's peers joked that it must have been a very confusing day for the audience—who to mob first: the national award-winning actors or the charming plasma physicist? But, as the story goes, Professor Kaw's quiet charisma and scientific stardust managed to draw more eyeballs than even the silver screen legends. Take that, Bollywood. Turns out, plasma physics can generate more heat than a blockbuster.

## Final Remarks

Professor Kaw formally retired from his role as Director at the end of January 2013. On February 6th, 2013, he delivered a heartfelt retirement address on the lawns of IPR—a copy of which I still have. In his speech, he reflected on the entire journey of the Institute and concluded with the following words:

*30 years ago we started with a handful of people. Today, we are like a large joint family, with patriarchs and great grand children rubbing shoulders while running the show. Time has come for the patriarchs to dissociate themselves from management affairs.*

*Dhiraj is our new director. He will carry the Institute forward and is sure to bring all his professional skills into action. I wish him the very best and invite him to present his speech.*

After stepping down as Director, Prof. Kaw devoted himself wholeheartedly to research. Freed from the demands of administration, he became even more accessible to those drawn to science. Holding a DST chair position and as a J C Bose Fellow, he continued to come to IPR regularly, where his presence alone was a source of inspiration. One could often find him in his office—surrounded by papers and deep in thought, or immersed in heartfelt discussions with young students and colleagues. For many of us, those quiet moments spent learning from him felt like a rare privilege. His door was always open, and so was his mind—generous, curious, and full of warmth.

His restless curiosity turned inward as he began to contemplate the mysteries of consciousness—what it means to be aware, to perceive, to know. In this quest, he was instinctively drawn to the nascent domains of artificial intelligence and machine learning, sensing in them not just technological promise, but echoes of deeper questions about mind, thought, and the nature of intelligence itself.

I had looked forward to many more years of blissful scientific pursuit alongside him. But nature had other plans. He passed away suddenly on the 18th of June, 2017. By today's standards, his was a short life (1948–2017), yet within that brief span, he touched countless lives—including mine. This article is my humble and heartfelt homage to an awe-inspiring personality, whose presence and influence left an indelible mark on me. I feel privileged to know him.

Fig 1. Professor Kaw in his office at the Institute for Plasma Research

Even in his absence, Prof. Kaw's presence continues to echo - in the minds he inspired, and in the questions he left us to ponder. He showed us that true greatness lies not in titles or accolades, but in the quiet dignity of thought, the generosity of spirit, and the unwavering pursuit of knowledge. As we carry forward his legacy, we do so not just with his ideas, but with his values etched into our scientific and human conscience. To remember him is not merely to look back—it is to look ahead, guided by the light he left behind.

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