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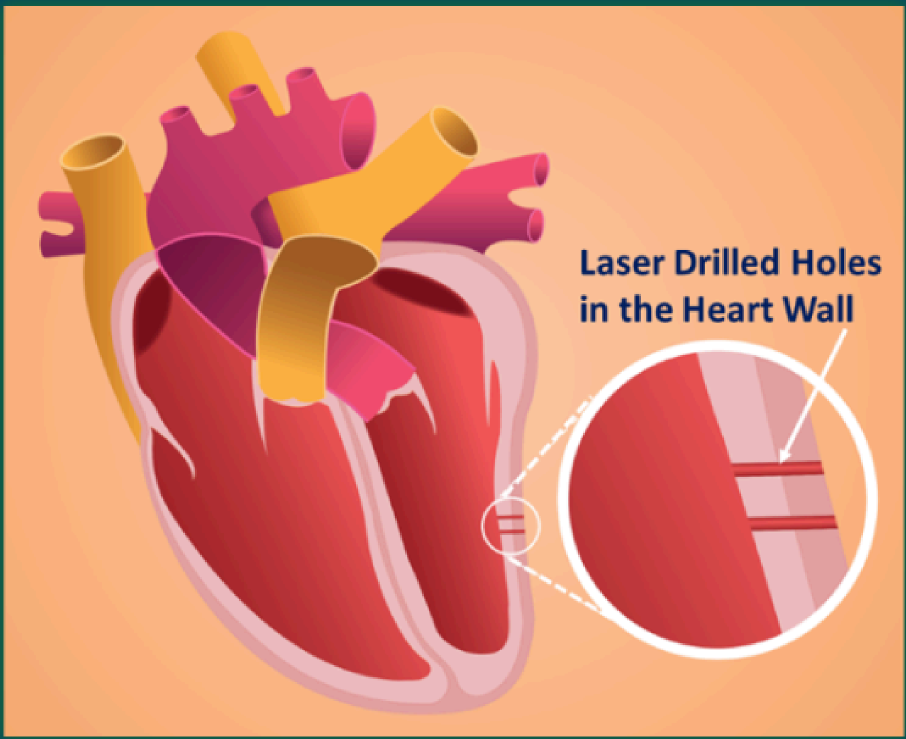
INDIAN NUCLEAR SOCIETY

NEWSLETTER



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President's Message

The buzz about nuclear energy around the world today is unprecedented. US President Donald Trump has signed a series of executive orders titled Reinvigorating the Nuclear Industrial Base, Reforming Nuclear Reactor Testing at the Department of Energy and Ordering the Reform of the Nuclear Regulatory Commission with the goal of "re-establishing the United States as the global leader in nuclear energy". The aim is to increase US nuclear energy capacity from 100 GW to 400 GW by 2050. However, most of the upcoming reactors today are in Asian countries, characterized by fast-growing economies, large populations, and rapidly-rising electricity demand of these countries led by China. Driven by the cost considerations, large reactors are coming up at a stunning pace. The country has nearly doubled its nuclear fleet since 2016, reaching nearly 60 gigawatts of total nuclear power capacity. It is likely to be the world leader soon if its nuclear fleet keeps expanding at the present rate.

While GOI has been taking affirmative actions in this area, our PM has been reiterating the commitment of the nation towards expansion of nuclear energy to achieve net zero carbon emission by 2070 at all relevant platforms within the country and even overseas. It includes his recent addresses in Innovation Summit at NICE in France on 14th June, 2026, in Slovakia on 15th June, 2026 and at an Indian diaspora gathering on 18th June, 2026 in Paris.

Several PSUs, Private industrial houses and other stake holders are evincing keen interest in joining NPCIL / Foreign nuclear establishments in pursuance of the national nuclear mission. Maharashtra Govt signs MOUs with Pvt Industries / PSUs to generate 25,400 MW of nuclear power. NTPC identifies 32 sites for setting up nuclear power plants. MOUs with Foreign SMR designers have also been signed by PSUs / Private industries. Awaiting notification of rules and regulations of SHANTI act, issues of continuous supply of nuclear fuel at a steady price, ease of long term financing and insurance coverage are being raised by the private stake holders.

It is heartening to learn that AERB has approved restart of operation of Units 1 and 2 of Tarapur Atomic Power Station after major refurbishment. These are Asia's first commercial nuclear power plant units, commissioned in 1969 and were producing power at most competitive price over several decades. **Another milestone in the journey of Atomic Energy in India accomplished on 6th April, 2026 is the first criticality of PFBR at Kalpakkam. It is a marvel of nuclear technology achieved by BHAVINI Engineers with thousands of tons of liquid sodium and tons of plutonium present in the core of reactor.** With an experience of four decades of operating FBTR (using mixed carbide as fuel and liquid sodium as coolant), nation trusts that success of PFBR will lay a strong foundation for the 2nd stage of our nuclear power program. INS members had the privilege to listen to Shri Allu Ananth (who has been closely associated with the project from inception) during a webinar held on 17th May at AERB auditorium. The first hand account of his experience spanning more than two decades was quite enthralling. (It may be relevant to mention here that Chairman AEC has inaugurated a prototype Sodium Cell at the Heavy Water Board Facility in Vadodara on 21 st Jan., 2026). The Chief Guest, Dr. Anil Kakodkar shared his valuable perspective on the successful realization of the PFBR project. He commended the dedication and perseverance of the scientific and technical teams involved in achieving this historic milestone. The Guest of Honour, Shri S. C. Chetal, delivered a comprehensive lecture on the evolution of the Fast Breeder Reactor (FBR) programme in India and traced journey of the PFBR from its conceptualization, design, and development to its successful achievement of first criticality.

I am pleased to inform our hon. members that American Nuclear Society has agreed to allow access to INS of its publications like Nuclear Technology, Nuclear Science and Engineering, Fusion Science and Technology, Nuclear News, etc. Consequently, an **INS member interested in any article in these publications can write to the society with complete reference and will receive the pdf copy of the desired article from INS office.**

Friends, INS has been receiving numerous requests for outreach as well as training programs from academic as well as industrial institutions from all over the country. INS EC decided to prepare a database of all those experts who have experience in teaching courses related to nuclear science and technology and are interested in joining the training program conducted by society. Response to our drive has been overwhelming. I am pleased to share with members that our first Training Program for a PSU with the help of faculty drawn from this data base is likely to start very soon. Many INS EC members receive invitation from academic/industrial institutions to deliver talks and they make every effort to respond positively. I had the privilege to deliver inaugural address entitled **Need for Energy Transition and the Journey of Atomic Energy Program in India at IIT**, Kharagpur on 24th May, 2026. It was a part of E-learning certification program conducted by IIT, Kharagpur for ONGC. Similarly, a lecture was delivered at INBP-2026 on **Perspective of Indian Nuclear Society towards National Nuclear Mission** on 16th June, 2026 for the representatives of pvt industry and foreign stake holders interested to join national nuclear mission

It gives me great pleasure to inform members that one of our senior EC members, Shri O.P. Rai has sown a mutant variety of rice in his field located at Azamgarh district in UP. INS acknowledges the support of BARC authorities to facilitate this cultivation. It is hoped that the success of this initiative will go a long way to create awareness and encourage the farmers to adapt to this increasingly relevant agricultural practice in the region. INS convened AGM on 27th May, 2026 which was attended by about 30 members. The agenda included presentation of audited statement of accounts for the AY 25-26, presentation of the Secy's Report, approval of Internal Auditors, Board of Trustees and Members of INS-FTGS advisory panel. I would like to once again request members to visit INS website www.ins-india.org regularly and share with us their perspective of our activities to achieve the objectives of INS and the possibility of contribution in the area of their choice. We are always keenly looking forward to their advice and believe that together we can make the society a vibrant body which can meet the aspirations of the nuclear community at large.

Jai Hind
Dr. Vijay Manchanda
President, INS

The recent approval by the Atomic Energy Regulatory Board for continued operation of TAPS 1 & 2 marks a significant milestone for India's nuclear power programme.

From Editor's Desk

Greeting from Indian Nuclear Society

Dear Members,

The editorial board is pleased to present this INS newsletter covering the activities of past quarter including scientific information, news, developments and innovations and over and above the progress being made in enlarging the space for nuclear energy to play more significant role in mitigating climate change. India's energy system is slated to undergo most significant transition in coming years as demand continues to rise and the types of energy supplying are shifting at an accelerating pace. Nuclear is expected to grow steadily maintaining a small but meaningful role as a base-load power. Though coal will show the steepest drop, oil and natural gas may continue to support base loads well beyond 2050. Meanwhile, other renewables must expand significantly, helping to diversify the low-carbon supply portfolio. This reflects both policy-driven phase-downs and competitive pressure from clean technologies.

Rising temperatures, erratic weather patterns, and increasing frequency of extreme climatic events have already turned up into a serious man made crisis making urgent mitigation efforts essential. In this context, Carbon Capture, Utilisation, and Storage (CCUS) have gained prominence. It is a practical and scalable solution that can significantly reduce emissions. The relevance of CCUS in India is profound where energy-intensive industries such as power generation, cement manufacturing, and steel production account for a substantial share of total emissions. It is difficult to de-carbonise solely through renewable and nuclear energy transitions. In this direction, NTPC and IIT-Bombay have taken a lead by drilling the country's first geological well in Jharkhand to test the feasibility of underground carbon dioxide (CO_2) storage. If India is ready to see energy demand beyond 2049, India's 2nd and the 3rd stage reactors have the potential to supply clean energy to Indian industries and export too. In this contest it is worth remembering word of caution by Dr Anil Kakodkar that "abandoning the thorium program would be catastrophic for the nation's future energy demand".

In this issue we bring the second part of the "The story of LASER" covering largely its use in medical applications. Laser in modern methods like eye welding, punching hole on eye, skin care, cleaning arteries, bloodless surgery and TRM easing blood flow in the heart are lucidly explained.

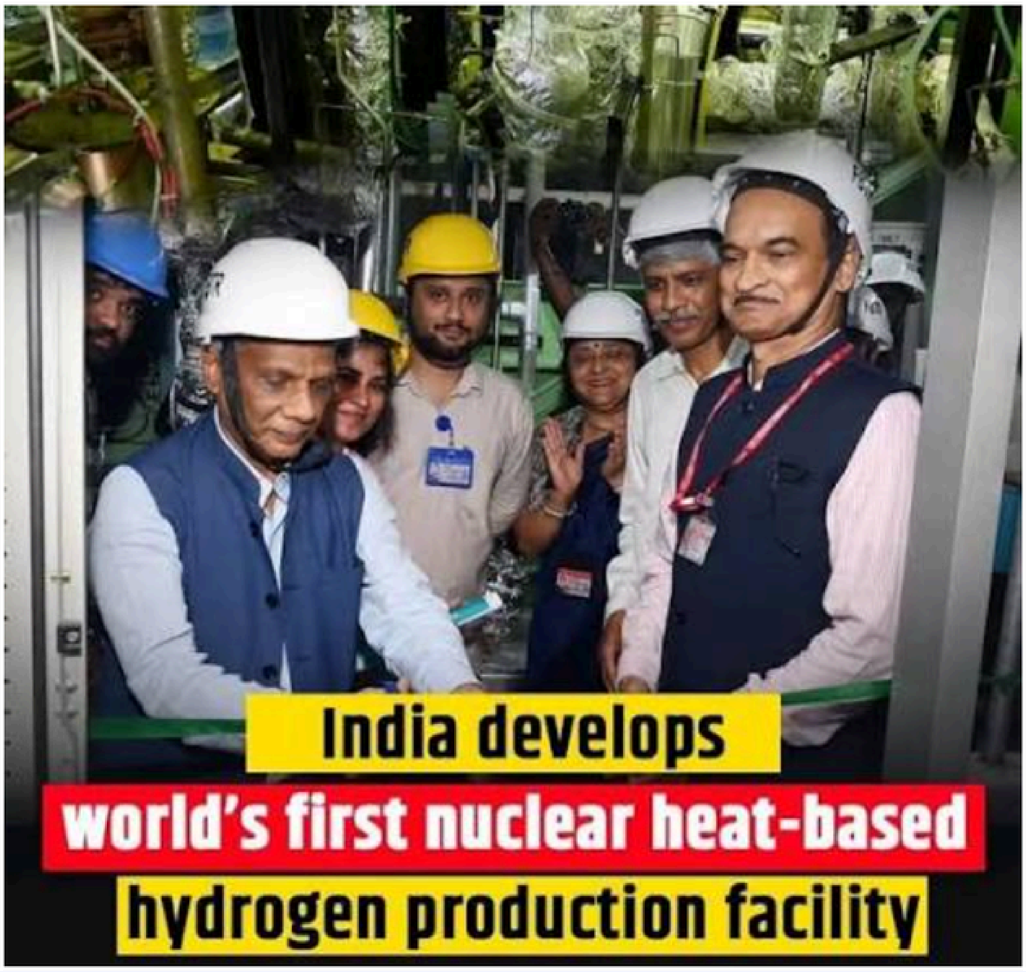
This quarter has witnessed a giant step forward in support of India's 2nd stage nuclear program by making PFBR critical. This event has been in discussion in the world and Indian media particularly highlighting the milestone and congratulating Indian engineers and scientists for achieving major step forward. For information of our members, there is an article by the title " From FBTR to PFBR : The story of India's fast breeder journey" which narrates the technological challenges overcome for enabling design, construction, erection and commissioning of many FOAK components that made PFBR critical. It is a very interesting account of events unfolding especially for members who saw FBTR and PFRB from a distance.

There is a third article on "Long term energy security and the national mission: perspective of Indian Nuclear Society" The article talks about India's position to meet shot term goal under nuclear mission, introduction of SHANTI act, DAE`s long term plan for energy security and the advent of SMR. In the end the article summarizes on how India must explore the unique power house in the form of FBR and thorium reactors to harness surplus energy beyond 2047 and looking forward to become supplier of energy to the world. INS believes that today's India is in a position to see beyond 2100 for robust growth of economy and achieve human development index comparable to advanced countries.

We also have book review on MY TRYST WITH SCIENCE. The review is a nice commentary of very interesting interaction with our past DAE stalwarts. For some of the members who have witnessed the era (1950 to 1990) will enjoy the reading.

As always, newsletter editorial board urges INS members to send their comments on the contents of the newsletter and suggest new ideas to better the subject coverage. Members desirous to contribute in the newsletter are welcome to do so. They may send suggestions, articles, reviews etc. to ***indiannuclearsociety@gmail.com*.**

Jai Hind
Dr. A Rama Rao
INS Member



Prof. Dhruba J. Biswas, Former Senior Scientist, BARC

Part -2: The story of Lasers: Impact of Lasers on Humanity-

Following its invention in 1960, the laser was famously—and perhaps cheekily—described as **"a solution looking for a problem."** This label emerged because, while the laser's properties of extreme directionality and spectral purity were scientifically fascinating, its practical utility was not yet clear. Yet, more than six decades later, lasers have not only found their problems but have quietly woven themselves into the very fabric of modern society.

Given the breadth and depth of this impact, it is impossible within the scope of a single article to capture even a fraction of the roles lasers play today. Instead, this part of the article focuses on a select set of applications that have most significantly shaped how we communicate, navigate, heal, manufacture, and explore. My approach will be intuitive and narrative-driven, guiding you through their impact in a storytelling manner—one example at a time.

3.1 Healing with Light: The Medical Revolution of Lasers-

Lasers entered medicine almost as soon as they were invented. Barely a year and a half after its invention, the laser found its first medical application when, on November 22, 1961, Dr. Charles J. Campbell (1926–2007) of the Edward S. Harkness Eye Institute at New York - Presbyterian/Columbia University Medical Center used a ruby laser to treat a patient's retinal tumor. A single pulse of red laser light, lasting scarcely a thousandth of a second, was sufficient to destroy the tumor—an angioma.

This pioneering success was soon followed by the use of a similar ruby laser to correct retinal tears, a condition in which the retina partially detaches from the underlying tissue, leading to impaired vision. The exceptional brightness, directionality and spectral purity of laser light, combined with an improving understanding of its interaction with living tissue, heralded a quiet but profound medical revolution.

Today, lasers are indispensable medical tools, used not only for treatment but also for diagnosis. Initially confined to regions easily reached by light — the skin, eyes, mouth and throat — their reach expanded dramatically with advances in fiber-optic technology[1]. Lasers can now be delivered safely and precisely deep into the interior of the human body, enabling procedures that once seemed unimaginable. They can reshape the cornea to correct refractive errors, remove facial wrinkles, break kidney stones, clear clogged arteries, and much more. It is hard to find a medical specialty untouched by lasers. What follows is a brief glimpse into how lasers have revolutionized medicine, beginning with their earliest and most natural domain—the human eye.

3.1.1 Laser Cures to the Eye -

In the early years, the medical use of lasers was predominantly focused on the eye, owing largely to ophthalmologists' long-standing familiarity with light and optical principles. Over time, lasers have proven indispensable in treating nearly every ailment known to hinder the normal functioning of our eyes.

[1] The underlying physics of transporting light through optical fiber without any spillage from refraction is elaborated in a latter section dealing with 'lasers in Communications'.

From delicately repairing damaged retinal tissue to precisely regulating intra-ocular pressure, laser technology has transformed ophthalmology into a field characterized by extraordinary precision, minimal invasiveness and rapid recovery.

While lasers now address nearly every major eye disorder, we focus here on two landmark applications: repairing retinal tears and treating glaucoma. Together, they show how carefully controlled light can preserve vision.

That said, the remaining laser-based cures deserve brief mention for the sheer elegance of their underlying concepts: In **LASIK eye surgery**, the laser functions as an ultra-high-precision optical grinding tool, sculpting the cornea to tailor its refractive power. In diabetic retinopathy, it seals the leaking blood vessels to prevent vision loss. In cataract surgery, lasers create exquisitely precise incisions and soften clouded lenses. Together, these applications hint at the vast and still-expanding potential of lasers in restoring, preserving and refining human vision.

3.1.1.1 Laser Remedy to the Retinal Tear: Eye Welding-

A retinal tear is a vision - threatening condition in which the retina separates from the tissue beneath it. If untreated, the tear can spread, leading to complete retinal detachment and blindness.

A cross-sectional view of the eye wherein the retinal tear is readily apparent is shown in Figure 5. To be able to appreciate the ill effects of a retinal tear and its possible mending by a laser, it is worthwhile to acquire a background knowledge on the working of the human eye. An oversimplified schematic illustration of the anatomy of the human eye is shown in Figure 6 (top trace). As seen, the retina is a thin layer of light-sensitive nerve tissue attached to the inner side of the eye ball.

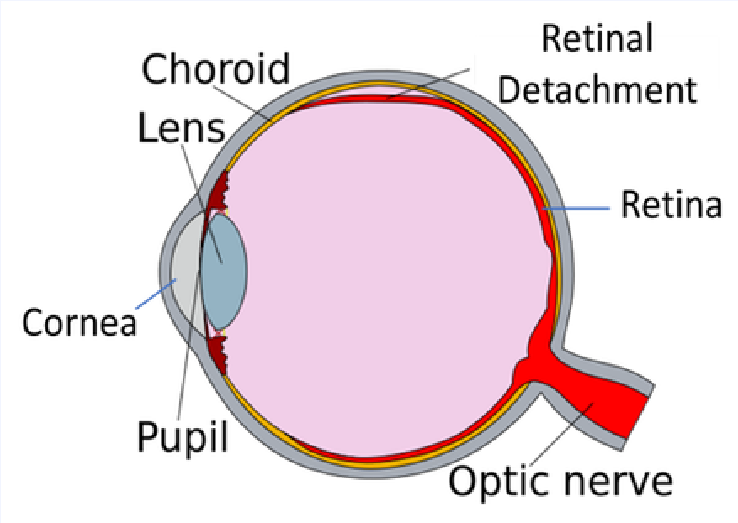


Figure 5: A cross-sectional view of the human eye showing a retinal tear at the top. (Credit – Erin Silversmith, Wikimedia Commons.)

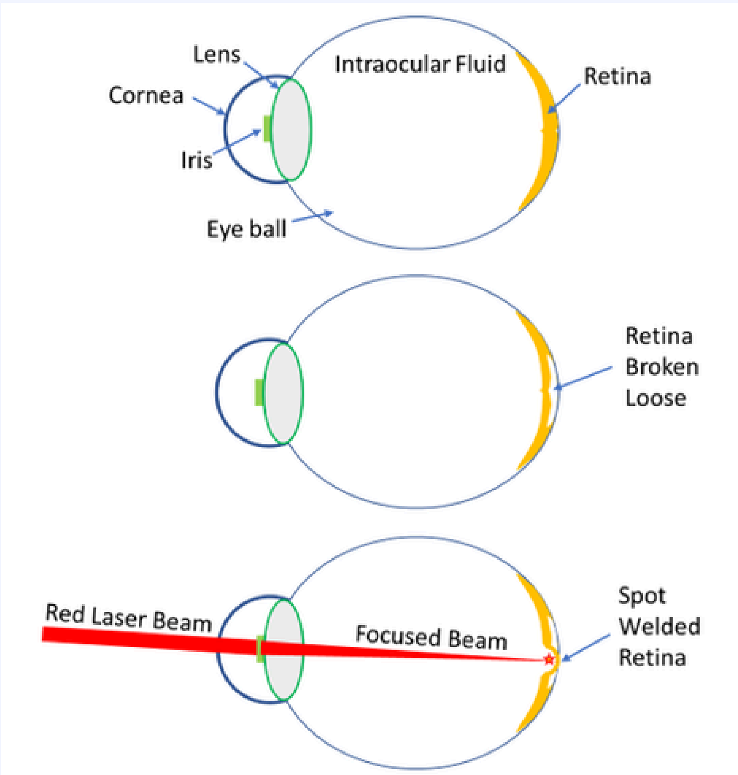


Figure 6: An oversimplified representation of the anatomy of the eye (top trace). In reality, the retina spans a much wider area, as seen in the cross-sectional view of the human eye shown in the preceding figure. With age, the retina can get partly detached at any arbitrary location (middle trace). A red pulse of light from a Ruby laser lasting barely for a thousandth of a second can seal the detached area of the retina back to the wall of the eye ball (lower trace)

When light originating from an object passes through the iris and shines on the eye lens, it forms the image of the object on the retina akin to the formation of an image by an ordinary lens on a screen. The retina makes an electrical analogue of the optical image that is carried to the brain by the optic nerve and provides the visual link to the object. At birth, a gel-like substance, called vitreous, attaches the retina to the inner wall of the eye ball. But as we age, the gel can get separated at some location from the retina. This is known as a retinal tear (Figure 6, middle trace). If not treated promptly, the tear can spread and the entire retina can get detached from the back of the eyeball, impairing the vision to that eye. Before lasers, repairing such damage required risky open-eye surgery, with no guarantee of success.

The advent of laser has presented an eye surgeon the luxury of accomplishing his task of attaching the torn retina back to the eyeball in a flash with the magical touch of a light pulse. Lasers changed everything. Visible and near-infrared light pass easily through the cornea, lens and the fluid-filled interior of the eye, reaching the retina almost unimpeded. When a focused laser pulse strikes the damaged region, its energy is absorbed by pigmented retinal cells, generating heat. This heat causes photocoagulation, effectively "welding" the torn retina back into place—much like fusing metal with a welder's torch (Figure 6, lower trace). The procedure is fast, contact-free, and typically performed in a doctor's office under local anesthesia. What once demanded invasive surgery can now be accomplished with a flash of light.

3.1.1.2 Laser Assisted Healing of Glaucoma: Punching a Hole in the Eye-

Glaucoma is a harmful condition of eye that occurs when the optic nerve gets damaged as a result of an unusual buildup of intraocular fluid pressure. The optic nerve, as we know now, is central to our viewing an object as it conveys the visual information of the image formed at the retina to the brain. The natural fluid of the eye[2] is normally drained away intermittently at an appropriate rate to balance the pressure and the eye stays healthy. When impaired with glaucoma, the fluid from the eyes do not leak out properly leading to the pressure build up (Figure 7). This, in turn, affects the vision, and blindness is not uncommon if untreated. While the damage cannot be undone, early treatment can slow or halt vision loss. Although glaucoma can occur at any age but is more prevalent in older adults. It is recognized as one of the leading causes of blindness, in particular for people above sixty.

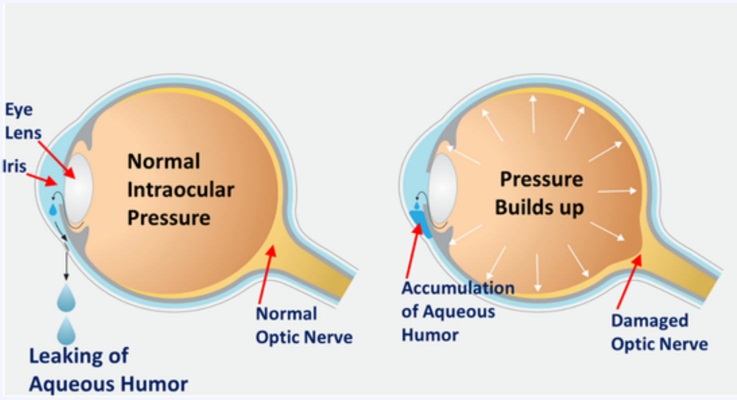


Figure 7: In a healthy eye, aqueous humor drains freely, maintaining balanced pressure and a healthy optic nerve. In glaucoma, blocked drainage causes fluid buildup, raising pressure and damaging the optic nerve.

[2] This clear fluid in the front part of the eye, called aqueous humor, nourishes the cornea and lens, removes waste, and maintains eye pressure. Blocked drainage can raise pressure and damage the optic nerve, as in glaucoma.

Before the lasers were available to treat glaucoma, treatment options included eye drops, oral medicines and a surgery that basically creates a new pathway for the eye to drain fluid. Eye drops and oral medicines often are prescribed together to reduce the intraocular pressure by increasing the drainage of fluid and/or reducing its production through medications.

Laser surgery, originally introduced as an alternative or a supplement, has now found acceptance as a first-line treatment. As a matter of fact, if the drug fails, eye surgeon now prefers laser procedure to avoid conventional surgery. The laser procedure, referred as laser peripheral iridotomy (LPI), and usually carried out with an argon or Nd:YAG laser basically punches a hole at a preplanned spot. The hole then allows drainage of fluid. LPI is found to successfully lower eye pressure in up to 75% of patients treated. Usually carried out with the application of an eye numbing drop, the procedure can be accomplished in a doctor's office rather than a hospital. The procedure is quick, usually painless, and performed in an outpatient setting. It successfully reduces pressure in a majority of patients, with minimal risk. If a patient has developed glaucoma on both eyes, the doctor often treats both the eye on the same day.

3.1.2 Laser in Skin Care-

Like ophthalmologists, dermatologists too had long relied on light for skin care and were not far behind in reaping benefits of laser sources. We shall touch upon here some of the applications of lasers in cosmetic surgery that have gained popularity e.g., skin resurfacing and removal of unwanted hair.

3.1.2.1 Laser Skin Resurfacing-

Smooth, youthful skin has been prized throughout history, and modern cosmetic medicine reflects that enduring desire. Laser skin resurfacing (LSR), introduced in the 1990s, marked a major turning point.

Although LSR can be effective on the skin of almost any part of human body, but its application usually involves removal of facial wrinkles, scars and blemishes. The skin that is tight and smooth at a young age shows onset of wrinkles at the middle age and, if unchecked, can grow with age. LSR offers a practical solution in checking the proliferation of facial wrinkles and has gained popularity among both young and older people, not to mention the ever-increasing number of celebrities across the globe who are embracing this technology to preserve their youthful exuberance.

Concentrated ultrashort pulsating beams of light are shone on the irregular skin of human body from where wrinkle is to be removed. This can remove the skin very precisely, layer by layer. The use of ultrashort pulses makes this happen. The duration of the pulse is too brief to allow the heat deposited by it to diffuse into the layers underneath. The local confinement of heat causes excessive heating of the irradiated layer leading to its ready vaporization.

Before **After-Age 70** **20 Years Ago**

Figure 8: The usefulness of laser skin surfacing is clearly evident in this picture showing a 70-year-old patient before and after undergoing a laser assisted facelift surgery. To provide a basis for comparison, the photograph of the same lady taken 20 years ago is also shown on the far right. (Credit: Sadi Erfani, MD, Wikimedia Commons.)

The story repeats for the subsequent layers. The exposure time of the laser is precisely controlled to allow removal of the entire outer sheet of the skin, called epidermis, eliminating thereby the normally superficial wrinkles. The exposure of the laser to the layer underneath, called dermis, only results in its modest heating but not ablation. This stimulates the growth of new collagen fibers over time resulting in the formation of new skin that is not only smoother and firmer but also better in both tone and texture. The same treatment is also effective in the removal of facial scars, blemishes, or birthmarks. It is of interest to note here that a facelift[3] is often preferred to be performed in conjunction with a full-face laser skin resurfacing. While the facelift surgery helps restore a youthful jawline and neck, the LSR serves to rejuvenate the entire facial skin. The decided advantages of the two procedures when performed simultaneously are clear in the images depicted in Figure 8.

3.1.3 Laser as a Hair Remover-

There is now an ever-increasing demand for removal of unwanted hair, in particular from young girls and women. Preferred locations of the body for the removal of hair are the face, armpits, legs and bikini lines. In the past, men were largely indifferent toward receiving beauty treatment but of late, more and more men, in particular the younger generation, are showing interest in hair removal.

For LHR to work safely, the laser light must be absorbed by the hair—not the surrounding skin. This is achieved by carefully choosing the wavelength to target pigment in the hair shaft. Dark hair on light skin responds best, while light hair on light skin or dark hair on dark skin remains more challenging.

From a humble beginning of the introduction of modern shaving razors in the late nineteenth century, the techniques of hair removal have gradually progressed through not so expensive to more costly methods using electrolysis and lasers. Figure 9 is an oversimplified and qualitative description of a human hair. A hair begins its journey from a tiny secretory cavity called follicle. (The follicle starts in the epidermis, skin's top layer, and extends to dermis, the second layer of the skin.)

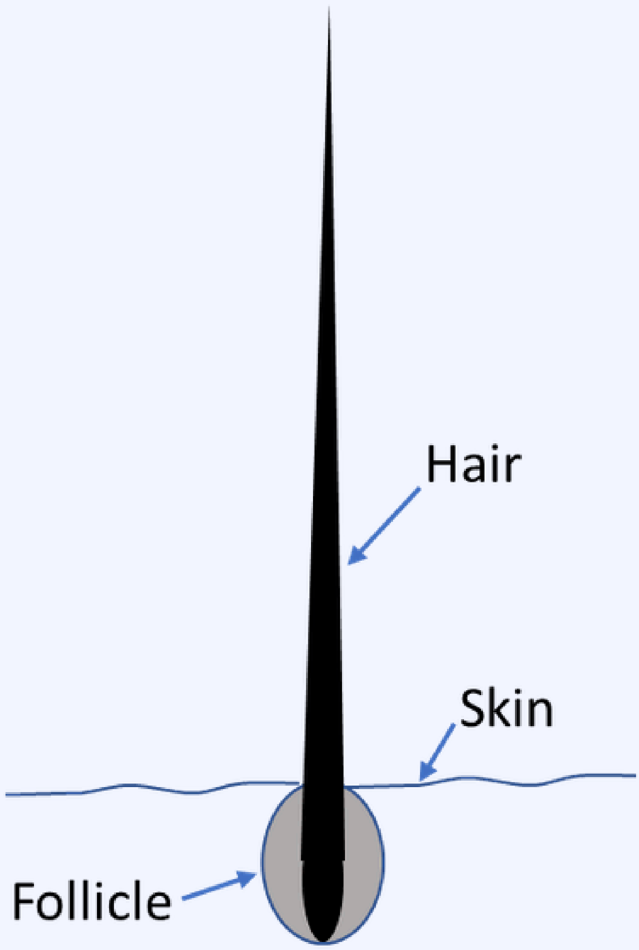


Figure 9: A simplified schematic representation of a hair and its follicle.

[3] A facelift is a cosmetic surgical procedure that reduces the sagging skin and gives the face and neck a more youthful look. The results of the facelift, however, is not permanent as it cannot arrest the natural drooping of the skin on the face and neck with age. A facelift usually lasts for about ten years.

Sprouting out of the follicle, it penetrates the skin and continue to grow at a rate that depends on the location of the body. A hair can be removed in three different ways. Severing it off the skin is the simplest of them all like what happens in the case of shaving. As this simply gets rid of the hair at the skin surface, a shaved hair with its intact root therefore grows back very quickly. The second method is pulling the hair out of the follicle along with the root like in the case of plucking or tweezing. This understandably slows down the regrowth of the hair as it must begin its journey afresh from follicle bed. And finally, a more sophisticated technique like electrolysis or laser hair removal (LHR) that essentially aims at destroying the follicle virtually preventing it from stimulating the growth of a new hair. A partial damage of the follicle, on the other hand, will only prolong the delay of regrowth of the hair.

The electrolysis technique involves the introduction of a fine needle into a hair follicle and apply an electric current to it. The procedure, when appropriately optimized, can result in the complete destruction of the follicle preventing it to create another hair. However, several treatments are usually required before a follicle can be incapacitated. The fact that each hair follicle is required to be individually targeted, makes the electrolysis procedure quite arduous as well as tedious.

Hair covers almost every surface of the human skin and so when the hairs are shone by the laser beam for their removal, the skin too gets inevitably exposed by it. For LHR to work safely, the laser light must be absorbed by the hair—not the surrounding skin. This is achieved by carefully choosing the wavelength of the laser. The selection of an appropriate wavelength is readily possible for fair skin and dark hair or dark skin and light hair.

Needless to say, blonde hair on fair skin and black hair on dark skin present the two most challenging problems for the laser assisted removal of unwanted body hairs. The skin tone here, as a matter of fact, camouflages the hair.

Common laser sources include ruby (694 nm), alexandrite (755 nm), diode (800 nm), and Nd:YAG (1064 nm) lasers. Shaving of the hair is often recommended before the treatment to avoid epidermal injury caused by the burning hair protruding out of the skin. A single treatment cannot cause permanent injury to all the hairs exposed to the laser. Multiple sessions are mandatory for the best result. A snapshot of the LHR procedure being performed on the legs of a light skin person is displayed in Figure 10.

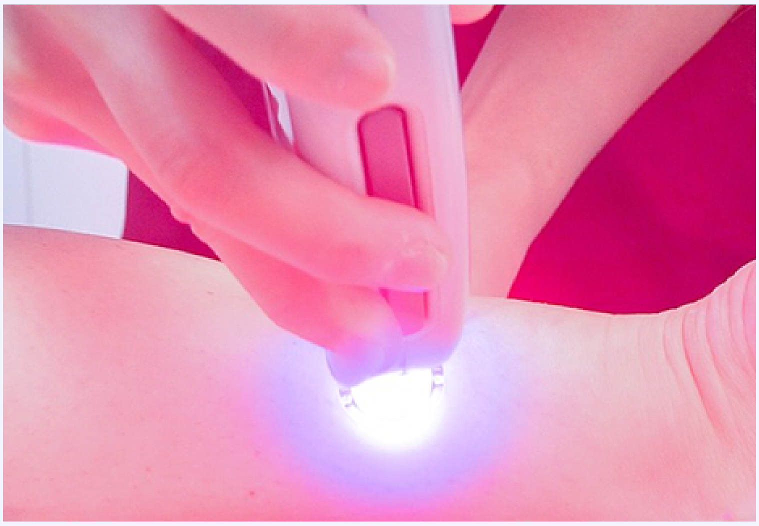


Figure 10: The procedure of laser hair removal is being carried out on the legs of a light skin person. (Credit: Amaregenmed, Wikimedia Commons)

3.1.3 Cleaning Arteries with Laser-

Cleaning of a clogged blood vessel is a fiber-optic laser therapy that has gained popularity over the years. A variety of fatty substances inevitably present in the blood stream begins to form deposits on the inside walls of the arteries as a person ages.

This deposit, called plaque, often builds up alarmingly for some people[4] obstructing the flow of blood through the arteries. A clogged artery is schematically shown in the illustration of Figure 11. A normal artery through which blood can flow without any obstruction is also shown here for the sake of comparison. In case of a coronary artery, this plaque buildup can easily impede the delivery of oxygen-rich blood to the heart, brain, and other vital body parts. It is not uncommon for such a condition to manifest as a stroke, heart attack or even death.

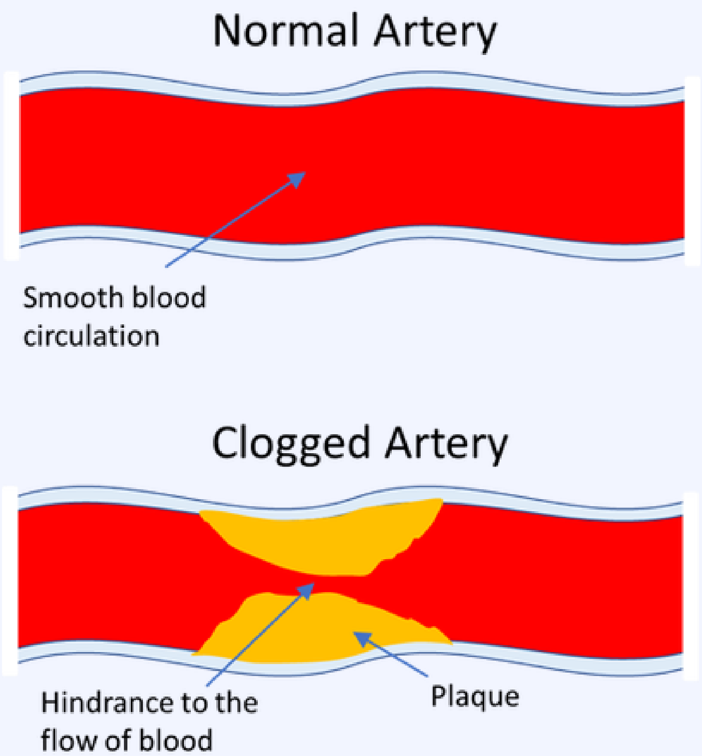


Figure 11: A 2-D view of normal and clogged arteries. While blood flows without any hindrance in a normal artery, the build-up of plaque on the inside walls hinders the flow of blood in a clogged artery.

The conventional method of removing the coronary blockage involves opening the chest, an elaborate and risky procedure nevertheless, wherein a healthy artery is grafted to create an alternative channel to restore unobstructed flow of blood[5]. There is yet another largely noninvasive procedure called balloon angioplasty, that cannot get rid of the blockage but relies on widening the blood vessel by inserting a metal mesh tube, commonly termed a stent, at the location of the obstruction. The angioplasty, however, is not possible for patients with multiple blocked arteries or multiple blockages in a single artery.

The laser procedure, called laser angioplasty, has the capability of burning away the plaque. The pulsating beam of intense light emitted by a UV laser is transported into the diseased location with the help of an optic fiber. The fiber is inserted into a blood vessel, usually, in the groin and gently maneuvered to reach the clogged coronary artery. The guiding to the problem area is facilitated by a second fiber connected to a miniature camera that is also inserted into the artery through the same opening of the blood vessel. When the fiber tip is aligned with the blockage, the laser is activated and the intense repetitive pulses emerging through the tip vaporizes plaque layer by layer, restoring blood flow. The ensuing debris is sucked out through a narrow tube also inserted along with the fibers.

While effective, laser angioplasty carries risks, such as debris entering the bloodstream or accidental damage to the artery wall. As a result, it is typically reserved for patients who are not candidates for other treatments.

[4] Besides the genetic component, the other factors that are largely responsible for the plaque formation are heavy smoking, frequent consumption of alcohol, and inadequate physical exercise.

[5] In the common parlance, this method of treatment is referred to as a 'Bypass Surgery'

Ongoing research continues to refine the technique and improve its safety[6] .

3.1.4 Bloodless Surgery with Laser-

Use of a conventional scalpel to perform surgical procedures on more vascular or blood rich tissues of human body can easily result in a substantial blood loss requiring blood transfusion and extended post operative care. The instances of the death due to excessive bleeding during and following a surgery are also not uncommon. As a matter of fact, the usually low mortality rate of ~0.1% for general surgical procedures can worsen by a factor of 10 or more for elective vascular surgeries. It is well known that an IR laser beam causes vibrational excitation of the water molecules when it shines on a human tissue. Vibrational energy being relatively small can rapidly realize as thermal energy causing vaporization of the water present in the tissue. As water is the major constituent of human tissues, its vaporization is as good as making an incision on the human body. The deposited heat also can cause sealing of the opening made by the laser as it cuts through the tissues. A laser of appropriate wavelength and intensity therefore has the capability of working simultaneously as a cutting and coagulation tool. Thus, when a surgeon uses laser as a knife of light, he or she can make incision on human body with practically no or very little loss of blood[7]. Understandably therefore use of laser as a scalpel to perform surgical procedures on soft and, in particular, blood rich tissues result in minimizing loss of blood.

There is yet another advantage of using laser as a scalpel. So long as the beam moves uniformly, the depth of cut does not vary. While using a conventional scalpel, a surgeon, on the other hand, can accidentally make part of the incision much deeper. A laser normally yields constant power meaning it produces light energy consistently over time. Of the three lasers viz., Er:YAG, diode and CO_2 lasers, that are commonly used in soft tissue surgery, the latter has gained popularity as it can make incision with negligible blood loss. Practically bloodless and painless surgery involving soft tissues can be performed with a laser even without local anesthesia. An example of a surgical procedure being carried out with a laser for the removal of an unwanted or diseased body part is shown in Figure 12.

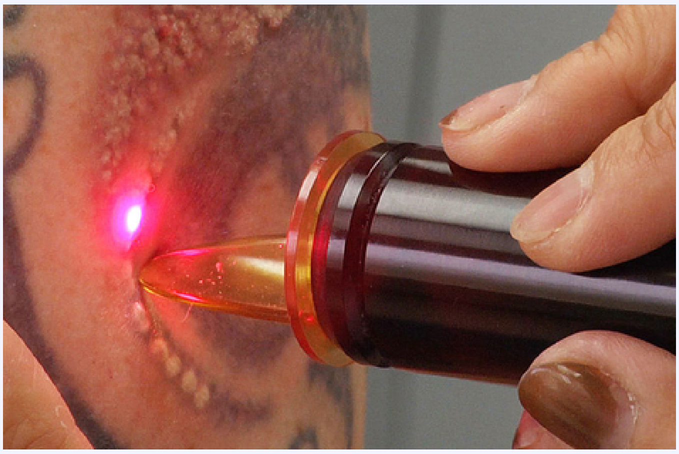


Figure 12: A surgical procedure is being performed with an IR laser beam to remove a part of the human body holding a tattoo. When the invisible IR laser beam interacts with the tissue, the energy it carries is converted into heat at the focal spot. This heat generation is clearly visible as a distinct, bright white glow surrounding the focus. (Credit- James Mutter, Wikimedia Commons)

[6] It may be of interest to note in this context of the very recent finding that when combined with ultra frequency sound waves, a low power laser too can photo ablate the coronary plaque. This gives rise to the prospect of the artery wall remaining unharmed in the event of a laser pulse with subdued intensity missing the plaque and striking it instead.

[7] The ability of the lasers to seal off the open blood vessels works well for the small vessels that do not circulate a lot of blood but not so well for larger vessels.

The tightly focused laser beam is made to scan around the flawed body part to coolly rid it off the rest of the body. The depth of tissue penetration can be readily varied by adjusting the light intensity at the focal spot. The heat generated from laser-tissue interaction also rids the surgical site of germs, minimizing the risk of infection. This results in faster healing of the wound, hastening the period of recovery. Excision of tumors, benign as well as malignant, is likewise possible with laser surgery. As we know, the laser beam can be readily transported through fiber optic delivery system into the interior of our body. This makes possible laser assisted excision of a tumor or diseased tissues located almost anywhere inclusive of liver, one of the most vascular parts of human body.

3.1.5 Microsurgery with Femtosecond Lasers[8]-

In many laser-based surgical procedures where the laser serves as an incision tool, conventional lasers operating in continuous-wave mode or producing pulses in the millisecond to nanosecond range can often perform satisfactorily. In such cases, heat transfer from the laser-irradiated region to the surrounding tissue —an unavoidable consequence of longer pulse durations—does not significantly interfere with the laser's function as a surgical scalpel.

The situation is very different in microsurgical procedures involving extremely delicate organs, such as the heart, where extraordinary precision and minimal tissue damage are essential. Under these demanding conditions, conventional lasers fall short.

Ultrafast lasers that deliver pulses in the femtosecond (10^{-15} s) regime are ideally suited for microsurgery, offering exceptional precision with minimal collateral damage. By delivering bursts of light that last only a few quadrillionths of a second, femtosecond lasers deposit energy so rapidly and so locally that surrounding tissue has virtually no time to heat up. As a result, unwanted burning or charring is largely avoided.

This unique capability allows surgeons to make highly precise cuts and perform microscopic ablations while preserving adjacent healthy tissue. Furthermore, precise control over the laser's focal volume enables selective ablation of targeted cells, significantly enhancing surgical accuracy and reducing the risk of complications during delicate procedures. It is therefore unsurprising that femtosecond-laser-based microsurgery has had a profound and transformative impact on modern medicine.

One such laser-based microsurgical application involving the heart is described below.

3.1.5.1 Femtosecond Laser-Assisted Transmyocardial Revascularization (TMR)-

Transmyocardial Revascularization (TMR) is a surgical procedure designed to improve blood flow to regions of the heart muscle that suffer from reduced or absent blood supply due to blocked coronary arteries. These blockages occur when cholesterol and other fatty substances accumulate within the arterial walls, forming plaques that restrict normal blood flow. Reduced blood supply to the heart muscle can lead to symptoms such as chest pain (angina), shortness of breath, and, in severe cases, heart attacks.

[8] Femtosecond lasers represent a special class of ultrafast lasers that deliver pulses on the femtosecond timescale. A detailed discussion of their operation is beyond the scope of this article. Readers interested in understanding how these lasers work may refer to Biswas, D J. (2023). A Beginner's Guide to Lasers and Their Applications, Part 1. Undergraduate Lecture Notes in Physics. Springer, Cham. http://doi.org/10.1007/978-3-031-24330-1

In many patients, standard treatments such as angioplasty—where a balloon is used to widen a narrowed artery—or coronary bypass surgery are effective. However, these options are not suitable for everyone. Some patients may be considered too high-risk for bypass surgery due to additional health conditions, while angioplasty may require repeated interventions as stents can become re-blocked over time. In other cases, blockages in very small or fragile arteries, multiple clogged arteries, or multiple plaques within a single artery can make angioplasty technically challenging or impractical.

For such patients, TMR offers an alternative approach by improving blood flow to oxygen-deprived regions of the heart and relieving severe angina symptoms, thereby enhancing overall quality of life.

Traditionally, TMR is performed as an open-heart procedure, in which narrow channels are created through the heart wall to allow blood from the heart's inner chamber to reach the affected muscle. While effective, this highly invasive approach involves longer recovery times and carries an increased risk of complications. Femtosecond laser-assisted TMR addresses these limitations by providing a minimally invasive and highly precise alternative. Using femtosecond laser pulses, microscopic channels can be created within the heart wall with minimal damage to surrounding tissue. This targeted ablation forms new pathways through which oxygen-rich blood can flow directly from the heart's inner chamber to the oxygen-starved muscle.

The procedure is performed under general anesthesia. A small incision is made in the rib cage, minimizing patient discomfort and recovery time, and the heart is accessed through this entry point.

Advanced imaging techniques are used to map the blocked arteries and identify optimal locations for creating channels within the heart muscle. Femtosecond laser pulses, delivered through a thin fiber-optic cable, are then used to precisely drill tiny channels through the heart wall. These channels connect the heart's inner pumping chamber to the surrounding muscle, enabling direct delivery of oxygen-rich blood (refer to Figure 13). The inset shows an enlarged view of the microchannels produced by the laser. Although only two channels are illustrated, in practice multiple channels are created to adequately supply blood to the affected regions.

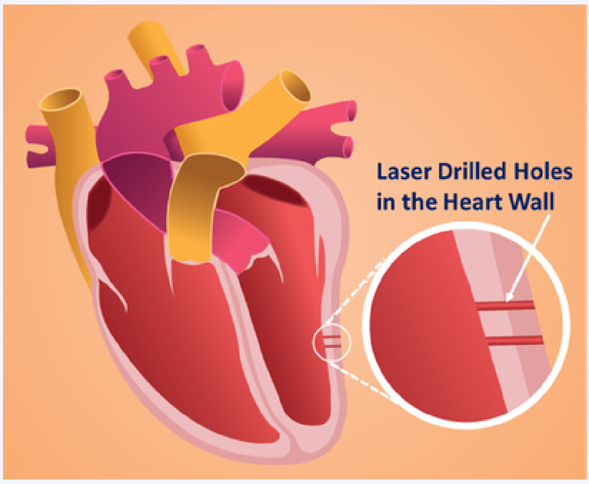


Figure 13: The laser beam delivered through the fiber drills micro-holes into the heart wall, creating micro-channels that facilitate the flow of oxygenated blood to the heart muscle. The inset shows an enlarged view of the micro-channels produced by the laser. Although only two channels are shown here but it is important to note that multiple channels are typically created during laser surgery to ensure adequate blood flow.

Following the procedure, patients typically experience shorter hospital stays and faster recovery compared to conventional TMR techniques. Femtosecond laser-assisted TMR represents an innovative and promising approach to treating severe coronary artery disease. As ongoing research refines the procedure and advances in imaging and surgical technologies continue, the precision, safety, and effectiveness of TMR are expected to improve even further in the future.

From FBTR to PFBR : The Story of India's Fast Breeder Journey

Dr B. Venkataraman, Former Director, IGCAR

India's three-stage nuclear power programme was articulated by Dr Homi Jehangir Bhabha more than 70 years back based on a clear understanding of the country's resource position. – a modest uranium resources but large thorium reserves. The sequenced path was the Pressurised Heavy Water Reactors (PHWRs) using natural uranium in first stage, fast breeder reactors in the second, using plutonium produced in the first stage, advanced reactors based on thorium fuel cycle in the third, using the Pu and U-233 produced in the second stage for long-term energy security. Thus, in this vision, it can be clearly seen that fast breeder reactors occupy a catalytic position acting as a technological bridge between the present uranium-plutonium fuel cycle and the future thorium fuel cycle.

A fast breeder reactor can convert the depleted Uranium (fertile uranium-238) into fissile plutonium-239, thereby extracting far greater energy from the same uranium resource. With the addition of thorium blankets, it can also convert the fertile Th-232 into U-233. It would produce more fuel than it consumes, thus enabling the Th-U233 reactors. The 500 MWe Prototype Fast Breeder Reactor, or PFBR, at Kalpakkam is India's first full-scale step into this journey.

The story of PFBR did not begin with the construction of the 500 MWe reactor. It began much earlier—with the Fast Breeder Test Reactor, FBTR, at Kalpakkam.

FBTR: India's School of Fast Reactor Technology

The Indian Fast Reactor Program had its humble beginings at the Reactor Engineering Division of Bhabha Atomic Research Centre in the mid 1960's. Work was initiated under Shri S. R. Paranjpe. At that time, fast breeder reactor technology was available only with a few countries and the experience base was limited.

It was also felt that rather than starting ab-initio we can build on the international experience. Dr Vikram Sarabhai the then Chairman of Atomic Energy Commission visited Cadarache in France and a major step came through collaboration with France, which had experience with the RAPSODIE-Fortissimo experimental fast reactor. Under the 1969 Indo-French collaboration, a joint team of Indian and French engineers prepared the preliminary design and project report for an experimental fast reactor to be built in India. A team of Indian engineers and scientists worked at Cadarachein France, and subsequently the Indian design group moved to Kalpakkam to execute the project.

FBTR was conceived as a test bed—for fuel, materials, sodium systems, instrumentation, maintenance methods and, above all, human resource development. Its primary sodium circuit was broadly based on RAPSODIE, but FBTR was modified to include steam generator modules and a turbo-generator in the secondary sodium circuit. This was an important decision. It meant that FBTR would not remain only an experimental reactor; it would also provide experience in operating a complete fast reactor power system.

Construction of FBTR began in 1972. For that period, it was a bold project. Liquid sodium had to be handled safely. Components had to be manufactured to demanding nuclear quality standards. Instrumentation and control systems had to be developed for an opaque coolant. Fuel handling had to be mastered. Most components were manufactured indigenously, with only a few exceptions such as the grid plate, one control rod drive mechanism and one primary sodium pump.

FBTR attained criticality in 1985. Its mixed plutonium-uranium carbide fuel was a significant technological achievement.

The prediction of criticality and associated reactor physics parameters for a high-plutonium carbide core, even with limited experimental support, demonstrated the depth of India's reactor physics capability. Over the years, FBTR became a fountainhead of competence for the design, construction and operation of future fast breeder reactors.

The Decision to Move Towards PFBR

The confidence gained from FBTR led DAE to consider a much larger step: a 500 MWe Prototype Fast Breeder Reactor. In December 1979, a Steering Group was constituted by Dr Raja Ramanna, the then Secretary, DAE, to draw up the plan for PFBR. The group submitted its report in July 1980 and a supplementary report in November 1980.

Following this, a PFBR Working Group was constituted in March 1981 under the chairmanship of Shri N. L. Char, with Shri S. R. Paranjpe, Shri K. V. Mahadeva Rao, Dr Anil Kakodkar and Shri S. B. Bhoje as members. The Working Group prepared the feasibility report and preliminary design report, which were submitted in June 1983.

The initial design proposed by the Working Group was a 500 MWe oxide-fuelled prototype reactor with four primary sodium loops, four primary pumps, four secondary loops, eight intermediate heat exchangers and twelve steam generator units. The plant life was envisaged as 30 years, and the design was essentially aimed at demonstrating technological feasibility.

One of the most important recommendations of the Working Group was strategic in nature: PFBR should be planned on the assumption that external assistance may not be available. This was more than a technical caution. It reflected the reality of advanced nuclear technology and the need for national self-reliance. IGCAR was to carry out the basic design and R&D, while coordinating collaborative development with industry, laboratories and academic institutions.

From Feasibility to Detailed Design

From 1983 onwards, detailed design work began under the guidance of Shri S. R. Paranjpe. The Nuclear Systems Division was formed in 1985 under Shri S. B. Bhoje to focus on the nuclear steam supply system. Specialist groups in thermal hydraulics and structural mechanics were also created, recognising that PFBR would require deep analytical capability in areas such as pool hydraulics, high-temperature structural design, seismic analysis and sodium-system behaviour.

The first Detailed Project Report was submitted in 1989 for financial sanction. However, DAE decided to examine broader policy and technology issues before proceeding. In 1992, a committee headed by Shri S. K. Mehta was constituted to assess indigenous manufacture of PFBR components, possible technological improvements, comparative cost with PHWRs and the time frame for commissioning. The committee submitted its report in 1993.

The committee made a crucial recommendation: cost comparison with PHWRs should not be the sole basis for sanctioning PFBR, because fast breeder reactors were essential for sustaining long-term nuclear power growth. It also recommended that PFBR should be built with proven mixed oxide fuel and that the main objective should be techno-economic demonstration.

This recommendation changed the emphasis of PFBR design. The objective was no longer only to demonstrate technology. PFBR also had to demonstrate that fast breeder reactors could be engineered for economy, reliability, safety and future replication.

The Major Design Transformation: Four Loops to Two Loops

After 1993, the PFBR design underwent a major transformation.

The earlier four-loop concept was carefully re-examined. A task force studied the factors affecting economy and concluded that the number of loops and components could be reduced without compromising safety or availability. The design evolved into a compact two-loop concept with two primary pumps, four intermediate heat exchangers and two secondary loops, each with one pump and four integrated once-through steam generator modules.

This redesign had far-reaching implications. It reduced material consumption, improved plant compactness and helped bring down the main vessel diameter from about 15 metres to 12.9 metres. The in-vessel fuel handling system was also optimised, and shielding design was refined through experiments conducted jointly by IGCAR and BARC at the APSARA reactor.

The plant parameters were also improved. The core outlet temperature was raised from 530°C to 547°C and the steam temperature from 480°C to 490°C. The design life was enhanced from 30 years to 40 years. The design adopted a steam reheat cycle instead of sodium reheat, balancing efficiency, economy and operational simplicity.

Materials were selected with equal care. 316LN stainless steel was chosen for the main vessel, hot pool components and hot piping. 304LN was selected for components operating at lower temperatures. Modified 9Cr-1Mo steel was chosen for steam generator applications , and D9 alloy was selected for fuel subassembly structural materials to support higher burn-up.

Technology Development: The Invisible Foundation

PFBR was not only a design exercise. It was a national technology development programme. Large test facilities, sodium loops, structural mechanics laboratories and thermal hydraulic models were developed to validate the design. The Large Component Test Rig, commissioned in 1994, became an important facility for qualifying prototype components and sodium mechanisms.

Sophisticated computer codes were developed for core disruptive accident analysis, high-temperature structural mechanics, pool hydraulics, plant dynamics and sodium-water reaction analysis. Codes such as FUSTIN, CONE, THYC, DYNA-P, DHDYN and SWEPT were part of this analytical ecosystem. Internationally developed codes and commercial CFD tools were also used where required.

The validation effort was extensive. Experiments were carried out for flow distribution, gas entrainment, free-level fluctuations, thermal stratification, fluid-elastic instability, seismic behaviour, fracture mechanics and buckling. About 40 R&D establishments and academic institutions participated through around 80 collaborative projects and more than 700 student projects contributed to reactor engineering development.

This is an important point for the public to appreciate. PFBR was not built by merely scaling up a drawing. It was built by creating a knowledge base—experimental, analytical, industrial and regulatory.

Learning from Global Fast Reactor Experience

Fast breeder reactors are complex systems, and the world's operating experience was carefully studied. Lessons from reactors such as EBR-II, Phoenix, Superphenix, PFR, BN-350, BN-600 and MONJU were incorporated in the PFBR design.

For example, international experience with coolant blockage, thermal striping, steam generator reliability, intermediate heat exchanger failures and thermowell leaks was examined in detail. In PFBR, multiple coolant entry paths, improved steam generator tube-to-tubesheet weld design, mixing devices, thermal striping limits and careful thermowell geometry were incorporated to address these lessons.

Thermal striping, in particular, was treated as a major safety and reliability issue. In sodium-cooled reactors, hot and cold sodium streams can mix and cause temperature fluctuations on metal surfaces. These fluctuations can lead to thermal fatigue. PFBR designers identified critical locations, carried out analysis and experiments and incorporated design features to remain within acceptable temperature limits.

In-service inspection was also considered from the early stages of design. Since sodium is opaque, conventional visual inspection is not possible during operation. PFBR therefore incorporated special inspection provisions such as remote robotic carriage for volumetric inspection of the main vessel, periscope-based viewing in the cover gas space and under-sodium ultrasonic scanning above the core.

Regulatory Review and Safety Assurance

One of the most important features of the PFBR journey was the parallel evolution of design and safety review. Safety criteria were not treated as an afterthought. They were developed while the design itself was progressing.

The then DAE Safety Review Committee constituted a committee to finalise safety criteria for PFBR. An eight-member subcommittee chaired by Shri S. B. Bhoje contributed significantly to this work. Operating experience from sodium-cooled fast reactors worldwide was considered and IAEA Guide 50-C-D was used as a reference. With inputs from IGCAR, BARC and NPCIL, AERB issued comprehensive safety criteria for PFBR in 1990.

AERB had constituted the Preliminary Design Safety Committee for PFBR in July 1988 under the chairmanship of Dr. Anil Kakodkar to review the four-loop concept. In 1995, the committee was reconstituted under Shri G. R. Srinivasan to review the two-loop design that later became the basis for financial sanction. This reconstituted committee reviewed the design from the viewpoints of safety and operation and provided inputs to AERB for clearances related to manufacture of long-delivery nuclear components and civil excavation.

In March 2004, after Government sanction, the committee was again reconstituted under Shri S. S. Bajaj for in-depth review of detailed analysis results and R&D aspects. Specialist groups were also formed to support this review. In addition, an Internal Safety Committee was introduced to examine issues specific to sodium-cooled fast breeder reactor systems, drawing on experts with experience in FBTR design, construction, commissioning and operation.

The depth of review was substantial. The PDSC and ISC had met 63 and 93 times respectively by the time of the 2006 IGC Newsletter report, and more than 600 design documents covering specifications, conceptual design, detailed design, structural mechanics and thermal-hydraulic analysis had been reviewed. Safety issues such as blanket subassembly monitoring, flow allocation through the core, leakage flow during commissioning, failed-fuel subassembly storage, neutron flux monitoring, pulse-coded shutdown logic and absorber rod drop time were examined and addressed.

This regulatory journey is central to the PFBR story. It shows that the project was not just a construction effort; it was a disciplined process of design, analysis, independent review, response, modification and re-review.

Initiation of PFBR and Technological Challenges

The activities undertaken from 1993 to 2002 formed the basis for the revised Detailed Project Report, which was submitted in 2002. The Government of India accorded administrative approval and financial sanction for the Prototype Fast Breeder Reactor in September 2003. Thereafter, BHAVINI was entrusted with the construction and operation of PFBR, while IGCAR continued to provide the design, research and technology support.

The project represented a major national industrial effort. PIB has noted that PFBR was indigenously designed and constructed with contributions from more than 200 Indian industries, including MSMEs.

It has also recorded that the Government approved the creation of BHAVINI in 2003 to construct and operate PFBR. This institutional arrangement was important because PFBR was not merely a scale-up of FBTR, but a transition from an experimental fast reactor to a grid-connected 500 MWe prototype power reactor.

This transition posed several technological challenges. PFBR demanded mastery over large liquid sodium systems, high-temperature structural materials, compact high-power-density core design, complex reactor internals, fuel handling in an opaque and chemically reactive coolant environment, and high-reliability steam generator systems with sodium-water reaction protection. Sodium technology itself required special provisions for purification, leak detection, inerting, preheating, draining, fire safety and remote maintenance, since sodium is opaque and reacts vigorously with air and water.

The construction phase involved large stainless-steel structures, sodium systems, reactor internals, fuel handling systems, steam generators, instrumentation and control systems, electrical systems, civil works, quality assurance, non-destructive examination and complex commissioning procedures. Many components were first-of-a-kind in India, including large and slender stainless-steel components fabricated to tight tolerances, and each required qualification, documentation and regulatory acceptance. Special materials such as SS316LN, SS304LN, modified 9Cr-1Mo steel and D9 alloy had to be deployed with stringent welding, inspection, quality assurance and traceability practices.

Several design and safety issues also required detailed analysis, mock-up testing, design reviews and regulatory scrutiny. These included thermal striping, creep-fatigue, seismic qualification, in-service inspection, fuel-handling reliability, decay heat removal and sodium fire protection. In parallel, Indian industry had to develop the capability to manufacture and qualify large fast-reactor components under demanding nuclear codes and documentation requirements.

The project also exposed supply-chain and logistics challenges faced by industry, including timely availability of special-grade materials, development of qualified vendors, long-lead procurement of critical items, transportation and handling of large components, sequencing of deliveries to match site requirements, and maintaining nuclear-grade documentation and traceability across multiple agencies. While these issues led to delays and repeated reviews in some areas, they also became important learning steps for IGCAR, BHAVINI and Indian industry, strengthening the national capability to execute future fast-reactor projects with greater confidence. Thus, PFBR became not only a reactor construction project, but also a national technology-development programme that converted the experience of FBTR into engineering confidence for future fast breeder reactors.

Core Loading and First Criticality

A major public milestone was reached on 4 March 2024, when the Prime Minister witnessed the commencement of core loading of India’s first indigenous 500 MWe fast breeder reactor at Kalpakkam. On 6 April 2026 at 8:25 PM, PFBR achieved first criticality. DAE described this as a landmark achievement for India’s nuclear energy programme. The criticality was achieved after meeting all stipulations of AERB, which had issued clearance after rigorous safety review of plant systems. DAE also noted that PFBR was indigenously designed by IGCAR and built and commissioned by BHAVINI.

First criticality means that a controlled, self-sustaining fission chain reaction has been established. It is a decisive milestone in the life of a reactor. The subsequent stages involve further testing, power raising, synchronisation with the grid and long-term reliableoperation.

Why PFBR Matters

For the general public, PFBR may be understood in simple terms: it is a reactor that helps India use nuclear fuel much more efficiently.

In conventional reactors, only a small fraction of the energy potential of natural uranium is used. In a closed fuel cycle with fast breeder reactors, plutonium is recycled and fertile materials are converted into new fissile fuel. This greatly extends the energy potential of limited uranium resources.

PFBR also prepares the ground for thorium utilisation. DAE has stated that PFBR uses uranium-plutonium mixed oxide fuel and is surrounded by a uranium-238 blanket, which can be converted into plutonium-239. It is also designed to eventually use thorium-232 in the blanket, which through transmutation can produce uranium-233 for the third stage of India's nuclear power programme.

For DAE, PFBR has an even deeper significance. It is the culmination of decades of work in reactor physics, sodium technology, fuel development, materials science, structural mechanics, thermal hydraulics, safety analysis, manufacturing, inspection, regulation and commissioning. It is the bridge from FBTR experience to future commercial fast breeder reactors.

A Tribute to Institutional Continuity

The PFBR story is a reminder that major strategic technologies mature over decades. They require continuity of vision, institutional memory, patient R&D, industrial partnership, regulatory discipline and national commitment. FBTR created the first generation of Indian fast reactor experience. The PFBR Working Group translated that experience into a prototype concept. The design teams refined it from a four-loop technological demonstrator into a two-loop techno-economic demonstrator. The safety committees and AERB review process strengthened it. Industry built it. IGCAR sustained the technology base, BHAVINI executed it with active support from BARC, NFC, ECIL, HWB and many others.

PFBR is therefore not merely a plant at Kalpakkam. It is a national capability rendered visible in steel, sodium, fuel and control systems and made possible due to the continued confidence and support of DAE management and the Government. It is a bridge between India's present nuclear power programme and its long-term thorium promise. It is also a tribute to generations of scientists, engineers, operators, safety reviewers, quality professionals, technicians and industrial partners who converted an ambitious idea into a working reactor. **In short, the journey of PFBR is not merely about building a reactor or mastering a technology; it is a story of national perseverance, institutional resolve, and the confidence of a nation in its scientists, engineers and technical staff to undertake and overcome complex technological challenges.**

Long Term Energy Security and the National Nuclear Mission : Perspective of Indian Nuclear Society

1.0 Introduction

Dark clouds over the nuclear industry in the aftermath of Fukushima have withered away and the world is gearing up to accelerate the contribution of nuclear power to meet the global target of net zero carbon emissions by 2050. It is indeed gratifying to learn that more than 400 new reactors are either under construction or are planned and proposed across the world. Incidentally, this number is close to the number of currently operating reactors worldwide.

If one looks at nuclear renaissance in other parts of the world, the US President has signed a series of executive orders titled Reinvigorating the Nuclear Industrial Base, Reforming Nuclear Reactor Testing at the Department of Energy and ordering the Reform of the Nuclear Regulatory Commission with the goal of "re-establishing the United States as the global leader in nuclear energy". The aim is to increase US nuclear energy capacity from 100 GW to 400 GW by 2050. To resolve the quandary of 100,000 tons of spent fuel waiting to find a permanent geological host, the U.S. administration is now dangling a radioactive carrot. States are being asked to volunteer to host a permanent geological repository for spent fuel as part of a campus of facilities including new nuclear reactors, waste reprocessing, uranium enrichment and data centres. Even with a conservative estimate of the success of planned and proposed projects worldwide, the projection has the potential to alter the global landscape with respect to nuclear power in the next 2-3 decades. In COP28 UAE declaration, 20 nations out of over 120 countries pledged to triple nuclear capacity by 2050. However, unlike today`s global geographic scenario of operating reactors, most of the upcoming reactors are in Asian countries like UAE, Egypt, Turkey, Russia, South Korea, China and India, characterized by fast-growing economies, large population and rapidly-rising electricity demand.

Post Fukushima, there has been particular interest in developing GEN IV reactors to address to nuclear safety, nuclear waste, nuclear proliferation and public perception concerns apart from the capital investment. China is the first country to operate a demonstration GEN-IV reactor, the HTR-PM in Shidaowan, Shandong, which is a pebble-bed type high-temperature gas-cooled reactor. It was connected to the grid in December 2023, making it the world's first Gen IV reactor to enter commercial operation.

2.0 India`s position to meet short term goals under Nuclear Mission

India is vigorously positioning nuclear energy as a major pillar in its energy mix aiming to emerge as a stable source of energy for the growth of the economy. The provisions for nuclear power in the Union Budget 2025-26 mark a transformative shift in India's energy landscape. The government has set an ambitious target of 100 GWe nuclear power capacity by 2047, which means raising the proportion of nuclear power from 2% to about 9% in the next two decades. It is a recognition of nuclear energy as grid compatible 24x7 base load supply with low greenhouse gases emission. It is an undeniable fact that in spite of the massive growth of renewable energy (RE), the sector may not be able to meet the perennial power demand. Even by 2030, RE would be able to meet less than a third of the peak demand, though it might account for two-thirds of the capacity. By promoting nuclear energy as a sustainable, scalable, and secure power source, the government aims to bolster energy security and meet the nation's long-term economic and environmental goals. There are several on-going projects of 700 MWe PHWRs, 1000 MWe VVERs, 500 MWe PFBR and pre-project activities for 10 fleet type 700 MWe PHWRs under NPCIL.

All these projects will increase the total installed capacity under DAE to around 22.5 GWe by 2032 (which is the steepest rise in the history of DAE`s power production program), leaving a challenging task of generating another 77.5 GWe for the policy makers, technocrats and industrialists. The role of JV between NPCIL and Indian PSUs will be important in this contest. NTPC has already taken a lead by starting work on multiple reactors at Mahi Banswara in Rajasthan as joint venture with NPCIL and has ambitious plans to add 30 GWe by 2047. Engineers India Ltd (EIL) has also partnered with NPCIL for conceptual design and Engineering Services. The biggest advantage for PSUs in this venture will be to be able to access the proven design, ready vendors, supply chain, material, fuel cycle, skilled labour, man-power, regulatory approvals and over and above the plants will be in line with the 3 phase program of DAE which is well laid out for country`s long-term energy security. PSUs will also be greatly benefited in terms of guaranteed returns on investment on producing clean energy at lower cost in comparison with current generation cost of nuclear energy in other parts of the world.

In addition, implementing large-scale imported reactors under ongoing international collaboration frameworks (such as the 6-reactor Jaitapur, MH and 6-reactor Kovvada, AP) are expected to add 13 GWe (by 2047)

3.0 Introduction of SHANTI bill

SHANTI (Sustainable Harnessing and Advancement of Nuclear Energy for Transforming India) Bill, 2025 was passed by the parliament and the bill has received the President's assent and the act has been notified. However, specific operational timelines and implementational rules are yet to be notified. It fundamentally restructures India's nuclear power framework by allowing private participation in nuclear power plant operations and related activities. Issues like statuary status of AERB, relaxation of supplier liability and linking operator's liability to the size of reactor are the major highlights of SHANTI act. Implications of these on ground have to be understood by all stake holders.

Whereas the licensing of the facility is the prerogative of DAE (Govt of India), the safety of design and operations need the approval of Atomic Energy Regulatory Board (AERB).

Several private companies like Reliance Industries Ltd (RIL), Adani Power, Tata Power, Hindalco, Jindal Steel and Power, JSW Energy are keenly evaluating the available options on national as well as international forums before making any commitments to join the national nuclear mission. These private players have been keenly awaiting the notification of the implementation rules of the SHANTI Act. To achieve the national nuclear target, India needs multiple players and multiple technologies. It is important to build large capacity reactors to meet the power requirement in general by constructing indigenously designed 700 MWe PHWR in multi fleet mode and importing PWRs with advanced safety features like VVERs from ROSATOM, EPRs from EDF or/and AP1000 from Westinghouse or equivalent type.

There are also challenges of the availability of finances, trained manpower and suitable land parcels. High capital investment requires careful hand holding of the interested parties all through the different stages of establishing the technology particularly through the gestation period. Additionally, these private entities may have to be prepared to deal with the safe disposal of radioactive waste, safeguards and security related issues. Accounting of critical materials like fuel and heavy water needs to be ensured as mandated under International Atomic Energy Agency (IAEA) safeguards.

4.0 DAE`s Long term plan for energy security

India's three-stage nuclear power program, originally formulated by Dr. Homi J. Bhabha, is a strategically designed closed fuel cycle roadmap. It was proposed to overcome India's limited domestic uranium reserves (about 1–2% of the global share) by tapping into its immense thorium reserves, which constitute roughly 25% of the world's total supply.

By utilizing the nuclear waste of one stage as the vital fuel for the next, the program multiplies the energy potential of India's domestic resources. This progressive architecture provides the foundation required to secure clean, reliable base-load energy for centuries.

In the stage 1, Pressurized Heavy Water Reactors (PHWRs) are built utilising natural uranium as fuel and heavy water as both a moderator and coolant. This stage has yielded 8.8 GWe and will sustain for estimated 40 year as base-load power. Beyond generating electricity, the primary strategic function of Stage 1 is utilizing the nuclear fission process to transmute non-fissile Uranium-238 within natural uranium into Plutonium-239.

In the stage 2, Fast Breeder Reactors (FBRs) are to be built by using the reprocessed fuel from the first stage. Traditional single-use (open) fuel cycles extract less than 1% of the potential energy available in natural uranium. By recycling spent fuel through Fast Breeder Reactors, India increases the energy yield from a given amount of mined uranium by up to 60 times. This radically stretches the lifespan of existing domestic resources. It is estimated that if 1 ton of spent fuel comes out of the first stage, 95 % of the spent fuel will be reprocessed and used in the second stage. The reactor utilizes a mixed oxide (MOX) fuel composed of the Plutonium-239 recovered from Stage 1 alongside depleted uranium. These reactors are "fast" because they do not use a moderator to slow down neutrons. They are called breeder reactors because they generate more fissile material than they consume. Neutrons converts surrounding blanket of fertile Uranium-238 into Plutonium-239. Crucially, as the fleet scales, thorium blankets will be introduced into these reactors to convert Thorium-232 into Uranium-233. U-233 is a fissile fuel like U-235 which fissions with thermal as well as fast neutrons.

India officially entered this second stage when the indigenously designed 500 MWe Prototype Fast Breeder Reactor (PFBR) at Kalpakkam successfully attained its first criticality, entering its operational testing phase.

It is estimated that FBR to be built in scales have a potential to generate 500 GWe to sustain for 100 years. FBRs will be fully dependent on indigenous fuel and related technologies. The technology to reprocess the spent fuel of first stage and to convert them into fuel assemblies for loading in the core of FBR has been mastered with decades of experience in running FBTR and recently started PFBR. For India this is the best option to add capacity of clean energy to the grid. Compared to PHWRs, fast reactors are simple to construct and operate. Successful generation of power in PFBR and recycle of fast reactor fuel is very important to sustain second stage of our nuclear power program.

5.0 Advent of SMR

If one sees the historical trend of nuclear energy in the world, the best phase was between 1970 and 1990 when nearly 300 nuclear plants were built mostly in Europe, Japan, Canada and USA. These reactors contributed about 360 GWe. Most of those reactors belong to Generation II. Today, if they have to be built, it will need to conform to either Generation III or III+ reactors with advanced feature and several passive systems in the design.

Economics of scale is based on maximizing megawatts against operating and maintenance (O&M) costs. This drove to produce larger designs, of today with power levels of up to 1700 MWe. Interest in reducing plant O&M costs led to the development of passive safety features that are adopted in Generation III and III+ reactors. After this there was little that could be done to make them more efficient. However, the market for large capacity power plants is limited to countries with a large grid capacity. China is churning out large nuclear reactors. Construction started on six new reactors there in 2025, and two more got underway in the first five months of 2026. The country is on course to overtake both the US and the European Union in installed nuclear capacity in near future.

However, in recent times there are significant political risk, public controversy, lengthened licensing procedures and risk of governments imposing nuclear phase out, etc.

Limitations of grid capacity and slow growth in power demand were leading factors in exploring whether smaller, more incremental nuclear power technologies can be built that can be used either instead of new large nuclear power plants, or to supplement existing installed capacity. In addition, with the growing use of intermittent renewable capacity such as solar, wind, small hydroelectric and tidal generation, there are advantages in introducing small base load nuclear plants with enhanced load-following capabilities to stabilize the grid. Nuclear industry recognized this gap in the market and responded with smaller reactor facility concepts that promised to meet the long term needs of power utilities.

The market for smaller nuclear facilities has the potential to be an order of magnitude larger than for current full scale nuclear power plants, given that most small countries either have small grids or are developing mixed generation grids. However, much of the infrastructure essential for larger plants is still needed for these smaller types of facilities, although scaled commensurate with risk. These include the regulatory regime; emergency planning; and security and safeguards.

The main driving force to develop SMR is

1. Meeting the need for flexible power generation for a wider range of users and applications.
2. Replacing existing ageing fossil fuel fired power plants or enhancing a grid which contains more intermittent renewables.
3. Enhancing safety performance through inherent and passive safety features.
4. Offering possibilities for synergetic energy systems that combine nuclear and alternative energy sources.

The key to the success of SMRs is the ability to demonstrate stronger economic efficiency. This is important because smaller reactors equate to a loss of economies of scale. Economic efficiency is possible if

a). There are no delays in construction and commissioning by following the model of shipbuilding and aerospace industries where modular engineering and construction is in practice for decades now.

b). Modern technology is used to reduce O&M costs and improve the overall plant capacity factor.

Many nuclear experts have long thought small modular reactors (SMRs) would revolutionize the industry. Advocates expect SMRs to shorten construction schedules and bring costs down through modularization and factory construction. IAEA's recent report notes 25 land-based water-cooled SMRs and another eight marine-based water-cooled designs are under development globally. It also lists 17 high-temperature gas-cooled SMRs, eight liquid-metal-cooled fast-neutron-spectrum SMRs, 13 molten-salt SMRs, and 12 micro-reactors. However, only two SMR designs have ever been built and placed in commercial operation. The KLT-40S is a Russian-developed 35 MWe (150 MWth) small modular reactor (SMR) utilized as the world's first operational floating nuclear power plant (FNPP) on the Akademik Lomonosov. It is a pressurized water reactor (PWR) derived from icebreaker technology, operating with a 30-36 month refuelling cycle and a 40-year design life. The second one is the HTR-PM project constructed at a site in Rongcheng, Shandong Province, roughly midway between Beijing and Shanghai in eastern China. Touted as the world's first commercially operational modular nuclear power plant with fourth-generation nuclear technology, the achievement marked an important milestone, transitioning the technology from experiments to the commercial market.

A key highlight of the Union Budget 2025-26 is the launch of a Nuclear Energy Mission, which is focused on the development and construction of Bharat Small Modular Reactor (BSMR-200), development and construction of SMR-55 (2 units), design and construction of a high-temperature gas-cooled 5MWth micro-reactor (HTGCR) for hydrogen production and molten salt breeder reactor for Th utilization. The government has allocated 2 billion dollars (₹20,000 Crore) for this initiative, aiming to develop and construct these indigenously designed reactors by 2033.

These days SMRs have also gained traction from proponents of captive plants for the assured 24 x 7 power supply to meet specific requirements. These are either emerging industries such as AI and data centres or energy intensive hard to abate industries located in remote areas like mining, cement, steel, copper, aluminium refining, fertilizers and desalination. The small reactors have not been new to nuclear fraternity. In the initial period, the nuclear programme in the presently so-called advanced countries had started with small size reactors. The purpose of the programme was then to serve as test bed for the large size reactors to make business more economically viable. Idea of going back to smaller size of the plant started sometime in the year 2012, an instance of such motivation was observed in the 2nd annual conference on Small Reactor held in the year 2012 in Columbia, South Carolina, USA. The participants advocated for small reactors to mitigate the financial risk involved in the large reactors. They opined that factory-built reactors having limited site activity will significantly reduce the construction time and therefore the financial risk. It may be worth noting that 'M' in SMR used to represent 'Medium' in the initial period of its coining was being interpreted as Modular to represent prefabricated modules. In today's time modular too is interpreted in two different ways. On one hand, it represents modularisation of reactor systems so that they can be built and tested in factory before being shifted to the site while on the other hand it represents self-contained standing reactor module which can be enlarged progressively to build the large capacity at a given site.

Globally, large numbers of companies, both state-owned and private are engaged in developing SMRs. There are more than 100 designs of SMRs under development. Nearly one third are based on the proven water cooled reactor technology. Some of the water-cooled reactor designs are being evaluated or are in the advanced stage of evaluation by the regulators of their originating countries.

Three designs one each proposed by Rolls Royce, NuScale and GE Hitachi are in active considerations of the British regulator, US regulator and Canadian regulators respectively. In addition, 25 MWe CAREM is under construction in Argentina. NUWARD in France and HOLTEC / TERRA Power / X-Energy/ Westinghouse in USA are among the other leading designers of a variety of SMRs. They are all developing their own designs based on different technologies such as PWR, BWR, Molten Salt and HTGR.

HOLTEC has been successful in seeking approval from US Department of Energy to transfer its SMR technology to its Indian partner's viz. Tata Consulting Engineers Ltd and Larsen & Toubro Ltd. It is prudent to evaluate the designs of other front runners of west as well as of KLT-40S before decision on their suitability for India is arrived at. Choice of availability for SMR designs and deployment bring competition to facilitate use of state of art technology appropriate for our requirements. These could be one developed indigenously or the ones already reviewed and certified by the regulators of the developed countries.

The small modular reactor (SMR) market is poised for steady growth, fuelled by the global demand for sustainable and reliable energy solutions. Valued at $6.3 billion in 2024, the market is projected to grow at a compound annual growth rate (CAGR) of 9.1%. This upward trend is expected to continue, with the market anticipated to reach $13.8 billion by 2032, driven by energy security needs, supportive regulations, rising electricity demand particularly from data centres and AI infrastructure, carbon emission reduction goals, and the shift toward decentralized power generation.

Indigenous efforts for design and development of SMRs are underway and may be ready for deployment only after few years. On the other hand, designs of SMRs developed by leading overseas companies have obtained regulatory clearances from their respective parent countries and are ready to be deployed in many countries.

As the trade restrictions may be introduced by early thirties, it is incumbent on the Indian companies interested in SMRs offered by overseas suppliers to seek clearance of DAE/ AERB for site, design, installation and operation once their commercial interests are aligned. Location of these captive power plants is a matter to be resolved by operators as per the guidelines of regulator. Whereas safety demands co-locating them on existing nuclear sites, private companies will prefer to co-locate them adjacent to their production units / business centres. As an alternative, BSR 200, an improvised version of time tested 220 MWe PHWR design is available to Indian Industries for using as captive power plant. Its standardised design with improved safety, long operating experience and regulator confidence will help replace the coal fired captive powerplants of energyintensive industries without hurdles. There is a distinct possibility that many private players will join hands with NPCIL to execute their nuclear plans once the nuances of SHANTI act and amendments in Atomic Energy act 1962 and Civil Nuclear Damage Act 2010 are comprehended by them..

6.0 Summarising

To sum up, Indian Nuclear Society observes that to achieve target of 100 GWe an optimal mix of large reactors, BSMR and SMRs is desirable. Apart from supplying electricity to AI data centres, desalination plants, metal refining in remote areas and driving cargo ships, SMRs / micro-reactors can serve remote locations in North East and islands like Andaman Nicobar and Lakshadweep in India. To facilitate use of brownfield locations (sites of retiring thermal power stations), there is a need to revisit ALARA concept and dose criteria so that plant boundary is considered as exclusion zone. Other requirements are transportation of SMRs through road and rail, provision of dry cooling and the possibility of renovation of boilers and turbines of thermal power stations.

It is estimated that with these innovations and gestation period restricted to 36 months, CAPEX can be reduced to 25 Cr Rupees per MWe. Use of indigenous designs can further reduce the cost of SMRs in India.

INS strongly believes that India must explore the potential of FBR now that we have successfully entered the 2nd stage. In coming days and months power operation from PFBR will validate physics and engineering design of the plant. DAE will have every reason to accelerate FBR projects. These reactors can operate independent of foreign fuel supply unlike any of the above new reactors tipped to cater to the nuclear mission of 100 GW by 2047. In fact, the second stage looks much beyond 100 GW by 2047. DAE must take proactive steps to accelerate finalising construction approvals of FBR series. When thorium will be ready for loading in 2nd stage reactors after sufficient inventory of Pu-239 is produced, the advent of 3rd stage thorium reactors will further guarantee sustained source of power for several centuries. That will be a stage when India can export power to the world. INS believes that India today is ready to see growth of its economy beyond 2100.

Indian Nuclear Society organized a theme meeting in February, 2026 to address to the apprehensions and curiosities of the representatives of Pvt Industries and public undertakings, interested in joining national mission of 100 GWe nuclear by 2047. INS invited distinguished nuclear technologists, who apart from delivering talks, addressed to the concerns and apprehensions of the participants. Proceedings of the two-day meeting has been uploaded on the INS website **www.ins-india.org** .

*Based on a study carried out by the INS Study group with Shri A.K. Anand as coordinator

MY TRYST WITH SCIENCE :

By Mahadeva Iyer

Dr. Bhamy V. Shenoy

"My Tryst With Science: Reflections in Verse and Prose" is a delightful book to read and reflect on. The author Dr. Mahadeva Iyer is a scientist, having retired as head of Radiation Safety systems from BARC, then served with the International Atomic Energy Agency and later as consultant to the Atomic Energy Regulatory Board. Despite taking up many responsible assignments in all important radiation safety field, the author springs out of this book as a person who wants to share the lessons he has learnt over close to nine decades as a human being. One can pick any page to read and will find it interesting. No read to go from beginning to the end as is the case with most books.

Initially, when I looked at the contents and saw Bouquet and Garlands of Poems, I thought of skipping that part and going straight to essay part. I did not want to spare time to read poems which are usually not easy to appreciate at first reading.

However, once I started to read the poems, I could not stop reading them. For every one, there are several poems of their choice to choose to read from and reflect upon. Let me give just one example of a Poem - Nuclear Weapons. "God converted natural plutonium, Eons back into more benign Uranium, Man not to be outdone, Converted Uranium back into Plutonium, And subrefuged to make lethal weapons, Tested on humanity to see how lethal it works, Like Basmasura tried his boon of weapon on Siva, And led the world to the brink of extinction.

Just the reading of titles of few poems alone is sufficient to arouse the curiosity of the readers to learn more: Truth is Bitter, Old is Gold, Yesterday Kal and Tomorrow Kal, Square peg holed in Round, Turning of Minds and Gita, Abhimanyu in Chakravyuha, etc.

When I started to read essays, it was a different kind of feast, equally pleasing. There was old history - some time going back four hundred years back when Dr. Iyer talks about his geneaology- and modern times to 2025. His school days where he recalls all the nicknames of his classmates and titles showered on his teachers for their unusual attire or food or attitude etc will be nostalgic.

His detailed description of traveling by train from deep south in Travancore to Delhi taking more than 36 hours shows how far we have advanced. His parents were worried how he could travel all by himself for the first time. There were many such simple but humane stories to give us a glimpse into the technological development - no mobile phones and not even land lines. Communications is through telegraphs.

Dr. Iyer has many stories to share with his readers. One such story of Velumoney who succeeded in building a huge company Thyrocare starting from a humble beginning should be used as a case study in our management schools. He was too poor and could not enroll for Science courses. Thyrocare Ltd. is a chain of diagnostic and preventive care laboratories. Velumoney sold his shares to earn Rs. 4546 crores - what a success story for a person whose parents were too poor to give education to his children.

Dr. Iyer describes his "Most satisfying moment in Life" which should inspire most. When he was celebrating his 88th birthday in 2025, he got a message from one of his old friends recalling how he played a major role 45 years back in conducting an aerial survey of Kerala using for the first time microprocessor based Aerial Gamma Spectrometer. The goal was to monitor large areas for potential radioactive contamination. When the report was submitted on the project, Dr. Iyer the brain child of the project was not mentioned. But he took it in stride.

There are many such stories throughout the latter part of the book. Even to a cursory reader of the book, it becomes obvious the great admiration Dr. Iyer has towards his guru and mentor Dr. A. K Ganguly who was pioneer in India to start Health Physics to deal with radioactive health related problems. Right in the beginning Dr. Iyer by mere luck despite not having the right kind of educational background was able to work for Dr. Ganguly.

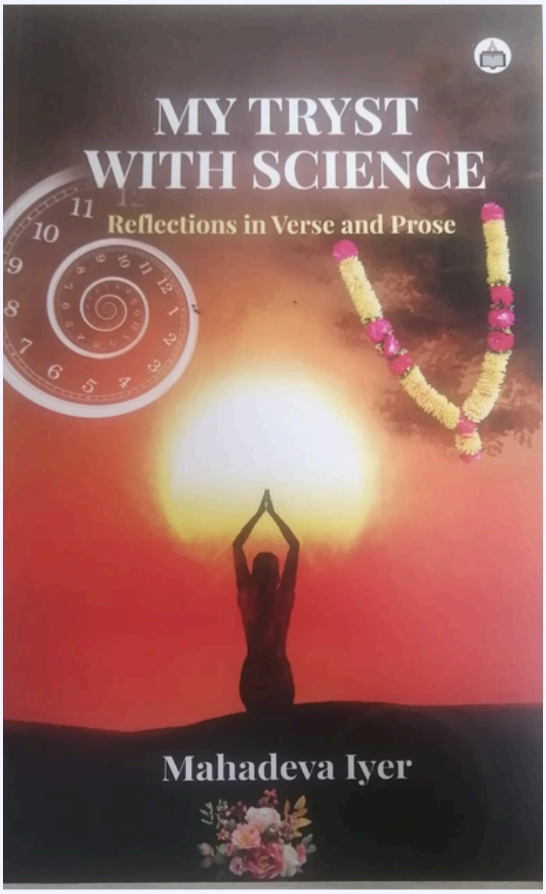
Dr. Iyer had the good fortune to work with the famous builders of Bhabha Atomic Research Center (earlier known as Atomic Energy Center) right from the founder Dr. Homi J. Bhabha, Dr. P. K Iyengar, Dr. Srikumar Banerjee, etc. In this book, while reading about his interactions with these illustrious stalwarts, one is reminded of how our top managers are different today from yesteryears.

There are insightful comments on a seminal book written by Dr. Iyer, "Saga of India's Atomic Energy in India" by Dr. Srikumar Banerjee which will compel any one interested in India's atomic energy to read it.

In his Foreword, Dr. Banerjee wrote that " I realized that such an authentic description of the evolution of the atomic energy program in India, as captured by Iyer within about fifty pages, has perhaps never been done before".

Role of Dr. Homi Bhabha in putting a strong foundation for BARC to give critical importance to safe operations of all atomic establishments should give comfort to readers. Soon after AEC started to function, Iyer quotes Bhabha stating firmly that " If there are no funds for environmental safety, we need not start a nuclear power program at all". AEC is also credited for having contribute to the genesis of Department of Environment in India.

In conclusion I want to recommend this book more as a book of history written by a scientist with a totally different goal to convey his Tryst with Science. No doubt the discussion is driven in the background of BARC/AEC and most individuals are connected with science. However we also learn about the economic, sociological, scientific, and political changes taking place in India.



Indian Nuclear Society Webinar on "Criticality of PFBR: A Milestone in the Journey of Atomic Energy in India"

Sunday, 17 th May 2026, 11:00 A.M., AERB Auditorium, Anushkatinagar.

The webinar commenced with a welcome address by **Dr. H. Mishra, Coordinator and EC member, INS**, who warmly welcomed the **Chief Guest, Guest of Honour**, the **Speaker**, Executive Committee (EC) members, Life Members of INS, and participants joining both in person and through the online platform.

This was followed by the address from **Prof. V. K. Manchanda, President, INS**, who outlined the objectives and key activities of the Indian Nuclear Society (INS) and provided a brief overview of the webinar. He referred to the contributions of Dr M.V. Ramaniah, the founder President of INS in the area of Science and Technology of Plutonium which includes mixed carbide and MOX fuels developed for FBTR and PFBR at RLG BARC and A3F Tarapur respectively

The **Chief Guest, Dr. Anil Kakodkar**, Ex-Chairman, AEC, **Guest of Honour, Shri S.C. Chetal**, Former Director IGCAR, and the **Speaker, Shri Allu Ananth,** Director (Operations) & Station Director BHAVINI, were formally felicitated by the EC members of INS with mementoes, shawls, coconuts and flowers.

The eminent guests were formally introduced by **Dr. Archana Mishra, Member, EC, INS.** The programme featured a series of highly informative and inspiring lectures delivered by eminent personalities who have played significant role in India's Fast Reactor programme. **The Guest of Honour, Shri S. C. Chetal**, delivered an insightful and comprehensive lecture on the evolution of the Fast Breeder Reactor (FBR) programme in India, with special emphasis on the 500 MWe Prototype Fast Breeder Reactor (PFBR). He traced the remarkable journey of the PFBR from its conceptualization, design, and development to its successful achievement of first criticality on 6 April 2026.

Subsequently, the **Chief Guest, Dr. Anil Kakodkar** shared his valuable perspectives on the pivotal role played by Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI) in the successful realization of the PFBR project . He commended the dedication and perseverance of the scientific and technical teams involved in achieving this historic milestone. Dr. Kakodkar emphasized the importance of strengthening indigenous capabilities and urged BHAVINI to formulate long-term strategies aimed at achieving greater self-reliance in reactor construction, operation, and associated technologies. Stressing the importance of nuclear energy in meeting India & growing energy demands, he underscored the contribution of nuclear power towards achieving the national target of 100 GWe He further highlighted the significant role of the Indian Nuclear Society (INS) in creating public awareness about nuclear science and technology. He called upon the INS to take up the role of Think Tank in view of the emerging challenges in the 3 stage program of our country.

Further, the **Speaker, Shri Allu Ananth** delivered an in-depth lecture titled **"Criticality of PFBR: A Milestone in the Journey of Atomic Energy in India."** He provided a detailed account of the developmental journey of the PFBR and explained the scientific significance of achieving first criticality. He described this achievement as a landmark event in the history of India's atomic energy programme, symbolizing decades of sustained research, technological innovation and national commitment. Shri Ananth elaborated on the strategic importance of the PFBR in advancing the second stage of India's nuclear power programme and highlighted its potential contribution towards the effective utilization of plutonium and the eventual deployment of thorium-based nuclear energy systems. He emphasized that the successful criticality of PFBR is not only a technological accomplishment but also a testament to India's capability in developing advanced nuclear reactor technologies through indigenous expertise and resources.

The session was followed by an interactive **question and answer session**, coordinated by **Dr. H. Mishra, Dr. S. Gangotra and Shri MK Mathur** during which eminent guests and speaker addressed the queries raised by participants attending physically and online, both.

The webinar was highly appreciated by the participants, with **75 attendees participating in person and 145 participants joining online**, reflecting strong engagement and interest in the subject.

The programme concluded with a **Vote of Thanks** proposed by **Shri K. U. Agrawal, Jt Secretary, INS** who expressed sincere gratitude to the Chief Guest, Guest of Honour and the Speaker for their valuable time and insightful contributions. He also acknowledged the efforts put by IT team, security and authorities of AERB , INS staff, President & EC members INS as well as participants for success of the webinar. The event formally concluded with singing of the **National Anthem** by all.

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2). Managing AI's Footprint in a Carbon-Constrained World

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3). The POWER Interview: Hardening Power Systems to Withstand Natural Disasters

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4). The POWER Interview: Quantum Computing's Importance for Utilities and Power Generators

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5). ZettaJoule Pursues a Second Act for Japan's High-Temperature Nuclear Reactor

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7). Europe Embraces Energy Storage to Enhance Power Flexibility

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12). Five Reasons the Clean Energy Transition Needs Nuclear Power

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13). Carbon Border Adjustment Mechanism: An Impact on India–EU Trade

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14). How the Hormuz crisis can push India towards energy transition

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Compiled by Dr. A. Rama Rao,
INS member