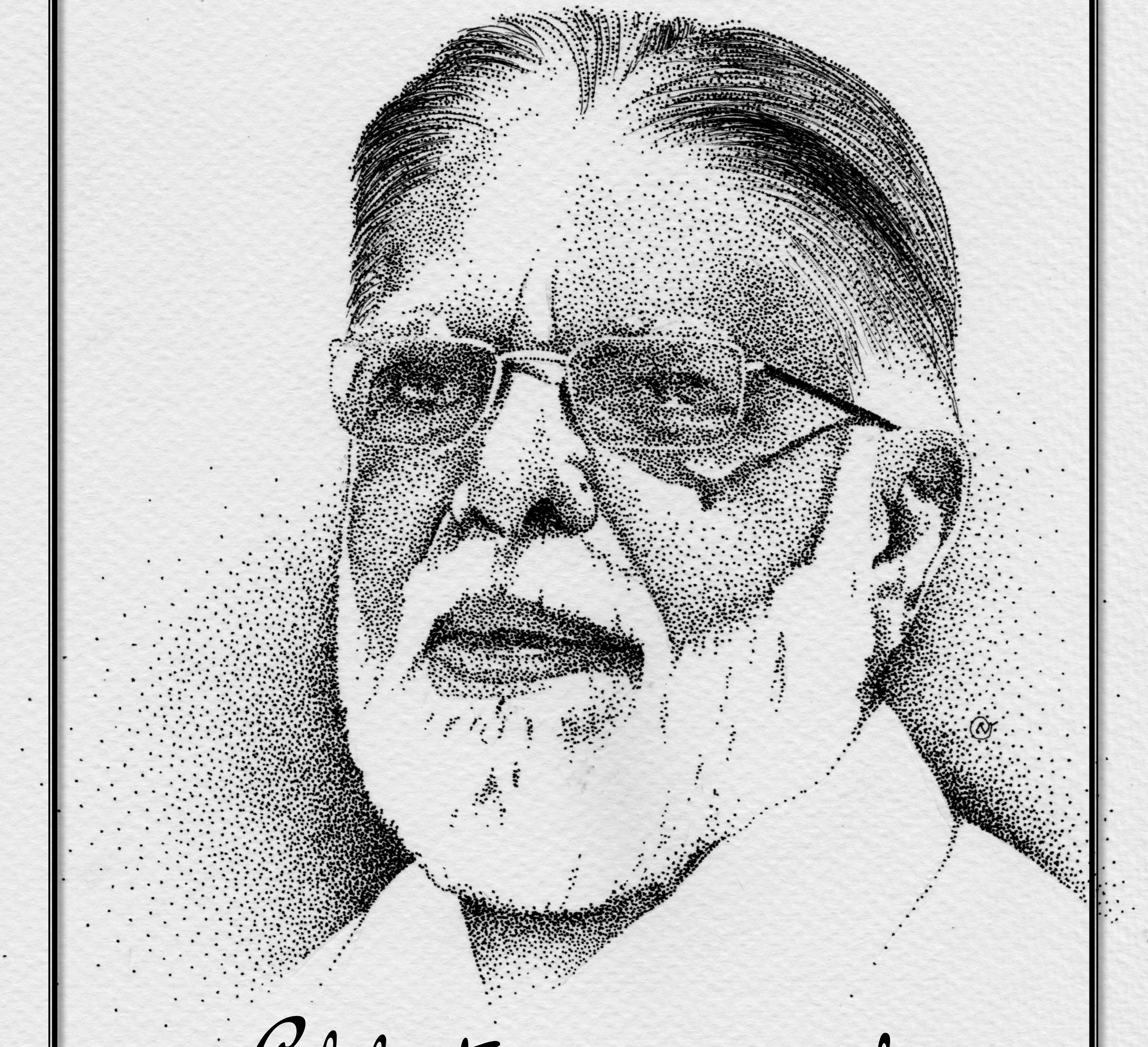
Plasma & Pucadyil



Celebrating 80 years of

Professor Pucadyil Ittoop John

Contents

के. एन. व्यास
K. N. Vyas

भारत सरकार
Government of India

अध्यक्ष, परमाणु ऊर्जा आयोग
व
सचिव, परमाणु ऊर्जा विभाग
Chairman, Atomic Energy Commission
&
Secretary, Department of Atomic Energy

MESSAGE

On behalf of the Department of Atomic Energy (DAE), it is a pleasure to convey my warmest wishes on your 80th birthday.

I had heard about your contributions towards development of plasma technologies from some of the friends in IPR. Subsequently, I was very happy when I had an opportunity to interact with you during ADNUTECH conference at Mumbai in 2010, at which I escorted you.

We appreciate the immense knowledge that you have shared with us in terms of intellectual inputs, research experience and constant encouragement during your journey with us in DAE. We are fortunate that you have left behind a legacy to continue in your footsteps, fulfilling the requirements for a better tomorrow using plasma science and technology.

I wish you good health and happiness for many years to come.

(K.N. Vyas)

अणुशक्तिभवन, छत्रपति शिवाजी महाराज मार्ग, मुंबई - 400 001, भारत • Anushakti Bhavan, Chhatrapati Shivaji Maharaj Marg, Mumbai - 400 001, India
दूरभाष/Phone:+(91) (22) 2202 2543 • फैक्स/Fax: +(91) (22) 2204 8476 / 2284 3888
ई-मेल/E-mail: chairman@dae.gov.in

Dr Anil Kakodkar
Chairman, Rajiv Gandhi Science & Technology Commission,
Former Chairman, Atomic Energy Commission

Message from Dr. Anil Kakodkar, former Chairman AEC and Secretary DAE

Dear Professor John,

I am delighted to offer my heartiest wishes on your 80th birthday. Since the establishment of the Institute for Plasma Research, you have made path-breaking contributions to the Indian nuclear fusion programme as well as societal applications of plasma science and technology. FCIPT, set up at your initiative, continues to lead in the indigenous development of industrial applications.

It is nice that IPR is organizing an event to celebrate your contributions to the field of Plasma Science and Technology on March 18,2021. Kindly accept my warm felicitations for the occasion.

Wishing you a happy 80th birthday and healthy, active and productive life in years to come.

Anil Kakodkar

7th fl. Central Complex, Bhabha Atomic Research Centre, Trombay, Mumbai 400085
Tel. +912225505210, Email kakodkar@barc.gov.in / kakodkaranil@gmail.com

Institute for **Plasma Research**
प्लाज़्मा अनुसंधान संस्थान
Bhat, Near Indira Bridge, Gandhinagar 382 428, Gujarat (India)
भाट, निकट इंन्दिरा पुल, गांधीनगर -382428, गुजरात (भारत)

Dr Shashank Chaturvedi
DIRECTOR

E-mail : director@ipr.res.in
Ph.: 079-23962050, 9040

Message from Director, IPR

Dear Prof. John,

On this very special occasion, as we look back on your path-breaking contributions, I would like to convey the thanks of the Plasma Science and Technology community in India.

You have played a major role in initiating and nurturing the Indian Fusion Research programme as well as the Plasma Science & Technology programme in India. The Facilitation Centre for Industrial Plasma Technologies (FCIPT), which was conceptualised, set up and nurtured by you, has made a major contribution to indigenous technology development for Societal applications of plasmas. FCIPT is rapidly increasing its contributions in a variety of areas and, it is hoped, will continue to break new ground.

Those of us at IPR are proud of our personal association with you. Your passion and drive has been a source of inspiration for the younger generation. We look forward to your continued guidance.

I wish you good health and happiness for years to come.

(Shashank Chaturvedi)
DIRECTOR

The Plasma Science Society Of India

(Regn. No. F-828, Ahmedabad)

Message from PSSI President

On behalf of Plasma Science and Society of India, I would like to wish you a very happy 80th birthday!

We are all proud of you and congratulate you on your accomplishments and the scientific contributions that you made to plasma community in large. You have indeed played a pivotal role in promoting and popularizing plasma based applications in the country. As member of several advisory committees of PSSI, your suggestions and inputs were valuable and much appreciated. After playing a leading role in building up the organizational structure of ITER India, you had taken a lead to develop the idea of a National Fusion Program. With India's entry into ITER, your contributions in human resource development in fusion science and technology through BRFST funding to universities, educational institutions and industries in plasma and fusion related research were indeed remarkable.

Once again, on this milestone event of your life, we wish you many more years of good health and happiness!

PKAtrey

(Dr. P. K. Atrey)
President, PSSI

Plasma Science Society Of India
Reg. No. F-828, Ahmedabad

http://www.psssi.in

PHONE 91-79-2396 2000
FAX 91-79-2396 2255
E-MAIL pssi@ipr.res.in
WEB http://www.pssi.in

Institute For Plasma Research
Bhat, Near Indira Bridge
Gandhinagar 382 428
Gujarat (India)

Institute for **Plasma Research**
प्लाज़्मा अनुसंधान संस्थान
Bhat, Near Indira Bridge, Gandhinagar 382 428, Gujarat (India)
भाट, निकट इन्दिरा पुल, गांधीनगर - ३८२ ४२८ (भारत)

Message from the PIJ@80 Organizing Committee

We extend our heartiest wishes on reaching a great milestone of your life on your 80th birthday. We are grateful to have a thoughtful and highly experienced person like you, who have made a significant contribution in many scientific fields. You were always an inspiration to students and colleagues with the immense knowledge you shared during your entire tenure in IPR. We are proud of your accomplishments and believe that your guidance will continue to help us in our future endeavours. We wish you good health and great life filled with prosperity and true happiness.

Subroto Mukherjee

Ravi A V Kumar

Alphonsa Joseph

Nirav Jamnapara

Shantanu Karkari

Chhaya Chavda

Govind Lokhande

Saroj Das

PHONE : +91-79-2396 2000 FAX : +91-79-2396 2277 WEB : http://www.ipr.res.in

An Autonomous Institute Of The Department Of Atomic Energy, Government Of India

CONTRIBUTORY ARTICLES

A Vision for Plasma Physics and Applications

P. I. John

7C, Skyline Hillview, Kanjikuzhy, Kottayam, Kerala
E-mail: john.pucadyil@gmail.com

When Prof. Mukherjee suggested that I should give a short talk during this event, I first thought that I would stick to the theme of a vision for Plasma Physics and Application. Then I realized that I would be expected to give out some words of worldly wisdom or even some philosophical insights on reaching the old age of 80.

Thoughts about my life leads to a recurring realization that I have been very fortunate to be at the right place at the right time on many occasions. It was an accident of going to Aligarh that made me choose Plasma Physics as a career discipline. It was also an accident that PRL was planning to start work in Experimental Plasma Physics when I was beginning to be disillusioned with continuing to work at Aligarh. After a decade in PRL, the Plasma Physics Programme and Aditya happened through the collective efforts of many people. An understanding Director and a supporting Council made Plasma Processing and FCIPT possible. The exposure to IAEA made me aware of the importance of ITER. The DAE dispensation supportive of Indian participation in ITER also happened at the right time. All these opportunities presented themselves and one needed only to have a reasonable competence and an honest commitment to fulfil the demands these opportunities made.

I would like to share a few thoughts on the choices of what one wants to do, how one interacts with one's peers and subordinates, how one balances self- interest with the interest of a greater good. All of these contribute to what you ultimately leave behind as a heritage.

When you start a career, you have two options in choosing what you want to do. The first option is to live within your zone of comfort, setting targets which are easily achievable and generally taking life easy. The second is to push boundaries, consciously selecting difficult targets and objectives.

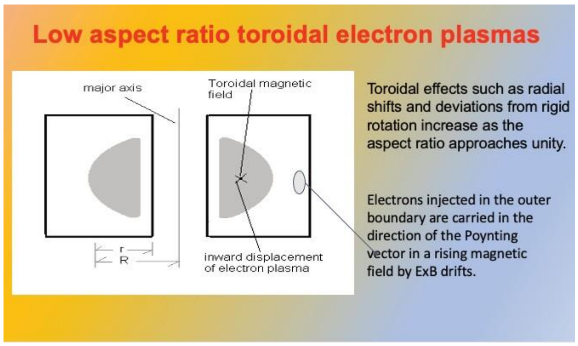
FCIPT is an excellent example of the latter. Developing technologies for industry is a very difficult task. Unlike basic research, where you can publish whether your experiment fails or succeeds, industrial technologies have to be delivered to a very demanding clientele who are generally not forgiving. This is generally true of all technologies where the benchmarks are very clear and measurable.

In my work I was blessed with co- workers who shared my vision in the activities I initiated. I was indeed fortunate to have students who were willing to take risks in choosing non- conventional topics for their thesis work. I was also blessed with Senior colleagues who were very supportive of my chosen options.

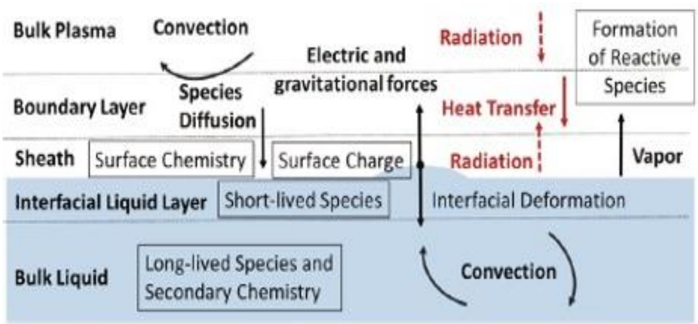
I am deeply touched by IPR's gesture in organizing this event. I would like to thank my colleagues in IPR and my friends from other institutions for all the kind words that were spoken about me. I sincerely believe that I have been fortunate to have been associated with all of you in our shared journey in research, development and outreach.

Let me share some thoughts on my vision for Plasma Physics, and Industrial Applications.

After watching a presentation by Prof. Walter Gekelman from UCLA on magnetic reconnection, where he showed a movie on the evolution of the magnetic field mapped by hundreds of magnetic probes, I realized that pursuing basic plasma physics with that kind of diagnostic arsenal was beyond me. The alternative option was to explore relatively unexplored areas of plasma physics, where a little effort in innovative thinking would give us many low hanging fruits. My foray into low aspect ratio toroidal non-neutral plasma was entirely driven by this consideration. The device was simple. An evacuated cylinder with a conductor through the central hole. A filament to emit electrons. A rising current in the central conductor creates a ring magnetic field, which sweeps in the electrons from the boundary into the minor axis and a toroidal cloud of non-neutral plasma is formed.

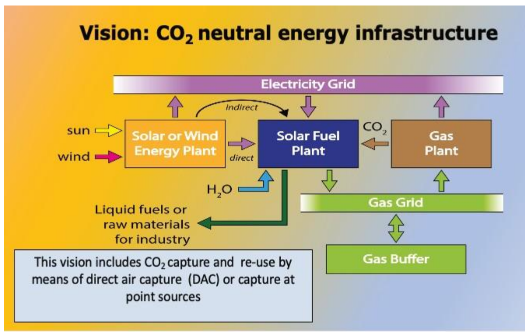


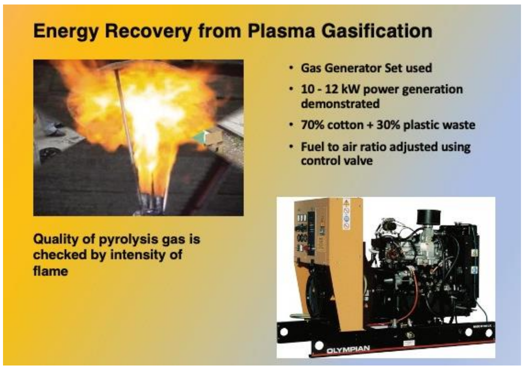
The fact that we have made major contributions to this field in understanding the basic properties and rich phenomenology of electron plasmas and publishing them in high-ranking journals without being swamped by excessive instrumentation is a proof that this approach was quite productive.



There is a paradigm in plasma physics: new plasmas produce new plasma physics. Plasmas of supersaturated vapours, dusty plasmas, plasma formed above and inside liquid surfaces etc. remain relatively unexplored. Photoionization from intense UV sources will produce high- density non-equilibrium plasmas. Electrode-less free-standing plasmas formed by microwaves, plasmas formed in dielectric gaps and inside gas bubbles in liquids etc. will be very novel configurations. There is great interest In laser cooled ultra-cold plasmas. I would strongly urge new students to consider exploring these avenues.

In Plasma Processing, the activities seem to be driven by concerns about climate change, environment and energy. There is great activity in CO2 reforming to help climate mitigation. China leads this research. The concept of solar fuels where renewable energy sources coupled with non-equilibrium plasma processing convert CO2 into hydrocarbon fuels leads the way to Carbon neutral hydrocarbon fuels. This makes CO2 the ultimate fuel,



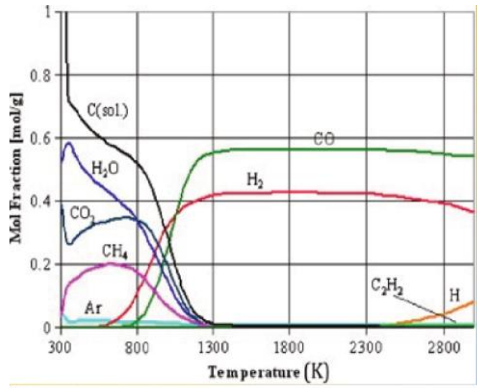


as startup activity in this led by Bill Gates and people with technological foresight show. The conversion efficiency and the throughput both are targets for improvement. Microwave plasmas and gliding arc plasmas seem to the favourites.

A relatively unexplored area is the plasma catalytic enhancement of these processes. This is an area worth pursuing. Plasma catalysis is best regarded as conventional catalysis perturbed by the presence of a discharge, which modifies its operating conditions, properties and outcomes often in a very localized way. The description “plasma-activated catalysis” is an apt one. The catalytic process is complemented using plasmas that activate the source gas. This combination is often observed to result in a synergy between plasma and catalyst. Energy recovery from plasma gasification was an area we had started working on earlier but did not proceed further. Following the submission of a report on Waste to Energy by a high-level task force in 2014, the Government of India has big plans to set up WtoE plants across the country. Niti Aayog has set a target of constructing 511 MW of

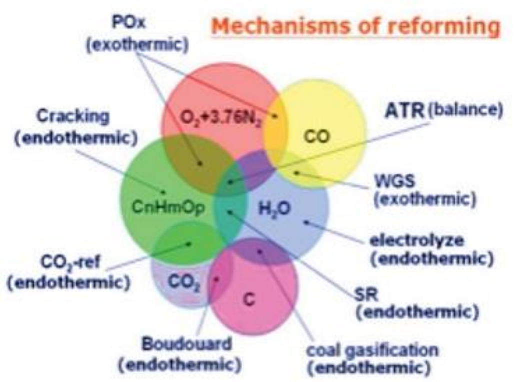
Vishal’s Torch : Microwave plasmas are warm plasmas. They have much higher electron temperature compared to DC or RF plasmas

Small scale, indigenous gasifiers which generate electricity from biomass are being built to treat agricultural biomass by a number of manufacturers. Converting them to plasma gasifiers would enhance their value because at higher temperatures, the gas component increases compared to liquid and char. Microwave torches would be ideal for such applications because of the high syngas component in the product gas as a result of the higher electron temperature.



From Klemen Ambrožič, Department of physics
University of Ljubljana
Seminar Ib - MICROWAVE STEAM PLASMA GASIFICATION

A major opportunity for plasma processing exists in the recently announced Hydrogen Mission. Because of the safety issues associated with Hydrogen storage, compact, portable Hydrogen sources is of great advantage in Hydrogen applications in transport. The performance target is Energy yield of 60 g(H2)/kWh (or 2US$ per kg of



WTE plants by for 2018–19 under the Swachh Bharat Mission (SBM).

hydrogen) in 2020. Natural gas reforming, reforming of ethanol and methanol from biomass can target 60 g(H2)/kWh.

In the case of distributed hydrogen production from gaseous fuels: gliding arc, and microwave discharges are the preferred plasma configurations. These are new types of plasmas that we must learn about. These can be based on fuel reforming reactions using non- equilibrium plasmas. Our knowhow on plasma pyrolysis will be of value here. Here too, plasma catalysis is a popular path for increasing performance parameters.

References

- The 2017 Plasma Roadmap: Low temperature plasma science and technology, I Adamovich et. al. Journal of Physics D: Applied Physics, 2017, 50, 32.
- Plasma technology – a novel solution for CO2 conversion? Ramses Snoeckx and Annemie Bogaerts, Chem. Soc. Rev., 2017, 46, 5805.
- Report of the Task Force on Waste to Energy, Volume (1), Planning commission May12, 2014, ChristosM. Kalamaras and Angelos M. Efstathiou, Conference Papers in Energy, 2013, Volume 2013, Article ID 690627
- Plasma physics of liquids – a focused review, Patrick Vanraes, Annemie Bogaerts, PLASMANT, Department of Chemistry, University of Antwerp, Universiteitsplein 1, 2610 Wilrijk- Antwerp, Belgium
- Report of the Task Force on Waste to Energy (Volume I), Planning Commission, May 12, 2014

Prof John's Contribution to Indian Tokamak And Fusion Program

Shishir Deshpande

Institute for Plasma Research, Gandhinagar

Prof. John's journey in plasma science started from Aligarh Muslim University, from where he moved to Physical Research Laboratory in 1972. This lab was already active in various exciting areas of plasma theory and experiments and so his transition to a more vibrant place contributed to the force of creativity. There is a great diversity and depth to his contribution over the years and I will restrict to tokamaks/fusion related activities only, while the other areas are being covered by the experts in the following sessions.

The vision of fusion research by Dr. Vikram Sarabhai had already made a deep impact on the scientists at that time and collective effects to convert those thoughts into action were visible. Energetic beams, HV systems, instability studies of toroidal systems bore the footprints of the dream. At last, the creation of an independent Plasma Physics Program by the DST in 1982 transformed the landscape of small experiments suddenly into a giant step towards fusion research. India was to build a tokamak, aptly named "ADITYA". A new team emerged. The large system was broken up into smaller sub-systems; each to be pursued from design-to-delivery, with Prof. John to spearhead the assembly and commissioning. New challenges emerged: drawing a huge power directly from the grid; manufacturability of vessel and components; power supply systems of the extreme kind; tight tolerances and getting people to coordinate with each other and deliver while residual uncertainties and risks remained very much visible.

The invitation to work as the head of the physics department in IAEA in 2002 turned another chapter in his fusion contributions. This section is the key player in fostering collaborations and oversight of various ongoing activities and especially the nodal point for the grand conference in fusion. The internal deliberations on how one can join ITER and what one can do were already afoot. In June 2005, India was invited to join ITER collaboration. There were many discussions on feasibility of supplying the systems that India could contribute in-kind. It seemed like an impossible task with the timescales and the unique specifications that were existing then. Prof. John was also a key contributor in steering the pre-ITER discussions, especially, bringing them to a focused deliverable. In order to harness the benefits from the collaboration, he created the idea of a National Fusion Program (NFP) framework which allowed Universities to participate in R&D on various small but focused needs of the fusion program at large. He continued to guide the ITER International Organization as a member in the ITER Management bodies like MAC and the ITER Council. During 2006-07, India was also invited to join the TBM collaboration. It was a challenge to provide the IO with a reviewable design, but it was done successfully in April 2008. Prof. John played an important role in the various committee meetings that led to the final outcome.

Prof John's Contribution to Plasma Technologies Developed at FCIPT

S.K. Nema & FCIPT Team,

Institute for Plasma Research, Gandhinagar

Today we are celebrating 80th birthday of Padmashri Professor Pucadyil Ittoop John who is the founder of Facilitation Centre for Industrial Plasma Technologies (FCIPT). This celebration is to express our gratitude to him for his contributions in Plasma Science and Technologies for the benefit of society.

My association with Prof John started since my Joining to IPR on 4th March 1993 at Plasma Processing Group (PPG) where he was the project leader. My first meeting was memorable, and he has expressed his worry towards Indian scientists that they are good to conduct successful experiments at laboratory scale however when it comes to deliver or demonstrate at large scale it becomes challenging. Further he added, therefore, the Indian industries do not believe us. My association with him was quite long and I could learn many things from him. He used to motivate us and push us to solve the problems by our own. He has written a thought-provoking book on “Plasma Sciences and the Creation of Wealth”. In January 2020 at the age of 79, he has visited Ankleshwar along with pyrolysis team to evaluate one MoEF & CC project on “Industrial Waste Disposal using Thermal Plasma” and travelled ~ 10 hours by road shows his keen interest and devotion towards plasma Science and Technology.

On his 80th birthday celebration function, I got an opportunity to present his contribution to Plasma Technologies developed at FCIPT. His contributions are significant in many technologies developed at FCIPT and I have tried to cover some of them.

1. Plasma Nitriding Technology

Plasma nitriding is an advanced thermochemical diffusion hardening process which was the first technology development work initiated by Prof. John at plasma processing group. Conventionally cyanide bath or ammonia gas nitriding processes are used which are environment polluting. In addition, cyanide bath technique provides non-uniform shallow depth of nitride layer. In plasma nitriding process the object that must be nitrided is made to be the cathode. The process is carried out at low pressure and at around 500^{0}C. Nitrogen and Hydrogen gas mixture plasma is produced using pulsed dc power source. The surface hardness increases typically 2-4 times. The case depth of a few hundred micrometre can be achieved. The improved hardness enhances the service life of the plasma nitrided components. This technology is an environment friendly and has been transferred to a few Indian vendors. During his tenure, a large capacity plasma nitriding system (Figure 1) was developed to nitride components like guide vanes etc. Prof. John has 5 patents on process and apparatus.

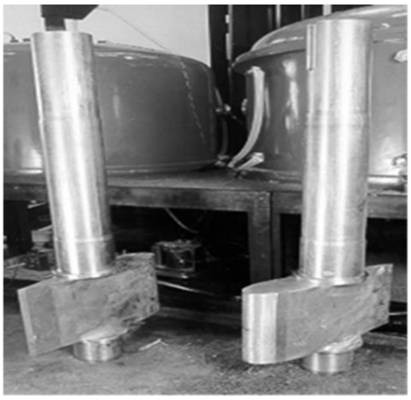


Figure 1: Plasma nitriding system to treat large components such as Guide Vanes

The progress of plasma nitriding has taken place in multiple steps and many scientists and engineers have contributed significantly including Prof. John:

- First Technology Transferred to M/s Indian Plasma System Ltd, Ahmedabad.
- Plasma Nitriding System developed and commissioned at M/s Metal Treat, Ahmedabad.
- Technology transferred to M/s Milman Thin Film Systems Pvt. Ltd. Pune
- Plasma Nitriding system commissioned at IGTR –Ahmedabad, CTR, Ludhiana
- Tech. Transferred to M/s Therelek Engineers Pvt. Ltd., Bangalore (recent).

2. Dissociation of Zircon Sand using Thermal Plasma

M/s C. S. Zircon Products Pvt. Ltd. Himachal Pradesh had approached IPR to explore plasma-based technology to dissociate Zircon sand. Conventionally, ZrO2 is produced by chemical route involves multiple steps and the process uses hazardous chemicals. The Zircon sand dissociation using thermal plasma into Zirconium oxide (ZrO2) and Silica (SiO2) is a single step process. At IPR, plasma plume was generated using 3 Graphite arc and sand along with nitrogen was fed into the plasma plume from the top. The sand got dissociated in high temperature plasma plume. Prof. John had an Indian Patent - A process for producing Zirconia (ZrO2) from Zircon sand (ZrSiO4).

$$ZrSiO_4 \longrightarrow ZrO_2 + SiO_2$$

3. Plasma Polymerization Technology

In his leadership, plasma polymerization process was developed using plasma enhanced chemical vapour deposition technique. Hexamethyl Disiloxane (HMDSO) precursor was polymerized in radio frequency plasma. Brass articles were coated (Figure 2) with glass like coating. This is an environment friendly technology has potential to replace lacquer-based coatings. Anti-reflection coating on solar cells was deposited changing the precursor. Subsequently, a plasma polymerization system was developed and commissioned at Metal Handicraft Service Centre, Moradabad through DST funded project. There are 2 numbers of Indian Patents have been granted to the Institute where Prof. John is one of the inventors.

Figure 2: PECVD process to polymerize HMDSO and SiOx coated brass components.

4. Teflon-Like coating Using PECVD

Getting fluorine based organic precursor gases were difficult because of their chemically hazardous nature. During one discussion in the evening, he gave an idea to use Teflon tailings which comes out from the workshop. Subsequently, the Teflon tailings were pyrolyzed and organo-fluorine precursors were generated. Using these precursors, Teflon like coating was deposited using plasma enhanced chemical vapour deposition. This novel technology was patented and subsequently used in IGCAR Kalpakkam projects.

5. Plasma Pyrolysis Technology

Conventionally, incineration technique is used to dispose organic and biomedical waste however, it releases extremely toxic compounds such as polyaromatic hydrocarbons (PAH), dioxins and furans. To solve this issue, a project to develop plasma pyrolysis reactor was submitted to TIFAC, New Delhi with Prof. John's initiatives. Subsequently, with enormous efforts the plasma pyrolysis technology was developed and demonstrated at GCRI, Ahmedabad. The technology was transferred to M/s Bhagwati Pyrotech Pvt. Ltd., Odhav, Ahmedabad.

Figure 3: N_2 Plasma torch and Plasma Pyrolysis System shown to CPCB

The first prototype system was commissioned at Goa Medical College, Goa through DST funding. The thermal plasma is produced using plasma torch or graphite arc system that disintegrates the organic waste into hydrogen, CO and methane.

Because of high temperature and oxygen starved environment, toxic molecules remain under the prescribed norms of Central Pollution Control Board or MoEF, Govt. of India. The nitrogen plasma torch and plasma pyrolysis system are shown in Figure 3. Prof. John has contributed to 2 patents granted to IPR on Plasma Pyrolysis Technology.

6. Angora wool and Triton valve projects

Use of non-thermal plasmas in textile has started in the year 1996 when Ahmedabad Textile Research Association had shown interest in smoothening the surface of jute fibre by plasma etching followed by coating the surface. The actual work on textile treatment using plasma has started when Prof. Jhala from NID, Ahmedabad had approached Prof. John for Angora wool surface modification. Dielectric plasma treatment was quite successful. The technology was transferred to M/s InspirOn Engg. Pvt. Ltd, Ahmedabad and 3 systems were commissioned in Himalayan region through DST funding. Figure 4

Figure 4: Atmospheric Pressure Plasma Angora Wool Treatment System at InspirOn

Concluding Remark

Prof. John has contributed significantly in various technologies and has shown us a path how we can benefit the society through our scientific and technological developments. Currently, at FCIPT, Atmospheric Plasma and Plasma Surface Engineering Divisions have taken the development work of technologies to different level. APD and PSED at FCIPT have developed various novel technologies such as plasma activated water, pencil plasma torch etc. for the killing of pathogens and cancerous cells. The plasma pyrolysis technology name has been included in MoEF's Gazette of India for the disposal of biomedical waste. IPR is developing 5 TPD system and contributing in 25 TPD plasma gasification system. IPR is working on radical nitriding and plasma carburising techniques.

References:

- Indian patent on " An apparatus for conversion of waste polymers into polymeric protective barrier coating" S.K. Nema, P. Kikani and P.I. John Patent No is : 195938
- Indian Patent :281257 on “Plasma pyrolysis system using novel endogenous gas source“– V.Jain, P.I. John, S.K. Nema
- Indian Patent 195943 on "Bootstrap Plasma Pyrolysis System" G. Prasad, S. K. Nema, Satya Prasad and P.I. John, 2002;
- A book on “Plasma Sciences and the Creation of Wealth” edited by P.I. John published by Tata McGraw-Hill Education, 2005
- Indian patent on " An apparatus for conversion of waste polymers into polymeric protective barrier coating" S.K. Nema, P. Kikani and P.I. John, Patent No is : 195938

Professor P. I. John & The National Fusion Programme

Ravi A V Kumar

Institute for Plasma Research, Gandhinagar

The National Fusion Programme (NFP) was the result of informal discussions amongst senior faculty members of IPR due to the need of collaborative research on areas related to plasma, its applications and fusion research. The need to tap the vast expertise and manpower available in the various Universities and Institutes across India to offset the lack of specific R&D expertise available at IPR was becoming important by the day, especially after India joined the ITER programme. In order to facilitate such a collaborative R&D, the NFP and the Board of Research in Fusion Science Technology (BRFST) was born. Professor John, who had by then, established FCIPT was the obvious choice to take the NFP and its various programmes forward.

In a short period of 10 years, BRFST and later, Plasma & Fusion Research Committee (PFRC) funded over 200 projects with a total budget of ~ Rs. 55 Crores in a verity of areas of R&D that were of prime interest to IPR's research goals. The beneficiaries of these funds ranged from Universities, Colleges, R&D institutions of CSIR, and Institutes like IITs and NITs across the country.

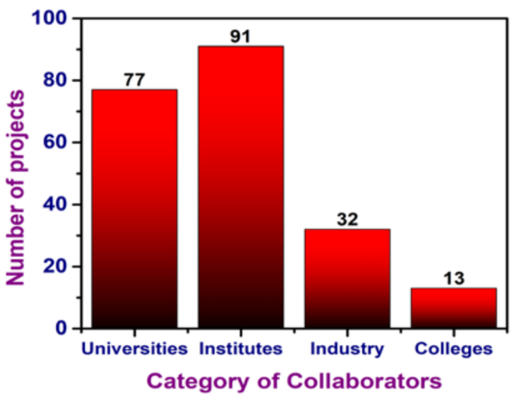
With India joining the ITER programme, the need for involving industry into R&D related to plasma & fusion was obvious if India needed to be self-sufficient in technologies related to fusion that were not available to us. A very bold move in this direction, spearheaded by Prof. John and strongly supported by the BRFST committee was initiated and for the first time in India, a government R&D funding agency was supporting private enterprises to carry out time bound, output-oriented R&D in very specific areas.

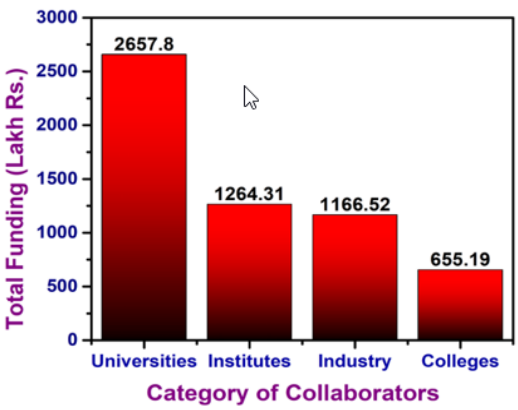
The key to a fruitful collaborative R&D programme was to ensure that BRFST did not repeat those things that collaborators were wary of with other funding agencies, such as humongous paperwork, delays in communications, not receiving satisfactory responses to queries by the collaborator, undue delay in disbursing the project funds etc. Professor John was clear that NFP should operate differently from other agencies. Over the next few years following 2007 and given a free hand to do so by Prof John, I was able to put in place, a simple but effective process which consistently ensured high level of interaction between NFP, the external collaborator and the IPR coordinator of the project, and most importantly, disburse the first installment of R&D funds to the collaborator's institution in less than 90 days of submission of the research proposal, something that was unheard of at that time.

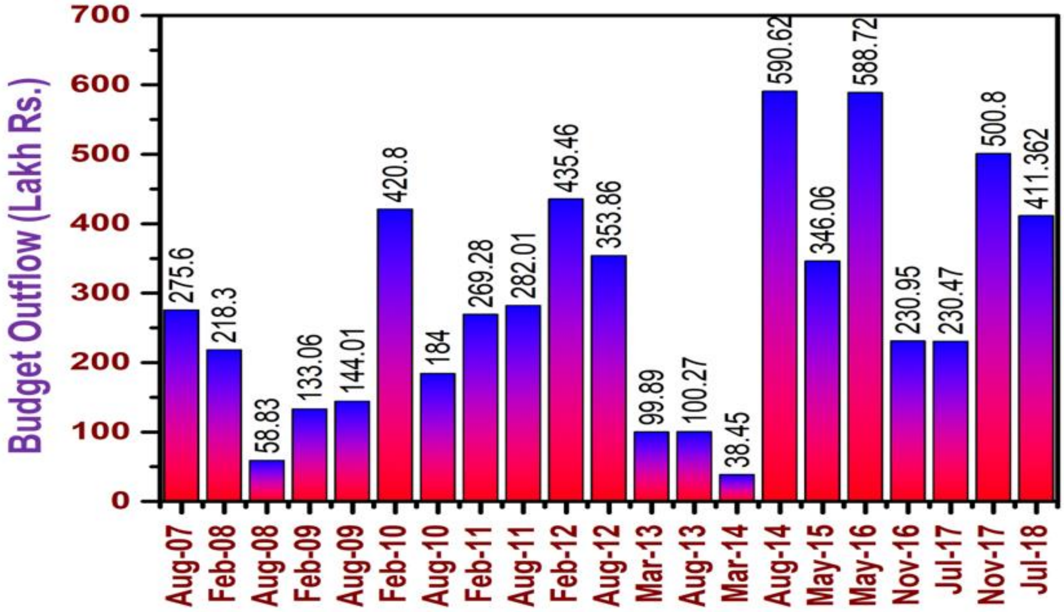
The next issue was to find the right collaborators from across the country. This problem was addressed in two unique ways by NFP. The first was to draw up a list of proposed projects from the various stakeholders at IPR and ITER-India and then conducting roadshows (followed by discussions) at major universities / IITs and NITs across the country, highlighting the areas where IPR required collaborations in R&D, along with those proposed project titles. Once an interested collaborator picked up a project that was of interest to them, the collaborator from IPR would hold discussions with them and NFP to formulate the project proposal. This yielded great results and faculty from over 40 institutions came forward and submitted research proposals in the same year*, i.e.,* 2007.

Prof. John always felt that there needed to be a strong synergy between the external collaborator, IPR coordinator as well as NFP so that the project could be executed smoothly. As the Member Secretary, I was given a free hand by Professor John to come up with a simple procedure for the operations of BRFST programmes. His advice to me was that I should spend ample time with every project right from its inception so that everything from the deliverables, optimizing the budget and timely execution of the project.

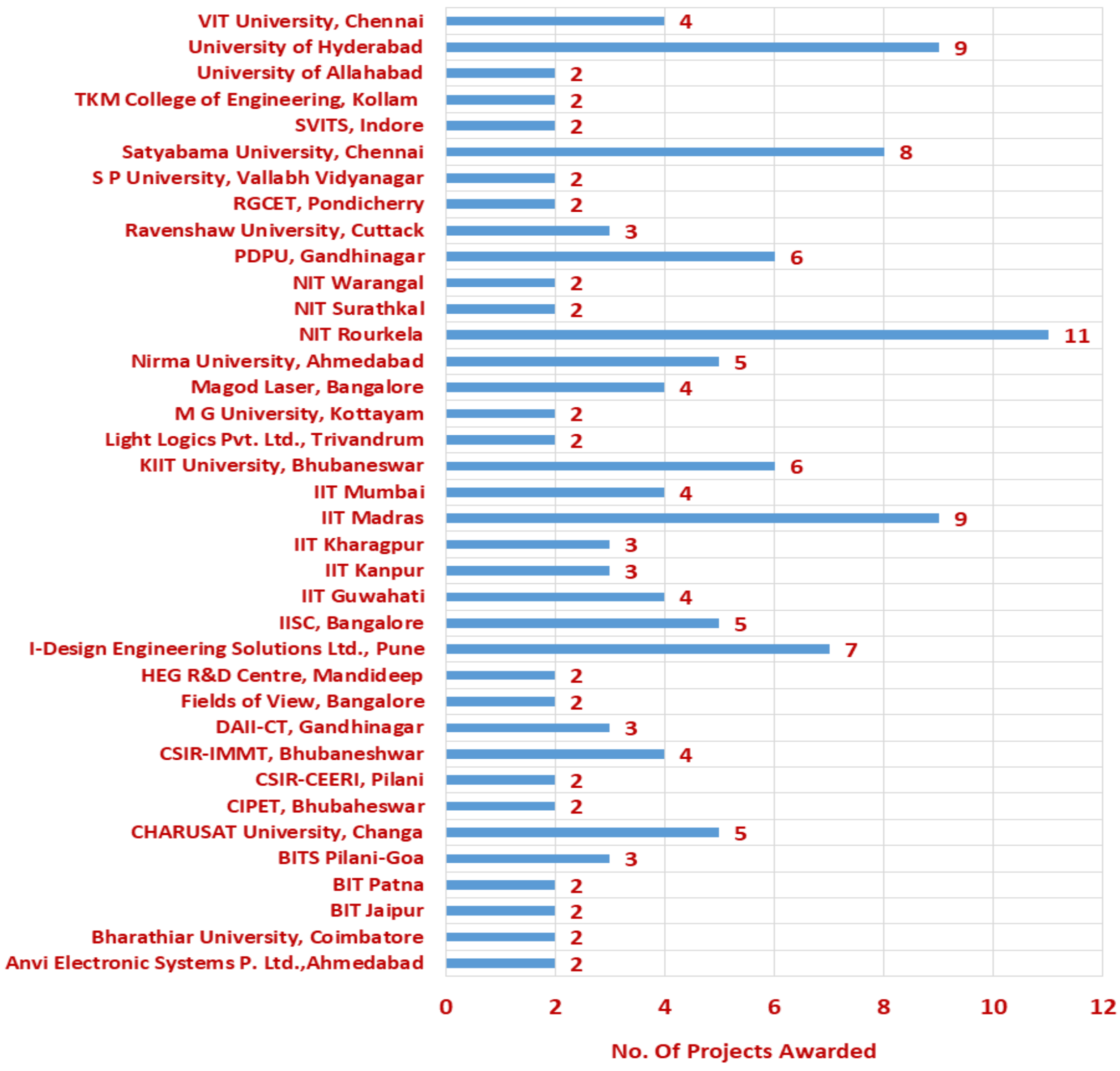
This not only boosted the confidence of the collaborator on NFP, but also ensured that the projects were on schedule, in both aspects of time and deliverables. Apart from R&D projects, Prof. John also felt the need to popularize NFP across the academic circles in the country and for this, he put forward several proposals such as supporting conferences in areas that NFP was involved in, partial financial support for project coordinator/project staff to attend international conferences to present data arising from NFP supported projects etc. Basic plasma based experimental projects were also actively supported by BRFST to encourage faculty at university levels to take up R&D in plasma. It was envisaged that this would foster growth of research groups working on plasma science & technology at university and college levels.



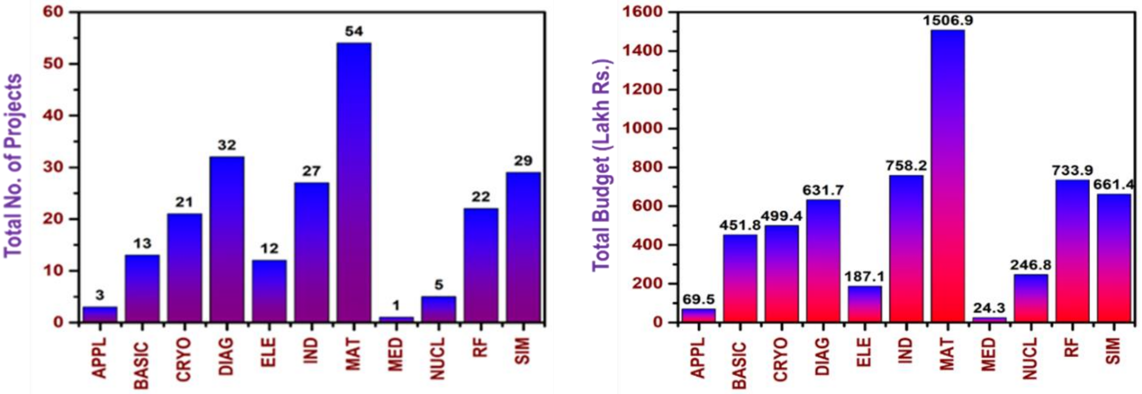




Budget Outflow (Lakh Rs.)
0
100
200
300
400
500
600
700
275.6
218.3
58.83
133.06
144.01
420.8
184
269.28
282.01
435.46
353.86
99.89
100.27
38.45
590.62
346.06
588.72
230.95
230.47
500.8
411.362
Aug-07
Feb-08
Aug-08
Feb-09
Aug-09
Feb-10
Aug-10
Feb-11
Aug-11
Feb-12
Aug-12
Mar-13
Aug-13
Mar-14
Aug-14
May-15
May-16
Nov-16
Jul-17
Nov-17
Jul-18



Receipients of 2 or more R&D Project Grants.
VIT University, Chennai 4
University of Hyderabad 9
University of Allahabad 2
TKM College of Engineering, Kollam 2
SVITS, Indore 2
Satyabama University, Chennai 8
S P University, Vallabh Vidyanagar 2
RGCET, Pondicherry 2
Ravenshaw University, Cuttack 3
PDPU, Gandhinagar 6
NIT Warangal 2
NIT Surathkal 2
NIT Rourkela 11
Nirma University, Ahmedabad 5
Magod Laser, Bangalore 4
M G University, Kottayam 2
Light Logics Pvt. Ltd., Trivandrum 2
KIIT University, Bhubaneswar 6
IIT Mumbai 4
IIT Madras 9
IIT Kharagpur 3
IIT Kanpur 3
IIT Guwahati 4
IISC, Bangalore 5
I-Design Engineering Solutions Ltd., Pune 7
HEG R&D Centre, Mandideep 2
Fields of View, Bangalore 2
DAII-CT, Gandhinagar 3
CSIR-IMMT, Bhubaneshwar 4
CSIR-CEERI, Pilani 2
CIPET, Bhubaheswar 2
CHARUSAT University, Changa 5
BITS Pilani-Goa 3
BIT Patna 2
BIT Jaipur 2
Bharathiar University, Coimbatore 2
Anvi Electronic Systems P. Ltd.,Ahmedabad 2
0
2
4
6
8
10
12
No. Of Projects Awarded



Areas of R&D

To bring on board collaborators from the industry to participate in R&D, their mindset itself had to be addressed as most of them were not used to operating in R&D mode. Prof John played a leading role in convincing industries to expand their expertise into areas that were new to them and were required by IPR in the long run. Many technologies that IPR currently has expertise in such as LN2 bubble panel heat shields, development of cryopumps, microwave diagnostics, tomography-based plasma diagnostics, Virtual Reality based training of tokamak devices, development of lithium blanket components, dissimilar metal welding techniques *etc*. have strong roots in NFP supported R&D projects awarded to academic as well as industry collaborators. Several patents also have arisen from NFP projects.

One of the mandates of NFP was manpower development and the Committee led by Prof John took special interest to ensure that the along with R&D, manpower development was also given prime importance so that when the country is ready to launch its own fusion power programme, we will have enough trained manpower available. One such encouragement was given to project research students to complete their PhD, by providing them with fellowship up to a year even after the project had officially ended. At post graduate levels (science & engineering), NFP offered Internships to students undertaking MSc/M.Tech courses to do their project work on areas mandated by NFP. Over 10 years, more than 200 students availed of this fellowship, which had become very popular amongst PG students.

Another aspect that Prof John emphasized was to conduct periodic discussions and subsequent updates of the goals of NFP and defining new thrust areas of R&D that needs to be supported. The idea of having theme meetings involving the collaborators was mooted by Prof. John in order to assess the progress of the several projects under a specific R&D area. This not only helped NFP provide a clear roadmap for R&D in that area, but also encouraged healthy competition amongst collaborators. Several such theme meetings were conducted and so also were regular visits by NFP representatives to laboratories where projects funded by NFP were being undertaken.

Professor John, with the support of the BRFST Committee members, was able to establish a robust, reliable and widely popular R&D collaborative project funding system that was able to produce several important deliverables that would go on to be useful to the long-term goals of IPR.

NFP / BRFST was indeed one of the major achievements of Professor John.

PFRC Committee members at the 3rd PFRC meeting held on 26 Nov 2016 at IPR (L-R) Dr. N. Ramasubramanian, Prof. P. K. Chattopadhyay, Shri. D. K. Dalal (BRNS), Dr. A. K. Ray, Prof. P.I. John, Dr. P. K. Atrey, Dr. Sangita (BRNS), Dr. Ravi A V Kumar, Prof. Amit Roy and Dr. T. Jayakumar.

Collaborators of BRFST/PFRC projects at the NFP-PFRC Vision Meeting held during 26-28 April, 2018.

(L) Last BRFST meeting, IPR (Aug-2014) (R) 1st PFRC meeting, IPR (May 2015)

Membrane Fission

Thomas J. Pucadyil

Indian Institute of Science Education and Research, Pune, India

Membrane fission or the division of a membrane-confined compartment is central to life. This process ensures that our cells can divide and form organelles, which in turn confines and coordinates cellular reactions in space and time inside the cell. Membrane fission requires the enclosing membrane around the cell or an organelle to be brought to close proximity, which from theory represents separation of 5 nm. Since cellular compartments are micron-sized entities, fission must follow a topological transformation of the limiting membrane into a highly curved tubular intermediate which is believed to then be acted upon by specific proteins. But membranes are elastic materials that resist bending and constriction and therefore such proteins have to overcome a significant energy barrier in order to manage fission. It is for this reason that such proteins are often referred to as catalysts.

The seminal discovery of paralysis in flies (a commonly used model organism in biological research) harboring a mutant of a protein called dynamin prompted a surge in research on membrane fission (Suzuki et al., 1971). Understandably so, since biology rarely provides such a graphic example where a complex neurological disorder like paralysis is linked to the function of a single protein among the 14,000 others present in flies. The cause for paralysis lies in the inability of the mutant dynamin to manage the fission-induced birth of synaptic vesicles. Without synaptic vesicles, neurons cannot dictate muscles to contract thus leading to paralysis in flies. Following this finding, numerous labs have tried to understand the specific chemical and physical attributes that have evolved and converged onto this one protein thus rendering it an expert in fission. Purified dynamin was shown to form ring-like assemblies in solution and to be capable of vesiculating artificial mimics of cells. The dynamin-catalyzed fission reaction has since been reconstituted on a variety of membrane templates using read-outs from light scattering, fluorescence microscopy and ion-conductance based approaches. Together, these efforts have unraveled three fundamental aspects about the protein; (a) that it binds and spontaneously forms 50 nm-wide helical polymers, (b) that polymerization triggers GTP hydrolysis (an energy currency in the cell), and (c) that GTP hydrolysis causes further compaction of the polymer forcing constriction and fission of the membrane. But as is the case with any active field, the community is still at debate on many aspects of dynamin in particular, and membrane fission in general.

Why does dynamin need to hydrolyze GTP for membrane fission? We know that GTP hydrolysis causes constriction of the membrane but how is this mechano-transduction of energy from GTP hydrolysis to forcing constriction managed in the polymer. It is likely that a series of segmental conformational changes in specific parts of the polymer ultimately affects constriction and fission. Recent data from monitoring conformation of different segments in the protein inform us of a power stroke-like movement in certain regions of the proteins to impose forces that constrict the membrane – a lot like how a catapult is released in one stroke. GTP hydrolysis could cause the release of the strain energy built up in the polymer. Further analysis of such models is a complex problem since one needs to estimate conformational changes in specific parts of a soft polymer with nanometer precision.

How universal is the dynamin paradigm? Dynamin follows a mechanism whereby the protein polymer utilizes GTP hydrolysis to constrict membranes. This paradigm however is built solely on monitoring the behavior of one protein. Unlike dynamin, fission has not been recreated even with other closely related proteins. Furthermore, the identity of catalysts that form several other compartments in the cell remain a mystery. Again, this is not a simple problem since complex organisms like humans encode about 20,000 different proteins and it would require a colossal effort to test which of these can catalyze fission.

To address some of these questions, assays that would allow a discovery-based approach to catalog proteins involved in the myriad pathways of fission in cells as well as reveal the specific mechanism by which these proteins function would therefore be required before we can truly appreciate the fundamental design principles of membrane fission (Pucadyil and Sedwick, 2015). The questions raised above are by no means trivial and require a community-wide effort, drawing from expertise in biophysics, molecular dynamic simulations, and cell biology. At IISER Pune, we meet these challenges by setting up assays that accurately report on the process of membrane fission. To facilitate both a molecular-level understanding of dynamin function and the discovery of novel fission catalysts, we have developed novel assay systems of artificial membrane templates that represent an array of membrane nanotubes resting on passivated glass coverslips which together allows for (a) the discovery of novel fission activity in cell lysates to expand the repertoire of fission catalysts, and (b) monitor reaction dynamics at the single fission event resolution and thereby inform us of mechanism. Given that these templates can be formed using standard resources available to most in the experimental community, we hope these assay systems would accelerate research into membrane fission.

While the past decade was dominated by structure-guided analyses of the workings of one fission catalyst, the coming years show the promise of vigorous research efforts into understanding dynamic aspects of membrane fission along with special emphasis on the discovery of novel fission catalysts. These developments should hopefully lay out a consensus mechanistic description of membrane fission, a process that is fundamental to life.

References

- Pucadyil and Sedwick (2015). Thomas Pucadyil: Piecing together membrane fission. J. Cell Biol. 211:720.
- Suzuki, Grigliatti and Williamson (1971). Temperature-sensitive mutations in Drosophila melanogaster. VII. A mutation (parats) causing reversible adult paralysis. Proc. Natl Acad. Sci. USA 68:890.

Toroidal Electron Plasmas: An Odyssey From 100 Microseconds to 100 Secs Confinement

Sambaran Pahari
Bhabha Atomic Research Center, Vishakhapatnam

This paper traces the evolution of toroidal electron plasma research in IPR and reviews the journey from a historical as well as contemporary perspective. The experiments pioneered in the late eighties has sustained over three decades through path breaking innovations and achieving several milestones drawing international attention and appreciation through peer reviewed publications. The experimental research well complemented by theoretical investigations occupy a pivotal place in the annals of Non- neutral Plasma Research and is continuing to flourish and mature.

1. Toroidal Electron Plasmas: Historical Perspective

Electron Plasmas belong to an interesting class of plasmas generically known as Non-neutral plasmas (NNP) as they are comprised of single species charged particles (electrons or ions) that exhibit rich collective behaviour [1]. In spite of the radial self-electric field of the un-neutralised charge cloud, such single species plasmas can be trapped over magnetic field lines or magnetic field surfaces. Typically, such low temperature pure electron plasmas are routinely confined in cylindrical traps popularly known as Penning-Malmberg traps [2]. In equilibrium, the electron cloud has a time-independent profile, and undergoes a self-rotation with all the electrons experiencing **EX B** drift, where **E** is the self-electric space-charge field.

Chronologically speaking, efforts to trap non-neutral plasmas in toroidal geometry preceded experiments in cylindrical traps. As early as 1970, NNP in toroidal configuration with pure toroidal magnetic field of closed field lines was considered as a promising application for producing high-Z ion source, heavy ion beam accelerator, inertial fusion, heating neutral plasmas using relativistic electron beam [3] etc. The neutral plasmas in toroidal assembly requires a complex combination of toroidal, poloidal and vertical magnetic fields to overcome the single-particle drifts (namely grad-B and curvature drifts). However, equilibrium theory [4] of toroidal electron plasmas, predicts that poloidal fields are not essential, since, in the presence of a toroidal B field, the E X B motion arising from the space-charge E field acts as an effective rotational transform. Yet toroidal electron plasmas, remained less explored, largely due to their poor confinement properties. It may be noted that cylindrical non-neutral plasmas are governed by robust confinement theorems that follows from conservation of canonical angular momentum. Experimentally these plasmas not only can be in steady state indefinitely but are also driven towards thermal equilibrium through electron-electron collisions [5]. In contrast, the toroidal counterparts, even while in stable toroidal equilibrium, are theoretically predicted to have limited confinement properties due to magnetic pumping transport (MPT). Proposed by O'Neil and Crook,[6] MPT arises due to ExB drifts of the plasma in a spatially inhomogeneous toroidal magnetic field that results in radial transport due to rapid expansion of the plasma.

Therefore, it was not surprising that with the initial experiments reporting poor confinement, efforts to trap such plasmas in toroidal geometries were largely abandoned. It was not until late eighties, that a group of theoretical and experimental physicists at Institute for Plasma Research, India (led by Prof P.I.John) revived investigation of such plasmas in a tight aspect ratio toroidal device, with two seminal Letters [7,8] that remain important milestones in the history of toroidal electron plasmas. The trap later underwent several innovative modifications and important upgrades resulting in efficient injection, complete control of instabilities and significantly improved confinement. The next few sections dwell on the brief description and important results from the SMall Aspect Ratio Toroidal Experiments (SMARTEX) in a toroidally Continuous and C-shaped trap.

2. SMARTEX-T: Device, Operation and Results.

The initial Small aspect ratio toroidal experiments at IPR were carried out in a low aspect ratio trap (R/a ~1.5) that was toroidally continuous (SMARTEX-T) with a pulsed magnetic field of few millisecond duration. The device is shown in Fig.1 (right). The plasma chamber is a torus with a rectangular cross section It produced electron plasma using inductive charging scheme in full torus with purely toroidal magnetic field [7], [8]. It also obtained potential contours in the poloidal plane confirming the inward shift of the charge cloud in toroidal magnetic field (Figure 1 left). The observed confinement time was limited to 250 μs. It proved the existence of the equilibrium even on tight aspect ratio of ~1.5 and equilibrium lasted longer than any other drift time scales in the system. Effect of radial electric field on this confinement was also investigated using high impedance Langmuir probe and found to shift the equilibrium towards geometric centre.

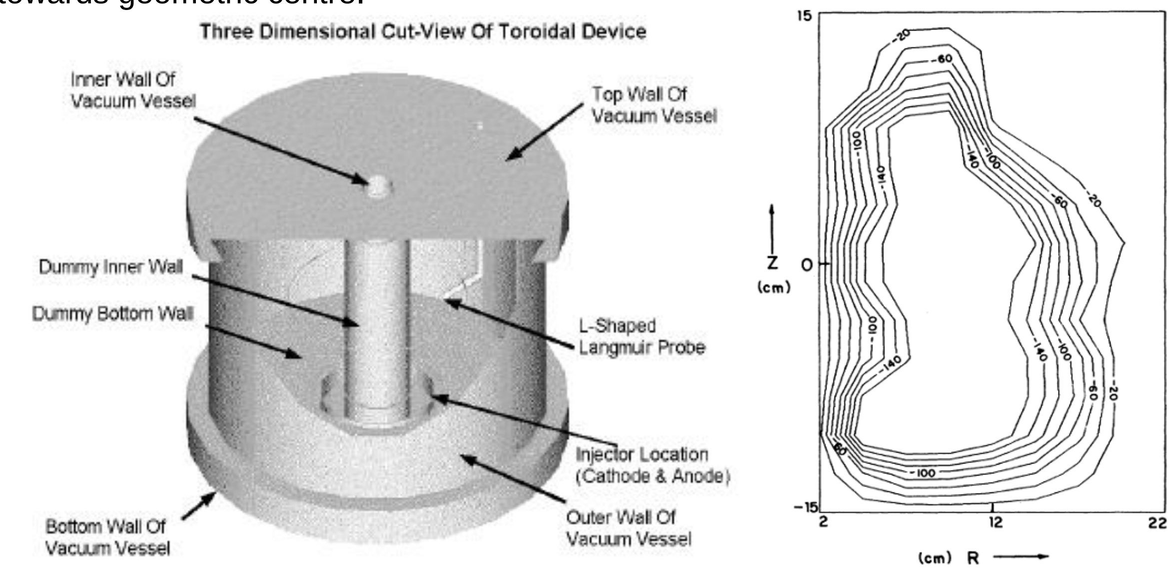


Fig. 1: (Left) SMARTEX-T device schematic and (Left) 2-D potential contours obtained using high impedance Langmuir Probe

3. SMARTEX-C:

Evolution, Design and Operation of a C-shaped Trap: The biggest limitation that inspired the concept of a C-shaped trap, was the inability of cross-field injection to build up a sufficient charge cloud in a small amount of time that would give it a robust E X B drift. Breaking the toroidal symmetry to introduce an injector assembly at a poloidal cross-section that would inject along the field lines was expected to circumvent the problem. An added attraction was the opportunity to place a collector at the far end of the C-trap that would allow to dump the plasma and provide additional diagnostic for charge measurements. In a sense, a C-shaped toroidal trap was similar to a Penning-Malmberg trap that would follow the inject-hold-dump sequence while retaining all the toroidal features. However, theoretical concerns about lack of equilibrium due to broken toroidal symmetry initially challenged such an idea.

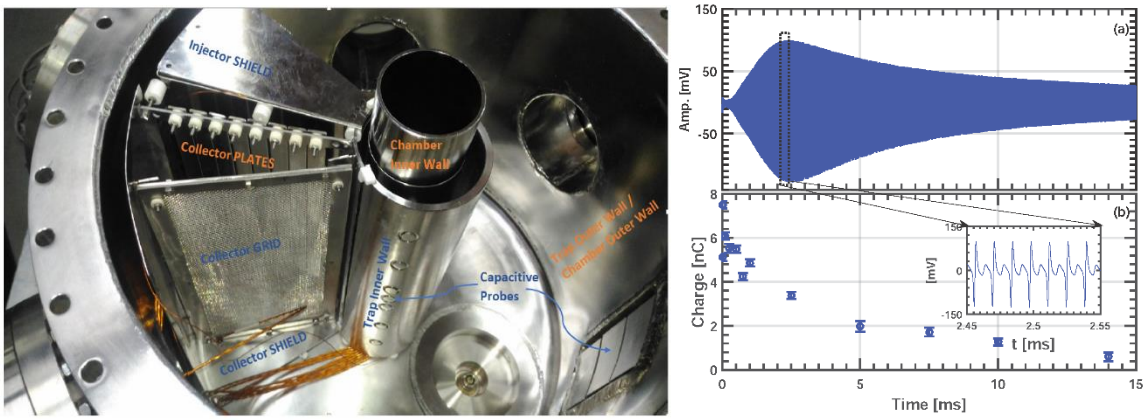


Fig. 2: (left) Photographs of inside view of SMARTEX-C and (right) (a) evolutions of capacitive probe signal and (b) stored charge in the trap, inset shows the zoom view of the double peaked oscillations.

The SMARTEX-C device is shown in Fig. 2 (left). It is maintained in ultrahigh vacuum conditions 10^{-7} to 10^{-9} Torr. A single circular tungsten filament loop, biased negative with respect to ground, placed on a poloidal cross section emits electrons thermionically. A grid injector placed in front of the filament is biased negative with respect to filament. Another grid – a collector – placed behind the filament in the poloidal cross section, is also biased negative. A toroidal magnetic field is established in the trap by pulsing a current through a multiturn field coil. As the *B* field reaches steady state, the injector grid is pulsed to 0 V, injecting along the field lines. Thereafter the grid reverts back to negative bias, ensuring no further fuelling. The injected electrons are now trapped toroidally between the negatively biased injector grid and collector grid and radially confined by the toroidal magnetic field. The rise time of the injector grid is about 30 ns and the fall time is within 100 ns. These times are well below the **EXB** times, but the fall time is comparable to the Trivelpiece-Gould transit time (~75-100ns) for the device. The relatively slow fall time is not important since the filament remains on, and the situation is analogous to the appearance of a barrier between two regions of a magnetic bottle that are already in equilibrium with each other.

Diagnostics: Principle diagnostics of the trap are capacitive probe (non-perturbative) and charge collector diagnostics (destructive) [9]. During the period that the plasma is held in the trap, the oscillations on the wall probes placed on the inner and outer wall allow a useful, non-destructive method of diagnosing the plasma. Besides mode structure, the duration of these oscillations gives an estimate of the lifetime of the plasma. Charge collector diagnostic is used to measure the total charge by dumping the plasma at predefined hold time onto the collector grid; many shots at different hold time gives evolution of total charge with time. Evolution of total charge stored in the plasma for the same parameters is shown in Figure 2 (right). In addition to this during quiescent state of the plasma, electron plasma density can be obtained by finding linear mode frequency of the externally excited m=1 diocotron mode using these capacitive probes. This also gives an estimate of the confinement time of the plasma.

Observation of Toroidal Diocotron Mode: Once injection is turned off, extremely coherent, periodic oscillations appear that gradually grow in amplitude and then decay, lasting right into the decay phase of the magnetic field (Figure 2 right). Oscillations have two alternating cycles with different peak amplitudes in a single period (inset view of Figure 2 right). These peaks, traced together, give the time evolution of the amplitude of the mode. Also, the inverse of the time instances of occurrence of these peaks gives a rough estimate of the frequency. The mode structure of these oscillations is investigated, through the simultaneous acquisition of signals from wall probes placed at different toroidal and poloidal locations, on the inner and outer walls of the trap. Cross-correlation of these signals also confirms that $k_{\parallel}=0$ suggesting that the wave activity that dominates the post-injection period is strongly flute-like in nature [10]. Linear to non-linear evolution shows the gradual appearance of coupled harmonics, a toroidal feature. Single particle trajectories have been used to simulate the image currents and heuristically reproduce the probe signals and their mode structure. All of these confirm that the mode is **E X B** drift phenomena of a toroidal vortex, like the well-known diocotron mode observations in linear machines [11].

Control and Characterization of Instabilities [12]. The growth in amplitude of the mode oscillations represent a destabilised diocotron mode. Experiments have been performed to delineate the growth rates of various instabilities. Ion resonance instability have been found to be primarily responsible. Energetic electrons (300 eV) emitted thermionically from filament can cause ionization of background gas via electron-impact ionization. In spite of the presence of negatively biased end-grids in the trap, ions born at room temperature (0.03 eV) can stay in the trap length of 75 cm for 500 µs before getting lost via the end grid. Ionization rate ($\nu^+ = n_n \sigma v$) at these electron energies and at typical pressures of $1\text{x}10^{-8}$ mbar is ~40 s^{-1}. The ion oscillation frequency trapped in the electron plasma potential well is 75 kHz (for $n_e \sim 1\text{x}10^6$ cm^{-3}) which closely resonates with the diocotron frequency 70 - 80 kHz observed in SMARTEX-C, making conditions suitable for the onset of the ion resonance instability. Observed growth rate of instability increases with pressure. To establish the role of ions, fractional ionisation was reduced by introducing He neutrals in the trap. With ionization cross-section of He nearly an order-of-magnitude less (He ~ 0.3 x 10^{-20} m^{-2}) the rate of ionization of He (ν^+ ~6 s^{-1}) is reduced by a factor of 6-7 (for 300 eV electrons at 1 x 10^{-8} mbar). Growth rates with He neutrals are evidently lower than that with N_2 for equivalent pressures. In addition to neutral pressures in the trap, a sufficiently strong toroidal B field helps in inhibiting the growth of instability triggered by any build-up of ion population. It is likely that the downward shift of mode frequency with increase in B shifts it away from the resonant ion oscillation frequency and assists in arresting the instability.

Steady State Confinement of Toroidal Electron Plasmas. The control of diocotron instability, achieved at higher B fields and/or lower background pressure, reduce the charge loss. This has been established through controlled experiments carried out under carefully chosen set of pressures and B fields and measuring the trapped charge present at different instances by dumping the charge onto a charge collector. The improvement in confinement in SMARTEX-C leads to a quiescent plasma; during this period, no electrostatic activity is observed on the wall probes. The presence of plasma under such conditions has been established by launching the mode. Wall probes, placed on inner and outer walls, have been used as exciter electrodes. The mode gets launched at the resonance frequency. Following linear theory, frequency of the launched m=1 mode is assumed to be related to the total charge (Q) trapped in the device. The frequency scaling with time, shown in Figure 3(left), gives us an estimate of the charge confinement. An exponential decay is seen with a characteristic decay time of 2.14 sec at trap pressures ~ 3.0 x 10^{-8} mbar and B field of 350 Gauss [12]. However, due to resistive toroidal field coils, current in the coils had a droop close to 35% resulting in steady drop of field over a period of 3 s. An upgraded TF coil and reduced B field allowed us to generate magnetic field with significant reduction in droop (< 1%) for a longer duration of B field (40 s). The significant improvement in confinement is visible from Fig. 3 (right). At 100 Gauss the confinement time is 109.4 ± 9.3 s. At 200 Gauss the time is nearly same (102.8 ± 18.9 s).

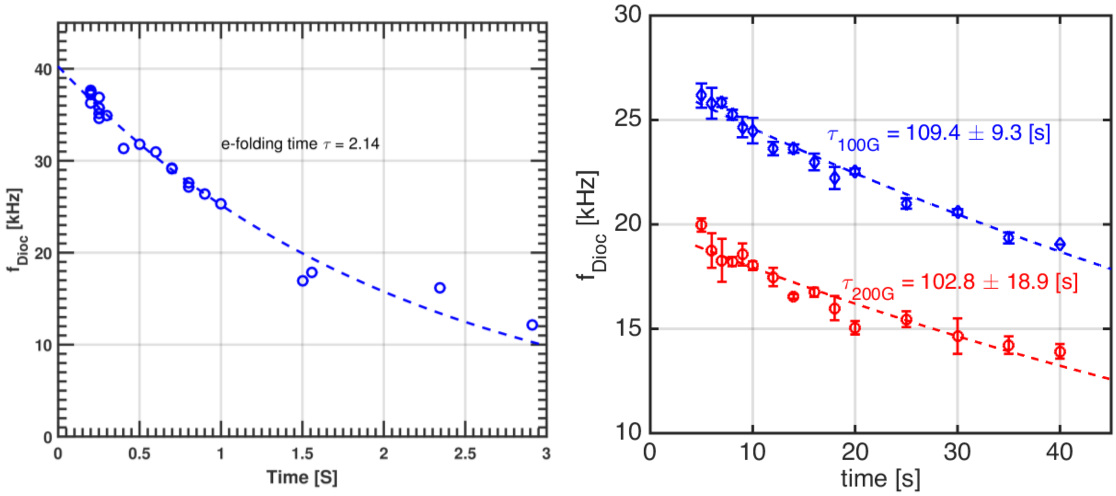


Figure 3 (left) Confinement time of electron plasma from e-folding decay of stored charge before up-gradation and (right) after up-gradation.

4. Future of Toroidal Electron Plasmas

Efforts to confine toroidal electron plasmas have stood the test of time and made significant strides in the last decade. With the recent results on confinement, the traditional transport theories have been put to test. Interestingly, the confinement time is independent of magnetic field strength suggesting that transport occurring could be due to magnetic pumping. But the confinement time scales far exceed that suggested by the transport theory for a typically 1-10 eV plasma even after accounting for the low aspect ratio of the trap. These confinement times are the longest reported and have breached the previous record by orders of magnitude. The device is being presently upgraded with a 500 sec steady state (less than 1% droop) magnetic field and additional getter pumps to consolidate the results. Additional diagnostics for temperature measurement are being developed.

Interestingly a series of contemporary large aspect ratio toroidal traps have also emerged in the last decade. A similar trap that strives to confine the plasmas on open field lines have succeeded up to 1 second, close to theoretical limit set by the transport theory. A stellarator has succeeded in holding the plasma for 100 ms on nested flux surfaces while one that employs dipole fields has achieved more than 100 sec [13]. Much of the recent motivation and interest in toroidal traps seem to follow from the possibility of creating electron-positron pair plasmas [14] due to the expected lack of instabilities in such plasmas and in view of their relevance to astrophysical objects. Amidst all this SMARTEX-C has a unique role to play as assumed incompressible nature of fluid is expected to break down in the presence of strong toroidicity. With recent advancements and promising results, it remains to be seen if thermal equilibrium can also be achieved in toroidal traps as in cylindrical geometries.

5. Tribute to Prof. P.I. John and his legacy

This paper is a tribute to Padmasree Prof. P.I. John and his manifold contribution to Experimental Plasma Physics, especially his pioneering contribution to field of toroidal electron plasmas.

The work presented here is a collection of contributions made by him together with his students, erstwhile colleagues and may others who joined later and have been associated with the experimental programme at different stages during its evolution. His early students Purvi Zaveri, Sameer Khirwadkar and Sambaran Pahari had the honour and good fortune to give shape to his vision. Theoretical work early on led by P.K. Kaw, Avinash Khare, S.N. Bhattacharyya and Hari Ramachandran went a long way in enriching the program. In later years the mantle of experiments has fallen on Lavkesh Lachhvani, Prabal Chattopadhyay and Yogesh Yeole who have turned this into a modern, state-of-the-art device. Several path breaking results have been reported from the device in recent times. The work is being sustained by us along with the latest entrant/student Nikhil Mohrule and is ably supported in theory by Rajiv Goswami, Sudip Sengupta and R. Ganesh,

The entire body of work has the hallmark of Prof. John's vision marked by innovative, out-of-box thinking and intuitive design. The legacy of Prof. John continues to inspire us, allowing the program to grow from strength to strength over the last three decades as it continues to flourish and make path-breaking progress in the ever-growing field of toroidal electron plasmas.

6. References:

[1] R. C. Davidson, *Physics of nonneutral plasmas*. Redwood City, Calif. Addison-Wesley, 1990.
[2] J. H. Malmberg and J. S. deGrassie, *Phys. Rev. Lett.*, **35**, 577–580, 1975.
[3] J. D. Daugherty, L. Grodzins, G. S. Janes, and R. H. Levy, *Phys. Rev. Lett.*, **20**, 369–371, 1968.
[4] J. D. Daugherty and R. H. Levy, *The Physics of Fluids*, **10**, 155–161, 1967.
[5] C. F. Driscoll, J. H. Malmberg, and K. S. Fine, *Phys. Rev. Lett.*, **60**, 1290–1293, 1988.
[6] S. M. Crooks and T. M. O'Neil, *Physics of Plasmas*, **3**, 2533–2537, 1996.
[7] P. Zaveri, P. I. John, K. Avinash, and P. K. Kaw, *Phys. Rev. Lett.*, **68**, 3295–3298, 1992.
[8] S. S. Khirwadkar *et al*, *Phys. Rev. Lett.*, **71**, 4334–4337 1993.
[9] S. Pahari, *et al*, *Review of Scientific Instruments*, **86**, 083504, 2015.
[10] S. Pahari, H. S. Ramachandran, and P. I. John, *Physics of Plasmas*, **13**, 092111, 2006.
[11] L. Lachhvani, *et al*. *Physics of Plasmas*, **24**, 102132, 2017.
[12] L. Lachhvani, *et al. Physics of Plasmas,* **23**, 062109, 2016.
[13] Yoshida, Z. *et al*. *Phys. Rev. Lett.*, **104**, 235004 2010.
[14] H. Saitoh, *et al*. J. Phys. Conf. Ser. **505**, 012045 2014.

Collaborators: Puravi Zaveri, Sameer Khirwadkar, Lavkesh Lachhvani
Institute for Plasma Research, Gandhinagar

On the Journey from FCIPT to Atal Incubation Centre

Nirav I. Jamnapara
Institute for Plasma Research, Gandhinagar

On this occasion of celebrating Prof. John's 80th birthday, it is a pleasure to talk about how his initiatives are becoming an important place for social and industrial transformation. Everyone is aware that the Facilitation Centre for Industrial Plasma Technologies (FCIPT) was a brainchild of Prof. P. I. John and he wished to see FCIPT as a sustainable centre working on technologies of relevance to industry and society. The uniqueness about FCIPT is that it was working on 'Market-to-lab' concept whereas most of the national labs were working on 'Lab-to-market' at the time when it was started. 'Lab to Market' flow is when the research labs develop a technology based on the interest of the scientists and when such technologies get mature, a search for 'user industry' is done by ways of commercialization. Such a concept was not largely efficient since it mostly depended on Govt. funds initially in development phase while the user agency was not involved during the conceptual phase. Furthermore, many a times, such technologies would go out of date by the time the scientists are ready for commercialization. Prof. John realized this and shaped FCIPT such that the 'user' agency or industry is right in place from day one of development. Thereby the need of developing a technology came from the Industry itself, and with industry funds (partly or fully) being invested in such research ensured that the industry continuously drives the need while the scientists try to nucleate an industrially or societally relevant technology. This concept also proved to be kind of win-win situation for both Industry and the research lab. The ultimate aim of Prof. John was to see that FCIPT nucleates as a sustainable not-for-profit company. FCIPT grew as it interacted and collaborated with various organizations including private company, research laboratories, public sector undertakings, universities etc.

In recent times, the policies of Government have been pro-business and sustainability and hence the importance of developing technologies in collaboration with industries has grown. With the programmes of the Government of India on 'Atmanirbhar Bharat', 'Make-in-India', '*Swatchh Bharat*', 'Startup-India', '*Namami Gange*' *etc*., many technologies developed by FCIPT have emerged as promising solutions.

As a part of the 'Statup-India' mission, the Niti Ayog has started '*Atal Innovation Mission*' which funds for setting up of 'Atal Incubation Centres' at various locations across the country. Such AIC would support the nucleation and growth of startups in India, thereby supporting the government campaigns mentioned above, especially '*Atmanirbhar Bharat*'. The Department of Atomic Energy (DAE) took this call and initiated the procedure to setup four Atal Incubation centres *viz.,* at BARC, IGCAR, RRCAT and IPR Gandhinagar on 30th October 2021. The AIC proposed to be setup at IPR will be located at FCIPT premises where the amalgamation of scientists, academicians, students and industry representatives can be done effectively.

Further, the location being in the industrial zone GIDC is an added advantage with fabrication expertise available at fingertips.

DAE has approved a policy of setting up the AIC at the above mentioned 4 centres, one of which is IPR. Such a centre has to be a non-profit centre under Section 8 or as registered as a Special Purpose Vehicle (SPV), as mandated by Niti Ayog. This centre will thus have the freedom to interact and act with aspiring entrepreneurs while working closely with the researchers at IPR. The processing and submission of the AIC documentation is in process and will be realized soon.

I'm sure Prof. John would be more than happy to hear this news as this would bring his dream idea closer to reality. He has been the source of inspiration for many, including me and will always be for future generations.

A few of FCIPT's customers/collaborators

MESSAGES FROM FRIENDS

Some thoughts on the occasion of Prof. John's 80th birthday celebrations

Prof. Abhijit Sen

Senior Professor
(Retired)
IPR

It is a great pleasure for me to be a part of this wonderful event celebrating the 80th birthday of Prof. P.I. John – my long-time colleague and a close friend. So at the outset, let me take this opportunity to first wish you John, a very Happy Birthday and Many Happy Returns of this Day. I would also like to congratulate and offer my good wishes to Mrs Minnu John – the person behind John's success and his inspiration in life!. Cake and flowers for you, Minnu and for you John, I offer a more traditional toast – Cheers!

Reaching the age of 80 is a landmark achievement for anybody – but to do that in such a glorious and trail blazing fashion is truly remarkable. Within the span of these four score years you have managed to pack in a lot of punch with outstanding contributions in science, technology, education and societal benefits. In your long and illustrious career you have made vital contributions in many areas of plasma science – ranging from space plasmas to fusion to basic plasma physics and also to the overall development of experimental plasma science in the country. From the first space simulation experimental device in PRL, followed by relativistic beam experiments, to BETA, to ADITYA, to SST and on to ITER – you have played a singularly important role in shaping our national programme in plasma science. Your pioneering work in setting up and nurturing the plasma technology programme culminating in the establishment of FCIPT has been truly path breaking. Over the years you have also trained and groomed a number of excellent students and younger colleagues who today constitute the leading edge of our scientific human resource. On top of all this you have led a very exciting and creative life. For all these wonderful achievements my heartiest congratulations to you and hats off to you.

On a personal note, I have had the privilege of knowing you for more than half of those eighty years – 47 years to be precise! – So we do go back a long way. As I think back today, I find this long association to be a treasure trove of wonderful shared experiences and one that has considerably enriched my life. As a colleague not only have I benefited from our scientific and professional interactions but I have also immensely enjoyed our friendship and fellowship over all these years. It wasn't always an easy task to become friends with you ☺ – your public image in the early years at PRL – was that of a man of few words and not given to much socializing! In fact you came across as a very intense and serious young man! In later years your beard afforded an even more formidable shield behind which you hid your real persona! It has been my great good fortune to have had an opportunity to discover the host of talents that you hid behind your quiet exterior. That opportunity came through spending several hours with you while commuting to work in the same car, on our many travels together on scientific trips both within and outside the country and while working jointly with you on various committees and projects.

One of the first things I remember of those early days is how our conversations used to be in short bursts – a long question or statement from me and a very short answer from you – after which a long pause while I am racking my brain to figure out what to say next. You were indeed a man of few words but - as I gradually realised - you used to choose your words very carefully and you did not need too many words to express yourself. You did not waste your breath on unnecessary verbiage. But what you said made eminent sense and was also very aptly put. This is a quality you have retained to this day – no old age garrulity for you – and a quality I have come to appreciate and admire a great deal. It reveals the clarity of your thinking process and the enormous discipline you exercise in expressing your thoughts. It also discourages any frivolous debate!

As a scientist you also have a very original and unconventional way of looking at things and arriving at a very intuitive and physical understanding of a phenomenon or an experimental result. This became very apparent to me when you visited me briefly at MIT while I was spending a sabbatical year there. This was at the time when we were contemplating starting our fusion program and a tokamak device was very much in our thoughts. You were not into Tokamaks then. You had mostly worked on basic devices and pulsed beam experiments at PRL. However when we went to see the Versator tokamak device – a simple tokamak that had been assembled and was being operated by graduate students - you became immensely excited and interested. Your probing questions and careful scrutiny of the device really impressed the Versator team. In subsequent discussions with me and later with Predhiman at Princeton you showed an uncanny understanding of the physics of tokamak operation although the language you were using to describe this toroidal `discharge device' was quite unconventional! Your physical insights and innate grasp of the engineering complexities came into full play when you started designing an early version of a tokamak after we had received a go ahead from DST. It is a pity that this early design was not adopted.

As our friendship grew and my understanding of your personality deepened, our conversations and discussions flowed more freely. They were also not restricted to just our research or office matters but ranged over a large number of topics. That is when I discovered the breadth and variety of your interests in life and the wealth of your hidden talents. Your fondness for books and reading found an immediate resonance in my heart and I enjoyed our many discussions centred around various books and literary readings. Like you, I too am fond of reading Indian authors writing in English and I remember our discussions on Arundhati Roy's `The God of Small Things'. I had read the book some time ago and was somewhat critical of her writing style when discussing with you – possibly because of some of her later writings which were in the form of political pamphlets. You gently disagreed and pointed out some of the strong points of her writing – particularly her power of descriptive narration. Thanks to our discussion I went back to the book and rediscovered the beauty of her language and her human insights. I was impressed by your ability to distil the beauty of her writing that was free of other considerations.

I was not aware of your interest in classical western music till one day you lent me a book by Aaron Copland – the famous American music composer and critic. While I was fond of listening to some of the famous symphonies and orchestral compositions I had no musical knowledge or training in Western classical music. Copland's book made me aware of the basic grammar of western classical music and how to enjoy some of the finer aspects of it. So music became one more topic of our mutual discussions and I soon learnt of your eclectic taste in it that extended from Beethoven all the way up to A.R. Rehman in modern times. Books, movies, music provided us with endless topics of discussion and made our daily car rides to work a very enjoyable experience.

Painting was another passion of yours that enthralled me as I watched you engage in it over the years. Your gracious gift of one of your works of art has adorned my study for many years providing a glimpse of the vision of your inner eye for capturing the beauty of nature.

Another topic that fascinated me was the Syrian Christian Church and the Syrian Christian community of which you were an active and enlightened member. Having studied in a Jesuit school I had a fair bit of knowledge about Christianity – particularly of the Catholic Church – so I was very curious to learn about the other branches of Christianity. Your detailed descriptions about the history and evolution of the Syrian Church in India and the cultural dynamics of the small Syrian Christian community kept me enthralled for many a session of our car rides. I was very impressed by the achievements and dynamism of this close knit talented community that has made so many worthy contributions in diverse areas of activity in our country. I also saw the pride you took in belonging to this community – not in the sense of a narrow religious identity – but in a broader context as the roots of your cultural heritage.

To me such solid cultural moorings struck me as the source of another one of your stellar qualities – one that I admire a great deal – namely a profound sense of self-confidence and independence of thoughts. In all your professional pursuits – whether it was basic research or technology development - you never looked to the West for approval or recognition but always chose to find your own path. This supreme self-reliance has been the hallmark of your style and personality and earned you the respect of all your colleagues and friends. To put it in one word you have been the epitome of `atma-nirbharta' – long before this term became a political buzzword!

But for me you are much more than that. With your many talents, your varied interests in life, your erudition and your sensibilities and the way you have led your life – you are a perfect example of a **Renaissance Man**!

So, let me end by expressing once again my great appreciation for your friendship and for your enriching contributions. You have been an inspiration to many of us. I hope you will continue to remain just as active and creative as you are today as you march towards the century mark! My best wishes to you and Minnu for many happy and healthy years together.

Professor P. I. John has been an inspiration to the entire group of Students and professionals working in the area of Experimental as well as industrial Plasma Science for the last five decades. Personally, I have been a great fan of Prof. John ever since I first met him at his PRL Plasma Lab. And the admiration continues. My Felicitations Sir, on attaining eighty years, and prayers to the Lord to keep blessing you with long life, good health and happiness. Please continue to shine for the young plasma scientists as ever.

Dr. A. K. Das

Vice Chairman,
Odisha State Higher Education Council (OSHEC)
Manipal Academy of Higher Education, Manipal

Seriously, Prof John had an illustrious career, as a scientist, technologist, innovator, organizer, coordinator and administrator (may be a few more). I am sure many of his admirers will be able to highlight his contributions.

Eightieth birthday marks an important milestone and it is often represented as The Man Who Has Seen Thousand Moons. I wish Prof John a Happy Birthday and a very happy and healthy life. I do hope to wish him on his hundredth birthday too.

Dr. N. Venkatramani

Senior Professor (Retired) BARC

John is an experimentalist par excellence. He and I have collaborated on a number of problems related to non-neutral plasma, dynamic sheath expansion etc. What I appreciate about him is his experimental clairvoyant reasoning by which he quickly arrives at the answer to complex problems. John, I wish you the very best for good life and health.

Prof Avinash Khare

Vice Chancellor Sikkim Central University, Gangtok, Sikkim

Happy Birthday to distinguished octogenarian Professor John.

Thanks for your continued support to enhance research activities in the universities and colleges in the country.

Best wishes for happy long life along with your family.

Dr. K.P. Maheswari

Former Professor of Physics, DAVV Indore; Guest Faculty, University of Kota

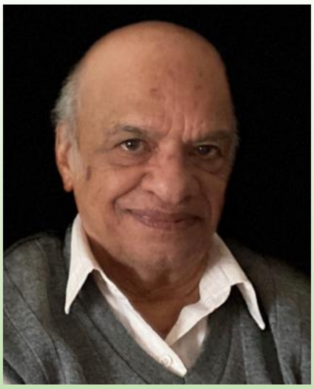
I have known Prof. John since 1972 when he joined PRL and we started an experimental program in Plasma Physics there. Our association has continued since then.

On the occasion of his 80th birthday I wish him a very happy birthday and many happy returns of the day.

Dr. Y.C. Saxena

Senior Professor (Retired)
IPR

Dr P.I.John, reached the summit of excellence in every one of the multifarious activities he undertook such as: arts, science, scientific team building, science administration, book authorship, among many others. In spite of having received highest recognition for his accomplishments in pulsed power, plasma and fusion research nationally and internationally, he has remained an outstanding human being: simple, loving and caring.



Dr. Prahlad Ron

Yoga Teacher and Ex. Head APPD, BARC

I feel proud and honoured to have known and interacted with him since his formative years at PRL from 1970 onwards. I am sure that his CREATIVE BEST will continue to unfold for the benefit of the society.

Wishing Professor John many happy returns of the day!

Dr. Sangeeta

Retired Scientist, BARC & Former, Scientific Secretary, BRNS, DAE

Besides being a very successful Plasma Physicist he is a Plasma Technologist par excellence. Aditya Tokamak and FCIPT are testimony to his design, development and management skills. Both of the facilities play a unique and indispensable role in Indian science and technology scenario.

Dear Prof. John, I and my family wish you a very happy birthday and pray that you remain active and healthy for many more years.

With warm and respectful regards, eagerly waiting for your future blogs.

Dr. Asish Kumar Ray

Former Raja Ramanna Fellow and Director Beam Technology Development Group

During the student days at IPR, I interacted very rarely with you. My interaction with you started with myself joining Plasma processing group as post-doc. I got an opportunity to work with you for almost eleven years in FCIPT. Those days are really memorable in my life till now. You are good mentor.

I will be finding short of words to describe my interaction with you. Please accept my best wishes on your birth day.

Dr. K.S. Ganesh Prasad

Director, SRTS Pvt. Ltd
and
Professor, Institute for Advanced Research

I have learnt a great deal about project formulation, its technical assessment & management during the 10 years that I worked with prof. John for NFP. I have also tried to adopt Prof. John's excellent work ethics. It was indeed a pleasure working with him.

I wish Prof. John many more years of happiness and good health. Will certainly look forward to reading more of his blogs and poetry!

Dr. Ravi A V Kumar

Head, Outreach Division, IPR

My first meeting was memorable and he has expressed his worry towards Indian scientists that they are good to conduct successful experiments at laboratory scale however when it comes to deliver or demonstrate at large scale it becomes challenging. Further he added, therefore, the Indian industries do not believe us.

My association with him was quite long and I could learn many things from him. He used to motivate us and push us to solve the problems by our own.

I wish you many happy returns of the day on your 80th birthday and good health in the coming years.

Dr. S. K. Nema

Head, APD
IPR

Congratulations and best wishes on completing 80 eventful years, Prof. John. The growth of Plasma Physics research and its application in the country owes a lot to your sustained efforts. Working with you in BRFST was a great educating experience for me. Thank you.

Prof. Amit Roy

Adjunct Faculty,
Manipal Academy of Higher Education,
Manipal

I have known Prof John for nearly four decades now and over the years, I have come to know him as a person of vision, who made great efforts to promote research and teaching of plasma physics in universities and colleges around the country. His vision also extended to the application of various plasma technologies to the

Dr. Ashish Ganguli

Emeritus Professor
IIT Delhi

It was with his initiative and leadership, FCIPT came into existence. Prof John's scientific and experimental acumen was no less. Under his guidance the first relativistic electron beam machine was built in PRL and the first experiments on nonlinear waves (solitons) were carried out. Subsequently, he played a stellar role in the setting-up of IPR and the building of the first Indian tokomak, Aditya.

On behalf of my colleagues in the Plasma Lab at IIT Delhi, I would like to wish Prof John a very happy birthday and we all wish him a long, happy and healthy life ahead.

Dear Prof. John,

Wish you many happy returns of the day.

Here's a toast to your life and times that continue to inspire a generation of plasma physicists, experimentalists and scientific entrepreneurs. The one lesson that I learnt from you is to view every achievement and accomplishment, as not the pinnacle of success, but just the turning of a new page. That is the reason perhaps, away from the hustle and bustle of scientific endeavours, your creative indulgences have not ebbed.

May you continue to regale us with all your intellectual pursuits as you continue to live a happy, healthy and prosperous life amidst all your loved ones.

Warm regards to You (and Ma'am),

Dr. Sambaran Pahari

BARC, Viakhapatnam

MESSAGES FROM STUDENTS

Hearty congratulations on completing 80 years!

Wishing you a very long and healthy life!

May all your wishes get fulfilled and you have a joyous life!!

Dr. Puravi Zaveri

Associated with Gujarat Vishvakosh Trust

He is man of many qualities. He is a leader, expert in setting-up plasma laboratories & plasma technology, known for plasma processing in India, man of few words and more actions, sincere & hard working, author, painter, poet, good human being etc. A remarkable journey by him i.e. school & college education in Kerala to Ph.D. from Aligarh Muslim university in U.P to scientist at PRL & IPR in Gujarat to Padmashri award from government of India.

I wish Prof. John a very happy 80th birthday and many more years of healthy & active life!

Dr. Kamlesh K. Jain

Shimadzu Research Laboratory (Europe), Manchester, UK

Prof. John, Very happy to be a part of this celebration and wishing you a very happy 80th birthday. When I started my doctoral work at PRL, you helped a lot in finding the right path. Even though I no longer do any Physics research work, your methodology and the training you provided was useful for my current job in the area of computing credit risk exposures for financial trading products.

Dr. M. K. Vijaya Sankar

New Jersey, USA

Prof John - you are my "Scientific Guru".

I learnt from you how to think like a scientist and how to lead a team.

It was a privilege to contribute towards development of FCIPT.

Dr. Subroto Mukherjee

Senior Professor,
Head – LIGO Division,
Former Head –
FCIPT, Division, IPR

My association with Prof. John goes back to 1982 when I joined under him for my Ph.D. I feel proud and privileged about this association.

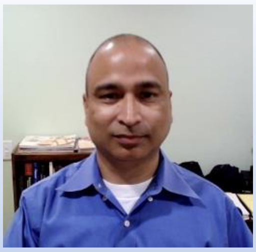
I regarded him as someone who knows the right knob to twiddle if something wasn't working the way it should. In my opinion he is an experimentalist par excellence! I noticed about him are the meticulous planning and disciplined approach, the hallmarks of Prof. John.

I wish him many more happy, healthy and purposeful years with his close family, relatives and friends.

Dr. Chenna Reddy

Former Senior Professor, IPR

Happy 80th Birthday! It is an honour to have you as a guru. Thank you for not providing the answers, but teaching me how to find my own. Whenever I got stuck or confused, a short meeting with you was good enough to put me back on track. Thanks for your humility and guidance. Many of your spoken words and actions are still with me. You will continue to inspire and motivate me forever. On this special day I wish you sound health and happiness for a lifetime.



Dr. Deepak Gupta

Lead Scientist
TAE Technologies, Inc.
Foothill Ranch, CA, USA

Prof. P.I. John symbolizes a true Philosopher, a source of immense Inspiration; and a judicious person in all walks of life. I feel very much privileged to have him as my thesis advisor.

He took the failure and success in the same spirit: Out of the box problems fascinated him, and there was no overlapping of research work done by their predecessors.

I learned from him, that Limitation was the source for invention! He has a tank full of un-conventional ideas to challenge any limitations..

His philosophical observation towards a problem was quite unique. Next, always ready to take challenge and come out from comfort zone. Get people under you motivated to get the jobs done.

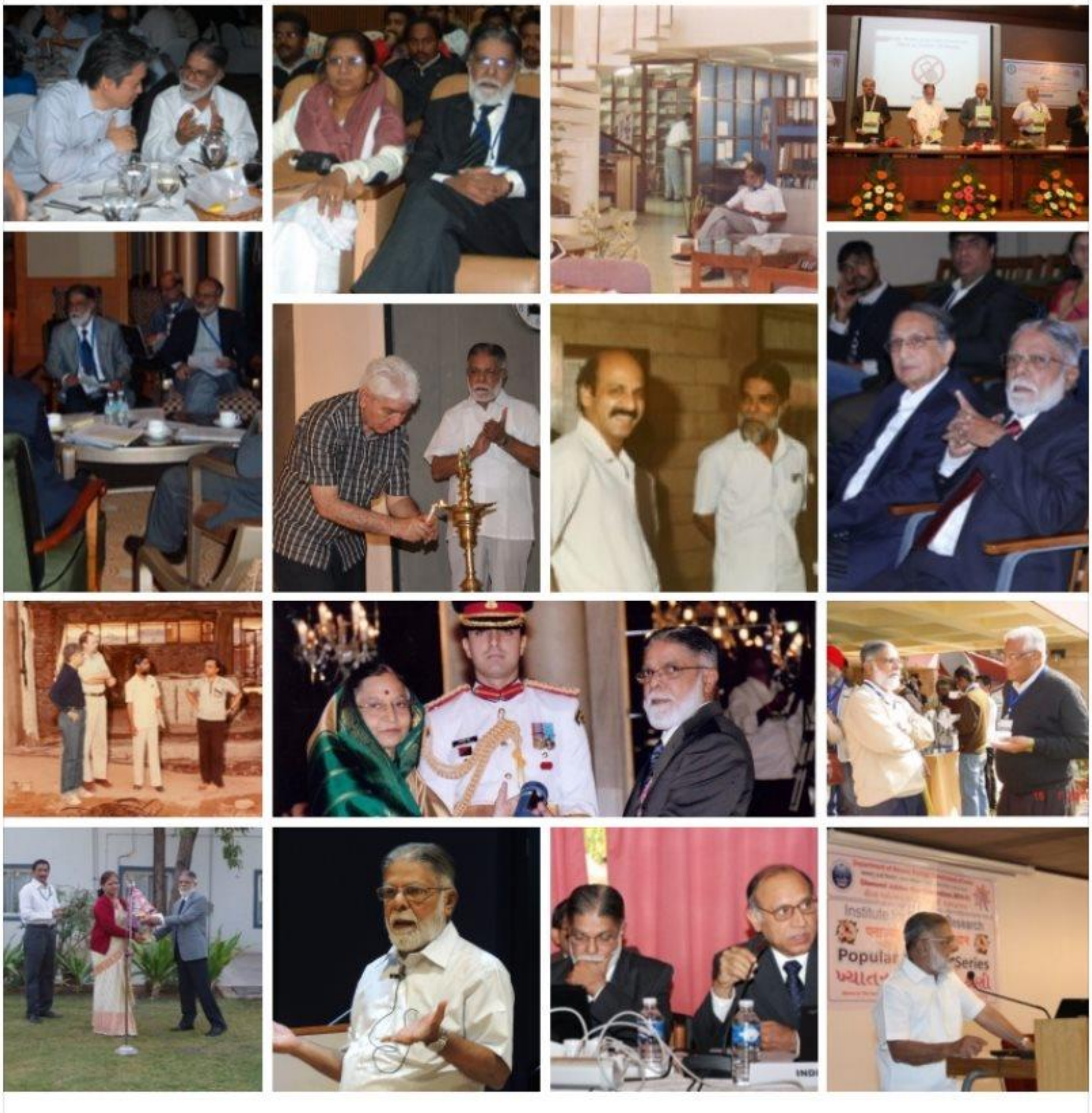
On his 80th birthday, I wish him a very happy and healthy life ahead!

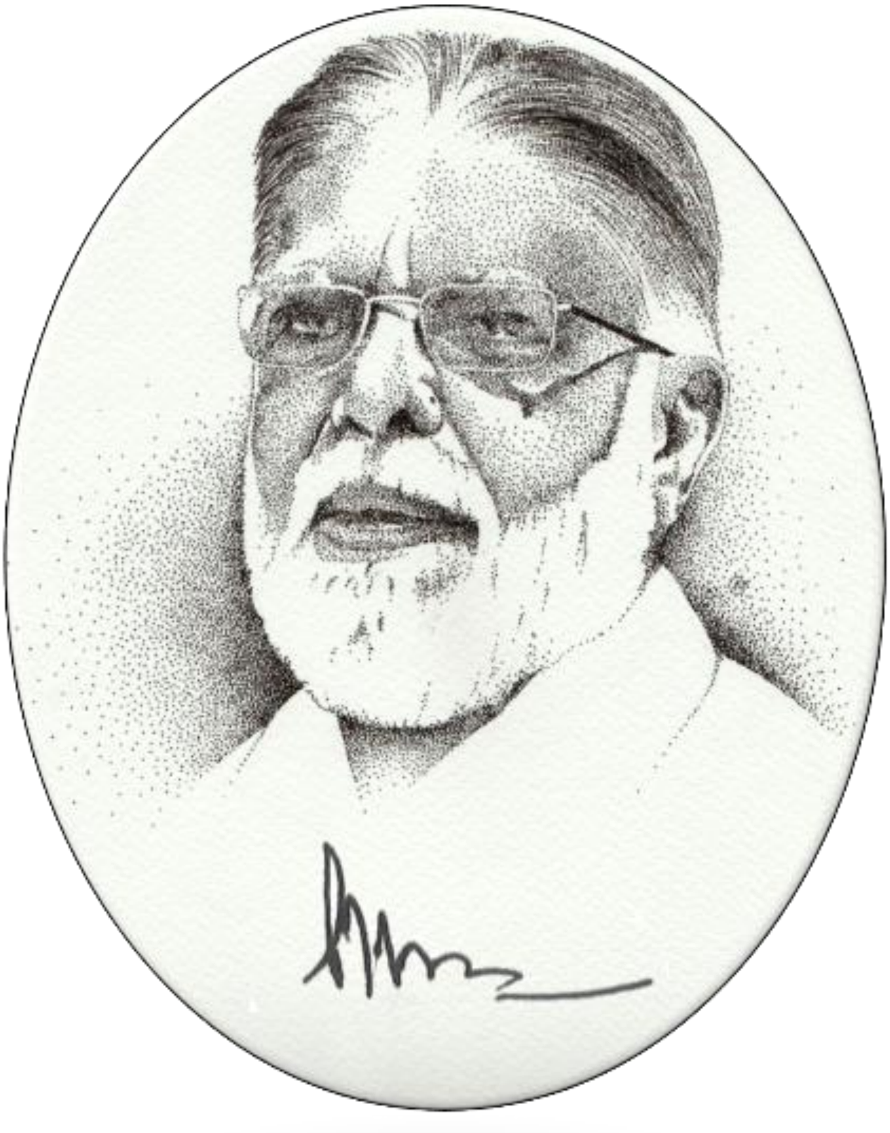
Dr. Shantanu Kumar Karkari

Associate Professor-F
Head, Magnetized Plasma Development Section, IPR

Happy 80th Birthday

We Wish You Even More Happiness And Good Health In The Coming Years!





Sketch by : Narendra Chauhan