

A conversation with K. S. Krishnan on the story of the discovery of the Raman effect

S. Ramaseshan

Prof. K. S. Krishnan, whose birth centennial we are celebrating this year, was perhaps one of the best scientists India has ever produced. Of him C. V. Raman once said to me in 1945, 'one can scarcely ever meet a person more intelligent, more astute and having a more thorough understanding of any subject in general, and in science in particular, and who is better endowed with such superb experimental skills'. In the thirties, Krishnan plunged himself into modern physics with gusto and his understanding of it was incredible. (One had to hear him expound a subject to perceive the depth of his knowledge and understanding.) He did much to propagate modern physics in India and has contributed greatly to its advancement by his exceptionally original scientific papers (both in theory and experiment). He was a good friend of my father's and they often used to play bridge together and also tennis. He could discourse on any subject with much insight. I met him first when I was a boy and he treated me like a grown-up and discussed with me the relative merits of football players of East Bengal and Mohan Bagan, the two top teams in the Calcutta football league. Later I have heard him delivering a few scientific lectures when

he came to the Nagpur University where I was an undergraduate. I still recall the clarity of his exposition and the humorous stories with which he laced these lectures. I remember taking him to play tennis in our college tennis courts. I met him everytime he came to Bangalore and lunch with me in the afternoon was routine. (Incidentally he enjoyed his meals greatly.) We also used to discuss optics and magneto-optics, subjects in which he was a master.

He was a man of many parts and a great respector of our traditional values. He was a well rounded human being. He made one feel that he was at peace with himself. His knowledge of the arts was substantial. Anything he did in science or otherwise, he did with some elegance and élan. It was a delight to meet him. His conversation was so vivacious and he was so full of fun.

One of the most memorable experiences I have had was the conversation I had with Krishnan about four or five years before he died.

In this conversation, he was so forthright in his statements and the phrases he used and sentiments he expressed were so vivid that they made a deep impression on me. However, one should consider

what follows as a recollection of something that happened four decades ago rather than an exact record of the conversation.

At about the time (1953), when the controversy as to who discovered the Raman effect had cropped up, I had occasion to go to Delhi. As was my custom I went to see Krishnan at the National Physical Laboratory. It was about 5.30 in the evening when I met him and I told him that I wanted to spend some time with him as I wanted to ask him some serious questions. He said 'as it is not the day on which I play tennis, I am going home. Why don't you come along with me and have some coffee'. After a delicious cup of coffee, when we were alone, he asked me what I wanted to discuss with him. I requested him to relate to me the story of the discovery of the Raman effect. He enquired as to why I asked him this question. I said there was a view that he (Krishnan) had discovered the Raman effect for Raman and this view had again surfaced. His reply was 'It is a blatant misrepresentation. The best I can say is that I participated actively in the discovery. Let me take out my diary to remind myself as to what happened. I really don't need

the diary at all because everything that happened in those momentous days in February 1928 is imprinted firmly in my mind.' However he referred to the diary once in a way when he told me the following.

'The story starts in the early February 1928 when Professor (Raman) came to my room and said "I want to pull you out of the theoretical studies in which you have immersed yourself for the last 2 or 3 years. I feel it is not quite healthy for a scientific man to be out of touch with actual experimentation and experimental facts for any length of time." I thought this was one of the finest pieces of advice I have ever received. I felt quite guilty that I had done no experimental work in the previous 2 or 3 years. I have ever since kept this advice foremost in my mind and to me this has been one of the cardinal principles of my scientific researches since then and even to this day.

'He asked me to study what he called the "so-called weak fluorescence" phenomenon displayed in the scattering of light which K. R. Ramanathan had found

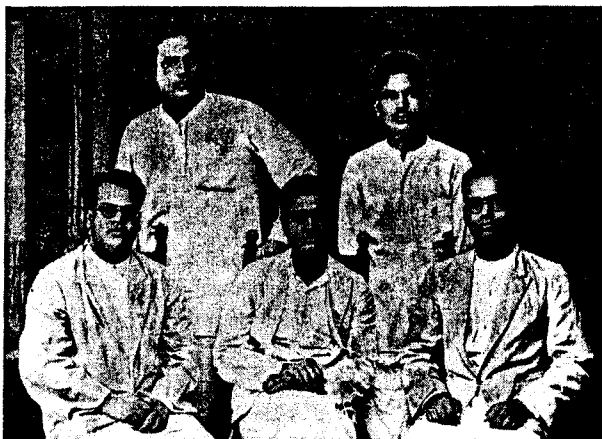
in 1923 using complementary filters. Professor never believed that it was fluorescence at all. Apart from molecular scattering of the Rayleigh-Einstein-Smoluchowski type, he felt strongly that there was yet another type of scattering of a feebler variety whose intensity was only about a hundredth of that of the usual classical scattering and that this differed from classical scattering in not having the same wavelength as the incident radiation. He felt this was the optical analogue of the Compton effect. This conviction grew in him by a greater measure after he wrote the well-known paper from Vijayanagaram on the classical derivation of the Compton effect formula.

'By the end of January 1928, S. Venkateswaran had observed that the "weak fluorescence" in glycerine was quite conspicuous and that it was strongly polarized, reminiscent of the observation K. R. Ramanathan had made in 1923 and I had made in 1924.

'Professor was very disappointed when Venkateswaran could not observe any polarization of the "weak fluorescence" in anthracene vapour. I feel it was then

that he decided to draw me into the fray. He asked me to verify Venkateswaran's observations. I devoted the first week of February studying the "weak fluorescence" of vapours. Most of the vapours showed quite INTENSE "weak fluorescence" but few appeared to exhibit polarization.

'For me the subject which Professor asked me to study was extremely interesting because there was no proper theory which could explain the facts we had observed—especially the polarization of the "weak fluorescence" in liquids. I was very happy coming back to experiment.' When he looked into his diary, I (SR) asked him "Did you always maintain a diary?". The reply was "Off and on"; but at that time I felt that Professor had an inspiration and that was why he had shifted me over to verify Venkateswaran's experiments. We all knew from experience that when Professor had an inspired idea, something new would surely happen. It was not clear to me why Professor wanted me to study the fluorescence of organic vapours. I studied this phenomenon carefully in many substances and most showed observable "weak fluorescence". As far as I was concerned, the subject was extremely interesting because there was at that time no theory of fluorescence which could explain the experimental findings we had made, especially the polarization of the "weak fluorescence" in liquids. In spite of my not being clear as to why I was making



A group of 5 students of Raman. *Front row – Left to Right*: 1) S. Venkateswaran, whose observations on the polarized 'weak fluorescence' of glycerine in early 1928 started the last lap of investigations which led to the discovery of the Raman effect. 2) K. S. Krishnan, he was 31 when this photograph was taken. 3) A. S. Ganesan – spectroscopist, later editor *Current Science*, who worked with Raman. He compiled the first bibliography of the Raman effect which Rutherford submitted to the Nobel Committee when he proposed Raman for the Nobel Prize.

Back row: 1) C. Mahadevan, who later became renowned geologist who did his post-graduate work with Raman on X-ray studies of minerals. He was present at the Indian Association for the Cultivation of Science in Calcutta during the momentous discovery of the Raman effect and he has left graphic accounts of what happened then. *Right*: S. Bhagavantam, another renowned student of Raman, who worked with him after the discovery of the Raman effect and is well-known for his application of group theory to the Raman effect.



K. S. Krishnan.

Extracts from Prof. K. S. Krishnan's Diary**5th February 1928, Sunday**

For the last 3 or 4 days, I have been devoting all my time to fluorescence. The subject promises to open out a wide field for research, since at present, there is no theory of fluorescence which could explain even the outstanding facts.

Studied anthracene vapour. It exhibits strong fluorescence which does not show any polarisation, when viewed through a double image prism. Professor has been working with me all the time.

Recently, Professor has also been working with Mr Venkateswaran on the fluorescence exhibited by many aromatic liquids in the near ultra-violet region present in sunlight and the fluorescence of some of the liquids are found to be strongly polarised. However, in view of the fact that the fluorescence of anthracene vapours does not show any polarisation, Professor has asked me to verify again his observations on the polarisation of liquids.

7th February, Tuesday

Tried to verify the polarisation of the fluorescence exhibited by some of the aromatic liquids in the near ultraviolet region. Incidentally, discovered that all pure liquids show a fairly intense fluorescence also in the visible region, and what is much more interesting, all of them are strongly polarised: the aromatics. In fact, the polarisation being the greater for the aliphatics than for the aromatics. In fact, the polarisation of the fluorescent light seems in general to run parallel with the polarisation of the scattered light, i.e. the polarisation of the fluorescent light is greater and the smaller the optical anisotropy of the molecule.

When I told Professor about the results, he would not believe that all liquids can show polarised fluorescence and that in the visible region. When he came in up to the room, I had a bulb of pentane in the tank, a blue-violet filter in the path of incident light, and when he observed the track with a combination of green and yellow filters, he remarked 'you do not mean to suggest, Krishnan, that all that is fluorescence'. However, when he transferred the green yellow combination also to the path of the incident light, he could not detect a trace of the track. He was very much excited and repeated several times that it was an amazing result. One after another, the whole series of liquids were examined and every one of them showed the phenomenon without exception. He wondered how we missed discovering all that five years ago.

In the afternoon, took some measurements on the polarisation of fluorescence.

After meals at night, Venkateswaran and myself were chatting together in our room when Professor suddenly came to the house (at about 9.00 P.M.) and called for me. When we went down, we found he was much

excited and has come to tell me that what we had observed that morning must be the Kramers-Heisenberg Effect we had been looking for all these days. We, therefore, agreed to call the effect 'modified scattering'. We were talking in front of our house for more than a quarter of an hour when he repeatedly emphasised the exciting nature of the discovery.

8th February, Wednesday

Took some preliminary measurements of the polarisation of the modified scattering by some typical liquids.

9th February, Thursday

Set up this morning the long telescope and made preliminary arrangements for observing the effect with vapours. Before the arrangements were completed, Professor left for the College for his lecture.

In the afternoon, tried ether vapour and it was surprising that the modified radiation was very conspicuous. Tried a number of others in quick succession without however the same success.

When Professor came from the College at about three, I announced to him the result, and there was still enough sunlight. All the time, he said, that it was a first rate discovery, and that he was feeling miserable during the lecture because he had to leave the experiment, and that however he was fully confident that I would not let the grass grow under my feet till I discovered the phenomenon in gases. He asked me to 'call in every body in the place to see the Effect' and immediately arranged in a most dramatic manner, with the mechanics to make arrangements for examining the vapours at high temperatures.

Evening was busy and when Professor returned after his walk he told me that I ought tackle big problems like that and asked me to take up the problem of the experimental evidence for the spinning electron after this work was over.

10th February to 15 February

Studied a number of vapours, though a number of them showed the effect, nothing definite could be said regarding the polarisation of the modified scattering.

16th February, Thursday

Studied today pentane vapour at high temperature and it showed a conspicuous polarisation in the modified scattering. We sent a note today to *Nature* on the subject under the title 'A New Type of Secondary Radiation'.

17th February, Friday

Professor confirmed the polarisation of fluorescence in pentane vapour. I am having some trouble with my left eye. Professor has promised to make all observations himself for sometime to come.

19th February to 26th February

Studied a number of other vapours.

27th February, Monday

Religious ceremony in the house. Did not go the Association.

28th February, Tuesday

Went to the Association only in the afternoon. Professor was there and we proceeded to examine the influence

of the wavelength of the incident light on the phenomenon. Used the usual blue violet filter coupled with a uranium glass, the range of wavelengths transmitted by the combination being much narrower than that transmitted by the blue violet filter alone. On examining the track with a direct vision spectroscope we found to our great surprise the modified scattering was separated from the scattering corresponding to the incident light by a dark region.

17 Feb Friday

Only compound the polarization of fluorescence in pentane vapour.

I am having some trouble with my left eye. Day was ~~not~~ passed to make all observations himself for some time to come. ~~not~~

19 Feb 28

Studied a number of other vapours.

27 Feb Monday

Religious ceremony in the house. Did not go to the Association.

these observations, I took up the subject as a general problem and not as a pressing one which required any IMMEDIATE solution.

'At that time, when I found that the "weak fluorescence" in anthracene vapour did not show any polarization, Professor tactfully suggested that I move over to the study of organic liquids, especially the polarization of the "weak fluorescence" and verify all the earlier observations that had been made in our laboratory.

'Professor and I started studying organic liquids. Professor was always working along with me. We confirmed Venkateswaran's observations. After these studies, I could categorically state that ALL pure liquids show fairly intense "weak fluorescence". When I use the word "intense" I mean quite observable

and in almost all of them interestingly enough the "weak fluorescence" was also polarized. I also found that the polarization of the "weak fluorescence" was weaker the smaller the optical anisotropy of the molecule. Professor systematically verified all my observations and Professor, as you must know, has a tendency to talk while making observations. He liked to verbalise his thoughts and describe his observations in words and to exclaim loudly whenever he saw something new or interesting. For some reason he repeated again and again that this was an amazing result and wondered why we had not followed up this critical lead even in 1923/1924. Again Professor asked me to verify all my observations in the whole series of liquids I had examined and I found again that all of them showed the polarization of the "weak fluores-

cence" without exception. Professor felt for some reason (which I did not completely comprehend at that time) that this was a momentous discovery and felt he had come to the final stages of the solution (to the problem) he was in search of since 1921. Professor is a 24-hour scientist, always thinking of the problem at hand with great intensity all day and almost all night (excepting probably when he slept). At 9 p.m. on that day (on Tuesday the 7th of February) after Venkateswaran and I had had our meals, Professor suddenly came to our house and shouted Krishna Iyengar, Krishna Iyengar, Krishna Iyengar (that was how he often used to call me in those days) and when we went down he told us in a most excited voice that he was certain that what we had observed that morning must really be the Kramer-Heisenberg effect we had been looking for all these days. I must confess I was greatly disappointed that I did not identify the "weak fluorescence" with the Kramer-Heisenberg effect about which we had been talking constantly. He suggested that we should call the effect we had observed as "modified scattering". I liked the expression *modified scattering* instead of "weak fluorescence" as it looked to me as though we could start thinking of explaining the facts of observations on a completely different basis (not in terms of classical fluorescence). He also repeated again and again in a most excited voice that we had made a very great discovery.'

I (SR) interrupted him and asked as to when they saw the paper on the Kramer-Heisenberg dispersion theory and when they felt it was important to the subject of their study. I informed him that Nagendra Nath had told me that Max Born was greatly impressed that Raman appreciated the implications and intricacies of the Kramer-Heisenberg dispersion theory. In response,

Krishnan said 'Professor is extremely sharp. He can extract real physics from any paper, however mathematical it be.' (See Post Script at the end of the article.) 'Professor felt after reading the paper that Kramer-Heisenberg had given one more channel for light to be scattered, which we must also pursue with vigour.'

'He then actually asked me to study some more vapours to see whether the *modified scattering* showed polarization. I arranged for this and found that in ether vapour the *modified scattering* was very conspicuous when I had just finished making this observation. Professor came back after his lecture from University and verified my observations and again got very excited and shouted that we had made a first rate discovery. He said that while he always enjoyed lecturing, on that particular day his mind was not at all in the lecture. He felt that he was wasting his time and that he should really have been spending time in the laboratory with me. In a loud voice he shouted and called everyone in the laboratory to come and see "the Effect". He also insisted that I should establish the phenomenon of *modified scattering* in gases also. Arrangement was made to vary the temperature and to study vapours and gases at high temperatures. In the next 4 or 5 days I studied large number of vapours and all of them showed the *modified scattering*. But one could not be very

definite about whether every one of them exhibited polarization. Pentane vapour showed distinct polarization. Professor felt that observations we had made so far were proof convincing enough to announce that we had observed a new type of secondary radiation and so a note was sent to *Nature* on 16 February 1928. These continuous and strenuous observations had strained my eye and I had to stop observing, but Professor continued to make the observations independently. When my eye became alright, we studied more vapours. It was a very great pleasure to report to Professor all my observations and to observe his enthusiastic response and to receive his encouragement.

'On 27th of February, I had a religious ceremony at home. I normally like these rituals. But this was the first time my mind wandered and I felt I should really have been in the Association. I could not concentrate on the ceremony. I actually liked the loud chanting of the *mantras* and their cadence gave me much peace of mind. I also liked the manner in which the words of the *mantras* were strung together like flowers in a garland and also the beautiful poetry in these words. I could even understand the intricate meanings and the profound philosophical implications in the *mantras*. Unfortunately, I did not feel all this on that day. My mind was wandering and I felt disappointed that I was not able to make

observations and report something new to Professor. Later I did a *prayaschiham* for my being inattentive to the mantras during the ceremony.

'Next afternoon on the 28th, I went to the Association. Professor was already there and we proceeded to examine the influence of wavelength of the incident light on the phenomenon. It was then that Professor thought of examining the track of the *modified scattering* with a direct vision spectroscope. I was very skeptical as to whether one would be able to observe anything at all because I remember that 3 or 4 years previously (1924 or 1925) Prof. Raman wanted to record the spectrum of the "weak fluorescence" and asked Venkateswaran to do it using a constant deviation spectrograph. Even after prolonged exposure, Venkateswaran failed to record any spectrum.

'The great shout or really squeal that Professor gave when he made the observation is unforgettable. He said that there was a new patch of colour in the spectroscope and that there was a definite gap between the spectrum due to the incident light and the new one which he interpreted as that due to the *modified scattering*. I too saw it with great happiness and satisfaction. Professor immediately asked me to photograph the *modified spectrum* using the baby quartz (Hilger) spectrograph which I proceeded to do. The experiment was quite successful. We then repeated experiment using monochromatic light from a quartz mercury vapour lamp with all the radiation excepting the blue cut off with filters. After a long exposure, the spectrum of the *modified scattering* exhibited itself in all its glory in the form of a series of beautiful discrete lines.

'I can say that Professor saw the effect visually in a spectroscope for the first time while I had the privilege of recording it for the first time on a photographic plate so that the world of science could believe that this effect did exist. I must confess that I had carried out dutifully all the experiments that Professor asked me to do. If I were immodest I can say I executed them rather well. As I said before those were wonderful days and all that we did remained permanently engraved in my mind and I recorded them carefully in my diary.'

I (SR) then asked Krishnan that Professor was being accused of taking away the lionshare of the credit of the discovery



Photograph taken when Arnold Sommerfeld (*centre*) came to India in 1928. Sommerfeld actually observed the Raman effect visually and has written detailed accounts of it. He gave a course of lectures on quantum theory which was written up by K. S. Krishnan for publication. Sommerfeld has written a letter to C. V. Raman complimenting K. S. Krishnan on the excellent manner in which his lectures were prepared for publication. K. S. Krishnan (*left*) and C. V. Raman (*right*).

depriving you of much of the credit due to you. He replied, 'that is another misrepresentation. Professor never tried to do this. If you read the Nobel Lecture, which is a true and honest account of the progress and history of the subject, Professor names all his collaborators in order starting with K. R. Ramanathan giving everyone (and including me) his due credit. Again and again in public lectures, he always mentioned that I collaborated with him in the discovery of the effect and that our collaboration was similar to that of Bowen and Millikan which was praise indeed.

'Some time later, Professor suggested that he wished to recommend me for a Professorship at the Andhra University.

In his letter of recommendation to the Vice Chancellor he wrote, (at this stage Krishnan took out a file from an almirah and read out) "If the Nobel Award for Physics made in 1930 had been for the work done in the year 1928 alone instead of the entire work on the scattering of light done at Calcutta from 1921 onwards, Krishnan could justly have come in for the share of the prize." Where is the question of Professor depriving me of the due credit? Professor is an extremely generous man.'

One should mention here that the citation for the Nobel Prize read: 'The Academy of Sciences has resolved to award the Nobel Prize for Physics for 1930 to Sir Venkata Raman for his work

on the scattering of light and the discovery of the effect named after him'. I am also tempted to quote R. W. Wood: 'Raman's brilliant and surprising discovery . . . I have verified his discovery in every particular. Raman's discovery thus makes it possible to investigate remote infrared regions hither too little explored. It appears to me that this is a very beautiful discovery which RESULTED FROM RAMAN'S LONG AND PATIENT STUDY OF THE PHENOMENON OF LIGHT SCATTERING is one of the most convincing proofs of the quantum theory.'

I then asked Krishnan 'What happened to make Professor make such vituperative statements about you. Is it because of

Certificate of a Candidate for Election.

Surname. **KRISHNAN, K. S., D.Sc**

Christian Names. **Kariāmarikkam Srinivasa**

Profession **Mahendralal Sircar Research Professor of Physics.**

Usual Place of Residence **Indian Association for the Cultivation of Science,
210, Bowbazar Street, Calcutta, India.**

Not to exceed 100 words.

Qualifications

Distinguished for his investigations on molecular optics and on magne-crystalline action; Collaborated with Sir C.V. Raman in extensive theoretical and experimental studies on light-scattering, molecular optics and in the discovery of the Raman Effect (1928). More recently, has published many valuable investigations (Phil. Trans Royal Society and elsewhere) on the significance of magnetic anisotropy in relation to crystal architecture and thermo-magnetic behaviour at the lowest temperatures. Has published important work on pleochroism in crystals and its relation to photo-dissociation. Leader of an active school of research at Calcutta. List of papers appended.

being desirous of admission into the ROYAL SOCIETY OF LONDON, we the undersigned propose and recommend him as deserving that honour and as likely to become a useful and valuable Member.

From Personal Knowledge.

C. V. Raman
Proposer.
M. J. Forster
Seconder.

Certificate written by C. V. Raman himself proposing K. S. Krishnan to the Fellowship of the Royal Society. Reproduced by kind permission of the President and Council of the Royal Society.

the accusation that he had deprived you of the credit due to you?" Krishnan said: 'Such an accusation was completely false. Professor's change of attitude towards me has been THE GREATEST TRAGEDY OF MY LIFE. It must be due to my sins in the previous births (*poorva janma papam*). As he said this his eyes filled with tears and large tear drops coursed down his shiny checks. His voice choked and he was actually crying like a child.

'I am convinced that some evil-minded jealous person has gone and talked ill of me to Professor and he, in his child-like innocence, has believed these scurrilous statements made about me and his mind was poisoned. But what surprised me is that professor could ever believe anything ill about me – his most favourite student, on whom he bestowed so much of trust and on whom he showered so much affection. Only explanation I have is that Professor's mind was in a greatly disturbed state at that time. You see his theories of the vibration spectrum of the crystal lattice had not been accepted by the international community of scientists. He was therefore in a very depressed state and he must have believed the scandalous statements made by someone about me.'

Krishnan paused a minute and his appearance took on a very contemplative look and he said: 'It is possible that the great God punished me for the pride I had harboured in my heart. I had become too proud and thought I was his best

student and that was the reason why he chose me from a large number of his talented students when the crucial experiment had to be done (*experimentum crucis* were the words I think he used). I have never said anything inimical about my *Guru*. I have examined my conscience and I am convinced that I had not committed any *gurudroham* (I think that was the word he used). I am greatly hurt and wounded. I do not think I shall ever recover from this terrible shock.'

I (SR) shall now ask you a question I always wanted to ask you. If you had not entered the experimental scene in February 1928 do you think India would have missed discovering the new Effect. 'It is a hypothetical and embarrassing question,' he said. 'If I were to answer it honestly and truthfully I have to bring in Professor's character into the picture. He had a one track and persevering mind. Once he was on a promising trail he would follow it persistently and would not give it up unless the solution was found to his satisfaction. The answer to your question is that the new Effect would have been discovered even without me. All the experiments were planned by Professor. I again say I executed them rather well. Professor is like the mythical philosopher's stone. He could convert any base metal into gold. If it was not me, he would have found some one else amongst his talented group to collaborate with him and do all the necessary

experiments. All that I can say is that probably I had the privilege of hastening the discovery.' I (SR) remarked that this was extremely important and crucial because Landsberg and Mandelstam were not too far behind in the discovery of the *modified scattering*. You and Professor, probably at that time, did not even know of Mandelstam's work.

'Let me conclude', he said, 'in answer to your two questions I would state that the most important decisions in the sequence of events that led to the discovery of the Raman effect were taken by the Professor and not by me. Firstly, he was able to recognize even in 1923 but definitely after Venkateswaran's observations on glycerine that the "weak fluorescence" and its polarization was the phenomenon which was the answer to the problem he had been seeking all these years (since 1921). It was he who identified the so-called "weak fluorescence" with the Kramer-Heisenberg effect, the effect which we had been constantly discussing almost every day, and he also was the first to call it courageously the *modified scattering*. He also had the perception to think of seeing the *modified scattering* through a spectroscope. Therefore in answer to your question you asked me I did not discover the Raman effect for Raman. I repeat I participated in quite an active way in the discovery. In reply to your second question, Professor did not, at any point of time, deprive me of

Extracts from Prof. Raman's address to the South Indian Association in Bangalore on 16th March 1928

'This encouraged us to use monochromatic incident light. Using the mercury arc as source we get a number of sharp lines in the scattered light which were not present in the spectrum of the incident light. A quartz mercury lamp with a filter which completely cuts out all the visible lines of longer wavelengths the indigo line 4358 A.U. was found to be very effective. When the light from such a lamp was passed through the bulb containing a dust-free liquid and the spectrum of the scattered light was observed through a direct vision spectroscopy, it was found to exhibit two or more sharp bright lines in the blue and green regions of the spectrum. These lines are not present in the spectrum of the incident light or in the unfiltered light of the mercury arc, and are manufactured by the molecules of the liquid.

'There has, as yet, not been sufficient time for photographing the spectra from a large number of liquids, or even for measuring the photographs already obtained. Visual observations have however been made with a large number of liquids. There is an astonishing similarity between the spectra obtained with different liquids. When only the 4358 line was used, most liquids showed in the spectrum of the scattered light, a bright line in the blue-green region of the spectrum (about 5000 A.U.) whose position was practically the same for chemically similar liquids such as pentane, hexane and octane for instance. There was however recognizable difference in the position of the modified line when other liquids such as benzene or water were used. When the 4047 line of the mercury arc was set in by removing the quinine sulphate solution, a second modified line in the blue region of the spectrum was seen with most liquids ...'

(Reproduced from *Science Week*, Andhra Pradesh Academy of Sciences, 1978.)

the credit due to me as can be seen from his Nobel Lecture and the recommendation he wrote to the Vice Chancellor of the Andhra University.'

As I said before, I was greatly impressed with what I had heard and left Krishnan's house with the greatest of admiration for this remarkable man.

Tailpiece

Much later when I met Subrahmanyan Chandrasekhar, the astrophysicist of Chicago, Professor's nephew, I asked him 'K. S. Krishnan and you were very great friends. Did you ever discuss the discovery of the Raman effect with him and did he ever tell you that Raman had deprived him of the credit due to him (KSK)?' Chandrasekhar said, 'I had discussed the matter with Krishnan and said to the best of my knowledge Krishnan had never said a word against Raman. Even so Raman made many statements impugning Krishnan's integrity.'

I also repeated to him of the concluding statements made by Krishnan to me. Chandrasekhar said 'I do not agree with him at all. When two scientists collaborate it is improper to ask whose idea it was as many ideas really emerge because of the mutual discussions they have had also

since they toss ideas between each other. I shall repeat what I have often said about the Raman effect. I stick to this statement I make in spite of what Krishnan told you.'

'My own view is that the discovery of the Raman effect was possible because two absolutely original scientists (Raman and Krishnan) complemented each other. I would also point out that Raman's Nobel lecture did not fail to acknowledge Krishnan's contributions. Since I was in Calcutta almost immediately after the Discovery, let me quote what I wrote to Raman in 1944 when he congratulated me on my election to the Royal Society.'

'It was a special pleasure receiving your cablegram and the greetings from Bangalore. Under the circumstances it was natural that my thoughts should have gone back to the summer of 1928 when as an undergraduate I had the unique privilege of witnessing a band of physicists exploring the possibilities of a great discovery made by one of them and with that disinterested enthusiasm which is possible only under a great master in the presence of fields of knowledge freshly revealed. That was sixteen years ago and meantime our scientific interests have diverged but the impression made on me then has remained with me ever since'

Post Script

I sent the above essay to a few senior scientists who knew both C. V. Raman and K. S. Krishnan well, for their comments. Each of them not only approved of the article, but said that it must be submitted for publication. One of them made the following comment regarding the Kramer-Heisenberg paper: 'Prof. Krishnan in his loyalty is rather generous to Prof. Raman in his statement regarding Kramer-Heisenberg paper. I feel that Prof. Krishnan being an expert in quantum mechanics must have played quite a substantial role in the actual physical interpretation of the Kramer-Heisenberg dispersion theory to the phenomenon of light scattering.'

Due to the efforts of A. Ratnakar, Librarian of the Raman Research Institute, we were able to get a copy of the certificate written by Raman himself when he proposed Krishnan for the Fellowship of the Royal Society, which we reproduce here with special permission of the Royal Society, London.

S. Ramaseshan is in the Raman Research Institute, Bangalore 560 080, India.