B B Ray and Controversy over the Spectral Raman-lines

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Abstract

In the beginning of 1930s, Professor Bidhu Bhushan Ray (1894-1944) of the University of Calcutta while experimenting with X-rays observed spectral lines. His contemporaries in Europe and USA were unable to reproduce the results. This led to the controversy over the existence of the lines. According to “oral history”, that is, information from B B Ray’s family members, he was humiliated as he was unable to show the spectral lines to his colleagues. To compare the “oral and written” history of the controversy; Niels Bohr-B B Ray correspondence, Arnold Sommerfeld’s publications and other contemporary articles are analysed. The results of the analysis of these documents are given in this communication.

Key words: A Sommerfeld, B B Ray, M N Saha, Scientific controversy, University of Calcutta, X-rays spectroscopy.

1. INTRODUCTION

Bidhu Bhushan Ray (also written as Bidhubhusan Ray or Bidhu Bhusan Ray or B B Roy, Fig. 1) is considered as one of the founders of the X-ray spectroscopy¹ in India.² Ray was member of the Indian National Science Academy, one of the editors of *Science and Culture* and Member of other scientific institutions such as Indian Physical Society and Indian Science News Association. Unfortunately, not much is known about his life and scientific work. In the beginning of 2017, a book on *B B Ray – A Pioneer of X-ray Spectroscopy* was published by me. The present article is largely based on one of the chapters. However, in the book, the issue of oral vs. documentary history is not dealt with.

Fig. 1. B B Ray
(Credit: “*Science and Culture*”)

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¹ For the history of introduction of X-ray’s in India, see, Roy S.C., Discovery of X-rays and its impact in India, *Indian J. Hist. Sci.* 52(2017):66-77. Roy, S C, Early years of X-ray research in India, *Sci. Cult.* 81(2015):72-75

² For biographical information, see, Singh R., *B B Ray – A Pioneer of X-ray Spectroscopy*, Shaker Publisher, Aachen 2017; Sen S N, Late Dr. Bidhu Bhusan Roy – A life devoted to science, *The Sunday Hindustan Standard*, Aug. 13, 1944; R C M., Obituary – Professor Bidhubhusan Ray, *Sci. Cult.* 10(1944-1945):111-112; Anonymous, Prof. B B Ray, *Nature* 154(1944):818-819. INSA, <http://insaindia.res.in/deceaseddetail.php?id=N350654>, Oct. 31, 2016.

Scientific controversies are parts and parcels of scientists' life.³ In the case of B B Ray it is rather a special case, because we have documentary and oral⁴ historical evidences (detail later).

2. CHANGE OF FREQUENCY IN VISIBLE LIGHT AND X-RAYS

In 1928, C V Raman and K S Krishnan found that visible monochromatic light scattered by a medium has not only the original colour, but also others (Raman and Krishnan, 1928, pp. 501-502). Raman in a later publication interpreted the discovery as an "analogy to the Compton Effect"

in X-rays, in which, also, the change of frequency takes place; but it depends on the angle of observation (Raman, 1928, p. 711). The first two articles on the discovery were based only on visual observations. The spectroscopic results were published by Raman in the *Indian Journal of Physics* (Raman, 1927-1928, pp. 387-398). Two years later, that is, in 1930 Raman alone received the Physics Nobel Prize⁵ "for his work on light scattering and the discovery of the effect named after him."

Raman's previous student B B Ray⁶ (Fig. 2) motivated by Raman's discovery; and suggestion by the German physicist Arnold

Fig. 2. Standing: Left to right: H Mitra, G Dutt, DD Banerjee, S K Mitra, S K Acharya, A C Saha, A N Mukherjee, B B Ray. Sitting: Left to right – S N Bose, P N Ghosh, C V Raman, M N Saha, D M Bose, B N Chukerbutty, J C Mukherjee (Credit: *Science and Culture*). Farewell party to Professor MN Saha at the University College of Science and Technology, Calcutta on the eve of his departure to UK in 1920.

³ For general discussion of scientific controversies, see, Engelhardt H T, Caplan A L, *Scientific Controversies – Case studies in the resolution and closure of dispute in science and technology*, Cambridge University Press, Cambridge, 1989.

⁴ I communicated with B B Ray's family members via e-mails.

⁵ For the controversy over Raman's not sharing the Physics Nobel Prize with K S Krishnan, and Russian physicists G S Landsberg and L I Mandelstam, see, Singh R., Riess F., The 1930 Nobel Prize for Physics: A close decision? *Notes and Records, Royal Society London* 55(2001): 267-283. Singh R., *Chemistry and Physics Nobel Prizes – India's Contribution*, Shaker Publisher, Aachen, 2017, pp. 61-88.

⁶ For C V Raman and B B Ray relation, see, Singh R., B B Ray under the influence of C V Raman and M N Saha, *Sci. Cult.* 83(2017):84-91

Sommerfeld⁷, who visited India shortly after the discovery of the Raman effect⁸, started to find out similar effect in X-rays. Before B B Ray, in the USA, B Davis and D P Mitchell (Davis and Mitchell, 1928, pp. 331-335), and D P Mitchell (1929, pp. 871-878); in Germany, W Ehrenberg (1929, pp. 234-236), and W. Kast (1929, pp. 519-522) tried to find the Raman effect in X-rays, but without success.

In 1930, B B Ray in a publication stated that he:

“observed that a part of the monochromatic X-rays in passing through carbon undergoes a change in frequency and appears on the longer wave-length side of the primary radiation. ... In addition to the original copper $K\alpha$ radiations and other lines in the tungsten L -series, a new diffuse broad line of wave-length 1592 X.U. ($\nu/R = 572$) appeared on the photographic plate (Ray, 1930, p. 746).”

About the interpretation of the results, he stated:

“The origin of this line may be explained by the fact that the copper $K\alpha$ radiation in passing through carbon loses a part of its energy equal to that of removing the electron from the K-shell either to the optical level or to infinity. The frequency difference between this line and the original copper $K\alpha$ lines is 20.1 (Ray, 1930, p. 746).”

He was of the opinion that this effect has similarity with the Raman effect, which was theoretically predicted by H A Kramers and W Heisenberg. A few months later, he produced a spectrogram, which showed the effect of copper $K\alpha$ radiation in passing through carbon, nitrogen, and oxygen (Fig. 3).

Fig. 3. “The known lines are marked as usual, while the new ones are shown by numbers.” The three line 1592 X.U., 1614 X.U., and 1643 X.U. are due to the scattering of copper $K\alpha$ radiation by carbon, nitrogen, and oxygen respectively (Ray 1930, p. 746)

Ray concluded:

“The absence of any modified lines by scattering (...) in any other direction than that of propagation suggests that in all probability in an interaction between a quantum and a bound electron (emphasis in original), the former on its passage through the medium loses a part of its energy and an equivalent amount of momentum in raising the electron from one orbit to the other, and is propagated in the original direction as a modified wave of lower frequency (Ray, 1930, p. 746).”

O Berg and W Ernst opined that if the lines observed by B B Ray really exist, they are of high interest (Berg and Ernst, 1931, p. 401). In the USA, J M Cork repeated B B Ray’s experiment. In order to emphasize that his instruments were sensitive enough to observe the effect, he stated –

⁷ B B Ray thanked D M Bose and A. Sommerfeld for many useful hints, see, Ray B B, Mehrfachabsorption und sekundäre K-Absorptionsgrenze im Röntgengebiet, *Zeitschrift f. Phys.* 55(1929):119-126.

⁸ For A Sommerfeld’s visit to India, see Singh R., Arnold Sommerfeld – The supporter of Indian physics in Germany, *Current Science* 81(2001):1489-1494

“Although it should have been possible to observe a modified line of $1/3000$ the intensity of the unmodified, *in no case has any trace of a modified line been observed* (emphasis in original) (Cork, 1931, pp. 1555-1558).”

In Sept. 13, 1930, issue of *Nature*, B B Ray, rebutted the American and Europeans. He stated that they were unable to:

“observe the modified line in a direction at right angles to the direction of propagation, where the Raman effect is usually observed, this experiment clearly shows that the modified lines produced by the ‘scattering of X-rays by bound electrons’ are observed in the direction of transmission of the incident radiation.”

And:

“It further follows that to be consistent with the current definition of scattering and absorption, the effect observed by me, which was described in my previous notes to *Nature* as ‘modified lines due to the scattering of X-rays by bound electrons’, would be more correctly described as modification due to part-absorption of the incident radiation by atoms (Ray, 1930, p.399).”

It must have been a great relief for B B Ray to know from M N Saha that former’s observation was correct. About it, B B Ray wrote to N Bohr: “Prof. Saha has just informed me that he has been able to detect this effect very easily in his laboratory & have found the same things as I have got.”⁹ The “things” found by Saha’s student, Saligram Bhargava were published in the same issue of *Nature* as Ray’s next publication. S. Bhargava reported that it is not scattering phenomenon as Ray seems to think; but it is photoelectric ionisation. However, Bhargava gave credit to Ray for having been “the first to analyse the modified (by absorption) beam of primary quanta by a spectroscopic method, and

supplemented the work of de Broglie and Black. It is therefore a remarkable experimental verification of photo-ionisation, and hence it easily explains why no modified beam is observed in any other than the forward direction (Bhargava, 1930, pp. 398-399).” Further work by R C Majumdar on “part absorption” (Majumdar, 1931, p. 92); and S Bhargava’s and J B Mukerjee’s on “modification of quanta by photo-ionisation” supported Ray’s experimental work and ideas (Bhargava and Mukerjee, 1931, pp. 273-273).

M N Saha, the head of Allahabad Group, personally intervened by writing a short article in *Current Science*. Saha wrote that at the initial stage B B Ray was inclined to interpret his observation analogue to Raman effect; but in a subsequent article in *Nature* he and other Indian physicists pointed out that the phenomenon is due to absorption of part of the quantum by the electrons in the K-shell of the medium traversed. So far as the inability of the Western scientists to reproduce B B Ray’s results were concerned, Saha argued - One of the reasons could be that the phenomenon is extremely rare. “Calculation with the data of one experiment has shown that only one quanta in 10^9 is modified by part-absorption on its passage through matter (Saha, 1932-1933, pp. 231-232).”

To defend his results B B Ray along with B B Datta continued experimental work. They were of the opinion that the conflicting results obtained by different authors are due to the thickness of the absorption screens used by other investigators. They wrote: “the increase in thickness of the absorption screen does not necessarily increase the intensity of the modified lines; or rather, on the contrary, if the absorption screen is too thick, the modified lines disappear completely (Ray and Datta, 1931, pp. 224-225).” So far as the terminology “part absorption” is concerned, B B Ray wrote to N Bohr:

⁹ Ray B B to Bohr N, letter undated, 1930 (Credit: Niels Bohr Archive, Copenhagen).

Fig. 4. Spectra sent by B B Ray to N Bohr (Credit: Niels Bohr Archive, Copenhagen)

“I have changed my opinion about it and have termed this phenomenon as part-absorption in X-rays. The fact is that these modified lines are only (underlined in original) observed in the direction of propagation of the incident radiation (see *Nature* Sept. 13, 1930)¹⁰.”

B B Ray sent the observed spectra to Bohr (Fig. 4) and a part of the measurements published in *Nature*.

B B Ray was not satisfied with his theoretical interpretation. He told Bohr:

“Neither in the new wave mechanics nor in your old quantum conception, this phenomena could be anticipated. It is only the question of direction that puzzles me. If it is Smekal-jump or Kramers & Heisenberg’s theory, then the radiation ought to be seen in every direction. The appearance of the Part-absorption radiation only in the direction of propagation makes the whole thing very difficult to understand.”¹¹

He asked Bohr to give idea, so that he is able to understand the physicality of the observation. He informed Bohr that his own ideas, he has written in the form of an article, and sent to press. The paper in press meant by Ray was his article “Teilabsorption von Röntgenstrahlen” (Part-absorption from X-rays) in *Zeitschrift für*

Physik, in which he published the spectra and measured values (Ray, 1930, pp. 261-268). In the paper, he gave experimental details such as the exposure time for plates from 8 to 14 hours. He also warned that the longer exposure does not lead to the quality of the relative intensity of some lines, because continuous scattering causes to blackening of the photographic plates. Under the discussion, he made clear that the expected scattering in all direction, that is, the Raman effect had yet not been found.

There are no evidences to show, how far N Bohr came to help. The fact remains that A. Sommerfeld proved to the scientific community in the USA and Europe that Ray had been misunderstood. His idea is correct (detail below).

3. A SOMMERFELD, A H COMPTON AND B B RAY

As far as B B Ray and the observation of the “Raman lines” are concerned, in the middle of 1930s Sommerfeld wrote a letter to A H Compton. The letter was published in *Physical Review*. In it Sommerfeld “suggested that the lines reported by B B Ray in 1930 may be interpreted as residue of Compton bands cut off” by a particular limit. He also stated that the

¹⁰ Ray B B to Bohr N, letter undated, 1930 (Credit: Niels Bohr Archive, Copenhagen).

¹¹ Ray B B to Bohr N, letter undated, 1930 (Credit: Niels Bohr Archive, Copenhagen)

observations of Ray and other Indian scientists had not been confirmed (Ray, 1930, pp. 261-268), (Majumdar, 1931, p. 92), (Bhargava and Mukerjee, 1931, p. 273) by Americans (Cork, 1931, pp. 1555-1558), (O'Leary, 1937, pp. 873-883). Sommerfeld showed that these lines in carbon, nitrogen and oxygen can be interpreted as:

“the residues of the X-electron contribution to the Compton band (in distinction to Mr. Ray, who speaks of a “partial absorption of the Roentgen rays”). No mention of the Raman lines is to be found in Ray's paper. These should lie between the Compton band and the Rayleigh line and it is probable that the conditions were not favorable for their observation (Sommerfeld, 1936, pp. 38-40).”

In *Annalen der Physik* Sommerfeld hoped to have explained, theoretically and experimentally, the remarkable results of B B Ray (Sommerfeld, 1937, pp. 715-720). Not only Sommerfeld, but also his student Fritz Schnaidt, who theoretically studied hydrogen spectrum, reported the existence of “Raman spectrum” as observed by B B Ray (Schnaidt, 1934, pp. 89-112).

Sommerfeld was sure about Ray's observations, because his theory was based on the experimental work of Hans Kappeler, Zürich, who studied the form and width of Compton lines for Neon, Oxygen, Nitrogen, Carbon and Lithium (Franz, 1936, pp. 129-168).

The author W Franz showed that the Europeans and Americans were unable to observe the Raman-lines, because their experimental conditions do not fulfil the conditions as predicted by the theory (Franz, 1937, pp. 721-740).

The Indian scientific community was informed about Sommerfeld's support to B B Ray by *Science and Culture* as follows:

“Sommerfeld has drawn attention to several facts connected with the structure of the Compton band, which incidentally contain a possible explanation of the

observation of Ray (Ray-Chaudhury, 1936-1937, p. 215).”

In 1950, the existence of partial absorption of photon as in the case of Raman effect was established by K Das Gupta – one of B B Ray's students, and others (Das Gupta, 1950, pp. 563-564; 1951, pp. 313-314; 1962, pp. 2181-2188). Today the “X-Ray Raman scattering (XRS) provides a means for obtaining the information content of soft X-ray spectra while maintaining the experimental benefits of hard X-ray techniques. At present, high-quality X-ray Raman spectra can be obtained in minutes to hours (Bergmann, Glatzel and Cramer, 2002, pp. 221-230).”

4. ORAL HISTORY OF THE IMPOSSIBLE SPECTRAL LINES

B B Ray's nephew (whose father was a student of S K Mitra, a colleague of B B Ray), believes that the controversy played a major role in his (Ray's) premature death. According to other nephew of B B Ray:

“Prof. Heisenberg told my father to tell his brother to carry on the research and he would definitely find the line in X-ray which he was trying to find out. Dr. Ray found the line experimentally once in the machine in his laboratory at University College of Science, but when he called the people to demonstrate the machine did not work. The scholars ridiculed him for the failure, resulted in a heart attack leading to premature death at the age of 49.”

The facts are:

1. With A Sommerfeld's articles in 1936-1937 the controversy was resolved. The controversy could not have played any role in Ray's death in 1944. The other fact is, Ray's correspondence with Bohr shows that soon after his arrival the former was involved in private, as well as official problems. He suffered bad health due to malaria and another

tropical disease, beriberi.¹² He never cured completely.

2. According to B B Ray's publication: "The time of exposure was varied from 8 to 14 hours in different cases ... (emphasis added) (Ray, 1930, p.746)."
3. In the end of 1930s, B B Ray *et al.* studied K-absorption edges of cobalt in its different compounds. They used a Siegbahn spectrograph. "The time of exposure varied from 50 to 60 hours (emphasis added) (Ray, Das and Bagchi, 1938-1939, pp. 528-529)."

Obviously, the probability of visual observation was far from reality. Thus the version – B B Ray wanted to show the lines to his colleagues, and when they came, there were no lines; cannot be correct, as the intensity of lines was too low to be observed visually.

The person who told me these stories, were kids in the 1940s. They heard such stories from their parents or relatives. After about 50 years or more, we human being have different memories.

5. CONCLUSIONS

From the forgoing we see that due to the observation of "Raman lines" in Carbon B B Ray was confronted by some Europeans and Americans physicists; who were unable to reproduce his results; in spite of the fact that they had better instruments. However, his Indian contemporaries were successful. This suggests that they applied similar experimental conditions. Unfortunately, the theoretical interpretation of the "Raman lines" did not come from the mother land of the Raman spectroscopy, but from Germany. Obviously, Indian physicists were not at par with the Western so far as the development of the theoretical physics is concerned.

The case study of B B Ray shows that the interpretation of historical facts can change

with time. The oral history needs careful interpretation.

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¹² Ray B B to Bohr N, letter, Oct. 12, 1926 (Courtesy: Niels Bohr Archive, Copenhagen).

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