BARC Q&A

Tête-à-tête with Dr. Sumit Som

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Dr. Manjiri Pande:* **DAE has been launching accelerator programs in a very big way. Your view on Indian ADS program, DAE accelerator program and its role in progress of India**

Dr. Sumit Som: The Indian accelerator driven sub critical reactor system (ADS) program is an ambitious and very useful program of DAE. ADS has attracted worldwide attention for its superior safety feature, incineration of minor actinides and transmutation of long lived fission products. From Indian perspective, it has additional and very important dimension of nuclear energy generation utilizing thorium as fuel. The major systems of ADS are sub critical core, spallation target and power accelerator.

DAE has made significant progress in accelerators and related technologies. Among the others, recently, low energy high intensity proton accelerator (LEHIPA) has accelerated proton beam up to 20 MeV energy.

Under in-kind international collaborations, DAE has delivered and deployed many indigenous accelerator technologies. Under Indian Institutes and Fermilab Collaboration (IIFC), for Proton Improvement Plan-II Injector Test facility (PIP2IT), BARC has delivered nine 325 MHz solid state RF amplifiers, magnets accelerator and RRCAT has delivered 650 MHz solid state RF amplifiers and high beta elliptical cavities. Along with this, VECC has delivered two numbers of 650MHz low beta (LB650) single-cell SRF cavities that have achieved the high accelerating gradient.

Under Facility for Antiproton and Ion Research (FAIR) project in Germany, DST & DAE jointly have delivered ultra-high vacuum (UHV) chambers, power converters via Indian industries and development of high energy detectors is in progress under the leadership of VECC. This definitely establishes the competence of DAE laboratories and local industries in accelerator field. These accomplishments have generated a lot of confidence on the proposed energy frontier future accelerators.

The journey of achieving 1GeV accelerator is going to give rise to a lot of exciting spin-offs in the uses of low and medium energy beam from intermediate accelerators. This will immensely help and open the doors of wide opportunities for Indian Micro, Small and Medium Enterprises (MSME) or Small and Medium Enterprises (SME) in both domestic and international markets.

Dr. Manjiri Pande: **Accelerators are increasingly being used for medical and societal applications. How do you envisage indigenous accelerators making significant contributions in these fields?**

Dr. Sumit Som: India is a populous country. It is envisaged that the percentage of cancer inflicted population will increase multi-fold in near future.

As per information published in Indian Journal of Med Research (IJMR) in its Oct-Nov 2022, issue (DOI: 10.4103/ijmr.ijmr_1821_22), the estimated number of cases of cancer in India for the year 2022 was found to be 14,61,427 (approximate rate:100.4 per 100,000). The incidence of cancer cases is estimated to increase by 12.8 per cent in 2025 as compared to 2020.

DAE is developing a number of indigenous medical cyclotrons and electron accelerators. These accelerators, especially medical cyclotrons will be critically useful, especially in cancer scenario. These will be immensely beneficial in every aspect of the cancer scenario i.e. starting from its early detection and diagnostics to cure by generation of radio isotopes for treatment. This will be greatly valuable in increasing the quality of life and life expectancy of cancer afflicted patients.

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Dr. Manjiri Pande: **How participation of Indian Micro, Small and Medium Enterprises (MSME) or small and medium enterprises (SME) can be increased substantially in accelerator technology?**

Dr. Sumit Som: The Indian MSME and SME are already contributing in the accelerator sector. Their footprint in accelerator domain can be increased substantially in quality and quantity. Their participation will improve significantly by handholding between the accelerator scientists, technologists, engineers and their industry counterparts. This will assist in transferring indigenously developed technologies into deployable engineering products. MSME and SME should join hands with accelerator community in participating in flagship initiative of Government of India like public private partnership (PPP), Atal Innovation Mission (AIM) etc. to promote the culture of innovation and entrepreneurship in India. This will further establish the requisite infrastructure and skilled manpower or human resources in the country. All these amalgamated efforts may converge in opening the doors of international accelerator market for these SME and MSMEs. This would lead to extra drive towards 'Make in India', under 'Atmanirbhar Bharat' initiative and substantial import substitute.

Dr. Manjiri Pande: **Today, Artificial Intelligence (AI) is a buzz word. AI is making inroads in every field. What will be the role and usefulness of AI in accelerators and in related technology?**

Dr. Sumit Som: Particle accelerator is a complex machine. It's a combination of a variety of subsystems and components related to different technological domains. An accelerator has to operate cohesively with a huge number of sensors and considerable number of subsystems to deliver the required beam. An artificial intelligence (AI) based algorithm(s) can aid to monitor the performance of accelerator, to perform automated beam tuning of the machine, to detect the operational concerns or issues, to identify the faults w.r.t. specific subsystem etc. This would enhance the reliability of particle accelerator and hence availability of the accelerated beam. The AI approach can further be configured to analyse the available operational data that can predict most probable failure scenarios. This will help the scientists in improvisation and enhancement in accelerator operation and also can assist in advance planning and maintenance of the accelerator inventory.

Dr. Manjiri Pande: **RF systems play a very significant part in accelerators as well in other fields and many other scientific applications. What are the futuristic options for RF Technology?**

Dr. Sumit Som: Radio-frequency (RF) systems are critical and integral part of linear and circular accelerators and deliver the power to attain and change the energy of a charged particle beam. RF Accelerators are large users of energy, mostly RF power.

In accelerator, the RF system is the key element that provides RF power for generation of electric field for beam acceleration. Integrated RF system drives the major part of the accelerator performance. Many state-of-the-art technologies are used in design and development of the RF systems, such as vacuum science, high-voltage / high current technology, surface physics, advanced materials, high speed controls, protections, advanced mechanical fabrication and processing etc.

In addition to particle accelerators, RF systems or technologies are used in broadcasting, communications, wireless power, medicine etc. Very high frequency (VHF) and ultra-high frequency (UHF) are used in the communication systems by military and industry sectors.

VHF frequencies are able to penetrate walls and ●●●

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other structures. It can also enter deep into the human body without causing any damage and hence, medical devices use VHF for deep penetration in human body. UHF penetrates at further deeper level. Medical institutions or medical fraternity use these properties to monitor internal organs and their respectively functions in a patient. In remote surgery, higher-frequency mm - wave based technology can be used by enabling precision operations with ultra-reliable data connections and with extremely low latency (lag).

Smart RF-systems comprising of RF transmitters, receivers, and transceivers send / receive data over the air. These are used in satellite communication, in defence for securing critical communications, to provide reliable Wi-Fi on trains and for high-performance private wireless networks.

Very high reliable data connectivity can be ensured using mm - wave frequencies in driverless car technology, intelligent traffic light controls and traffic-management etc. The high end RF / MW technologies are being developed for quantum technologies.

To summarize, RF technology is used in a variety of important fields and hence, will always remain in high demand and has a very promising future. Globally, it will experience significant growth and innovation in the coming years.

Dr. Manjiri Pande: **Globally, food security is an important topic. How RF systems can participate in such a prominent domain?**

Dr. Sumit Som: Food security, as defined by the United Nations' Committee on world food security, means that all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life.

Food security is an important global need. Safe and nutritious food can be achieved by customizing RF as an innovative technology, in numerous food processing and preservation purposes like inactivation of pathogens, pasteurization, fungi inactivation, and disinfestation etc. RF drying technology for food and agricultural products have characteristics like fast, steady, and volumetric heating, high energy efficiency and moisture reduction. However, the RF drying as a single stage method may be insufficient or can have drawbacks. Utilizing multi-stage drying approach in conjunction with RF technology can effectively address the limitations of one-stage strategy using diligently the combination of other drying methods.

DAE has designed and developed a variety of matured indigenous RF technologies, which can be customized for RF drying of food and agricultural produce for our domestic purposes. This will enhance the quality and storage life of these items and thereby will contribute to food security.

Dr. Manjiri Pande: **World is transitioning towards Green Energy. How the upcoming technology initiative of 'Radio Frequency Energy Harvesting' can contribute towards this?**

Dr. Sumit Som: In today's modern era, most miniature electronic devices are being used in automation, medical treatment, environmental monitoring etc. In these applications, electronic devices are conventionally battery-powered to ensure their operation. But, as power source, these batteries impose serious limitations because of their size, lifespan, bio-compatibility etc. Consequently, electronic device gets affected in their weight, portability, miniaturization, lifetime etc.

Additionally, limited battery life and need for regular replacement greatly limits the performance and reduce the quality of service. In some special implanted electronic devices, the replacement and maintenance cost of the battery is very expensive.

In recent years in particular, the disposal of

...RF technologies can play a crucial role in addressing food security. The bouquet of DAE RF technologies can be customized to meet the challenges faced in food preservation chain, particularly for maintaining high quality and safe post-harvest storage...

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battery waste has become a significant environment issue. Battery waste is primarily disposed off in landfills that contribute to land pollution and the contamination of underground water due to the harmful chemical contents of the battery. This problem is more aggravated with Lithium batteries, as they are considered hazardous and their safe disposal poses a huge challenge.

Therefore, moving towards green energy, it is meaningful and very natural to develop the low-cost and pollution-free energy resource to replace the battery.

Our mother earth's natural environment, have abundant energy resources in the form of solar energy, motion/vibration energy, thermal energy, wind energy, tidal energy and man-made RF energy.

Globally, huge interest is generated in energy-harvesting technologies that use ambient power sources such as heat, vibration, and electromagnetic waves. Radio frequency energy harvesting (RF-EH) is a promising technology that operates using electromagnetic waves. This advanced RF-EH technology proposes the supply of wireless power to battery-free devices, thus making it a potential and strong alternative energy source for future applications.

In addition to the dynamic energy recharging of wireless devices and a wide range of environmentally friendly energy source options, the RF-EH technology is advantageous in facilitating various applications that require quality of service.

The proposed RF-EH technology possesses numerous distinctive advantages such as, it can function in any location with a strong radio frequency signal, including areas with no sunlight or indoor spaces with specialized transmitters. As RF energy is not much influenced by weather and location, it can be effectively used by RF-EH system. It is an alternative method to reduce the cost of regular maintenance in terms of device improvement. It will be cheaper and eco-friendly. Thus, RF energy harvesting proposes a very worthwhile and workable substitute that circumvents some of the environmental issues or limitations.

Dr. Manjiri Pande: **Nationally and internationally, large accelerator programs with latest science and technology are either being commissioned or are upcoming. What is your advice to the young budding engineers, scientists on having a career interwoven with accelerator and RF?**

Dr. Sumit Som: Accelerator is an ever developing field and is progressively attaining higher energy frontiers. Ambitious accelerator programs are being launched both nationally and internationally. Science and technology of accelerators is growing very fast, which gives opportunity to learn many new and advance technologies and do the scientific researches as well. Working in accelerator and in RF is a very challenging job.

The young budding engineers and scientists will gain multi-disciplinary knowledge and exposure while working in accelerators. The knowledge gained in these RF and accelerators field will be at par with international laboratories. The young scientists and engineers should utilize this perfect opportunity and give their valuable contribution for our motherland.

**Dr. Manjiri Pande is currently heading Radio Frequency System Section of Accelerator Control Division in BARC. Dr. Manjiri specializes in diversified areas that include particle accelerators, klystrons, Solid State RF technology, RF breakdown and multipacting, high power RF systems etc. She is a recipient of DAE Scientific and Technical Excellence Award, DAE Group Achievement Awards, S.N. Seshadri Award and VEDA award.*