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JOURNEY OF AMARJIT SINGH FROM PHAGWARA TO PILANI

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—Dedicated to Dr S.S.S. Agarwala—

An Introduction with an Apology from the Author for Digressions

My association with Dr. Amarjit Singh (AS) and CSIR-CEERI Pilani goes a long way back in time when I was employed briefly as Scientist-B at CSIR-CEERI (19th September 1977 - 28th July 1978). At CSIR-CEERI, I was fortunate to be a member of the team led by Dr. S.N. Joshi, under the overall guidance of Dr. S.S.S. Agarwala¹, that was credited with developing the first-ever travelling-wave tube (TWT) in India. Motivated by AS and with support from Dr. Agarwala, I undertook the task of measuring the AM-to-PM conversion coefficient of the TWT with Dr. Joshi. It was an honour for me to learn that the measured value, based on the data which Dr. Joshi and I had collected, helped AS to obtain for CSIR-CEERI Pilani the project of developing TWTs for ISRO. Professor OPN Calla provided the support of ISRO to CSIR-CEERI through a project on the development of a ground-station TWT for ISRO. Dr. Surendra Pal, similarly, supported CSIR-CEERI in initiating a project on the

development of the first ever space-TWT (C-band) at CSIR-CEERI for ISRO; he associated me with a review committee for the project.

While at CSIR-CEERI I also worked on the electromagnetic analysis of helical slow-wave structure (SWS), the outcome of which was documented as research work in two of CSIR-CEERI's internal reports in quick succession. For one of the reports, Dr. Joshi was my co-author^[2,3].



Dr. Amarjit Singh (Director) demonstrating the Black & White Television developed by CSIR-CEERI at Prime Minister Smt. Indira Gandhi's residence

¹In addition to this article, I have dedicated one of my earlier works a book titled Technical Writing ^[1] also to Dr. Agarwala

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Besides this, I did not have other publications then in related areas. It was thus that Dr Agarwala was taken by surprise when I was invited by AS to deliver a preparatory lecture on Pierce electron gun as a primer to the lectures series by the eminent scientist Dr. J.R.M. Vaughan of Litton Industries at CSIR-CEERI. That I had worked on electron gun was not evidenced by any of my publications so far, and Dr. Agarwala's surprise was justifiable given that. Incidentally, I also got an invitation to attend Dr. Vaughan's lecture series, whence it was my turn to be surprised to find that Dr. Vaughan held in his hand my handwritten lecture note! He had chanced upon the note in the drawer of a table in the dining hall of the CSIR-CEERI guesthouse, and to my gratification, I noted that he used the note extensively during the delivery of his first two lectures of the series.

My next close association with CSIR-CEERI was as a Distinguished Visiting Scientist of CSIR at CSIR-CEERI while I was serving at Electronics Engineering Department of Institute of Technology (IT), Banaras Hindu University (BHU), Varanasi (now known as IIT-BHU). This distinction allowed me to carry out collaborative R&D with CSIR-CEERI in the area of vacuum electron devices more precisely, in the microwave tubes area with support from Dr. Agarwala and Prof.(s) S.N. Joshi, L.M. Joshi, R.S. Raju, A.K. Sinha, Lalit Kumar, R.K. Gupta, S.K. Ghosh, and many others. I was able to play a key role in establishing memoranda of understanding between (i) CSIR-CEERI and IT-BHU and (ii) CSIR-CEERI and Seoul National University. I visited CSIR-CEERI a good number of times to deliver lectures, attend conferences and serve on the selection committees for recruitment of scientists for CSIR-CEERI. I also participated in several project review committees of CSIR-CEERI, notably the DST Steering Committee for a multi-institutional project on the development of gyrotron with CSIR-CEERI as the nodal centre. In continuation of my association with CSIR-CEERI, I now co-chair with the director of ISRO a committee that monitors a project on the indigenous development of space-TWTs for ISRO-SAC, Ahmedabad, at CSIR-CEERI.

At the time of my leaving CSIR-CEERI for Regional Institute of Technology (RIT), Jamshedpur (now known as NIT, Jamshedpur) in 1978, both AS and Dr. Agarwala advised me to continue doing my work on electromagnetic analysis of helical SWS. I was able to do so with the active support from Dr. Raju of CSIR-CEERI. Dr. Sinha, a research scholar at RIT who partnered me in this work, subsequently joined CSIR-CEERI as a Scientist-B.

It was during one of my visits to CSIR-CEERI along with AS that I was advised by him to analyse the stop-band created in the omega-beta dispersion characteristics of helical SWS due to the asymmetry of the dielectric helix-supports arranged around the helix. I, in turn, passed on the problem to Dr Sinha, who developed the needed analysis and documented it^[4]. Later on, Dr. Sinha became instrumental in establishing a gyrotron laboratory at CSIR-CEERI with support from Professor Chandra Shekhar, the then director of CSIR-CEERI, and Prof. Joshi, while executing a multi-institutional DST-sponsored project which led to the development of the first-ever gyrotron in India. Incidentally, after his retirement from CSIR-CEERI, AS continued to pursue his interest in the area of gyrotron with his research at the University of Maryland. His efforts were directed at improving the efficiency of gyrotrons using a multi-stage depressed collector in the device.

I mention here another incident of my CSIR-CEERI association which greatly humbled me. In an unprecedented gesture, Prof. Chandra Shekhar, together with Prof. S.N. Joshi, honoured me for my modest research efforts in the area of microwave tubes with a special felicitation function held at CSIR-CEERI Pilani immediately after my retirement from BHU. As far as I am aware, this has never happened before in the history of CSIR-CEERI.

In what follows, I present *a review of the life and work of AS* from the perspective of a vacuum electron devices community member based on the information collected from different sources^[5-11].

However, AS has research contributions in other research areas of electronics engineering, too. The achievements of Dr. Singh in those research areas have been kept outside the purview of this article, which is, therefore, only a partial sketch of AS's contributions.

The above preamble recounting some of my associations with CSIR-CEERI and AS is nothing but an attempt to justify my privilege of writing this article, which I hope the reader will take in the spirit intended.

I have organised the article into six sections. Sections 1 and 2 provide an account of the education of AS, beginning with his schooling at Phagwara, followed by details of higher education leading to a doctorate from Harvard University. In section 3, the journey of AS from Harvard University to CSIR - National Physical Laboratory (CSIR-NPL), New Delhi, via Delhi University is narrated. The founding of CSIR-CEERI at Pilani where AS carried out most of his scientific missions and the journey of AS from CSIR-NPL Delhi to CSIR-CEERI Pilani are outlined in sections 4 and 5 respectively. The concluding section, 6, is an attempt on my part to point out to the youngsters of the vacuum electron devices community how they could derive inspiration from the life and work of legendary AS so that they take up challenges that come their way with perseverance and dedication to achieve objectives they have set forth for themselves.

In this article, I have extensively used the acronym 'AS' for Amarjit Singh right from the beginning.

1. Early Education

AS was fortunate to have in his father, Sardar Jagdish Singh, a renowned science teacher who taught at a high school in Phagwara, Kapurthala, Punjab. His father used to demonstrate science experiments for instance, using Wimshurst machine, a class of electrostatic generators, to motivate his students to learn. When he was a child, his father demonstrated to him at home how to prepare oxygen.

Thriving in this scientific environment at home, AS tried to experimentally implement James Watt's principle of steam engine. AS was also fortunate to have in his school Mr. Banwari Lal, a science teacher par excellence, who stoked his enquiring mind by lending him books from his personal library. Reading these books AS learned more science than what was taught at school. Hertz's experiment attracted him particularly, eventually leading to his interest in communication engineering^[5-11].

2. Higher Education

One of the faculty members from whom AS received immense inspiration was Prof. J.B. Seth of Sikh National College, Lahore, where he had joined after school for a Physics Honours course. All his classes, however, used to be held at Lahore University, and it was from here that he obtained his master's degree in Physics in 1945. Sir C.V. Raman, who was the examiner of his thesis titled "A Small Shielded Transmitter", was greatly impressed with his work and praised it highly. For further higher studies, AS benefited from the "Sargent Scheme" (named after British civil servant John Sargent, Educational Adviser to the Government of India) that enabled him to go to Ohio State University for Radio Engineering course and thereafter to Harvard University for Applied Physics course. The objective of his doctoral thesis, set by advisor Prof. Roland W.P. King, was to extend the tuning range of magnetron^[5,6].

3. Return from Harvard University first to Delhi University and then to NPL New Delhi

On his return to India from Harvard University, AS was offered appointment at Punjab University, Defence Science Organisation and Delhi University. He chose to join the Physics Department of Delhi University as lecturer, teaching Electronics and History of Science to postgraduate and undergraduate students. Unfortunately, the Physics Department did not find anything 'pure' physics in the extension of his research in 'applied' physics on magnetrons carried out by AS at Harvard University. Fortunately, however, AS discovered four SCR 584 (fire-control) radar sets lying around

in the Department that had been procured earlier from defence disposals with the intention of reusing the magnetrons in the radar sets for developing a medical LINAC. As it happened, AS was familiar with the working principle and circuitry of SCR 584 radar, having studied it at Harvard University, and he used the knowledge to make one of the radar sets operational at Delhi University. In the meantime, posts of Scientific Officers at CSIR-NPL New Delhi were advertised by its first Director, Dr. K.S. Krishnan. But as luck would have it, AS was still on the contractual two-year service period at Delhi University and could not avail of the opportunity. However, he started working at CSIR-NPL during summer vacation and helped build up the facilities there for developing magnetrons^[5,6].

Further, a talk by AS on the development of magnetrons based on his doctoral work at Harvard University was convened at CSIR-NPL by the would-be British Chapter of IRE in India. The audience, including Dr. K.N. Mathur, who was a senior colleague and close associate of Dr. Krishnan at CSIR-NPL, were highly impressed with the talk. Dr. Mathur proposed that AS be asked to join CSIR-NPL, a suggestion which was wholesomely accepted by Dr. Krishnan^[5-11]. Subsequently, all hurdles in the way of AS in joining CSIR-NPL were overcome and he was able to leave Delhi University for joining CSIR-NPL. Fortunately, he continued to enjoy access to the magnetrons of SCR 584 radar sets at Delhi University for the purpose of his research work at CSIR-NPL.

At CSIR-NPL, AS had as a co-worker another highly dedicated scientist, Nagesh C. Vaidya. In an exchange programme, Prof. Vaidya went to Sweden to earn his doctorate degree. He later joined CSIR-CEERI where he engaged himself in developing indigenously an electron microscope. From CSIR-CEERI Prof. Vaidya moved to BHU as Prof. and Head of Electronics Engineering Department, where he established Centre of Research in Microwave Tubes (CRMT). Incidentally, it was on an invitation from Prof. Vaidya that I left RIT Jamshedpur and joined CRMT. I have dedicated a book authored by me to Prof. Vaidya^[12].

At CSIR-NPL, AS was successful in developing an interdigital magnetron with a wide tuning-range. Many distinguished visitors flocked to the laboratory to see the equipment, including the first Indonesian President, Sukarno. Dr. Krishnan also arranged the visit of Pt. Jawahar Lal Nehru to the laboratory, finding an opportunity when the latter was in CSIR-NPL to attend a conference of the directors of CSIR^[5-11].

4. Foundation of CSIR-CEERI at Pilani

CSIR established Central Electronics Engineering Research Institute (CSIR-CEERI) at Pilani, the birthplace of Mr. G.D. Birla who had donated Rs. 21 lakh for the purpose. Pt. Nehru laid the foundation stone of CSIR-CEERI on 21st September 1953. The Birla Educational Trust (BET) allotted 14 staff quarters as temporary residential accommodation for the employees of CSIR-CEERI. Dr. N.B. Bhat was deputed from DRDO New Delhi as the Planning Officer of CSIR-CEERI. He engaged two architects to plan the design of CSIR-CEERI laboratories, one of whom had the experience of designing the CSIR - National Chemical Laboratory of CSIR along the lines of Bell Laboratories in the US. Incidentally, the two architects happened to be contemporaries of AS at Harvard University/MIT. Dr. Bhat relocated the foundation stone of CSIR-CEERI to the base of 110-ft tower built at CSIR-CEERI, similar to one at the Bell Laboratories. The tower served the purpose of sending and receiving microwave power over long distances. Dr. Bhat arranged for a power plant to supply electricity to the campus; he also planned for obtaining enhanced power supply from the hydroelectric power plant at Bhakra Dam. However, there was no sanctioned position of a Director at CSIR-CEERI then, and a change in designation from Planning Officer to Assistant Director-cum-Officer-in-Charge was not acceptable to Dr. Bhat. He returned to his parent organisation DRDO New Delhi after serving CSIR-CEERI^[5-11] during 1954-56 (Table 1).

5. Journey of AS from CSIR-NPL to CSIR-CEERI

The loss of Dr. Bhatt from CSIR-CEERI

became a point of worry for Prof. M.S. Thacker, the then Director General of CSIR, who consulted Dr. Krishnan on this. Dr. Krishnan considered the possibility of relinquishing the services of AS at CSIR-NPL for meeting the need of CSIR-CEERI, and eventually, AS appeared for an interview at CSIR for the post of Assistant Director, CSIR-CEERI, and was offered the same. AS was, however, in a dilemma, as he had a simultaneous offer of a research position at Stanford University from Prof. M. Chodrow. Dr. Krishnan was in favour of AS joining CSIR-CEERI and tried to convince his wife, Ms. Surinder, of the advantages of her husband joining CSIR-CEERI when he chanced upon her once during her evening walks with family. Matters fell in place when AS discovered CSIR-CEERI Pilani to be much richer than CSIR-NPL in terms of equipment for the development of vacuum tubes, thanks to the substantial grant received from Technical Cooperation Mission (TCM) of USA. He overcame his dilemma and joined CSIR-CEERI in 1959 (Table 1) ^[5-11].

After joining CSIR-CEERI, AS came across Dr. B.H. Wadia who had returned to India after obtaining his doctorate from Stanford University. Dr. Wadia joined CSIR-CEERI as Assistant Director-cum-Officer-in-Charge. As the availability of residential quarters was a primary requirement to persuade competent staff to join CSIR-CEERI, Dr. Wadia at first engaged the services of CPWD to construct 52 residential quarters. The construction of the laboratories, offices and tower was assigned to qualified construction contractors selected through the standard bidding process of CSIR via public tender. Later on, it was decided that CSIR-CEERI could expedite the construction work of various facilities on its own provided the costs did not exceed the limit stipulated by CPWD^[5-11].

There were only 15 scientists at CSIR-CEERI at the time when AS joined the Institute. In order to carry out R&D activities 4 Groups were formed: (i) Physical Electronics, led by Dr. B.H. Wadia; (ii) Special Circuits, led by Dr. A.K. Kamal; (iii) Audio Engineering, led by Dr. D.L.

Subramaniam; and (iv) Vacuum Tubes, led by AS. The equipments received from the grant of TCM of USA were distributed among these groups according to their respective relevance to the groups, and Mr. Jaswant Singh, the principal foreman (who had migrated from CSIR-NPL to CSIR-CEERI) took the charge of the workshop machines.

However, soon after, CSIR-CEERI had to part with the services of Dr. Wadia and Dr. Kamal. Dr. Wadia left for IIT-Bombay and Dr. A.K. Kamal went back to France. Therefore, AS had to take over the charge of the Institute from Dr. Wadia despite his reluctance to do so, as he was then very much involved in R&D in the Vacuum Tubes group. After taking charge, AS expedited the construction work being carried out by the CPWD as well as by the Institute. He also developed other amenities (or expanded them) which included dispensary, school, auditorium, guesthouse complex, hostels for trainees, canteen, auditorium, open-air theatre, community centre with indoor and outdoor game facilities, TV tower, market complex, bank, post-office, etc. Incidentally, thanks to the initiative taken later by Prof. Chandra Shekhar, who was the Director of the CSIR-CEERI during 2003-2015 (Table 1), a railway booking counter came into being adjacent to the CSIR-CEERI campus.

AS also focussed on enhancing manpower at CSIR-CEERI. For this purpose, he invited scientists from the CSIR Scientist pool to join CSIR-CEERI. It was thus that Dr. G.N. Acharya and Dr. Birendra Prasad joined CSIR-CEERI and became leaders of the two new Groups namely 'Instrumentation' and 'Communication', respectively. Similarly, Dr. O.P. Gandhi joined CSIR-CEERI to take charge of the Vacuum Tubes Group from AS. Also, Dr. K.S. Balain joined CSIR-CEERI and became the leader of Solid-State Devices Group. Another addition to the Vacuum Tubes Group was Dr. S.S.S. Agarwala, whom I have already mentioned in the introductory section. With a postgraduate diploma of Membership of the Imperial College (DIC) in Electrical Engineering and PhD (Microwaves) from the University of London, both in 1958, Dr. Agarwala

first joined CSIR-NPL and then migrated to CSIR-CEERI. It was only apt that Dr. Agarwala was given the responsibility of developing TWTs, given that the theme of his PhD was “Investigation of a non-reciprocal slow-wave structure” and his experimental cold test setup of the SWS of a TWT at Imperial College of Science and Technology, London, was appreciated by none other than the legendary Prof. John Robinson Pierce.

Now that the expertise of both AS and Dr. Gandhi was available to CSIR-CEERI, the Vacuum Tubes Group was well set for an accelerated growth in its objective of developing a working model of the magnetron. The magnetrons available from the radar set procured by Dr. Bhat from defence disposal procurement helped, and the Group developed a magnetron and tested it in the said radar set. The performance of the radar set using the magnetron developed by the Group was successfully demonstrated from the CSIR-CEERI tower before the Indian Navy represented by a Commodore. Convinced of its efficacy, the Indian Navy specified their requirement of power and operating frequency of the magnetrons (S-band 500 kW), which set the laboratory and workshop at CSIR-CEERI in a batch production mode for meeting the requirement. Thus, a batch of 75 magnetrons was delivered to the Indian Navy. The Group also developed magnetrons to the specifications of Indian Air Force (S-band, 1.0 MW in six variants of frequency from 2910 to 3100 MHz). The technology of producing this class of magnetrons



Fig. 1. Pt. Nehru expressing curiosity about the magnetron developed by Dr. Amarjit Singh and his team^[10].

was later transferred to Central Electronics Limited. This was a landmark achievement of CSIR-CEERI under the leadership of AS. Jawaharlal Nehru, who visited CSIR-CEERI accompanied by his daughter Indira (Mrs. Gandhi, who later became the Prime Minister of India) (Fig. 1), congratulated AS and his team for the outstanding work. AS packaged and presented a magnetron developed by his team to Pt. Nehru.

Some of the magnetrons developed later by CSIR-CEERI include X band, 200 kW coaxial magnetron; and S-band, 1.0/2.0/2.6/3.0 MW tunable pulsed magnetron. A 35GHz, mm-wave magnetron was also developed at CSIR-CEERI. Recently, the technical know-how of a 2.6 MW, S-band magnetron has been transferred to M/s Panacea Medical Pvt. Ltd., Bengaluru, for production. Currently, the development of low-power CW magnetron, spatial harmonics magnetrons, and system-based on low-power CW magnetrons are being explored at CSIR-CEERI^[10].

Now that AS had worked at CSIR-CEERI for more than three years as a scientist in the area of vacuum electron devices while at the same time discharging duty as Officer-in-Charge of the Institute, he felt an urge to explore frontier areas to gain more experience. He got an opportunity for the same in an offer of a visiting position from Prof. J.E. Rowe, the Director of Electronics Research Laboratory at the University of Michigan, for a period of one year. Without attempting to obtain study leave for the purpose, AS resigned from CSIR-CEERI and handed over the charge of the Institute to Dr. D.L. Subramaniam, leaving for Michigan in the year 1962. The problem assigned by Prof. Rowe to AS was to develop a high-frequency source through an electron beam passing the interaction region between two closely-spaced electrodes. The problem turned out to be one of developing a device that accrues beam-plasma interaction for an electron beam penetrating through a plasma medium, a device similar to Haeff tube or double-stream amplifier in which two intimately mixed electron beams of slightly different velocities interact with each other.

Such a device would do away with the SWS such as that required for a TWT^[9,13]. Incidentally, I also carried out my doctoral research on a related problem under the tutelage of Prof. N.B. Chakrabarty of IIT-Kharagpur. (I have dedicated another of my books to Prof. Chakrabarty^[14]).

During his stay at Michigan, AS visited Bell Telephone Laboratories to observe developments in the field of semiconductor devices that were competing with vacuum electron devices in function. An emergent political situation in India, the war between India and China, however, made it expedient for AS to return to India without completing his one-year tenure at Michigan University. He responded to an SOS from CSIR asking him to join back as the Director of the Institute. He rejoined CSIR-CEERI in 1963 (Table 1).

Table 1 Period-wise tenure of various scientists spearheading CSIR-CEERI^[8]

Duration	Scientist	Position
1954-1956	Dr. N.B. Bhatt	Planning Officer
1957-1959	Dr. B.H. Wadia	Assistant Director-cum-Officer-in-Charge
1959-1962	Dr. Amarjit Singh	Assistant Director/ Assistant Director-cum-Officer-in-Charge
1962-1963	Dr. D.L. Subramaniam	Assistant Director -cum-Officer-in-Charge
1963-1984	Dr. Amarjit Singh	Director
1984-1989	Dr. G.N. Acharya	Director
1989-1993	Dr. W.S. Khokle	Director
1993-1999	Dr. R.N. Biswas	Director
1999-2003	Dr. S. Ahmad	Director
2003-2015	Dr. Chandra Shekhar	Director
2015-2016	Dr. R.K. Sinha (Director, CSIO)	Director, Additional Charge
2016-2018	Prof. Santanu Chaudhury	Director
2018-2019	Prof. Raj Singh	Acting Director
2019-2020	Dr. D.K. Aswal (Director, CSIR-NPL)	Director, Additional Charge
2020 onward	Dr. P.C. Panchariya	Director (continuing)

Subsequently, CSIR-CEERI, under the overall leadership of AS, developed the know-how for TV receivers^[6-8]. Likewise, CSIR-CEERI developed an indigenous control system for Diesel Electric Locomotives in a project sponsored by Bharat Heavy Electricals Limited, which was extensively employed by the Indian Railways in hundreds of their locomotives^[6-8], and so on.

AS served CSIR-CEERI for about quarter of a century; see Table 1. The table also lists the tenures of other scientists who have spearheaded the progress of the Institute from inception to present. Prof. Chandra Shekhar, a former director of CSIR-CEERI (Table 1) and an illustrious follower of AS, chaired the felicitation function held at CSIR-CEERI to mark the 90th birthday of Padma Bhushan Amarjit Singh on 19th November 2014 (Figs. 2 and 3). The august audience present included the family members of Dr. Singh; a number of ex-employees of CSIR-CEERI; Prof. G. Raghuram, former director



Fig. 2. CSIR-CEERI greeting Dr. Amarjit Singh with flower bouquet on his 90th Birthday celebration on 19th November 2014^[11].



Fig. 3. Padma Bhushan Amarjit Singh blessing the audience on his 90th Birthday celebration at CSIR-CEERI^[11].

of BITS Pilani; Dr. Krisna Saraswat, Distinguished Alumnus of BITS Pilani; besides the employees of CSIR-CEERI and their families^[11].

Dr. Amarjit Singh thanked his colleagues for their cooperation extended to him. In his brief speech he advised everyone to focus on their aims for the progress of their respective organisations and the nation. He drew example from the well-known incident in *Mahabharata*, where Arjuna is shown as having remained focussed on the eye of the fish to achieve his objective^[11]. Prof. S.N. Joshi, the Coordinator of Microwave Tubes Area (previously, Vacuum Tubes Group) recounted the unparalleled contributions of Dr. Singh in general and the vacuum electron devices community in particular. He also talked about how Dr. Singh always remained concentrated on his objective, never compromising with anything on the way of his journey to truth. He also said that Dr. Singh showed us the 'day', beginning with the 'morning', which can be equated to the development of the first ever magnetron in the country, and circumvent all the hurdles on the way^[10,11] through 'day', the latter a metaphor for life. Prof. Chandra Shekhar thanked the audience for their gracious presence at the event. He gave his salutation to the great scientist on his 90th Birthday. He also expressed his gratitude to Dr. K.S. Krishnan for convincing Dr. Singh to join CSIR-CEERI (as already elaborated earlier in this section), and touched upon the fact that it was the genius of Dr. Singh and his expertise in all branches of electronics engineering (vacuum electron devices, solid state devices, control system, communication, etc.) that helped CSIR-CEERI scale great heights and contribute significantly to the progress of the country. Prof. Chandra Shekhar concluded his speech with best wishes for the good health of Dr. Singh with the Vedic prayer: "जीवेम शरदः शतम्, पश्येम शरदः शतम्, शृणुयाम शरदः शतं प्रब्रवाम शरदः शतम्, अदीनाः स्याम शरदः शतम्, भूयश्च शरदः शतात्"^[11].

6. Conclusion

I have tried to present a brief review of the life of Dr. Singh mainly from the perspective of his outstanding contributions to the areas of vacuum electron devices/microwave tubes, as they are areas

that I too have an interest in. I have not attempted to highlight the achievements of Dr. Singh in other areas of research. My endeavour through this small effort has been to bring to fore some of the events from Dr. Singh's life which has many a motivational message for all, but youngsters in particular, on the path to achieving their objectives in life. The life of Dr. Singh is a testimony to the fact that with passion, perseverance and focus, there are no hurdles that cannot be overcome.

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Bibliography

- [1] B.N. Basu, "Technical Writing," Prentice-Hall of India, New Delhi (2007).
- [2] CSIR-CEERI-IR-01/VT/78: B.N. Basu and S.N. Joshi: Equivalent circuit analysis of a helix in free space.
- [3] CSIR-CEERI-IR-02/VT/78: B.N. Basu: Field analysis of dielectric supported and shielded sheath helix.
- [4] Y.D. Joo, A.K. Sinha, and G.S. Park, "Electromagnetic wave propagation through an azimuthally asymmetric helix slow wave structure," *Jpn. J. Appl. Phys.* Vol. 42, 7585–93 (2003).
- [5] S.C. Dutta Roy, private communication.
- [6] Amarjit Singh, private communication, referring to his unpublished note: Towards a Shining India: Recollection and Reflections of a Research Scientist.
- [7] Chandra Shekhar, private communication.
- [8] S.N. Joshi, private communication.
- [9] U.N. Pal, private communication.
- [10] S. Mourya, "Past and present status of the magnetron development in the country and the efforts at CSIR-CEERI leading to the product development for the users," in Proceedings, Webinar 2 on VED Thinkers Group platform (Ed. V. Kesari and B.N. Basu).
- [11] Available: www.ceeri.res.in. "सीरी में प्रथम निदेशक पद्म भूषण डॉ. अमरजीत सिंह का का सम्मान": Dr. Chandra Shekhar

- and Dr. S.N. Joshi giving their respective speeches in Felicitation of Padma Bhusan Amarjit Singh, the first Director of CSIR-CSIR-CEERI, on his 90th Birthday.
- [12] Vishal Kesari and B.N. Basu, High Power Microwave Tubes: Basics and Trends, Volume 1 and Volume 2, Morgan and Claypool Publishers, San Rafael (California)/Bristol: IOP Publishing (2018).
 - [13] B.N. Basu, Electromagnetic Theory and Applications in Beam-Wave Electronics, World Scientific Publishing Co. Inc., Singapore, New Jersey, London, Hong Kong (1996).
 - [14] B.N. Basu, Engineering Electromagnetics Essentials, Universities Press, Hyderabad (2015).