Jagadish Chandra Bose

In the late 1850s, India had just witnessed the First War of Independence. In Bengal, national fervour and tremendous intellectual activity at that time led to what is popularly termed as the Bengal Renaissance, which saw the rise of people like Raja Rammohun Roy, Rabindranath Tagore, Iswar Chandra Vidyasagar, Swami Vivekananda and Ashutosh Mukherjee[1]. It was into this environment that Jagadish Chandra Bose (1858–1937) was born. He was a pioneering Indian scientist, known for his work on microwaves and plant electrophysiology (Figure 1). Bose's scientific calibre is described thus in the foreword of a book, *Remembering Sir J. C. Bose,* which was published in 2009 as part of Bose's 150th birth anniversary celebrations: '. . . he created science in India at a time when there was hardly any science. He built instruments when instrumentation was not heard of. He did research on problems related to transmission of radio waves when radios did not exist. He worked on aspects of plant biology which were unknown at that time'[1].

This article is based on a conversation with D. P. Sen Gupta, one of the authors of *Remembering Sir J. C. Bose,* about Bose's life and work. D. P. Sen Gupta retired as Professor from the Indian Institute of Science, and is currently a Visiting Professor at the National Institute of Advanced Studies, Bangalore.

Bose – the scientist

It was in fact by accident that J. C. Bose became a scientist. He went to England in 1880 to study medicine. But recurrent fever due to kala azar that he contracted on a hunting trip in Assam made it impossible for him to pursue his medical studies, and he took up science instead[1].

Figure 1. Sir J. C. Bose.

After returning to India in 1885, J. C. Bose joined Presidency College as a Professor of Physics. He started doing research in 1894, when he was 36 years old. Working from the small laboratory that he had furnished for himself at Presidency College, he contributed to the science of his day in a big way.

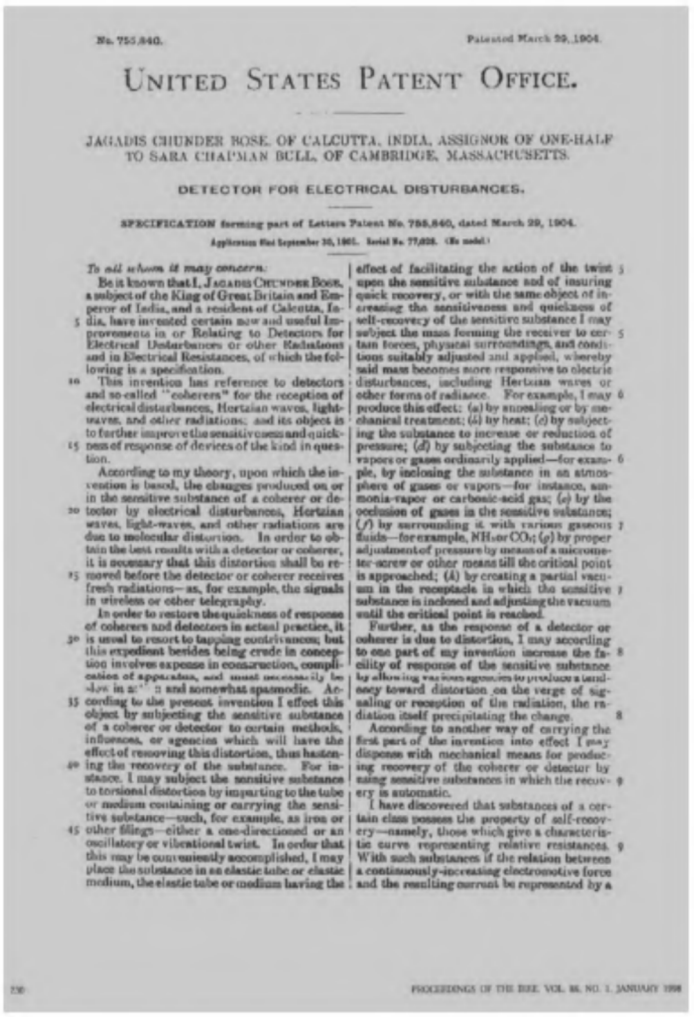
Bose is most famous for his discovery of millimetre waves and his work on elucidating their properties[1]. James Clerk Maxwell was the first to mathematically conceive the idea of electromagnetic waves (in 1873); but he died early at the age of 48. After him, in the late 1880s, Heinrich Hertz tried to produce electromagnetic waves which had optical properties, based on Maxwell's hypothesis that visible light is just a fraction of the total electromagnetic spectrum. Hertz, and later Popoff and Oliver Lodge were all using 66 cm waves[2]. Bose, in the 1890s, revolutionised this field of research by producing 5 mm waves, called microwaves or millimetre waves. These could be polarized using smaller crystals, than would be required if 66 cm waves were used, and thus Bose could show that electromagnetic waves do indeed have optical properties[1].

Another of Bose's celebrated contributions to science is his work on improving the coherer. When Hertz and the others were working on the properties of electromagnetic waves, one of the most difficult problems they faced was that of receiving the signals. In order to solve this, Lodge modified an instrument invented earlier, called the coherer, which consisted of iron filings that would transmit the signal. But every time a signal passed, the iron filings would cling to each other and clog the coherer, making it obligatory to tap the instrument after every signal was received. Bose modified the coherer completely and thus greatly improved it – he employed spring action so that the instrument automatically reverted back to its original state after every signal was transmitted. This was such a remarkable improvement that a journal, *The Electrician*, commented, 'Should Prof. Bose succeed in perfecting and patenting his coherer, we may in turn see the whole system of coast lighting throughout the navigable world revolutionised by the discoveries made by a Bengali scientist working single-handedly in our Presidency College'. But Bose did not patent this innovation despite pressure brought upon him. Rather, in a letter to Tagore he said, 'I'm aghast to see the greed of people in this country that they want to make money out of knowledge'[3].

Something that is probably not very widely known is that Bose is also acclaimed as one of the first inventors of the semiconductor diode. D. P. Sen Gupta terms this the 'foundation stone of all the electronic revolution that took place during the last century.[3]' Bose discovered that galena (lead sulphide) has semiconductor properties, and this has been mentioned in his 1904 American patent – the first patent in the world for a semiconductor device[1], and J. C. Bose's only patent (Figure 2).

Around 1900, Bose the physicist started working on plant electrophysiology. It is interesting to see how he began working with plants in the first place. When Bose was developing the coherer that was to receive microwave signals, he noticed that after some time the coherer does not respond well enough. But when the instrument was given some 'rest', it began working well again. This phenomenon reminded him of the behaviour of muscles, and that of whole organisms, and he began wondering where the border line between the living and the non-living is. This was perhaps because 'his Upanishadic mind, which believed that there is a soul running through everything and there is no difference between things, suddenly felt this was an experimental expression of what ancient sages of India had said 3000 years ago'[3]. While trying to find the 'border line' between the living and the non-living, Bose thought that the most sensible thing to do would be to study responses of plants, that apparently were on the border line[3]. When Bose showed to people the similarity in graphs representing the behaviour of metals, plants and animals' muscles, he caused a sensation, particularly at the International Congress of Physics held in Paris in 1900. A concept which had engaged the minds of many philosophers, poets and writers suddenly found an experimental expression[3].

Bose's ingenuity as a designer of scientific instruments and his genius in physics helped him in his botanical work too. He conducted experiments such as treating the roots of a tender plant with an acid and measuring electrical response to this stimulus in other parts of the plant. In those days recording systems were almost non-existent, but Bose devised very sensitive equipment to record the electric impulses and instruments to amplify the responses of plants many times. Researchers in Bose's time typically used 'pen-drives' to record responses obtained from experimental systems. These 'pen-drives' consisted of an ink pen which would move on a rotating drum and draw curves on a graph sheet, which would indicate the type of response. But Bose found that the signals that he obtained in his plant experiments did not have enough energy to drive those pens, due to inertia. So he devised an instrument such that the pens would not keep touching the paper but would put dots at regular intervals. The friction, which would be there if the pens were constantly touching the paper, was removed that way. And the graph could be determined based on the dots that were obtained from the experiment. Another example of Bose's genius is the crescograph which measured the growth of plants. All these instruments that he fabricated required a tremendous knowledge of physics, and as D. P. Sen Gupta remarks, 'It is difficult for us to think how he devised these things in those days'[3].



No. 755,840. Patented March 29, 1904.

UNITED STATES PATENT OFFICE.

JAGADIS CHUNDER BOSE, OF CALCUTTA, INDIA, ASSIGNOR OF ONE-HALF TO SARA CHAPMAN BULL, OF CAMBRIDGE, MASSACHUSETTS.

DETECTOR FOR ELECTRICAL DISTURBANCES.

SPECIFICATION forming part of Letters Patent No. 755,840, dated March 29, 1904.

Application filed September 30, 1901. Serial No. 77,028. (No model.)

To all whom it may concern:

Be it known that I, JAGADIS CHUNDER BOSE, a subject of the King of Great Britain and Emperor of India, and a resident of Calcutta, India, have invented certain new and useful Improvements in or Relating to Detectors for Electrical Disturbances or other Radiations and in Electrical Resistances, of which the following is a specification.

This invention has reference to detectors and so-called "coherers" for the reception of electrical disturbances, Hertzian waves, light-waves, and other radiations, and its object is to further improve the sensitiveness and quickness of response of devices of the kind in question.

According to my theory, upon which the invention is based, the changes produced on or in the sensitive substance of a coherer or detector by electrical disturbances, Hertzian waves, light-waves, and other radiations are due to molecular distortion. In order to obtain the best results with a detector or coherer, it is necessary that this distortion shall be removed before the detector or coherer receives fresh radiations—as, for example, the signals in wireless or other telegraphy.

In order to restore the quickness of response of coherers and detectors in actual practice, it is usual to resort to tapping contrivances; but this expedient besides being crude in conception involves expense in construction, complication of apparatus, and must necessarily be [illegible] and somewhat spasmodic. According to the present invention I effect this object by subjecting the sensitive substance of a coherer or detector to certain methods, influences, or agencies which will have the effect of removing this distortion, thus hastening the recovery of the substance. For instance, I may subject the sensitive substance to torsional distortion by imparting to the tube or medium containing or carrying the sensitive substance—such, for example, as iron or other filings—either a one-directional or an oscillatory or vibrational twist. In order that this may be conveniently accomplished, I may place the substance in an elastic tube or elastic medium, the elastic tube or medium having the effect of facilitating the action of the twist upon the sensitive substance and of insuring quick recovery, or with the same object of increasing the sensitiveness and quickness of self-recovery of the sensitive substance I may subject the mass forming the receiver to certain forces, physical surroundings, and conditions suitably adjusted and applied, whereby said mass becomes more responsive to electric disturbances, including Hertzian waves or other forms of radiance. For example, I may produce this effect: (a) by annealing or by mechanical treatment; (b) by heat; (c) by subjecting the substance to increase or reduction of pressure; (d) by subjecting the substance to vapors or gases ordinarily applied—for example, by inclosing the substance in an atmosphere of gases or vapors—for instance, ammonia-vapor or carbonic-acid gas; (e) by the occlusion of gases in the sensitive substance; (f) by surrounding it with various gaseous fluids—for example, NH_3 or CO_2; (g) by proper adjustment of pressure by means of a micrometer-screw or other means till the critical point is approached; (h) by creating a partial vacuum in the receptacle in which the sensitive substance is inclosed and adjusting the vacuum until the critical point is reached.

Further, as the response of a detector or coherer is due to distortion, I may according to one part of my invention increase the facility of response of the sensitive substance by allowing various agencies to produce a tendency toward distortion on the verge of signaling or reception of the radiation, the radiation itself precipitating the change.

According to another way of carrying the first part of the invention into effect I may dispense with mechanical means for producing recovery of the coherer or detector by using sensitive substances in which the recovery is automatic.

I have discovered that substances of a certain class possess the property of self-recovery—namely, those which give a characteristic curve representing relative resistances. With such substances if the relation between a continuously-increasing electromotive force and the resulting current be represented by a

PROCEEDINGS OF THE IEEE, VOL. 88, NO. 1, JANUARY 1998

Figure 2. Bose's 1904 patent.

Bose made extraordinary contributions to both physics and biology. But there are instances of injustice done to him in both these fields. Of these, the more well known is probably the one regarding Marconi and Bose's coherer.

Marconi had a friend in the Italian navy, whose name was Solari. He had modified the receiver that Bose developed – the improved version of the coherer, which Bose could have patented if he wanted to, and Marconi used this in his famous transatlantic radio signalling experiments in 1901. Around the same time as Bose, Nikola Tesla was working on sending radio signals, and he had patented his findings. Marconi used these findings too. So for the transmission of signals, Marconi used Tesla's patents and for the receiver, he used Bose's coherer[3]. Marconi had excellent marketing skills. When Queen Victoria's son, Edward VII, was ill out at sea, the Queen was anxious to get news about her son. Marconi took this opportunity to send signals from land to the ship and to receive signals from the ship about Edward VII's health. This, of course, got a great deal of publicity. In another instance, Marconi got the President of America to wish the King of England, and this was flashed in all the newspapers of his time[3]. In 1909, Marconi and Ferdinand Braun received the Nobel Prize: Marconi for his efforts to commercialize and make wireless telegraphy widely useful, and Braun for his 1874 discovery that lead sulphide could conduct electricity better in one direction. Bose was not included for the prize though it was he who used galena in receivers for wireless signalling for the first time[3].

Another instance of injustice done to Bose was with regard to his work on plant electrophysiology. When Bose submitted his papers on his work on plants to the Royal Society, there were four reviewers – two were great physicists, who accepted his papers, but the other two, B. Sanderson and A. Waller, were plant electrophysiologists and they rejected them. The papers were archived. But later, Waller, who was instrumental in rejecting the papers, used Bose's results from the archives and published them as his own without acknowledging him. A crestfallen Bose was to discover this much later. Sydney Vines, a biologist who was one of Bose's professors at England, invited him to give a talk about his work on plant electrophysiology to the Linnaean Society. It was only when his paper was being considered by the Society for publication, around 1902, that Bose came to know that Waller had already published these results[3].

On Bose's writings

Bose was a prolific researcher and published numerous papers. The technical papers that he started writing in 1895 were published by the Asiatic Society. A large number of Bose's papers were also published in the *Journal of the Royal Institution*. These were forwarded by his mentor, Lord Rayleigh. But when Bose moved on to plant electrophysiology, for several years, the Royal Society would not publish his papers. And that is when he started writing books, since whatever he studied did not find expression in the standard papers. Perhaps, one of the reasons why his researches did not get to be known so widely as they would have been known had they been published by the Royal Society is because books published in those days did not have very wide circulation[3].

Bose was also possibly the first science fiction writer in Bengali. His famous 1894 work, *In Search of the Source of the Bhagirathi*, is a remarkable piece trying to explain science and the water cycle through a travel tale up the Himalayas, going to the source of the Ganga. Throughout the book Bose keeps asking, 'Ganga, where do you come from?' – this was an example of his extraordinary skill of writing in Bengali. A famous collection of his Bengali writings is *Obyakta* – '*The Unsaid*'. Bose sent this collection to Rabindranath Tagore, a close friend of his, with a note saying, 'I'm sending a firefly to the Sun'[3].

Bose and the spirit of the freedom struggle

Bhagaban Chandra Bose, J. C. Bose's father, was a patriot and was one of the thousands who tried to assert the 'Indian' as a way of opposing the British. He tried to create an Indian economy by buying up forests in Assam and trying to grow tea in those regions. But his investments, unfortunately, did not do very well[3]. By the time Jagadish Bose returned to India from England in 1885, his father had lost his wealth and was ill and too weak to carry on with his fight. He had incurred debts, and had no means to repay them. Around this time, J. C. Bose was appointed as an Officiating Professor of Physics at the Presidency College, but was offered only one-third the salary of an Englishman in the same position. Jagadish Bose accepted the job, but refused to take his salary for three years, bravely subjecting himself and his wife Abala to severe privation. Ultimately, the authorities decided to pay him on the same scale as an Englishman and Bose was able to repay his father's debts[1].

This was only one of many problems that Bose had to face during his lifetime. He was once accused of using the college facilities for doing his 'personal' research. When he applied for a grant later, a secretary of the Governor wrote that if a native cannot make do with five hundred rupees a month, his 'head is a bit turned'. But fortunately, the Governor, who was favourably disposed towards him, granted Bose two thousand rupees. Another episode pertains to Lord Rayleigh's visit to Calcutta. He spent a whole day with J. C. Bose. Later, Bose received a show cause notice from the Principal, demanding an explanation from him for allowing an 'outsider' into his laboratory[3]. But the same spirit that made him fight for equal pay helped him overcome all these inconveniences.

Bose's teachers and students

It is well known that at various points in Bose's life, many of his teachers influenced his way of thinking and his scientific outlook. Prominent among them was Fr. Lafont, who taught him at St. Xavier's College where he studied before he went to England, Francis Darwin, the son of Charles Darwin, Sydney Vines, who later stood by Bose when Waller's paper on plant electrophysiology was found out, and Lord Rayleigh, who was Bose's mentor and perhaps the one who influenced Bose's science the most.

It is interesting to note that there were a number of great scientists among Bose's students too, such as S. N. Bose, Meghnad Saha and S. K. Mitra. However, although they might have been influenced while learning science from J. C. Bose, their science developed in a different direction. D. P. Sen Gupta says, 'When J. C. Bose had switched over to plant electrophysiology, he was not in step with what revolution was going on in Europe at that time in physics. And there you have to forgive him because mathematics was not his point of strength. He did physics all right. He did chemistry all right. He did botany all right. But he didn't do mathematics to a level you had to know to come up to the level of modern physics in those days. S. N. Bose was a good mathematician. So was Meghnad Saha, but he switched over to astrophysics. And also S. K. Mitra. So they went in different directions. I think that the influence must have been there but I have very little knowledge of any scientific interaction between these people. I have seen photographs of Bose sitting with Meghnad Saha and S. N. Bose but there was no room for joint research'[3].

150 years later

J. C. Bose is often called the pioneer who brought modern science to India. Yet, his life and work are not known to many people in his own country. This might perhaps be because of the general Indian apathy towards heritage and documentation, and our failure to talk to our people about our science. 'Nobody taught us about the achievements of Acharya Prafulla Chandra Ray. We had the famous Upendra Brahmachari who invented the vaccine for kala azar. How many people know about it?' Sen Gupta asks[3]. He points out that this ignorance among students and teachers about the people who shaped our science is because history of science is never taught at schools and colleges. Perhaps we are forgetting the heroes of our past, and thus letting the most important source of inspiration and guidance slip away. Perhaps J. C. Bose is one such hero.

1. Sen Gupta, D. P. *et al.*, *Remembering Sir J. C. Bose*, IISc Press–World Scientific Publishing Co. Pte. Ltd, 2009.
2. Rao, C. N. R., Foreword. In *Remembering Sir J. C. Bose* (eds Sen Gupta, D. P. *et al.*), IISc Press–World Scientific Publishing Co. Pte. Ltd, 2009.
3. Interview with D. P. Sen Gupta, 16 January 2010.

ACKNOWLEDGEMENT. I am grateful to Prof. D. P. Sen Gupta who graciously allowed me to interview him, and provided me with most of the information in this article.

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