

C.V. RAMAN AND THE AMERICAN SCIENTISTS

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Sir Chandrasekhara Venkata Raman (1888-1970), India's only Nobel Laureate in the field of natural sciences appreciated American political system and interacted with the American scientists for about half a century. In this article, an attempt has been made to explore Raman's contacts with the American men of science using unpublished correspondences and newspaper clips.

Key words : A.H. Compton, Compton effect, C.V. Raman, K.S. Krishnan, Nobel Prize, N.S.N. Nath, Physiology of vision, P. Nilakanthan, Raman effect, Raman-Nath diffraction, R.A. Millikan, R.W. Wood.

INTRODUCTION

In 1928 C.V. Raman and Kariamanikam Srinivasa Krishnan (1898-1961) observed that if monochromatic light is passed through a transparent medium, thereafter the scattering light is accompanied by other colours. This phenomenon was later named as Raman effect. The effect helps to find out the molecular structure of substances. In 1930 Raman was awarded the Nobel prize for his work on "*light scattering and the discovery of the effect*"¹ named after him. Raman was the first Asian to receive this honour. This made him extremely popular. During Raman's lifetime and there after a number of biographies appeared². However, none of them explores his contacts with the American scientific community. The following communication is intended to fulfil this gap.

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C.V. RAMAN'S VISIT TO USA, HIS CONTACTS AND THE HONOUR BY THE FRANKLIN INSTITUTE

It is a well known story that in 1907, the young C.V. Raman (see Fig. 1) after finishing his education and competing the Finance Services Examinations came to Calcutta as a bank officer. During his spare time he did research at the Indian Association for the Cultivation of Sciences (IACS) and was offered a Professorship due to his popularity as a researcher. After some consideration, in 1917, he accepted the "Palit Professor Chair" of the University of Calcutta. First time in his life, in 1921, he went to Oxford (England) at the Congress of British Universities to represent the Calcutta and Banares Hindu Universities³.

In the 1924 *Annual Report of the IACS*, before informing about his participation in the *International Congress of Mathematician* held in Toronto in August 1924, Raman reported that⁴:

"He received an invitation from the British Association for the Advancement of Science [BAAS] to attend the meeting to be held at Toronto in Canada in August and to be opener of a discussion on the scattering of light".

The report of the BAAS shows that Raman delivered a lecture on light scattering research being carried out in his laboratory⁵. The BAAS and Calcutta University gave him a substantial grant that enabled him to travel to Canada and then proceed to America⁶.

C.V. RAMAN, ARTHUR HOLLY COMPTON AND LIGHT QUANTA

In 1923 the American physicist A.H. Compton (1892-1962) observed that the x-rays scattered by the free (loosely bounded) electrons experience a change in wavelength⁷. This effect was later named as the Compton effect. Just a year later at the BAAS meeting he presented the experimental results that were interpreted in terms of light quanta⁸ - a concept disputed in those days. His countrymen William Duane of Harvard University and Raman took active part in the discussion. Particularly Duane who could not reproduce Compton's results did not believe Compton⁹. In his memoirs,

Compton recalled that Raman said to him, "*Compton, you're a very good debater; but the truth isn't in you*"¹⁰. The authors Roger H. Stuewer¹¹ and A. Sur¹² interpreted Raman's statement as evidence that he did not accept Einstein's light-quantum hypothesis. In a separate article I have refuted these views¹³. Here the details are omitted.

After Toronto meeting Raman left for the USA and stayed with Robert A. Millikan (1868-1953).

C.V. RAMAN AND THE NOBEL LAUREATE ROBERT A. MILLIKAN

It is not quite clear, how Raman came in contact with Millikan. However, *The New York Times* of November 22, 1970 hints that Millikan encouraged Raman to come to the USA. In September (1924), at the Centenary of the Franklin Institute, he represented the IACS¹⁴. Between September 20, 1924 and December 16, 1924, Raman was appointed as a Research Associate and Visiting Professor at the California Institute of Technology¹⁵. During this period, he also met scientists Irving Langmuir (1881-1957), Albert W. Hull (1880-1966), William D. Coolidge (1873-1975) and other staffs of General Electric Company¹⁶.

It was entirely different experience for the Americans to have an Indian physicist, because, in general, the Indians were seen as persons related to religion and philosophy. It is clear from the statement of President of the Institute Clinton K. Judy who introduced Raman as follows: "*Most Hindu coming to this country talk on philosophy and the occult, and it is a distinct novelty to have one who is more in accord with Western scholarship*"¹⁷.

The Pas Star News (presently Pasadena, California) on November 12, 1924 announced Raman's lecture on the musical instruments as follows:

"Raman stands out as one of the most productive scientists of the Orient. He has already done a surprising amount of high-grade scientific work himself and has stimulated a great deal more among his students. His publications on the mechanical theory of stringed instruments have made him an internationally known authority upon the subject about which he is speaking".

About five weeks later again on December 19, 1924, *The Pas Star News* wrote:

“Prof. C.V. Raman, noted Indian scientist, yesterday addressed an enthusiastic audience of more than 300 teachers, students and graduates of the California Institute of Technology on the subject of *‘The scattering of light and its relation to atomic and molecular structure’*”.

And further:

“His lecture was illustrated with many experiments, given in such a simple and direct manner that they could be easily understood by less scientific audience than that present. In one demonstration, the scientist gave a remarkable view of the setting sun, which he obtained by using liquid encased in a square glass receptacle in the receptor of a projector instead of a scale”.

The above descriptions written shortly after the lectures show that there were many audiences and Raman’s lectures were well attended. This is in contrary to the observation of the Norwegian physicist Svein Rosseland’s (1894-1985) conversation with S. Chandrasekhar (1910-1995), who once recalled: *“Apparently Raman was not too happy that he was not generally known in the United States. He was even more disappointed that so very few came to his lectures”*¹⁸.

Another American scientist from the University of California Ernest Orlando Lawrence (1901-1958) also had correspondence with Raman. For instance, on February 9, 1932 he thanked Raman for reprints of his paper on the spin of photon, which was published in *Nature*. He informed Raman that his name is in their mailing list and the latter will get the reprints whenever he (Lawrence) will publish¹⁹.

With Millikan, Raman’s contact remained in tact for long time. In the beginning of 1940, Millikan and his co-workers Henry Victor Neher (1904-1999) and William H. Pickering (1910-present) came to Bangalore to perform experiments on cosmic rays. They also delivered 4 lectures²⁰. Millikan’s first communication of January 26, 1940, was on the history of cosmic rays and their measurement. *The Hindu* of February 4, 1940 wrote an article on *“The mystery of cosmic rays—Prof. Millikan on the investigations”*.

A few years later, that is, on January 5, 1945 Raman wrote a letter to Millikan and introduced K.L. Ramaswamy who was visiting the USA for his chemical business. Due to some circumstances, Ramaswamy was unable to meet Millikan. The latter, on June 9, 1945 sent the following message for Raman: "*Please extend to Sir C.V. Raman and his whole family my greetings. Mrs. Millikan and I still treasure greatly the memory of the two or three weeks which we spent under his hospitable roof*"²¹. Obviously, Raman had cordial relations with Millikan. As we shall see below, it was not the case with his contemporary W.H. Zacheriasen - an X-ray physicist at the University of Chicago.

W.H. ZACHERIASEN, C.V. RAMAN AND DIFFUSE SPOTS IN THE LAUE X-RAYS PHOTOGRAPHS

In one of my papers, I have discussed that in the end of 1930s and the beginning of 1940s some diffuse spots were observed by American, Indian, British and French scientists independently. From India C.V. Raman and P. Nilakantan (1910-1964) from the Indian Institute of Sciences were the two persons who observed the phenomenon. Due to the question of priority and the theoretical interpretation of the spots, there was controversy between the first three groups²².

Unfortunately, too less is known about Raman's partner P. Nilakantan. The fact is, while the controversy was going on, in the beginning of 1940s he visited Zacheriasen. About the visit the latter wrote as follows to the theoretical physicist Max Born (1882-1970) - who was supporting the British group and opposing Raman²³:

"You may be interested to learn that I yesterday had a visit from Dr. Nilakantan who collaborated with Raman. Although he was very pleasant person, he is quite as stubborn as his teacher and is still insisting that their explanation is the only correct one".

Due to the Second World War, Zacheriasen was forced to leave his field of research. However, Raman was in better position. To make his theory of lattice dynamics known and to counter his critics in the USA, Raman sent the *Proceedings of the Indian Academy of Science* to Leonard

Benedict Loeb, who on February 25, 1942 replied that "*I have received the complimentary copy of the symposium of papers on the 'quantum theory of X-ray reflection'*". Loeb stated that although these papers were somewhat outside his own field, yet he read them with considerable interest. In order to make them more generally available to the Department he has turned the volume over to the department library.

In the following years, "*Born-Raman lattice dynamics controversy*"²⁴ continued, but Americans were not involved in it.

It seems, the American scientific community was not influenced by the controversy and decided to honour Raman with the Franklin Medal.

THE FRANKLIN MEDAL FOR C.V. RAMAN

On March 12, 1941 Indians got the news that the Franklin Institute of Philadelphia, USA has honoured Sir C.V. Raman with Franklin Award. In the recent years the other scientists to get this honour were Albert Einstein (1879-1955), R.A. Millikan and A.H. Compton. (A Newspaper clip; copy with the author).

Raman was awarded the Franklin Medal in "*recognition of his many brilliant contributions to Physical Science and of his leadership in the renaissance of scientific work and scientific education that has occurred in India during the last thirty years*"²⁵. The Selection Committee was of the opinion that Raman has trained and inspired more than one hundred young scientists who now occupy strategic positions in the scientific and educational life of India. And further, it observed that nearly every institution in India devoted to research and education in science has benefited by Raman's influence and support²⁶.

The available documents show that officially, in May 1941, Raman was supposed to get the Franklin Medal and Diploma of Honorary Membership of the Franklin Institute²⁷. *The Indian Express* of July 15, 1942 informed its readers that due to the Second World War, Raman could not go to USA to receive the medal. It was handed over to the British Ambassador Lord Halifax in Washington, who transmitted it to India. In

the presence of small gathering at Mysore Residency, Arthur Hope - Governor of Madras decorated Raman. Other persons present were Lt.-Col. Fraser, J.C. Ghosh—Director of the India Institute of Sciences, Bangalore.

This honour did not remain the only one. As we shall see below, the American scientific community took interest in Raman's scientific achievements and in the last part of his life, he was honoured with the Fellowship of another American Society.

AMERICAN'S INTEREST IN RAMAN'S SCIENTIFIC WORK

Raman largely worked in the fields of musical acoustics, light scattering, crystal dynamics, ultra sonic waves and the physiology of vision. It will be shown below that at all stages the American's scientific community took interest in Raman's work.

Raman effect and Robert William Wood (1868-1955)

After the discovery of the Compton effect, in 1923, P.A. Ross (USA) tried to find similar effect in the case of visible light. He experimented with paraffin using Lummer-Gehrcke interferometer of resolving power 360, 000 and a wavelength of 546,2 nanometers. But he was not successful²⁸. Also according to the Indian astrophysicist Meghnad Saha (1893-1956), unsuccessful experiments to verify Kramers-Heisenburg theory (of dispersion and scattering of light) were carried out at Niels Bohr's laboratory at Copenhagen²⁹. Surely, Raman was aware of these results. *The Statesman*, which announced Raman discovery on February 29, 1928 after describing Raman's results wrote³⁰: "*Shortly after the publication of Prof. Compton's discovery, other experimenters sought to find out whether a similar transformation occurs also when ordinary light is scattered by matter and reported negative results*".

At last the Indian physicists in Calcutta discovered the effect. However, their results were met with scepticism in Germany and the USA. In Germany at the University of Munich the physicists remained unsuccessful in producing Raman's results and even on theoretical basis

the physicist Georg Joos (1894-1959) thought that the intensity of the light is too low to be observed³¹. So far as the American R.W. Wood was concerned, the editor of *Nature* described his reaction as below³²:

“He [Editor] received a letter from the Professor [Raman] referring to certain spectroscopic lines and putting forward what seemed to be an impossible theory. So incredible was Professor Raman’s discovery, that before feeling prepared to publish it in *Nature* - ...He [Sir Richard] consulted Professor R.W. Wood of Baltimore who happened to be in London at the time. After reading Professor Raman’s letter, Professor Wood declared, “I don’t believe it!” Three weeks after the letter appeared in *Nature*, Professor Wood visited Sir Richard and said, ‘Raman is right’”.

In the Compton effect only the increase in wavelength takes place and also it depends on the angle of incidence. Whereas in the case of Raman effect both the increase and decrease in wavelength are observed and also it is independent of observation angle. Clearly, the second effect shows that a quanta (later named as photon) can take or give energy to a molecule. Probably, due to the generality of the effect, Wood hailed Raman’s discovery as “*one of the most convincing proofs of the quantum theory of light which we have at the present time.*”³³.

In the beginning of 1933 Raman left Calcutta and came to the Indian Institute of Sciences, Bangalore. Just about 3 years later, he did a marvellous work in the field of ultra-sonic, that is, the sound waves which cannot be heard.

RAMAN-NATH DIFFRACTION AND THE AMERICAN REACTION

In 1932 the multiple diffraction of monochromatic light by the ultrasonic waves was observed by Peter Debye and Francis Weston Sears³⁴ in the USA, and independently by René Auguste Lucas and Pierre Biquard³⁵ in France. Richard Bär (1892-1940) and his colleague at Zurich (Switzerland) modified the experimental technique and studied the phenomenon in detail³⁶. In a sequel in the *Proceedings of the Indian Academy of Science*, Bangalore, Indian physicists Raman and Nagendra S.N. Nath - from the Indian Institute of Sciences, developed a theory and gave the explanation for the observed effects³⁷. About this work and the reaction

of others *The Madras Mail*, on May 1, 1936 wrote: "*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.*"

After that Raman studied the properties of crystal and diamonds. His theory of lattice dynamics led to a long controversy with Max Born. As mentioned before, its detail are given by different authors.

Raman devoted the last phase of his scientific life to the studies on the physiology of vision.

C.V. RAMAN, GEORGE WALD AND THE PHYSIOLOGY OF VISION

Between 1960 and 1970, Raman wrote a number of papers³⁸ and a monograph³⁹ on the physiology of vision. Raman was convinced that "*his later work was even more grander and would have earned him a second Nobel Prize if only the academic world could comprehend it*"⁴⁰.

Reading of Raman scientific papers related to this field shows that he hardly made use of existing literature. In the papers only once a list of books is recommended⁴¹. In 1968, in the monograph "*The Physiology of Vision*" Raman seems to justify the omission of others work as follows: "*The aim of the studies was to obtain an insight into the subject by independent study without being influenced by ideas and belief inherited from the past*"⁴².

There are different opinions about the quality of this work. The editor S. Ramaseshan observed that the others working with complicated modern instruments "*felt, quite justifiably, that Raman's elementary experiments, ... were too simplistic for this complex field*"⁴³. Partially due to his theories and partially due to ignoring the work of others, one of the renowned American bio-chemist George Wald had dislike for Raman.

Shortly after starting this new topic, Raman sent the *Memoirs of the Raman Research Institute* on the perception of light and colour to George Wald and his wife Ruth Hubbard - who were working in the Biological Laboratories of the Harvard University⁴⁴. G. Wald though not quite agreed with Raman's ideas, on April 18, 1961 wrote to Raman that:

“I read it with great interest and enjoyed very much its clarity and directness. I am very happy also that vision has come to interest you to this degree, since I am spending most of my life with it and am happy to have much distinguished company”.

In the same communication Wald informed Raman that at some points the former did not agree with. According to his [Wald's] years long work; pigment serves not as a photosensitive pigment in the blue receptors in eye, but as a filter. The pigments in human and primate retinas help to compensate the chromatic aberration of the eye, which is large in the blue region and tends to lower visual image resolution.

Raman promised to write on the role of the chemical xanthophyll ($C_{40}H_{56}O_2$) in the human vision in his letter of April 28, 1961 to Wald. In the same communication he also wrote that:

“I am looking forward eagerly to receiving the publications of Dr. Ruth Hubbard and of yourself that you have sent. Some of them I have probably not read already and I have no doubt that the collected papers of your both on the subject would be most helpful to me in my further work in this field”.

At least according to Raman's own statement, he was aware of Wald's work, however, he did not mention in his publications.

On June 1, 1961 Raman thanked Wald for the 11 reprints he received. After that the communication ceased.

Raman in between had spent a few years on the physiology of vision. Donald L. Fuller - Scientific Attaché of the USA Ambassador in Delhi, on December 31, 1964 wrote a letter to Frederick Seitz - President of the National Academy of Sciences and informed the latter that at the occasion of the 30th session of the Indian Academy of Sciences at Poona, Raman delivered a lecture on December 25, 1964. *The Hindustan Times*, dated December 26, 1964 wrote about Raman's lecture on “*Vision and the Nature of Light*”.

Immediate reaction of the American Embassy and writing a letter by a high official on a holiday, particularly December 31, clearly shows, how serious was Raman's work for him. The “*Analysis and Distribution*

Branch" sent to various departments (including the famous CIA - Criminal Investigation Agency) a letter that was accompanied by four pages text entitled "Raman explores nature of light and vision" (see Fig. 1)

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Enclosed is a Press Trust of India (PTI) report appearing in the Hindustan Times, dated December 26, 1964, on Dr. C.V. RAMAN

Fig. 1: A part of D.L. Fuller's letter to Dr. Seitz – President of the National Academy of Sciences, USA. The left side is of particular interest, showing various departments which received the letter.

It will be worth while to reproduce in detail D.L. Fuller's letter of December 31, 1964, as it gives glimpse of Raman's conclusions. It reads:

"India's only Nobel Laureate in science, Dr. Raman is seventy six years old and perhaps the only Indian scientist at that age still engaged in active research. Dr. Raman was discussing his most recent investigations on the relation between the physical nature of light and the physiological sensations excited by its incidence on the retinae of the eye. He said that his work in the past year had thrown new light on the subject of vision, which completely destroyed old theories. According to the new theories he has pronounced he maintains that the perception of light by the human eye is essentially controlled by the number of light corpuscles or quantas that reach the retina of the eye; that the material in the eye that absorbs light does not exist in the 'rods and cones of the eye' but it exists in the portions on and behind the retina; and that the colour perception of the

human eye is controlled by a very small area only a millimetre in diameter in the fovea of the human eye. He also claimed that he had developed new techniques for the study of human visual sensations and the structure and functions of the retinae of human eyes".

Wald, who probably had forgotten the whole story, received a letter from F. Seitz. The latter on February 8, 1965 wrote to Wald as follows:

"I wonder if the accompanying report from our Embassy in New Delhi concerning Dr. Raman's work on 'Vision and the Nature of Light' makes any significant sense. For a number of years Raman's work has run on the whole somewhat at cross gain with much of traditional science".

Wald who was not quite happy with the past experience lost no time and on February 10, 1965 replied to Seitz. After informing him about the *Memoir of the Raman Research Institute*, No. 133 on "*Perception of light and colour*", and another *Memoir* on "*The role of the retina in vision*" from the year 1962, he wrote:

"These are most extraordinary documents in which Raman goes at these things as though no one had ever examined them before. I find nothing that even resembles an interesting contribution. I have the impression that Raman is so dominant figure in India, and surely in his own Institute, that no word of criticism reaches him. It is a sad thing that this very distinguished physicist should be publishing this nonsense in his old age".

The main reason for the criticism was somewhere else. Namely the negligence of his work by Raman, as is clear from the following statement: "*I had back a very courteous letter assuring me that he knew all about my work and valued it; but he paid no attention to it whatever*"⁴⁵.

It seems Wald was informed about "Born-Raman controversy on lattice dynamics theory". At this stage, he brought Max Born in the game as follows:

"You might be interested in knowing that another great physicist, Max Born, (...), recently published a really beautiful and penetrating essay on human colour vision in the *Zeiss Journal*⁴⁶. I have been in correspondence with him since. He writes me that he has put colour vision behind him; yet he does have continuing interest, and if you are thinking of having a visitor to our symposium, he'd be a good one"⁴⁷.

Just two years later, that is, in 1967, H.K. Hartline from the Rockefeller University in New York in the financial matter wanted to help Raman, as a letter from Ward Morehouse - Director of the University of the State of New York, to Wald indicates. Wald being a recognised expert in the physiology of vision was again asked by Morehouse for his opinion. The latter had met Raman in Bangalore and was impressed from his theories. He wrote to Wald on June 16, 1967 as follows:

“I [Ward Morehouse] have no scientific competence in this field but am anxious to have some idea of the relative scientific significance of his more recent work, because, if it is as significant as Raman himself suggests that it is — or even in substantial measure so — it may be worth making concerted efforts to find ways and means of helping him expand his work in Bangalore — at the present time, almost entirely confined to what he himself, now at a venerable age — can do”.

Unfortunately, Wald’s reply is not to be found in the archive. But it is not difficult to imagine that it was certainly not positive.

Wald’s last letter in this connection is of December 14, 1981. One Indian historian X asked Wald to comment on Raman’s work. To which the latter replied on January 8, 1982 politely as follow:

“As you see, my impressions do no differ greatly from your own. I would hesitate however to make the content of this correspondence public. With Raman’s death these last emanations died also, and should be allowed to rest forgotten”.

However, in other quarters in the USA, even in the late 1960s, about 80 years old Raman still had his fans. The last honour came from them, as we shall see below.

RAMAN’S RESEARCH ON MUSICAL INSTRUMENTS AND CATGUT ACOUSTICAL SOCIETY OF AMERICA

The Catgut Acoustical Society came into existence in 1963. It was due to the efforts of Carleen M. Hutchins, Frederick A. Saunders, John C. Schelleng and Robert E. Fryxell, who were working on string instruments like violin⁴⁸.

On August 30, 1968 Carleen M. Hutchins - later Secretary of the Society, informed Raman (who had worked in the same field in the first two decades of the twentieth Century and that work is still being referred⁴⁹) that very often people in their group refer to his monograph (presumably, "*On the mechanical theory of vibrations of bowed strings and of musical instruments of the violin family, with experimental results - Part I*", *Bull. IACS* 15 (1918) 1-158, which he sent to F.H. Saunders years ago. She requested Raman to accept the Honorary Membership of the Society.

On November 23, 1968 Raman thanked for this honour. He also revealed that his work on the bowed string instruments was done between 1914 and 1918, and due to his call as Professor at the University of Calcutta and the intensification of his interest in optics brought halt to further studies of the violin family instruments.

Soon followed another letter of December 6, 1968 from C.M. Hutchins with the following remarks:

"One thing that has concerned many of us for a long time is that we feel, insufficient attention has been paid to your very remarkable researches on the violin string, and we most certainly hope that as the work of the society organizes, this condition may be remedied".

In one of the letters, the Editor of the *Newsletter* of the Society - Robert E. Fryxell on February 7, 1969, thanked Raman for accepting the membership. He also sent Raman the *Newsletter* and reprints of papers of members of the Society. He requested Raman to send papers or any comments on the work of the members. "*I and all of our members would be highly gratified if you, with your great insight into the intriguing problems of stringed instruments, would occasionally feel inclined to send a 'letter to the editor' with your views*", wrote Fryxell.

In the same year one of the members of the Society - Arthur H. Benade was in India. He was asked to enquire and if possible to purchase complete collection of Raman's published work on violin acoustics⁵⁰.

On June 23, 1969 in a letter to Raman, Benade wrote:

"On a more personal note, let me pass on the greetings of my father, Professor J. M. Benade who was for so many years at Forman

Christian College in Lahore. He has often spoken of your hospitality when he and my mother called upon you a few years ago in Bangalore. I myself have still very vivid memories of a beautiful public lecture you once gave at the Punjab University about 1937. I can describe some of what I saw, and can say what particular things I learned at this lecture, which was one of the formative influences of my professional career as a physicist."

Further, he told Raman that about six years ago he met Professor S. Bhagavantam who visited the Case Physics Department for a week for lectures. During private talk Benade told his guest about an impressive lecture of Raman, which the young 12 years old Benade had heard and after so many years was able to give its details. However, Benade did not recognise that Raman's assistant on that particular day was his guest himself. In the end Benade wrote: "*I hope you will accept this brief account as an expression of my respect for you as a great physicist, and impressive lecturer.*"

On July 4, 1969 Benade thanked Raman for his June 27, 1969 letter, the monograph and the list of publications in acoustics.

After Raman expired, in the fall of 1971 C.M. Hutchins wrote to the authorities of the Raman Research Institute and asked for permission to reproduce his papers "*Vibrations of bowed strings and instruments of the violin family*" *Bulletin IACS* 15 (1918) 1-158 and "*Experiments with mechanically played violins*", *Proc. IACS* 6 (1920) 19,.

In fact these two and one more paper "*On the 'Wolf-Note' in bowed strings instruments*" were reprinted by the Society⁵¹.

From the above discussion we see that Raman had contacts with the individual as well as Institutions and Societies. He also personally visited America. This gave him chance to know the political and educational aspects, about them he had his own opinions as given in the next section.

RAMAN'S VIEWS ON THE AMERICAN POLITICAL AND INDUSTRIAL SYSTEM

There are at least two incidences in record showing Raman's discrimination in the USA due to his colour and race. The one deals with

Raman and Compton's servant⁵² and the other with Dean Gale at the University of Chicago, who simply ignored Raman in the Faculty Club⁵³. The authors S. Ramaseshan and C.R. Rao have quoted Raman's reaction as follows: "As in India, there are many stupid fools in every country. I would like to remember the United States as the country of Jefferson and Franklin, Walt Whitman and Thoreau, Edison and Graham Bell, or my own friends Millikan and Compton"⁵⁴.

Raman was a great admirer of American educational, industrial and political systems. Though, India is a democratic land, but still Raman had problems with Indian system. On the very first day of Indian Independence Day, i.e. August 15, 1947, he expressed his views to *The Indian Express* as follows:

"Looking round and sizing up the situation, it seems to me that the real danger before our country in the days to come is the crushing down of individual freedom and initiative by the steam roller of government authority.... already visible from taxation and other bills".

On January 3, 1948 Raman suggest the freedom of individual as in the USA. On the model of American system, he suggested that in India the Government, Industrial and scientific institutions should come together to establish industry. He did not minimise the value of foreign assistance in industrialising the country. However, he stated that the industrial and economic progress of Indian could be firmly established only on the basis of self-help and self-reliance⁵⁵.

On July 26, 1948 while addressing a press conference he said, "*The scientists must be free from Governmental interference if they were to do their best. This, .., was one of the reasons for the United States' scientific achievements*". (Newspaper clip with author; Original in the archive of Raman Research Institute, Bangalore).

According to *The Hindu* from September 13, 1948 Raman went to America as a representative of the *Advisory Council of the International Bank of Reconstruction* and also to attend the *First International Congress of Crystallographers* at Harvard. *The Hindu* wrote further⁵⁶:

“He (Raman) visited on invitation of several famous Companies like the American Optical Company at South Bridge and the Bell Telephone Company at Merry Hill near New York. He spent some days at the Bureau of Standards in New York, one of the largest institutions in the world engaged in fundamental scientific research, where nearly 2000 scientists are engaged in research and delivered a lecture at the institution”.

After returning back he delivered three lectures in Bangalore. On October 10, 1948 a newspaper published a short review under the title, “*America To-day, Sir C.V. Raman’s Impression*”. Raman praised the American for punctuality, enthusiasm and hard work. He observed that:

“The average American evinces enthusiasm even for the hardest kind of work, and this is because there is practically unlimited scope of reward from private enterprise-which according to the distinguished scientist, is the real secret behind American abundance”.

And further:

“The vast majority of the American citizens live a full life, in an atmosphere of complete freedom, thus calling into play each of one’s natural gifts and faculties. This, .., is yet to be become as true in India as it is already so in America”.

Raman who was worried about the going on development in India, in the end of 1949, while addressing Jaipur Convocation stated that India is today as the US 100 years ago. Again he repeated his criticism that country cannot become great by borrowing millions of dollar or sending their students in foreign countries for training. He observed that after 100 years of education, other countries have conquered Indian spiritually, intellectually and culturally.

So far as the USA was concerned, he stated⁵⁷:

“I have watched the United States and how it has reached the present position. Fifty years ago, the United States was in a particular position. Its students were sent out in shiploads to other countries to study and bring back knowledge. To day, America stands almost, certainly in the very front rank in educational and scientific progress. We all know it as the most powerful nation, financially, economically and politically. ...The source of that strength, .., was unquestionably not in the action of one or two but hundreds of wealthy men, who

having made immense money under the system of private enterprise,...".

From above we see that Raman believed in a democratic system. Most probably, his pro USA statements made him a sympathetic scientist among the American scientific community.

CONCLUSIONS

Raman was a lecturer par excellence. The high quality scientific work at the initial stage and the Nobel Prize made him a scientist special from the non-European countries. Due to these reasons the Americans took interest in his work at each stage.

Raman, though from a different continent and with different clothes, was seen at the California Institute of Technology as a man "*in accord with Western scholarship*" due to his physical researches. The appreciation and criticism of his work by the Americans show that he was accepted as an integral part of the American scientific community. Though the racial issue cannot be neglected, on the whole, we see that in this particular case the boundaries of the natural sciences were broader than the racial issue.

Raman saw the American political system as an ideal model. According to his interpretation, it offers an individual the freedom and chance to come further. In particular, Raman was fascinated by the American political policies towards education and industrialisation in which the private institutions and persons played important role.

In the last phase of his life, Raman started ignoring the work of his contemporaries. It was against the rules of the game and affected Raman's status as a scientist.

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