Indian Journal of History of Science, 38.4 (2003) 377-387

RICHARD BÄR AND HIS CONTACTS WITH THE INDIAN NOBEL LAUREATE SIR C.V. RAMAN

RAJINDER SINGH*

(*Received 13 Feburary, 2003*)

Richard Bär, a physicist from the University of Zurich (Switzerland), gave convincing experimental support to the existence of the fundamental electric charge, *electron*. This came out as a disputed issue due to the results of Vienna physicist Felix Albert Ehrenhaft, who was supposed to have observed the *sub-electrons*. Sir C. V. Raman, India's the then Nobel Laureate in the field of physics had some communications with Bär in 1920s and 1930s. The present author has procured those old letters from Bär's family. In this short communication, the author has developed a brief view on Bär's scientific achievements and his relation with Raman.

Key words: C.V. Raman, K.S. Krishnan, Light scattering, N.S. Nagendra Nath, R. Bär, Raman effect, Raman-Nath diffraction, ultra-sonic waves.

INTRODUCTION

The FRS and Nobel Laureate Sir Chandrasekhara Venkata Raman (1888-1970) is a well known name in Indian physics. In my previous paper "Sir C.V. Raman and his Contacts with Hungarian Scientists" I have referred to Raman's biographies which deal with different aspects of his life[1]. According to my knowledge, his contacts with Richard Bär, Zurich (Switzerland) physicist, have not yet been explored. In this short communication an effort is made to fulfil this gap.

To start with, a short biography of Richard Bär[2] is worth noting.

*FB Physik - EHF, Research Group on Higher Education and History fo Physics, Universität Oldenburg, Postfach 2503, D-26111 Oldenburg, Germany.
E-mail: rajinder.singh@mail.uni-oldenburg.de

RICHARD BÄR

Richard Bär was born on September 11, 1892 in Basel (Switzerland). In 1897 the family moved to Zurich, where Bär got his early education. In Würzburg (Germany) he studied Mathematics with Astronomy and Physics as optional subjects. In 1915 he did a doctorate in Mathematics "Über Greensche Randwertaufgaben bei der Schwingungsgleichung" (On Green's boundary value problems in the vibration equation)[3]. Besides being a mathematician, he worked for some time in the laboratory of the physicist Wilhelm Wien (1884-1928). Next year he was invited by the renowned Mathematician David Hilbert (1862-1943) to work at the University of Göttingen (Germany). However, due to family reasons, in 1917 he went to Zurich and took a position in the Physical Institute of the University.

In 1917 Bär began working on the elementary electronic charge. A physicist from Vienna, Felix Albert Ehrenhaft (1879-1952) claimed to have carried out experiments where the particles showed *sub-electronic* charge (see details below). Bär, who in between had specialised in this field, presented the results of his studies in Jena at the "Deutsche Naturforscherversammlung" (German Naturalist Congregation) in 1921. Wilhelm Wien, the Editor of the renowned German journal *Annalen der Physik* was present there. He was convinced by Bär and was of the opinion that the latter once and for all had settled the dispute on the electronic charge. He decided to publish Bär's "Habilitation" (postdoctoral) thesis in the Journal. In fact it appeared under the title[4]: "Über die scheinbaren Unterschreitungen des elektrischen Elementarquantums bei Ladungsmessungen an submikroskopischen Partikeln" (On the apparent downward deviation of the electric elementary quantum in charge measurements of submicroscopic particles). For this work Bär was given the "Habilitation" degree by the University of Zurich.

Not only the experimentalists but also the theoretical physicists were impressed by Bär's achievements. For instance, Erwin Schrödinger (1887-1961), founder of wave mechanics, recalled at the time of Bär's death as follows:

> "To most physicists R. Bär is best known by his vigorous and fully successful attempt to disprove by clear and decisive experiments the doubts which Ehrenhaft (Vienna) had thrown on the reality of the 'elementary quantum electricity'. The doubts were serious, and a detailed experimental refutation was needed to support our theoretical convictions" [5].

In 1933, Adolf Hitler came to power in Germany. Due to political and racial reasons many scientists had to leave the country. Professor Philipp Schwartz, an anthologist and an anatomist from Frankfurt am Main, immigrated to Zurich. He met Bär and suggested to search for an organisation which should help the refugees. This led to the establishment of the "Hilfsgemeinschaft deutscher Wissenschaftler im Ausland" (Community in aid of German scientists abroad). Bär (though he gave most of the financial support) remained in the background. He was also one of the persons to take the initiative and contact the University of Istanbul (Turkey) where it was possible to find positions for 30 professors.

Bär had personal relations with imminent scientists such as Max Planck, Arnold Sommerfeld, Monsieur and Madame Curie-Joliot, Max von Laue, James Franck, Albert Einstein, Erwin Schrödinger and C.V. Raman.

Bär expired, after a long and serious illness on December 13, 1940.

RICHARD BÄR'S SCIENTIFIC ACHIEVEMENTS

In 1907 Felix A Ehrenhaft suggested the oil-drop method for the precision measurement of the elementary electronic charge. As stated in Bär's dissertation[6], Ehrenhaft's experiments in Vienna in 1910 gave contradictory results to the prevailing opinion about the elementary charge. His measured value in the case of Platin particles was $9x10^{-11}$ electrostatic units [esu], while results of other scientists for the same value varied between $2x10^{-10}$ and $6x10^{-10}$ [esu]. The American physicist Robert A. Millikan (1868-1953) in his experiments on oil particles gave the elementary charge equal to $4,774x10^{-10}$ [esu]. Within experimental error, it was close to the theoretical prediction. In spite of the recognition of this value, there was no experimental evidence against Ehrenhaft's results. In 1917 Bär started with a similar experimental set up as used by the Vienna School. In his "Habilitation thesis" he refuted Ehrenhaft's views by concluding that without taking Brownian movement (that is, zigzag, irregular motion exhibited by minute particles of matter when suspended in a fluid) into consideration the results of Ehrenhaft and his school can be explained. He showed that one can carry out charge measurements on particles which are probably not spherical and surely do not show constant density for all of them; in this case one has to determine the density of each particle separately. Then there is not the slightest hint of the existence of charges which lie under the charge of an electron. The main reason for the subelectrons apparently found by Ehrenhaft and his students is their assumption of too a big density[7].

Shortly after that, Bär diverted his attention to electric gas discharge. Soon he became an authority and was asked by the editors of the *Handbuch der Physik* (Physics Encyclopaedia) to write an article[8].

In 1928 the Raman effect i.e. the change in wavelength of monochromatic light after scattering through a medium, was discovered in India by Raman and his student Kariamanikkam Srinivasa Krishnan (1898-1961). Shortly after that, Bär initiated this field of research in Zurich. He improved the apparatus which made it possible to visually observe some prominent lines in a Raman spectrum[9] and studied the Raman spectra of crystals[10]. In particular his results on the polarisation of Raman scattering[11] and the continuum to be found in the spectra must be mentioned. In the latter case he had shown that the effect can be either due to fluorescence or due to the incident light i.e. Rayleigh scattering [12,13].

Bär devoted the last phase of his life to the study of ultrasonic waves i.e. sound waves of high frequency that cannot be heard.

BÄR AND RAMAN-NATH DIFFRACTION THEORY OF ULTRASONIC WAVES

In 1932 the multiple diffraction of monochromatic light through the ultrasonic waves was observed by Peter Debye and Francis Weston Sears in the USA, and independently by René Auguste Lucas and Pierre Biquard in France. Bär and his colleague E. Meyer at Zurich modified the experimental technique[14]. Bär pointed out that in the diffraction spectrum the maxima and minima depended upon the intensity of the sound radiation, the ratio of the sound's to light's wavelength and the length of the path travelled by light in the medium[15]. He also observed that if the path traversed by the light through the sound is decreased, the diffraction lines of higher order did not appear; and further, with decrease of wavelength (from blue to violet) the number of higher order bands increases. However, there was no theoretical explanation of these observations. The solution was given by C.V. Raman and his student N.S.N. Nagendra Nath of the Indian Institute of Science, Bangalore. In a sequel of publications in the *Proceedings of the Indian Academy of Science*, Bangalore, they developed a theory and gave the explanation for the observed effects[16-20]. The general validity of their theory for lower frequencies (1500 kHz) was testified by Bär[21], and in the case of standing waves, that is, the waves that oscillate about a fixed point, and progressive waves (the waves which move across the surface as in the case of sea) by F.H. Sanders[22].

After the discovery of the Raman effect at the Indian Association for the Cultivation of Science, Calcutta, once again "Raman and his school" stood in the focus of the Western scientific community. For instance, *The Madras Mail* of May 1st, 1936 informed its readers as follows:

> "An important scientific discovery - results of research at the Indian Institute of Science - diffraction of light waves. Raman received letters of congratulation from Europe and USA for Raman-Nath diffraction".

The work of Indians and in particular the Bangalore School published in the Proceedings of the Indian Academy of Sciences in the years 1936-1940 was extensively quoted in Germany by Ludwig Bergmann in his book[23] *Der Ultraschall – und seine Anwendungen in Wissenschaft und Technik*'.(Ultrasound – and its Applications in Science and Technology). It was an important and inevitable book for the research in this field. For instance, Bergmann stated in the preface of the fourth edition of his book that the first edition was sold out after one year, and in early 1939 a second edition appeared. In spite of war, this was sold before the autumn of 1941. In the beginning of 1943 the third version of the book was sold immediately and the author produced an almost unchanged fourth version[24] in 1944.

Like Raman scattering, Raman-Nath diffraction had a continuing effect on future scientific work in the field of physics. In modern physics textbooks the Raman-Nath diffraction is still to be found[25-30]. Even in the last decade of the twentieth century the authors R. Reibold and P. Kwiek had to say the following:

> "The landmark in acoustic-optics was without doubt the discovery of light diffraction by ultrasonic waves by Debye and Sears, and Lucas and Biquard in 1932, and the analytical description of the phenomenon by Raman and Nath in 1935".[31]

BÄR - RAMAN CONTACTS

The contact between Raman and Bär started after the discovery of the Raman effect. In the following two decades Raman visited Zurich and they exchanged a few letters.

So far Raman spectroscopy was concerned, in the 1920s many laboratories possessed the simple apparatus (i.e. a source of light – mostly a mercury lamp, a liquid or gaseous sample and a spectrograph) required for Raman scattering experiments. Also the technique gave a simple method to determine molecular structures. Thus physicists and chemist started working on this field. Bär was one of them. However, the interest did not remain limited to the discovery but also the discoverer. On October 12 [1929] Bär wrote a letter and invited Raman to visit the University of Zurich[32]. Raman apologised for his delayed reply due to his unsettled travel programme. He informed him (Bär) about his date of arrival in Zurich namely November 27 and his intention to stay for 2-3 days. He suggested his host to fix a date on November 28 or 29 for his lecture on "Light Scattering and the Quantum Theory"[33].

Fig. 1: C.V. Raman and Richard Bär (Courtesy: Richard Bär's family)

The theoretical and experimental applications of the discovery led to Raman's nomination for the Nobel Prize. In 1930 the Swedish Academy of Sciences gave its prize adjudication in favour of Raman "for his work on light scattering and the discovery of the effect named after him"[34]. After the Nobel Prize was announced, on November 15, [1930] Bär wrote a letter and congratulated Raman[35].

The newspaper clips (in possession of the author) show that after receiving the Nobel Prize, Raman made a tour and visited scientists in Germany, Denmark, Sweden, France and Switzerland. He was also invited by Bär, but Raman had to apologise. He wrote[36],

> "It was with greatest regret that I found, the limited time at my disposal did not permit me of my stopping off at Zurich again".

The contact did not break. It intensified due to their work on ultrasound. In the middle of the 1930s they communicated on this topic as is evident from one of Raman's publications[37].

In 1937, Raman went to Europe again (Fig. 1). On October 11, 1937 he informed Bär from Paris that on October 12, he will leave Paris for Geneva and will stay with Kurt H Meyer for two days. He will be in Zurich on October 15 and leave next day. Raman also suggested to fix his lecture on the day of his arrival. However, due to some unknown circumstances, he had to make some minor changes. From Geneva, on October 13th, 1937 he wrote another letter and informed Bär that he will stay in Zurich from Friday to Saturday and leave for Bologna on Sunday. He expressed his desire to see the work of his host and that of physicist Paul Scherrer (1890-1969) and the future Nobel Laureate in the field of chemistry Leopold Ruszicka (1887-1976). In the same letter he wrote: "I can speak either on ′High Frequency Sounds in Liquids′ or on ′Magnetism in Organic Chemistry′. I should prefer the latter as I would like to the Chemists to be particularly interested".

After Raman's visit, scientific contact started with the younger generation of Indian physicists, due to a visit of N.S. Nagendra Nath, the co-founder of Raman-Nath theory. In 1937 he was an "1851 Exhibition Scholar, Trinity College, Cambridge". Nath stayed in Zurich for a few weeks and worked with a young physicist Fritz Levi as is evident from their publication[38]. Later a young (unknown) physicist was sent to Zurich to work under Bär.

Raman's last letter to Bär was written in 1940. He thanked the latter for his correspondence of May 7 and the reprints (from the Swiss Journal *Helvetica Physica Acta*). And further he wrote[39]:

> "I hope you are not finding it too difficult to carry on your researches in the present very difficult conditions. I often recall with pleasure my visits to Zurich and keep hoping that when all these troubles are over I shall once again be able to visit Switzerland and have a long holiday amidst your wonderful scenery."

Unfortunately, Bär died a premature death and their contact ceased.

It is worthwhile mentioning that in the following years the contact between India and Zurich University strengthened. Particularly the Nobel Laureate Ruszicka was the point of attraction. For instance, an Indian named Bandhuvula Krishnaswamy who did his PhD at the University of Liverpool under A. Robertson FRS requested Ruszicka to allow him to work for two months in latter's laboratories[40]. Presumably, the Indian chemist stayed there for some time.

The continuity in Zurich-Calcutta can be followed up to the 1960s. For instance, on December 29, 1961 Jogendra Chandra Bardhan (1896-1964), Head, Department of Chemistry, University of Calcutta wrote a letter to Ruszick and requested him to send some chemical, which the former required for his research.

Conclusions

Theoretical physicists could not explain the existence of *sub-electronic* charge observed by Ehrenhaft. Replication of experiment by Bär helped him to find out the mistakes made by Ehrenhaft. With new results the issue of elementary charge was settled.

Raman was one of the first generation physicists from India, who acted as a catalyst for initiating contacts of Indian physicists working at the Indian Association for the Cultivation of Science (Calcutta), Calcutta University, and the Indian Institute of Science (Bangalore) with that of the University of Zurich. The following years also witnessed the contacts between Indian and Zurich scientists.

Acknowledgements

I am thankful to Professor Falk Riess, University of Oldenburg, Germany for valuable comments and suggestions. My sincere thanks are due to Richard Bär's son Mr. Hans J. Bär, who supplied me Bär's Obituary and Raman's correspondence. Last but not least, I thank the library staff of the Raman Research Institute, Bangalore for newspaper cuttings and the ETH Library, Zurich for L. Ruszick's correspondence.

Notes and References

1. R. Singh, Sir C.V. Raman and his Contacts with Hungarian Scientists, *IJHS*, 37.2 (2002) 175-191.

2. Bär's biography is largely taken from the obituary written by Edgar Meyer (a colleague from the University of Zurich) for Bär's family for private use.

3. R. Bär, *Über Greensche Randwertaufgaben bei der Schwingungsgleichung*, B.G. Teubner Verlag, Leipzig 1916.

4. R. Bär, Über die scheinbaren Unterschreitungen des elektrischen Elementarquantums bei Ladungsmessungen ans submikrosckopischen Partiklen, *Annalen der Physik* (Leipzig), 67 (1922) 157-200.

5. E Schrödinger, "Prof. Richard Bär", *Nature* 147 (1941) 536.

6. See ref. 4, R. Bär.

7. Ibid.

8. R. Bär, Die Glimmentladung (in: *Handbuch der Physik*, Eds. H. Geiger & K. Scheel), Julius Springer Verlag, Berlin 1927, pp. 171-323.

9. R. Bär, "Einige Versuche über den Raman-Effekt an Flüssigkeiten", *Helvetica Physica Acta* [abb. *Helv. Phy. Acta*] 2 (1929) 154-156.

10. R. Bär, "Raman effect from powdered crystals", *Nature* 124 (1929) 692.

11. R. Bär, "Über eine Anomalie bei der Polarisation der Ramanstrahlung", *Die Naturwissenschaften* 22 (1931) 463.

12. R. Bär, "Über die Frage nach der Existanz eines kontinuierlichen Ramaneffektes in Flüssigkeiten", *Zeitschrift für Physik* [henceforth *ZSf. Phy*] 79 (1932) 455-470.

13. R. Bär, "Über den Ramaneffekt des Glycerins; zugleich Erwiderung auf die Arbeit von Carrelli und Went "Über den Ramaneffekt in Flüssigkeiten", *ZSf. Phy* 81 (1933) 785-789.

14. R. Bär & E. Meyer, "Über einige Verusche zur Beugung des Lichtes an Ultraschallwellen", *Helv. Phy. Acta* 6 (1933) 242-244.

15. R. Bär, "Über einige Demonstrationsversuche zur Beugung des Lichtes an Ultraschallwellen", *Helv. Phy. Acta,* 6 (1933) 570-580.

16. C.V.Raman & N.S.N. Nath, "The diffraction of light by high frequency sound waves: Part I", *Proceedings of the Indian Academy of Sciences*, Bangalore [abb. Proc. IAS] A2 (1936) 570-580.

17. C.V.Raman & N.S.N. Nath, "The diffraction of light by high frequency sound waves: Part II", *Proc. IAS,* A2 (1936) 413-420.

18. C.V.Raman & N.S.N. Nath, "The diffraction of light by high frequency sound waves: Part III, Doppler effect an coherence phenomena", *Proc. IAS,* A3 (1936) 75-84.

19. C.V.Raman & N.S.N. Nath, "The diffraction of light by high frequency sound waves: Part IV. Generalised Theory", *Proc. IAS* A3 (1936) 119-125.

20. C.V.Raman & N.S.N. Nath, "The diffraction of light by high frequency sound waves: Part V. General considedrations - oblique incidence and amplitude changes", *Proc. IAS* A3 (1936) 459-465.

21. R. Bär, "Über Versuche zur Theorie von Raman und Nagendra Nath über die Beugung des Lichtes an Ultraschallwellen", *Helv. Phy. Acta* 9 (1936) 265-284.

22. F.H. Sanders, "Intensity measurements in the diffraction of light by ultrasonic waves", *Canadian Journal of Research* 14A (1936) 158-171.

23. L. Bergmann, *Der Ultraschall – und seine Anwendungen in Wissenschaft und Technik*, Vierte Auflage, VDI Verlag GmbH, Berlin 1944, pp.399-433.

24. Ibid. p.IX.

25. J. H. Cantrell and W. T. Yost, Ultrasonic velocity (in: *Encyclopedia of Acoustics*, vol.2, Ed. M.J. Crocker), John Wiley and Sons, Inc., New York 1997, pp.629-639.

26. B.E.A. Saleh and M.C. Teich, *Fundamentals of Photonics*, A Wiley-Interscience Publication, New York 1991, pp. 813-815.

27. O. Leroy and M. A. Breazeale, *Physical Acoustics - fundamentals and applications*, Plenum Press, New York 1991, p 209 & p 232.

28. K. lizuka, *Engineering Optics*, Springer-Verlag, Berlin 1985, pp. 394-396.

29. C.B. Scruby and L.E.Drain, *Laser Ultrasonics - technique and applications*, Adam Hilger, Bristol 1990, pp 37-75.

30. R.G.W. Brown and E.R. Pike, A history of optical optoelectronic physics in the twentieth century (in: *Twentieth Century Physics* vol.3, Eds. L.M.Brown, A Pais and B.Pippard), IOP publishing Ltd AIP Press Inc., New York 1995, pp. 1385-1504.

31. R. Reibold and P. Kwiek, Optical near field of ultrasonic light diffraction, (in: Physical Acoustics - fundamental applications, Eds. O Leroy and M.A. Breazeale), Plenum Press, New York 1991, pp.129-142.

32. C.V.Raman's reply to Bar, November 12, 1929.

33. C.V.Raman's to R. Bar, ibid.

34. R. Singh and F. Riess, "Sir C.V .Raman and the story of the Nobel Prize", *Current Science* 75 (1998) 965-971.

35. C.V.Raman's to R. Bar, February 11, 1931.

36. C.V.Raman's to R. Bar, ibid.

37. See ref. 20, Raman & Nath.

38. F. Levi & N.S.N. Nath, "Zur Theorie des Durchgags von Ultraschallwellen durch eine feste Platte", *Helv. Phy. Acta* 11 (1938) 399-431.

39. C.V.Raman's to R. Bar, October 19, 1940.

40. R. Krishnaswamy to L. Ruszicka, April 27, 1950.