Indian Journal of History of Science, 52.1 (2017) 66-77 DOI:10.16943/ijhs/2017/v52i1/41301

Discovery of X-rays and its Impact in India*

S C Roy**

(Received 05 June 2016)

Abstract

This paper presents some unknown or less known facts related to the discovery of X-rays. The impact that it made immediately after the discovery of X-rays in 1895, in the scientific community of India has also been presented.

Keywords: Discovery of X-rays, J. C. Bose, Mahendra Lal Sircar, Roentgen, X-ray photograph.

1. Introduction

Wilhelm Conrad Roentgen (1845-1923) has been credited with the discovery of X-rays and was awarded the first Nobel Prize in Physics in 1901 based on this discovery. Roentgen's discovery is known to be the result of an accident while he was experimenting with a discharge tube. The objective of the current article is to present less known facts, such as that X-rays were produced experimentally much before Roentgen's discovery in 1895 as has been found in literature and also to study the influence of this discovery on the scientific community of India.

According to conventional scientific protocol, the date on which the paper has been first submitted for publication is considered as the date of the discovery. According to this, December 28, 1895 is considered as the date of discovery when Roentgen submitted his first "provisorial" communication *Uebereineneue Art von Strahlen* (On a New Kind of Rays) which was published in the Proceedings of the Würzburg Physico-Medical Society (*Sitzungber der WürzburgerPhysik.-MedikGesellschaft*). First oral presentation of the discovery was made before the same Würzburg Society on January 23, 1896. According to the report published in the Münchener Medicinische Wochenschrift of January 29, 1896, the meeting was chaired by the famous anatomist Albert Rudolf von Kolliker (1817-1905). After the lecture Roentgen produced an X-ray picture of Kolliker's hand in a glass plate (Fig. 1). It was Dr. Kolliker who proposed that the new rays be known henceforth as Roentgen rays (Grigg, 1965).

Fig.1. First X-ray picture made in public by Roentgen during his first oral presentation before the Würzburg Physico-Medical Society on January 23, 1896. The picture shows the hand of Albert Kolliker who chaired the talk.

*The work has been performed under the sponsorship of a project: "History of X-ray Research in British India" by the Indian National Science Academy (INSA), New Delhi.

**Indian Science News Association, 92 Acharya Prafulla Chandra Road, Kolkata 700009.
E-mail:editor.scienceandculture@gmail.com

Like Jagadis Chandra Bose who refused to take patent of his microwave discovery, Roentgen also refused to take patent of any part of his discovery and rejected all commercial proposals connected to this discovery. However, unlike J.C. Bose he lost all his savings due to post war inflation and suffered financial and other difficulties in the last years of his life.

Roentgen's discovery was shrouded with mystery, stories and controversies which sometimes reached a stage of humiliation to the great scientist. The discovery was accidental. As we all know, a screen in his laboratory began to fluoresce even though the running Hittorf discharge tube (not Crookes tube) was covered with dark paper. There is not much difference between Hittorf and Crookes discharge tube except that the vacuum is more in the latter. It is to be remembered in this connection that X-ray tubes that we are talking about were known as cold discharge tubes in which ionization of gas by high voltage was the source of electrons in contrast to modern X-ray tubes which contain a heated filament for producing electrons.

It is believed that fluorescence was first noticed (Peh, 1995) by Roentgen's laboratory assistant Ludwig Zhender in 1890, who while working with the discharge tube covered with black cloth observed the fluorescence in the fluorescent screen placed nearby. Although Zhender was loyal to Roentgen throughout his life and had not claimed any recognition, but this story was severely distorted to humiliate Roentgen and he was accused of stealing his *Diener's* discovery (Grigg, 1965). The exact date of his discovery—when he understood the importance of the penetrating power of this new ray—is not known for sure. In accordance with Roentgen's will all his notes were destroyed after his death. From a letter (Grigg, 1965) written by his wife Anna Bertha Ludwig to one of his cousins Mrs. L.R. Grauel of Indianapolis in March 1896, it was found that Roentgen first noticed this new radiation sometime in November 1895. As Bertha mentioned in her letter, on one evening of November 1895 she became angry with her husband for the quality of food. In order to soothe her, Roentgen took her downstairs to his laboratory and introduced her to the mysterious new rays. However, it was not mentioned whether her hand with a ring was exposed to this ray (Fig.2.) on the same day, but according to Edgar Ashworth Underwood, Director of Wellcome Historical Museum the picture of his wife's hand was taken on November 8, 1895. This date was accepted by Konrad Weiss, the historiographer of Austrian Roentgen Society and is accepted as the date of the discovery.

Fig. 2. X-ray picture taken by Roentgen in 1895 of his wife Bertha Ludwig's hand. (Courtesy: Prof. Alok Mukherjee of Jadavpur University, Kolkata)

2. X-rays produced before Roentgen

There are evidences that X-rays had been produced experimentally before Roentgen's date in 1895. This is not surprising because the basic physical process to generate X-rays is the passage of electricity through gases which had been started studying in eighteenth century. Francis Hauksbee (estimated to be died in 1713) who was the Curator of Experiments to the Royal Society, London described seeing 'the shape and figure of all parts

of his hand' while working with electricity and vacuum (Peh, 1995). Interest in the study of discharge in gases was revived in the middle of nineteenth century after Faraday's experiments with "radiant matter" and many scientists were involved in producing different improvised discharge tubes to study discharge of gases. Heinrich Geissler, Johann Wilhelm Hittroff, and Sir William Crookes were some of the people who worked with discharge tubes and they had unknowingly exposed to X-rays while working.

Interestingly, in 1879 William Crookes (1832-1919) produced X-rays when the vacuum of his discharge tube was high enough as he found the photographic plates stored near his work table were fogged. Without knowing the real cause of fogging he blamed the manufacturer for supplying 'defective' plates (Grigg, 1965).

Philipp Lenard (1862-1947) worked on cathode rays and it is believed that he was very close to the discovery of X-rays. In fact both Lenard and Roentgen was nominated for the Nobel Prize in Physics for the year 1901, and the Committee recommended that the prize should be divided equally between Roentgen and Lenard. However, the Royal Academy of Science did not follow this recommendation and decided to award the prize to Roentgen alone. On October 12, 1892 Lenard had been able to show for the first time that cathode rays can penetrate the aluminium window and can travel a few inches in air by observing the fluorescence produced on granules of potassium phosphate placed outside the tube (Glasser, 1934). After about four years in 1905, the Nobel Committee decided to award the Nobel Prize to Lenard for his ingenious work on cathode rays. Lenard, however, considered himself to be "the mother of X-rays" while Roentgen was "the midwife who happened to deliver the child". There are other scientists who are believed to have observed X-rays before Roentgen and we are not going into the details of those stories.

However, the first recorded evidence to produce Roentgen rays was about hundred years before Roentgen by William Morgan (1750-1833), the Welsh mathematician and Chief Actuary of British Equitable Assurance Society. He (Morgan, 1784) reported in the Philosophical Transactions that based on the length of time for which mercury was boiled in vacuum—the 'electric' light turned violet, purple, then beautiful green and finally the light became invisible! His success was based on the use of an improved vacuum, made possible by 'boiling mercury' which was a method developed by a certain Walsh (exact identity not known) (Grigg, 1965). Morgan also presented this discovery to the Royal Society in 1784 which was witnessed by Richard Price and one of Richard's friends an American 'electrician', famous Benjamin Franklin (1706-1790)!

3. The First X-ray Roentgenograph: Claims and Counter-claims

The first 'shadow graph' or 'Roentgenograph' of metal objects was obtained by accident in 1892 by a Philadelphia experimentalist Arthur Willis Goodspeed (1860-1943). The story goes like that Bill Jennings was counting his coins after the Bill Jennings' Carfare on the Woodland Avenue trolley when Goodspeed asked Jennings to help in photographing the spark gap of a Ruhmkorff coil. Jennings put his coins on the top of a plate while assisting in the positioning of the electrodes. The plate was later found to have black patches. Rounded shadows shown in Fig. 3 are the images of coins. They paid little or no attention to those circular shadows till the announcement of Roentgen's discovery was made when they repeated the experiment and understood the reason. However, Goodspeed expressly and repeatedly denied any claims to priority because at that time he had failed to interpret these shadows.

Fig. 3. Goodspeed's first shadowgraph produced in the University of Pennsylvaniaon February 20, 1890. The rounded shadows are coins. (Taken from: *The Trail of the Invisible Light*)

What we described above is the shadowgraph or roentgenogram produced unintentionally but who produced the first roentgenogram after the discovery of X-rays is again marred with claims and counter-claims. As described in the book *The Trail of the Invisible Light* (Grigg, 1965), the most legitimate claim is that of a Scottish engineer Alan Archibald Campbell Swinton (1863-1930) who tried to replicate X-ray photos in the beginning of 1896 immediately after the discovery. He conducted his experiment using a homemade tube and his plates were first reproduced in *Nature* on January 23 and subsequently in *Industries and Iron* and the *Electrical Review* of London the next day.In the reconstructed timetable that he maintained, the following were captured: first (poor) roentgenogram on Tuesday January 7; first satisfactory "metallic" (a razor in its paperboard casing) roentgenogram on January 8; first roentgenogram of a hand on January 13 (shown to the Prince of Wales); and first exhibit of those two plates on January 16, 1896.

A bold claim was made by Michael Idvorsky Pupin (1858-1935) of USA, an immigrant from former Serbia, that he produced the first roentgenogram on January 2, 1896 after Roentgen. In 1924 he wrote: "I obtained the first x-ray photograph in America on January 2, 1896 two weeks after the discovery was announced in Germany". This claim is self-contradictory in the sense that Roentgen made the first announcement of his discovery on January 23, 1896 before the Würzburg Society, Germany, and therefore, Pupin's claim of January 2 is unrealistic. February 2, instead of January 2, seems to be reasonable which is also closer to "two weeks" as claimed after Roentgen's first announcement. There are enough evidences to reject the date as claimed by Pupin. Literature search shows that Pupin's first paper on Roentgen rays (dated Saturday, February 1, 1896) was published on February 5 in *Electricity* of New York which was essentially a summary of data from European sources (Grigg, 1965). His first roentgen plate as mentioned in his article was published in *Science* around February 14. Interestingly, this claim was widely accepted in the American literature as if it had been undoubtedly true.

Thomas Edison (1847-1931), inventor of electric bulb, realized the importance of the Roentgen rays as soon as the cable announcement reached the USA and immediately started replicating the roentgen apparatus. According to a statement made by his secretary William Henry Meadowcraft "Mr. Edison was the first to recognize the importance of the cable announcement of Dr. Roentgen's discovery. The same day he started to make the apparatus and had it finished the next day. Three of the metropolitan dailies heard of it and for three weeks more than twenty newspaper reporters were stationed at the Laboratory." First interview of Edison was made on February 7, 1896 and published in *Times* on February 8. Edison strongly believed that some practical (commercial) application would emerge from Roentgen's "purely scientific" discovery and he employed his staff to find out the most favourable conditions for taking roentgen photograph. A sketch of the design of one of his earliest apparatus using Hittrof tube is presented in Fig. 4.

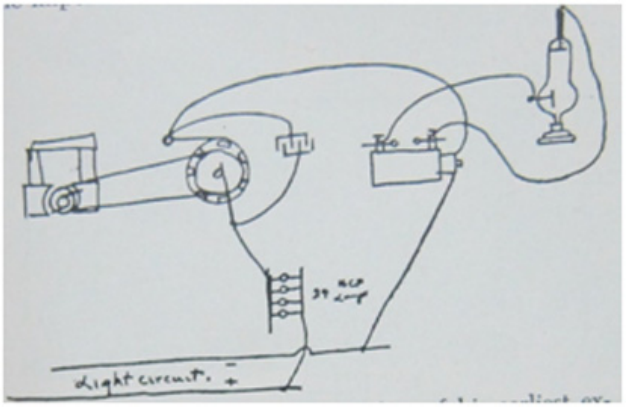

Fig.4. Sketch of Edison's early X-ray apparatus. (taken from: *The Trail of the Invisible Light*)

4. What's in a Name?

What's in a name? Roses are roses, in whatever name we call them might be true in literature but not to scientists. There were a lot of debates, controversies, personal choices and etymological discussions in choosing the name of the pictures taken by X-rays. The very earliest terms used were the unabbreviated easily understandable combinations of words such as 'X-ray photograph' or 'shadow photograph'. 'Roentgenography' is a shorter version of the Roentgen photography and therefore 'roentgenogram' originates in more than one way from roentgen photograph. All scientists have their own choice of names for the phenomenon, e.g. Frederic C. Whitmore of Philadelphia wanted 'silhougraph', to Louis Bell of Boston everything except 'X-ray picture' is barbarous and sophomoric; A.F. McKissick of Alabama Polytechnic Institute at Auburn was in favour of 'Röntgraph', which W.F. Magie found it hideous; C.F. Brackett of Princeton College contended that 'skiasmagram' (meaning shadow-picture) would be just perfect; Alex Roy of Toronto selected 'ethergraph'; Renigald Fessenden of Pittsburgh suggested 'Lenardograph'and F.L. Woodward of Harvard had the combination 'electro-sciagraph'; Edison for 'fluorography'; Max Osterberg of Columbia College, New York for 'skotograph'; A.W. Wright of Yale for 'cathode'or 'roentgen' pictures. Finally Arthur Goodspeed, who accidentally obtained the X-ray picture of metal objects before the discovery of X-rays by Roentgen and could not therefore explain the cause of the pictures, indicated that he had coined the term 'radiograph' on February 7, 1896, which was published it in *Science* of February 14 and he learned that Dr. Lodge (Sir Oliver Joseph Lodge) had suggested the same term a few days later.

Then came the etymological discussion on the origin of the word (suffix) -gram, -gramm, -gramme. The word suffix '-gram' implies a combination of words as in pro-'gram' or pro-'gramme' etc. Similarly, the word suffix 'graph' will mean words like photograph, chronograph etc, which in subtle way refers to instruments which draws or records. While the use of the terms Röntgraph and Röntgenograph was not uncommon, but the first official entry of the word Röntgenogram was found in the March 1898 issue of the *American X-ray Journal*. Interestingly, 'radiogrpah' was described as an instrument designed to 'inscribe the duration of sunshine' as far back as in April 1881 (about fifteen years before the X-ray discovery) in the *Journal of Science*.

As detailed in the book *The Trail of the Invisible Light*, the colloquial term for roentgenogram has been derived in many languages from the respective word for snapshot (photographic), as the Russian *snimok* or the Hungarian *kép*. In Italian it comes from the word for plate, *lastra*, which originally meant 'polished stone'; in French it is a feminine abbreviation *la radio*; in German the *Röntgenbild* has always been and still is an acceptable term

5. Impact of Discovery of X-rays in India

The news of discovery of X-rays started propagating rapidly throughout Europe and reached America at the beginning of January,

1896. Roentgen started mailing reprints of the paper of his discovery from January 2, 1896 to his colleagues in Vienna, Germany, Paris, England. His discovery was first printed in public domain in the January 5 1896 edition of the newspaper *Freie Press* in Vienna. From there the news reached several European newspapers the next day and it reached the United Sates on January 7, 1896 by cable from the newspaper *Standard* (London) and was published in several American newspapers on January 8, 1896. *The New York Times* reported this discovery on 16th January 1896 as a new form of photography which revealed hidden solids and also exposed the bones of the human frame. Roentgen's discovery in a scientific periodical was first published in the USA under the title *Electric Photography Through Solids* in the *Electrical Engineer* (New York) dated January 8.

It will not be out of place to mention here is that work on discharge tube and electric ray (as it was called at that time) also attracted the attention of science loving people in India as we found that Father Lafont (1837-1908) of St. Xavier's College, Calcutta brought a Crooke's tube from Europe at a time (1878-79) when vigorous research on discharge of gases was in progress in Europe. Father Lafont delivered a lecture in 1880 titled "Crookes on Radiant Energy" in the Science Association (Biswas, 2001). Lord Lytton, the then Viceroy of India invited Dr. Mahendra Lal Sircar to demonstrate the actions of Crookes tube. A contemporary report described:

> "It is not possible for any individual to forget the evening Dr. Sircar had such a wonderful mastery over the subject that he very easily explained the amazing behavior of one millionth of atmosphere to the entire satisfaction to His Excellency. Two ancient European professors of science were present there and they directed their arguments in a sophisticated way against Dr. Sircar. They had no belief in the bombardment of ions. But the wheels of mica placed at forty-five degrees revolved like a well-conducted machine. That was the triumph of science."

It is not known exactly when and how the news of this discovery reached Calcutta (now Kolkata), but it is fascinating to note that it had produced a huge interest among the science loving people in India, although still under British rule.Within a few months of the discovery of X-rays,we find that Mahendralal Sircar (1833-1904), who was the founder of the Indian Association for the Cultivation of Science (IACS) in Calcutta, ordered a Roentgen tube from Ducretet Company in Europe and received it in June 1896. As noted in his diary (Biswas, 2000) on Thursday 11th June 1896

> "The cases (3 in number) from Ducretet containing apparatus for experimenting with Roentgen Rays were brought from the Customs House to the Association today. With Amrita opened them and found that they have omitted to send the Flourescent Screen. The cathode disc was slightly bent. The cells were too big".

Here Amrita is his son Dr. Amritalal Sircar. He carried out experiments on 20th June 1896 to produce photograph of hand with the procured Roentgen machine but he failed to produce good images. He noted in his diary

> "Made experiments on the X-rays with our newly arrived apparatus. The hand at first was not successful, but afterwards it was".

He repeated his attempts to obtain photograph and became successful on 23rd June, as he noted in his diary

> "After visiting the patient at Maniktala, came to the Association and performed experiments on the X-rays, The first was a failure, evidently from over-exposure. The second (frog) was particularly successful. The third (a coin on a plank) was very successful".

Therefore, according to this diary, the first successful X-ray photograph was produced in India on 23rd June 1896 in Calcutta by Mahendra Lal Sircar. However, it is difficult to comprehend how he got X-ray photograph without the fluorescent screen. It is possible that the fluorescent screen was obtained from Father

Lafont on loan as we found in his diary noted on 2nd July 1896, the day before the public lecture to be delivered by Mahendra Lal Sircar on X-ray photography, he 'went to Father Lafont after 5 p.m. for loan of fluorescent screen'. Sircar delivered a one and half hour lecture on the New Photography with X-rays of Prof. Roentgen on 3rd July at the Association before an audience of more than 300 persons. The Proceedings of the Twentieth Annual IACS meeting held on 11 September 1897 recorded

> "The Association had thus the honour of being the **first** to place this remarkable discovery before the Indian public"(emphasis put by the author).

Experiments using X-rays continued at the IACS by Amrita Lal Sircar under the guidance of Mahendra Lal Sircar with blocks of wood and books of different thickness, with sheet of iron, tin foil and zinc foil as has been recorded in the diary of 13th December 1899. This is the beginning of X-ray research in India after the discovery of X-rays and thus IACS became the nucleus of X-ray research in India (Biswas, 2001, Appendix XXXV).

6. Jagadis Chandra Bose and his X-ray Apparatus

Acharya Jagadish Chandra Bose (1858-1937) was "the first person in India to reproduce Roentgen's discovery in 1895 of the generation of X-rays in a cathode ray tube" remarked D.M. Bose (Bose, 1949) in his article titled "The Scientific Activities of Acharya J.C. Bose". He also remarked that 'reading a newspaper account of Roentgen's discovery' he built an X-ray apparatus in Presidency College, Calcutta. The statement finds its meaning when we see that Acharya Bose was visiting Europe in 1896 at a time when the excitement of the discovery of Roentgen rays in Europe was at its peak. It is no wonder that Jagadish Chandra Bose, being a physicist and an exceptional experimentalist, was attracted to this discovery and studied in detail about the production of Roentgen rays. Jagadish Chandra Bose returned to India in April 1897. It is clear that the idea of producing X-rays crystalized in his mind while he was in Europe and took fruition after his return to Calcutta. Although we find mention of Jagadish Chandra's X-ray apparatus in different places, there is a controversy regarding the exact date when he built the X-ray apparatus and we intend to investigate, further on that.

Arun Kumar Biswas (2000) in his book *Gleanings of the Past and the Science Movement* mentioned that "we have reports of Jagadis setting up his own X-ray apparatus in 1887, quite a few years before such a machine was imported to India and showing the image of a broken bone on a screen coated with barium platinocyanide". It is evident that the year 1887 is not correct (which is eight years before Rontgen's discovery of X-rays). To us 1897 appears to be more reasonable (this might be a typo). More authenticated mention we found in a letter written by Jagadish Chandra Bose to his friend Rabindranath Tagore. In a letter (without any date) to Rabindranath Tagore, Jagadish Chandra (Sen, 1994) wrote "if possible please come to Presidency College at 8 in the morning. I have to examine a patient using Roentgen *kol* (machine) he has broken his back. You may feel that this is not as dangerous as malaria which is prevalent in this country. I too had mentioned this but could not avoid Dr. Nilratan Sircar's request. In case you can not go to the college, come directly to no 85 at 9. I will be back by then". According to Shri Dibakar Sen (Sen, 1994), the author of *Patrabali* (collection of letters written by Rabindranath Tagore to Jagadis Chandra Bose), the letter was written sometime in February 1898.

Shri Jogendra Kumar Chattopadhyaya reported in the magazine *Prabasi* (Chattopadhyaya, 1935) that "Shri Jagadindu Ray who lived in Serampore was an assistant of Jagadish Chandra Bose" and "the machine was

built at Presidency College by Jagadindubabu under the guidance of Jagadis Chandra Bose." The author also reported that he came to know from Jagadindubabu that "Satyendranath Thakur will come today to see the machine at 3 pm. I went to Presidency College with one of my friends at 3 o' clock and learnt from Shri Jagadindubabu "Satyendrababu is in the next room with one of his I.M.S. friends Captain Chatterjee". When I entered into the next room with my friend, Professor Bose, Doctor Chatterjee and Satyendrababu looked at bones of my broken hand with great interest. Satyendrababu told to his friend in English that this is probably the first picture of broken hand taken using X-rays in Calcutta. There was no X-ray machine available then in Calcutta."

This date seems to be reasonable because we have been able to locate a press report published on the 5th May 1898 edition of *The Amrita Bazar Patrika* (an important English daily, now discontinued) in which description of X-ray apparatus and demonstration of X-ray picture of hands etc. by Jagadish Chandra Bose was presented (Press Report, 1898). The press report describes the apparatus as well as emphasized on the improvement he made over the apparatus built by Roentgen.

Unfortunately we have not found any authenticated description of the apparatus in his diary nor a photograph of his apparatus. Only documented evidenceis the Press Report titled "Professor Bose and the New Light" published in the 5thMay 1898 edition of *The Amrita Bazar Patrika* (Sen, 1994) published from Calcutta. From this it is clear that Jagadish Chandra built his X-ray apparatus which was sometime between coming back to Calcutta after his Europe tour in April 1897 and May 1898. It reported

> "We were shown a photograph of human palm taken by the Professor with the new light, and the ghastly sight will long be vividly imprinted in our memory, for there, in the photograph, instead of the ordinary fleshy palm is seen depicted a long range of bones presenting a skeleton like appearance".

Professor Bose also shown some other experiments like "a leather money bag, containing a rupee and a knife was interposed between the fluorescent screen on when the images are projected and the vacuum tube through which sparks were passing. No sooner was the leather money bag interposed, than there appeared on the screen an image of the rupee and knife reproduced with the astounding fidelity".

Fortunately for us, the Amrita Bazar Patrika Report described the improvement that Jagadis Chandra had made in his apparatus over that of Roentgen. Roentgen used Ruhmkorff's coil as a source of transient high voltage in discharging the gas in the discharge tube. A schematic diagram of Roentgen's apparatus is presented in Fig. 5. Ruhmkorff's coil produces high voltage pulse in the secondary coil by electromagnetic induction when a DC supply in the primary is interrupted by a mechanical contact. Every time there is an interruption there is a high voltage pulse in the secondary coil. This secondary coil is connected with the X-ray tube. By coupling a Tesla coil with the secondary of Ruhmkorff's coil (which then acts as the primary of the tesla transformer) Jagadis Chandra was able to produce a higher voltage, many times more than that can be produced using a single Ruhmkorff's coil. The news report mentioned

> "He has managed to get for better results by connecting the induction coil with a Tesla Transformer and then allowing the sparks to pass through the vacuum tube. The simple function of the piece of apparatus known as the Tesla Transformer when connected with a Ruhmkorff's coil is to increase its power enormously and hence it is evident the new arrangement cannot but yield excellent results."

On the basis of this information we have produced a schematic diagram (Fig. 6) close to the apparatus he had probably used (Roy, 2015). The paper reported that Jagadis Chandra intended

to procure another huge Tesla Transformer from Europe, which will be thousand times more powerful than the one in his possession. The paper reported "He would join it with the Dynamo Electric Machine in the Presidency College and with this splendid apparatus, (which would be at least 5,000 times more powerful than the present arrangement) in the hands of so skilful an experimenter, we anticipate brilliant achievements in a hitherto dark and unexplained region of science. Even with the poor means in his hands he has got excellent results, results which would be creditable to the experimental skill of any scientist."

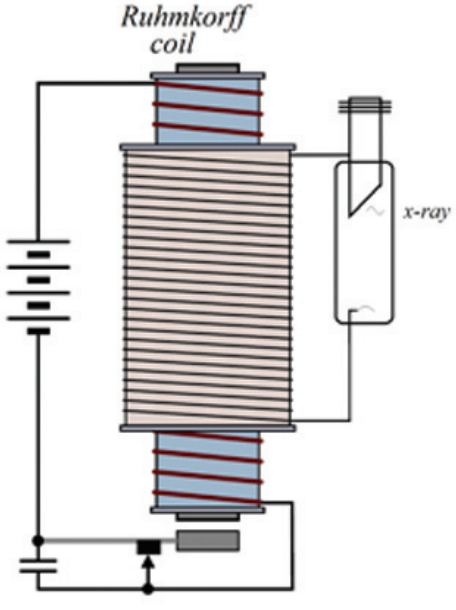

Fig. 5. Schematic diagram of X-ray apparatus using a Ruhmkorff's coil as a high voltage source as was used by Roentgen.

It is evident that Jagadish Chandra developed an improved high voltage source to be coupled with the X-ray tube. But it is not known from where Jagadish Chandra got the X-ray tube. Was it the same X-ray tube that was imported by Mahendralal Sircar with which the improved high voltage system was connected? This requires further investigation because what was written in the diary of Mahendralal Sircar is startling and has enough reasons to dig further to find the truth. The diary dated 6th March 1899 recorded the following "Went in the evening to see the case of cystic tumor in Bechuram Chatterjee Street. Suresh's (Dr. Suresh Prasad Adhikari) apparatus for photographing Roentgen Rays did not act well. He said it has been spoiled by J.C. Bose."

The Amrita Bazar Patrika (Press Report, 1898) did not give detailed mechanism of the photographic process used by Jagadish Chadra Bose, but it was mentioned that the photographic process is a tedious one and reported that "Professor is completing an arrangement by which an image may be projected on a screen and thus viewed directly by a number of curious spectators". Jagadish Chandra, being a scientist of excellent calibre, did not stop there by taking photographs of different objects but started investigating the action of X-rays on various bodies.

Jagadish Chandra used barium platinocyanide screen to record X-ray photograph as was done by Roentgen. He made barium platinocyanide screen in his laboratory as has been recorded by D.M. Bose (Bose, 1949). In his article he mentioned that Jagadish Chandra set a young research assistant Nagendra Chandra Nag in Presidency College "to prepare barium platinocyanide screens with which he took X-ray photographs of different objects like a human hand, coins enclosed in a purse; some of them were reproduced in a juvenile monthly '*Mukul*' for which he used often to write popular articles on scientific topics in Bengali." However, our search of *Mukul* during the period did not produce any such photographs.

The Amrita Bazar Patrika also reported that on the suggestion of Professor Bhaduri of the Chemical Laboratory, Jagadish Chandra has succeeded in finding another substance, Potassium Platinocyanide, "which is far more easily obtained than the corresponding Barium compound, is equally effective and hence may be substituted for Barium Platinocyanide in these researches." The

report ended with "The researches, however, are not yet completed and we await the result with interest." Unfortunately we did not know more about his X-ray research after that, one of the reasons being that Jagadish Chandra himself became more interested in bio physics and left the mainstream research in physics.

It will be proper here to mention that Pradyot Kumar Tagore, son of Sir Jatindramohan Tagore, who was trained in England on photography, specially X-ray photography, teamed up with Father Lafont to take an excellent photograph (Ghosh, 1991) of the right hand of Earl of Elgin, the then Viceroy of India, wearing rings. The picture was published in the Journal of Photographic Society of India in 1897.

7. Building X-ray Machine

It is interesting to note that although use of X-rays was started immediately within a few months of the X-ray discovery by importing X-ray machine from abroad and a X-ray machine was fabricated in the laboratory within about two years of the discovery, production of indigenous machines in India took many more years. It appears from the book published on the history of X-rays entitled "The Trail of the Invisible Light" (Grigg, 1965) that the first X-ray machine in India was built in India by Shri Bibhu Bilas Bhowmik (Fig. 7) of Calcutta a few years before independence.

Bibhu Bilas Bhowmik got interested in X-ray machines while working as an assistant to Dr. (Capt) Phanibhusan Mukherjee in the X-ray department of Patna Medical College while he was a student of B.Sc. class. After his M.Sc. in Applied Physics in 1933 from Calcutta University he went to London in 1934 on Guruprasanna Ghosh scholarship. After obtaining M.Sc. degree in engineering from London University he worked for sometime in a reputed company in London involved in manufacturing X-ray equipment. He

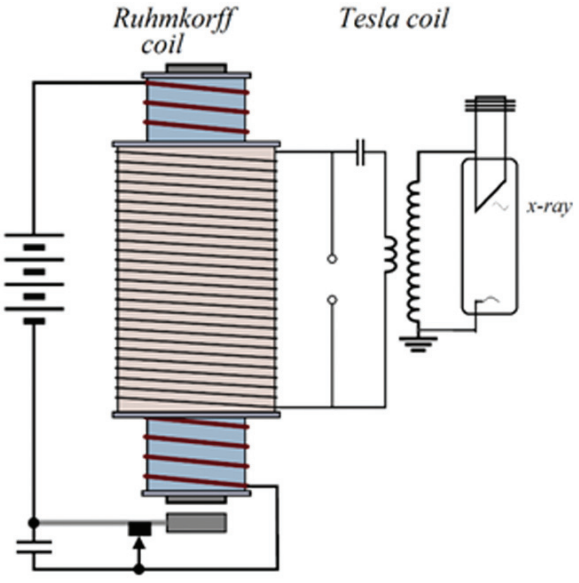

Fig. 6. Schematic diagram of Tesla coil coupled with Ruhmkorff's coil, the apparatus which Jagadis Chandra probably used as a high voltage source to the X-ray tube

then worked in Radium Institute in Paris and was awarded a scholarship by French National Scientific Research Fund and finally received hands-on training in a German company involved in manufacturing electro-medical instruments and X-ray machines.

Fig. 7. Bibhubilas Bhowmik

After his return to India in 1939 he used all his skills towards indigenous ventures. He received support in this endeavour from Prof. Meghnad Saha, Dr. Bidhan Chandra Roy, Dr. Shyama Prasad Mukhopadhaya and many others

and within a few years he was able to establish a company of his own by the name "Radon House" which became the first X-ray manufacturing plant in India. Within a few years it started producing high voltage generators, became one of the important training centres to educate people on practical engineering and started producing other electrical instruments indigenously. Fig. 8 shows the appreciation that was received by the founder of Radon House from Pt. Jawaharlal Nehru, Indira Gandhi, Bidhan Chandra Roy. In recognition of his scientific and technical talents, Indian National Science Academy (INSA) offered him its fellowship (FNA), he became the President of Engineering and Metallurgy Section of the 1955 Indian Science Congress session. A postage stamp was also released by the Indian Government to commemorate his endeavor (Fig. 9). After independence, other companies also started producing X-ray equipment

Fig. 8. Pt. Jawaharlal Nehru, the first Prime Minister of India with his daughter Indira Gandhi watching the instrument at Radon House. Seen in the picture are Dr. Bidhan Chandra Roy, First Chief Minister of West Bengal and Bibhubilas Bhowmick (extreme left). (Source: Bengali Magazine *Desh*)

Fig.9. Fascimile of Postage stamp released commemorating Bhowmik's achievement, (Taken from: The Trail of the Invisible Light)

5. Conclusion

X-ray was present since the time the work on discharge of gases started in the nineteenth century. William Goodspeed while working with discharge tubes had unknowingly obtained an X-ray picture of metal objects (coins) before the discovery of X-ray by Roentgen but was unable to explain its cause. It was Roentgen who was able to relate the cause and effect and was awarded the Nobel Prize for this discovery. The discovery of X-rays generated a huge interest world-wide including in India. X-ray machine was imported to India within about six months of the discovery of X-ray.Jagadish Chandra built X-ray apparatus on his own between 1897 and 1898 and took X-ray photograph of broken hand using his apparatus with the help of Dr. Nilratan Sircar. First X-ray research in India was started at the Indian Association for the Cultivation of Science (IACS), Kolkata, after the discovery of X-rays, and proliferated from here to the other parts of the country.

Acknowledgement

The author is grateful to Prof. Barun Kumar Chatterjee of Bose Institute, Dr. Rajinder Singh of Germany, Dr. Gauri Roy, (daughter of Bibhubilas Bhowmilk) Formerly at the Indian Association for the Cultivation of Science and Prof. Alok Mukherjee of Jadavpur University and many others for providing important information

and valuable discussions. The author also thanks the authorities of Bose Institute for giving access to the news report published in *The Amrita Bazar Patrika* in 1898.

Bibliography

Biswas, Arun Kumar. *Gleaning of the Past and the Science Movement (in the diaries of Drs. Mahendra Lal and Amritalal Sircar)*, The Asiatic Society, 2000.

Biswas, Arun Kumar. *Father Lafont of St. Xavier's College, Calcutta and the Contemporary Science Movement*, The Asiatic Society, March 2001.

Bose, D.M. The scientific activities of Acharya Jagadish Chandra Bose, Science and Culture 14 (1949):366.

Chattopadhyay, Jogendra Kumar. *Amar Dekha Loke* (Person I saw), *Prabasi*, Ashar (1342 beng), 1935.

Ghosh, Siddhartha. *Kaler Sahar Kolkata*, Ananda Publishers, Kolkata, 1991.

Glasser, O. The Genealogy of Roentgen Rays II, *AJR* (1934):349.

Grigg, E.R.N. *The Trail of the Invisible Light*, Charles C Thomas Publisher, 1965.

Morgan William, *Philosophical Transactions*, Vol. LXXV (1784):278.

Peh, W.C.G. Controversies surrounding and following Roentgen's discovery, *Singapore Med. J.*36 (1995):54.

Press Report titled "Professor Bose and the New Light" published in the 5th May 1898 edition of the Calcutta based English daily *The Amrita Bazar Patrika* (discontinued).

Roy, S.C. Early years of X-ray research in India, *Science and Culture* 81 (2015):72.

Sen, Dibakar, (Ed.) *Patrabali* (Collection of letters of Acharya Jagadis Chandra Bose written to Rabindranath Tagore), Bose Institute, Kolkata 1994.