

An Interview of Prof.A.Jayaraman

Conducted by Indira Chowdhury and Prof.T.V.Ramakarishnan on December 23,2009.

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Indira Chowdhury (**IC**): We are sitting at the home of the host of Prof. Jayaraman in Indiranagar. With me is Prof. Ramakrishnan(**TVR**) and we will both be talking to Jayaraman(**AJ**). Thank you so much for agreeing to talk to us. We would like to begin by getting to know a little bit of your family background and education . Would you like to say a little bit about yourself.

AJ : Certainly. I was born in a village called Marathurai ,near Kumbakonam,Tamil Nadu on Nov 18 , 1926. After elementary education in the village school I went to a small town called Kuttalam for High School and then to Annamalai University in Chidambaram for intermediate and then to Pachayappas college in Madras for the B.Sc degree in Chemistry, which I finished in 1946. Then I spent two years at the College of Engineering in Guindy, Madras as a research scholar and also served as a Demonstrator in Chemistry for over a year. I moved to Bangalore in 1949, when Prof.Raman took me under his wing. Right from high school I developed an interest in chemistry because of my teacher. As an youngster I used to tinker with toys and build simple electrical devices. When in college I listened to some lectures on Galaxies, Radioactivity, Electrical discharge producing different colors fascinated me. I had a strong interest in Science and always tried to experiment with things. When in the college of Engineering Guindy I tried to learn the principles of electrical and mechanical engineering.

IC: Which years were these in Guindy ?

AJ: 1948 – 1949.

IC: You worked there?

AJ: Yes ,I did both research and had duties as a Demonstrator. The Engineering students were required

to have some exposure to Physics, Chemistry and Geology and conduct Lab experiments. The duty of the Demonstrator was to supervise their Lab work and do some teaching also. During my years in Guindy I picked up quite a bit of knowledge in Electrical and Mechanical Engineering, which came in handy later on, when I joined Raman Research Institute. There was this physical chemist Dr. Srikantan, and I did some research work on Catalysis under him. My meeting with Raman was the most important event in my life. Earlier, I had listened to a Lecture by him in Loyola college and it made a great impact on me. Since then I was dreaming if I could ever get to work under him.

IC: Can you remember the year?

AJ: Yes. This was in 1947. Raman gave a talk on Faraday Effect in Loyola college Madras and it was an inspiring talk. Even though I did not understand the subject then, the talk made a deep impression on me. I entertained the thought, if I could become his disciple. During a visit to Bangalore in November 1949, I took the courage to call him on the telephone. Luck was on my side, for he took the telephone and asked who I was and what I wanted. After a bit of explanation I said "I want to meet you Sir".

He asked me if I know where to come and I said "I will find out sir". Raman Research Institute in those days was a desolate place and I walked from IISc and entered the gate. Raman was walking in the grounds and signaled to me to join him. He inquired about my background and asked a few general science related questions. This went on for about an hour or so. He talked about plants and his garden and asked me if I know anything about them. Fortunately I had some knowledge in the field and he was pleased about it. Then he talked about his Institute and said, "I want to take an assistant to help in my research and want to be careful in selecting the right person. He said he must be competent, good with the hands and totally honest. I said "if you give me an opportunity I will try my best to serve you sir". He thought for a while and said I like the broad background you have, and I will take you on probation for six months. If you prove to be good you will stay with me." That is how I started my scientific Career with Prof. Raman. He liked me and that is the beginning of a new era for me. I learnt from him all the physics I know, supplemented by my own efforts. That is how our relationship started.

IC: You found him approachable?

AJ: Very much so.

IC: How old were you when you met Raman?

AJ: I was 23.

TVR: Raman was 61?

AJ: Yes. He was 61. After the interview he took me to his office, dictated a letter of appointment to his secretary, and handed it over to me. It said that A.Jayaraman B.Sc. is appointed as Research Assistant on a salary of Rs.100/month, on probation for six months. Handing over the letter he asked me “when can you join”. I said “I will go back to my village and get my mother's blessings and report in ten days. He said that will be fine. He gave me a ride in his car to the Bus stand at the IISC circle.

IC: In his car?

AJ: Yes. I felt elated and euphoric about the outcome. I found my Mentor.

IC: How many people were there at R.R.I at that time?

AJ: There was one Balakrishna who was his secretary at that time. Prof.Raman had appointed J.Padmanabhan from Trivandrum as a Technical Assistant before me and he was about to join.

IC: So when you came back what was the first day of work like?

AJ: For the first few days I familiarized myself with the place and surroundings. There were all kinds of optical microscopes, one or two spectrometers, and a lot of electronic things acquired from the US Army surplus equipment. These were kept in Steel almirahs in the rooms on the ground floor. In one room there were several musical instruments. To my surprise there was no electricity.

IC: What did you do?

AJ: Raman said we are not going to wait for electricity to do research . We will use sunlight. Two rooms were painted black, and windows covered with plywood and painted black. On one window a circular opening was made to admit sunlight and a reflecting mirror(hand operated Heliostat) directed

sunlight in to the hole. Focusing lenses(Aerial camera lenses from the US army surplus) shaped a bright beam. Color filters were used to isolate narrow bands of color when needed. Predominantly a direct beam of sunlight was used for most studies in those days. We investigated a whole lot of specimens, minerals and crystals, light scattering in liquids and solids and transmission in them.

IC: All this was using Sunlight?

AJ:Yes. I did not realize at that time that Raman was a great believer in the efficacy of sunlight. The Raman Effect was discovered in 1928 using sunlight and complementary filters. Only at the very end Raman asked Krishnan to employ a mercury arc lamp to record the spectrum of the scattered light, to demonstrate unambiguously the frequency shifts involved in Raman scattering.

IC to TVR: Would you like to ask him something about the science that period?

TVR: Yes. So what kind of optical studies he was involved in?

AJ: Raman had collected a variety of minerals and crystals. Actually he bought them from Mineral dealers in New York. He went to USA at that time as a member of the Indian delegation to the World Bank. He utilized his free time for this purpose. He must have had in his mind that he should have a Museum in his Institute which would serve as the source materials for his research. Soon after Padmanaban and I joined , several boxes containing the specimens arrived . Our first job was to unpack and arrange them. Later they were all transferred to Glass cases in several rooms on the upper floor. Many of these specimens exhibited one optical effect or other and these were the objects of our study.

TVR: Even now the Museums exist.

AJ:Yes. Very much so. Raman had a finely honed aesthetic sense. The specimens have to be kept in the proper place and setting, to bring out the optical effects they exhibited, their geometry, and color. He gave the task of fabricating Glass cases and shelves to EKG and sons in Bangalore and they did a magnificent job. Padmananhan and myself helped Raman to organize the collection ,one by one.

Reverting to your question, we started with studying the optical effects in many Feldspars. One of the first material that we studied was labradorite, a feldspar which showed a spectacular

iridescent color when viewed in particular directions. Raman devised an ingenious way to study this, using a beam of sunlight and a white card held in front of the sample to the side. Some times we immersed the samples in a liquid medium to eliminate surface effects. This study immediately revealed the nature and geometry of the optical effect in relation to its crystallographic orientation. I photographed the effect and Raman was very pleased. From a detailed study we could establish that the iridescent color had its origin in the physico- chemical aspects of this material and the precise way in which they were oriented. The double halo seen with some specimens were connected to twinning in the matrix sample and its geometry and crystal chemistry. Then he worked on many other feldspars.

TVR: What did he work on?

Then we studied Moon Stones, another feldspar which exhibited a fine blue diffusion when viewed in certain directions. In this case we immersed the samples in a liquid medium and held the card in front of the specimen, to photograph the diffusion halos, a term christened by Raman. From the size, shape and color of the halo he was able to get a rough estimate of the size and shape of the particles responsible for the effect. During the observation sessions I learnt a whole lot of crystal optics, for Raman would be talking all the time the underlying physics. This is the best way to learn a new subject for me.

TVR: The particles which were causing the effect?

AJ: Yes. We used to demonstrate these optical effects to visiting dignitaries and scientists. When Raman's nephew S. Chandrasekar of the University of Chicago visited our Institute, Raman asked me to show the optical effects in feldspars. Chandra carefully observed the phenomenon and commented that Mee's theory of scattering may be the right approach to theoretically explain them.

TVR: I think that without getting involved in a detailed theory, the simple approach of Raman was good enough to explain the phenomena, and draw inference about the size and shape of the scatterer. This is very important. For example if you go too much into theoretical treatment one can get lost in the minutiae and miss the gross effect, which is the main thing. This indeed is the mark of a great

experimentalist that Raman was.

AJ: Quit right. At this time Raman got interested in the colored reflections exhibited by Potassium Chlorate crystals. D. Krishnamurthi who had joined as research scholar was assigned to study the optical effect. It was found that the crystals which show the effect were multiply twinned in a perfectly periodic manner, to cause Bragg like reflections, and the colour was highly monochromatic. I could determine from a Laue diagram the crystal orientation for the twins. By this time we had electricity and a Siemens X-Ray generator functioning. This is a beautiful piece of work. When physicists talk about beauty in Physics this must be one of the examples.

TVR: It is indeed a beautiful effect. You know Raman-Nath theory for diffraction of light waves in liquids under the influence of Ultra sound. Raman guessed that the ultra sound field produce a grating in the liquid which diffracts light.

AJ: Yes. This was explained by Raman intuitively as a phase grating and he asked Nagendra Nath to work out a mathematical theory using Bessel functions. This was most successful and the work is considered as a classic contribution.

TVR: It was a great discovery. In this case it was actually a man-- made grating, unlike the case of potassium chloride.

AJ: Yes.

TVR: The remarkable thing was that the spacing was equal and hence functions as a grating. For this there must be a deeper reason That may be the most stable arrangement. I dont know how Raman hit upon the right reason to explain the effect .

AJ: Yes. He was always very imaginative and thought of ideas which dont occur to most.. He asked someone to grow crystals of potassium chlorate. When this person grew the crystals by evaporating a saturated solution in a Petri dish, there were very brightly colored crystals in the dish. Raman examined the colored reflection with a pocket spectroscope and came up with a very good number for the periodicity of the twins. In the modern context this would be called a photonic -crystal ,for the

periodicity is of the order of a wave length of light.

TVR: I have heard that Raman carried a direct vision optical spectroscope.

AJ: That is correct, and a pair of polaroids too.

TVR: He would look at flowers and objects and make scientific statements. Is this true?

AJ: Yes. It was a small instrument with a direct wavelength scale in it, which enables one to make quantitative statements. One of the objects he studied was the wings of flying ants. These come out in large numbers after a rain and he would go out and collect them. There was a diffraction grating structure in the wings which gave rise to colors in transmission.

TVR: They are the wings of the insect, right?

AJ: Yes. The fine structure is inlaid in them. Raman would wonder about them with awe. He had an uncontrollable curiosity for colors in Nature. He had a large collection of Butterflies from different parts of the world, of which the Morpho Brazilius and the Himalayan species had brilliant iridescent blue colors. Raman had studied them to find out the structure causing such beautiful colors.

He was fascinated with fibrous gypsum and I carried out X-ray diffraction studies on them to find the fiber axis. Along the length of the fiber the bundles would transmit light freely but in the perpendicular direction there is hardly any transmission of light. This is some thing like the situation in modern fiber optic transmission, except it occurs in Nature.

TVR: So in those years he was more or less alone and carried out all this work?

AJ: In a way yes. I was the one assisting him. In 1950 he recruited six Research scholars and they were supported by CSIR, and were paid a stipend of 200 Rs. a month. The first of them was TKSrinivasan a geologist, D.Krishnamurti and S. Chandrasekar physics major. K.S.Viswanathan had graduated in Mathematics. Raman is known to take students with other back ground and shape them in his mold.

AKRamdas and Bhat joined soon after and were junior research scholars initially. Two more additions in the course of the year were Venkateswaran and lastly Pancharatnam.

TVR: Was Pancharatnam also his student?

AJ: Yes. For the first two years the research scholars were sent to Central college to attend some advanced lecture courses in Physics and Mathematics given by well known Professors there Prof. Madhava Rao, Subbaramiah and Srinivasa Iyengar ,a highly regarded Mathematics Professor. Ramdas was assigned to study Infra red absorption in crystals, Bhat on Christensen effect, which is related to selective light transmission in a medium consisting of uniformly sized tiny glass spheres in a liquid medium. This problem was studied by Raman and Ramaseshan and they had published a paper on it. As in the case of iridescent feldspar ,iridescent agate and quartz and several materials, could be studied with sunlight.

IC: For the first two years Raman and yourself did all this work just using Sun light?

AJ: Yes. We also studied the fluorescence of Diamonds. Raman had a huge collection of diamonds,cut and uncut. He had studied them before but came back to the subject. We filtered the sunlight to allow the near UV radiation and focused the beam on the diamond specimens and studied their fluorescent properties. He employed the pocket spectroscope to characterize the emission and determine the principal emission and the side bands. We could use the constant deviation spectrometer to photograph the emission spectrum. We studied the birefringence patterns in diamond platelets under an optical microscope. All this we could do just using natural light. Raman had a life long interest in diamond and he will come back to it again and again. We will show the fluorescent emission of diamond to chosen visitors. Of them the strong Blue diamond which Raman called my Kohinoor was spectacular. Raman used to quip that he can read a Newspaper with this blue light. The gem cut green emitting diamond was so beautiful. There were diamonds which emitted yellow and even white light.

TVR: You mean this UV light you filtered out from the beam of sun light was invisible and when it impinges on the diamond produce visible light.

AJ: Yes. I should say a very deep violet colour, almost invisible. Diamonds can be classified luminescent and non luminescent. We know what causes the emission.

IC: He used to give them names?

AJ: He gave them fancy names and was very proud of the collection. The Maharaja of Mysore decorated him with a diamond studded necklace called “Gandaberanda”. The pendant had 54 or so diamonds, and rubies. As soon as he got back to Bangalore he studied the luminescence characteristics of the diamonds and published a paper on it.

IC: You mentioned a couple of times visitors coming to Raman Research Institute. Who were they?

AJ: A few of them I can remember. Most of them eminent scientists : J.D.Bernal of Birbeck college London, S.Chandrasekar ,University of Chicago, Norbert Weiner of MIT, P.A.M.Dirac of Cambridge, Homi Bhabha, K.S.Krishnan, G.Wentzel of Chicago, Linus Pauling of Caltech, N.V.Belof from Russia, Chain the discoverer of Penicillin, E.C.Bullard of NPL England. Bhagavantam, C.G. Darwin, J.B.S.Haldane, George Gamow, M Oliphant, Rudolf Peierls, PMS Blackett and many many prominent Indians, starting from Jawaharlal Nehru, Maharaja of Mysore, Governors of many States .

IC: This was in the fifties ?

AJ. Yes. When visitors came I have to be near Raman and he will usually introduce me as his research Assistant. If time permitted he will introduce research scholars to the visiting dignitaries. I will be called upon to demonstrate some experiments. He will take the visitors upstairs and show the panoramic view from the front portico and then through the Museums. The finale would be the luminescent minerals room.

TVR: So you were formally with C.V.Raman as a scientific assistant?

AJ: Yes. I started in that capacity and in due course became an Assistant Professor, as well as Assistant Director of RRI. I had many duties to perform. Setting up the Labs, ordering Instruments and sometimes look after the Institute when he and Lady Raman had to go out of station, for a longer period. He would hand over the keys to me, as he gained full confidence in me and discuss all matters concerning the operation of the Institute. This was a big responsibility for me but I had to do it. He had much confidence in my ability to deal with a variety of problems. Right from the beginning he would put my name as a coauthor. I was a coauthor in a dozen papers he published in the Proceedings of the

Indian Academy of Sciences. in the early fifties. Once The electrification project was completed the research scholars started to do the experimental work assigned to them.

TVR: I remember that there was some study on mirages.

AJ: Yes there was. Raman was very interested in the phenomenon and asked Pancharatnam to investigate it. There was a whole lot of optical problems he was interested in.

TVR: After sometime you also started working for your PhD.?

AJ: After three years he asked me to submit a thesis for the M.Sc degree to the University of Madras and he was my official guide. He told “you have done a lot of studies on Cryptocrystalline silica. Do some X-ray studies and write up all that”. I did and was awarded the degree in 1954. The question of PhD did not come up then. He once told me that all this degree business is really not important. It is the scientific work you do that matters. Only in the late fifties I raised this issue of getting a PhD. He would simply brush it off. Only towards the end of 1959 he agreed to the idea, and said that I can do some additional studies on Iridescent feldspars and submit a thesis. Once he told me that he had literally dozens of students who got Doctorates and then go Abroad. He did not want that happen with me. He wanted me to continue with him for ever. Finally I convinced him that a PhD is a ticket to the scientific fraternity and it would be useful for me in the future.

IC: To Madras University.

AJ: Yes. While this was going on I applied for a post doctoral position at UCLA, California. I wanted to get into a new field of research and wrote to Prof G.C. Kennedy at the Institute of Geophysics in UCLA., on the advice of Dr. Sourirajan, a friend of mine, who was himself with GCK at that time. It was the time when many new fields were opening up; Lasers, Magnetic resonance, physics with Microwave radiation, Research at high pressures. A golden period to get into modern physical research. I got a positive response and that hastened everything. The letter even suggested that I could get a doctorate from UCLA. At this point ,towards the end of 1960 I had to tell Raman about this.

IC: How did you do that?

AJ: I showed the letter and Raman was very upset about it. He said “why did you write without telling me”. I just kept quiet. He looked at the letter of offer again and again. He said “Well I think you want to go. But if you go you cannot come back to the Institute.” I said “sir I will go only for two years and then come back.” He said “that wont be possible, If you leave you leave .”I said “I will think about it sir” and then left. After a few days I went to him and said 'I have decided to leave sir.’’Then he said “you can submit your thesis for PhD before you leave. “I had about six weeks time to write the thesis and get his signature, and left Raman Research Institute and Bangalore on a bright crispy day in October 1960.

IC: To come back to to the Raman Institute there were a couple of question I wanted to ask you. One is about his relationship with scientific community in India once he had the RRI going. Did he feel isolated?

AJ: He felt somewhat left out. The influence of Bhatnagar, Bhabha and Krishnan on the shaping of the scientific policy in the country was getting stronger and stronger. Raman felt left out out. He resigned from all committees. He did not want to apply for Government grants with strings attached. He said “ I want nobody to dictate what I should do. I want to carry out my work with full freedom”. Later he said this to Nehru and the education minister Chagla. He took only a small amount of money as government grants. He had invested in a company with Dr. P.Krishnamurthi, a student of his from the Calcutta days. This company made and sold Mantles for Gas light. Raman used to get over a Lakh of rupees annually from this which he passed on to the Institute.

TVR: Is it Petromax?

AJ: Yes. He had also an interest in another chemical manufacturing company which yielded money and this was also passed on to the Institute. He took a lakh of rupees from CSIR as grant and disliked very much filing a half yearly report for this. I

IC: I see. It was his money, over a lakh that was used for research.

AJ: Yes. He gave away all his personal property to RRI, including the spacious grounds and Bungalow

in Malleaswaram.

IC: He did not take grants from the Government?

AJ: Not much and he wanted it that way. Raman Institute at that time was a small scale operation and he could manage with modest amount of money, to pay the small research staff and a few technical supporting staff.

IC: what about his relationship to IISc? Did it continue in some way?

AJ: He was very bitter about the way he was treated by the Council of IISc, and would not have any relationship at the official level. However with individual scientists there was no problem. His personal relationship with the Physics Department was good. He helped PSNarayanan to write his thesis.

Occasionally RS Krishnan used to come to RRI.

IC: I wondered what his relationship with Homi Bhabha was? He had a good relationship with him when he came to IISc.?

AJ: It was very good in the beginning and he used to visit Raman Institute when he came to Bangalore. Bhabha at that time was the Director of TIFR and his team often came to Bangalore to launch high altitude Balloon experiments to collect cosmic ray data. Then Bhabha was asked to start the Atomic energy program by India Government and huge amounts of money started to flow for this purpose. By mid fifties Bhabha hardly came to visit Raman, Similarly Batnagar was going in a big way setting up the CSIR Labs. KSKrishnan's influence with Nehru was growing stronger . Raman felt left out

IC: Also with the International community at some point? I forget the exact year- he resigned from the Royal Society.

AJ: That was much later, in the sixties. I had left and gone to USA. I don't know about that period.

IC: Okay. So now coming to your own science “what did you do in UCLA? Would you like to talk about it.

AJ: Yes. Gladly. Research at high pressure was a brand new subject and I had to learn the techniques

by myself. The confidence I gained with Raman helped me to quickly come to grips and I learnt many things from Robert Newton, a graduate student with Prof. Kennedy at that time. During the three years I was there we struck new grounds and for the first time discovered that with pressure one can break covalent bonds, and a semiconductor could be turned into a metal. This phenomenon was first discovered by me in InSb, a member of the well known III-V compound semiconductors. We established that this is a general effect for all covalent semiconductors. We worked on fusion curves of several metallic elements and could show evidence for electronic transitions and their effect on the fusion and transport properties. All this triggered a lot of theoretical studies later by many groups. This initial success helped me to get launched in the field and accord a premier status. Willard Libby the Nobel Prize winning chemist was attracted to my work and he became a big supporter for me. He was at the time Director of the Institute of Geophysics in UCLA where I was an Assistant Professor. In 1963 I got an offer from Bell Labs to start high pressure research there. So I moved to New Jersey that year.

IC: Now if you can explain a little on what was the nature of Libby's interaction with you?

AJ: Soon after I showed that a covalent semiconductor can be converted to a metallic system under pressure and the transition is reversible, but has a large hysteresis, namely it is reluctant to go back to its original state. The question was, can one quench this phase and retain it at ambient pressure. Libby wanted to try this and I helped his graduate student in this task and it was successful. Further, Libby was able to show that it was also superconducting, an experiment he did with Prof Hans Bommel of the physics department at UCLA. Libby was quite impressed with my work and offered a joint appointment with Geophysics and Chemistry Department. Before his offer came I had already accepted the Bell Lab's offer.

TVR: I just wanted to ask two questions. You showed that Samarium sulphide, normally a semiconductor black in colour turned in to a gold colored material. This is well known to condensed matter physicists, as well as the the transition in V₂O₃, which is an insulating oxide. How did this work

come about. I think both these were done by you in Bell Labs.

AJ: Yes. Both these studies started when I was in Bell Labs. I had developed some new way of generating truly hydrostatic pressure and to make precise resistivity measurements at high pressure, as well as at elevated temperatures. I used these techniques to investigate Cerium metal, SmS and V₂O₃. In Bell Labs we had any excellent person to grow crystal of all kinds. One was J.P..Remeika and another was E.Bucher, a fine physicist who got in to synthesis of new systems. All the rare earth chalcogenide crystals I studied were prepared by Bucher. I made a detailed study of many of these materials under pressure and was able to show pressure induced electronic transitions and the phase relationship in them. Remeika made doped V₂O₃ crystals and we were able to provide experimental support for the metal-insulator transition, proposed by Mott for this material. The work on SmS led to the recognition of mixed valence systems and their special properties, viz heavy fermion systems. All this stimulated much theoretical work and interest in these systems. When Bucher stabilized the Gold coloured metallic phase of SmS with chemical substitution I did a simple experiment on it; I dropped a small piece into a flask containing liquid nitrogen and the piece immediately shattered into a black powder which upon warming became a golden powder. This proved to be a very fine demonstration experiment, of the electronic transition in SmS. PW Anderson was so fascinated with this simple experiment he used to bring visitors to my room for a demo.

TVR: Yes, that is the genesis of this entire field.

AJ: Yes.

TVR: Also I thought that the advances in High pressure generation initiated by you was helpful for physics research. Would you like to say a little bit about this?

AJ: In Bell labs I developed the so called Teflon cell technique to generate truly hydrostatic pressure to 50 kbars and proved this with precision electrical measurements, using Si as a probe. Having done it we could study a whole lot of semiconductors and devices that were being developed in Bell Labs. We could follow the pressure effect on the electronic band structure very accurately. One of our successes

was to explain the Gunn Effect in GaAs, as a phenomenon arising out of inter band electron transfer. We could do pressure experiments with fragile devices, such as p-n junctions and transistors. We could tackle a whole lot of problems in semiconductor physics. To establish the Mott transition in V₂O₃ precision of this kind was needed. Transport properties are very sensitive to deviations from non hydrostaticity.

When we were doing the work on V₂O₃ Prof Mott used to come to Bell Labs and have sessions with us to know the progress we made. My colleague D B. McWhan and Maurice Rice were the principal players and we all worked as a team, discussing the results of our work and how it fitted in to the Picture.

TVR: The development of the diamond anvil cell for high pressure research was an important landmark in high pressure research. Is it not? When did it begin? 1970?

AJ: The diamond anvil cell was first invented in the National Bureau of Standards in Washington DC by S. Wier and Lippincott in the early sixties and latter improved. For almost a decade not much notice was taken, until pressure generated could be precisely measured using the shift of Ruby emission line. It was a simple spectroscopic measurement, very quick and convenient and was introduced by D. Barnett, Stan Bloch, Van Walkenburg and Piermarini at the National Bureau of Standards. Since than the use of diamond anvil cell grew by leaps and bounds. I used the Bassett type cell for X-ray diffraction studies, calibrating the pressure with the change in the lattice parameter of NaCl or Ag and using the appropriate equation of state. This was good enough and I used it to study phase transitions and compressibility of rare earth chalcogenides to almost 500 kbars, which was a record in those days(late sixties). However, the pressure distribution was far from being hydrostatic. I took to DAC of the NBS version from mid seventies and did a whole lot of high pressure spectroscopy on materials under pressure. Following the lead of the Geophysical Laboratory to reach much higher pressures I fabricated DAC's in the early eighties and started using Raman spectroscopy extensively in my studies. It proved to be very useful and convenient in the study of pressure induced phase transitions. I never

did any Raman scattering work until then, but now it became a principal tool for me to study materials at high pressure.

TVR: I thought the design which was developed and perfected by you was used for a fairly long period of time, as the main source for new discoveries in high pressure physics.

AJ: I made full use of the DAC and introduced changes to make it effective for a number of situations. For instance I used DAC to demonstrate the spectacular electronic phase transition in SmS from black to gold, and to observe directly the band gap changes (a crystal of GaAs normally opaque turned red in transmission under 40 kbar) and to study resonance Raman scattering, as one tunes the band gap. A decade later when I moved to the University of Hawaii I used gases like argon and helium as pressure media, following the lead given by D.Mao of the Geophysical Lab.

TVR: I remember you brought Diamond cells when you came to NAL in 1970?

AJ: Yes. Diamond cell of the Bassett type and we did a lot of X-ray diffraction studies on rare earth chalcogenides with it.

TVR: I have seen your demonstrations of the valence transition in SmS from black to gold. It was so simple to observe. You could see it happen -and it was reversible.

AJ: Yes indeed. You could see an electronic transition just by sight. This kind of demonstrations is a Raman legacy. He taught me to observe things carefully, and simple experiments are the best way to make good science. Having a simple picture is the most important thing.

IC: Did you keep in touch with Raman after you left Bangalore? Did you talk to him about what you were doing in Science?

AJ: For a few years I was sending him reprints of my publications. He never responded. In 1968 I attended Raman's 80th birthday celebration Meeting that was held in Ahmedabad. Dr. Vikram Sarabhai had arranged a memorable Meeting. Raman was happy to see me and specially mentioned my attendance; that I have come all the way from the US for the event. I presented Raman with a bunch of crystals Grown in Bell Labs, plus a special package of synthetic diamonds made at the General Electric

Company and sent to me by Dr Bundy who was one of the persons involved in the synthetic diamond project. I said a few words about them and presented the crystals. Raman was very much moved. I gave a talk on my high pressure work and Raman asked the session Chairman to give me extra time to finish all I wanted to say. He remarked to someone that I did the right thing in going to America. When I was awarded the Krishnan Gold Medal by Vikram Sarabahi during that Meeting Raman told me "I knew very well that you will do good Science. Did I not propose you a decade back to the Fellowship of the Academy. During the meeting I tried to be with him as much as possible. His comments made me feel good and that he had reconciled with my leaving him in 1960, after all these years.

TVR: When you were with Raman did you live in RRI campus.,or nearby?

AJ: I lived in RRI campus. Prof Raman had a few quarters built in the Campus and one was for me. He saw to it that it had all the comforts. He himself planned it and it had western type Bath room with a Water heater included. He said" You must live in reasonable comfort." I was very much interested in Gardening and he was very pleased with my effort.

IC:He did carry it out?

AJ: Yes.

IC: Before that where did you live?

AJ: I was living in Malleswaram and cycled to the Institute four times a day, used to come home for lunch. Quite often he used to drop me and then pick up after an hour or two. He was so generous.

TVR: So you lived in RRI quarters for almost seven years?

AJ: Actually close to eight years.

IC: Did Raman take women students?

AJ: In IISc he had a few but none in RRI.

IC: He had Anna Mani?

AJ: That was at IISc. She was associated with RRI, long after Raman passed away,during Radhakrishnan's time.

TVR: You said Raman was very approachable. How was he to talk to and discuss things? The impression we have is that he was very commanding and charismatic figure. People tend to set up a distance from such people. How was his relationship to you?

AJ: Anyone could go to him and talk to him; ask questions about science. He would answer them. If you have something interesting to say he would listen, If it was concerning scientific topics. On certain matters he had set views and he held on to them. I had a wonderful relationship with him. Sometimes I had to be diplomatic, not to touch certain sensitive areas. I never had any argument with him. He was of course such a towering figure and so much senior to me, my approach was always respectful.

IC: He was nurturing the Indian Academy of Sciences as well as RRI. How did you see him in those two rolls?

AJ: The Indian Academy of Sciences was his own creation. He saw to it that the Institution held on to the highest standards, as a scientific body and in the matter of Publications. It brought out a Journal called Proceeding of the IASc, A and B sections, the latter for biological subjects. All papers were first scrutinized by Raman, and then refereed, when necessary. The publications came out promptly, without fail at the end of the month and mailed out to Fellows and subscribers. Raman published all his papers there, after the Journal came in to existence.

Raman very carefully selected the Fellows. People were chosen based primarily on their scientific merit. Initially some heads of Institutions got in, because of their contribution to science or technical education. Some young scientists were also elected if Raman was sure that they will make it good sooner or latter. But all prospective Fellows must pass the Raman test.

IC: What was the Raman test?

AJ: Scientific merit and the impact of one's contribution on the scientific thinking in the particular area.

TVR: one thing I have heard from many people, especially Fellows is that Raman was very fond of encouraging young scientists who were dedicated and held much promise. In fact it was one of the

things that he must do. He selected fairly young people as Fellows. Is that what you feel?

AJ: Very much so. I know many instances including my own which proves the point you made.

IC:Raman had strong reactions to ,let us say,when Hindi was proposed as the national language. I think he was quite upset with the whole thing.

AJ: Yes. He was outspoken on that issue. He told the Kerr Commission in no uncertain terms that it was a backward idea. His statement was, to quote “You are putting India back by two hundred years. If I have to choose a National language other than English why cant it be Sanskrit. I think it is utterly foolish to give up English.”When this came out in the News Papers C.Rajagopalachari,the elder Statesman wrote a post card the very next day,”Raman I appreciate your forthright views on the language issue.”

IC: It is also said that he rejected -although perhaps not publicly-his Bharat Ratna when the language issue went the other way. Is it true?

TVR: Did he ever say that he would ever return or reject it for some reason or other.?

AJ: I dont think so. He was very proud of the honor.

IC: No. When Hindi became principal language ,I think he was angry.

AJ: He might have made some statements in private. He was proud of the two honors conferred on him by the government of India. One was the National Professorship and the other Bharat Ratna.

TVR: Dr Jayaraman, my father was a member of the Sanskrit commission. I remember when I was a boy this Commission went round interviewing people and they interviewed C.V. Raman. He said positive things about Sanskrit, which was somewhat similar to what you quoted.

IC: Did Raman play any role in going and giving talks to school children,or college students When he was at RRI?

AJ: He was always very enthusiastic on this. When school children were brought to RRI he would take them round the Museums, Once a group of high school students came from Tamil Nadu and the teacher wanted Raman to explain to the students in Tamil ,what Raman Effect was, and he did it. He gave

popular lectures at the Annual Meetings of the Academy and on these occasions his audience were predominantly college and University students. Raman as a lecturer was brilliant. He had a supreme command of the English language, and an orator.

IC: He was obviously very encouraging to the young?

AJ: Very much so. He had this tremendous capacity to present scientific subjects in an understandable way.

IC: Thank you very much. Is there anything we have not asked that you want to talk about?

AJ: Yes. I must say Raman was a warm hearted person. When I left RRI he was very upset with me ,but I have no doubt that I did not disappoint him as a scientist. My 1968 meeting with him confirmed this. I hold him in the highest esteem. I owe him for everything I have been able to do: he shaped and nurtured me and encouraged me in all possible ways. I am ever grateful to him.

He was a very unique person. Raman's devotion to science and his ability to appreciate Nature is well known. He could talk about Egyptian history off his cuff, about weather and clouds and many other topics.

TVR: That kind of human being have become almost extinct. I always felt he was one of the last Natural Scientists.

AJ: Yes.

TVR: Has that disappeared in the pressure of specialization? Is it detrimental, or does not matter?

AJ: It seems so. Specialization is OK. But I think at some stage a person must strive to broaden their appreciation of science. To be called a Scientist one must have at the least a conceptual understanding of Science in general, be it cosmology or biology, evolution etc. Raman was a total scientist.

IC: I wanted to ask you one thing. This a recording that we did ,so that the Indian Academy of Sciences can keep it as a research resource. Do we have your permission to use it as a research resource.

AJ: Surely. You have my permission.

IC: Thank you very much.

TVR: My own personal idea was and is that if we could get firsthand knowledge of this period of Science, this group of scientists, then this would be a resource for our future, which cannot be replicated.

AJ: Yes. I believe in it.

TVR: You might find documents and people who would interpret these documents according to their own predictions. But this is a direct statement of people who have had direct exposure of these things. This is the reason, and I am happy that we are starting here.

IC: Thank you very much. I learnt a lot.

AJ: I thank you too for giving the opportunity. Raman is my favourite subject. I can speak volumes of him. I have given a lot of details in my Book on him.

TVR: We will get hold of a copy.

AJ: Raman delivered the Convocation address at IIT, Madras in 1965, a marvelous speech, typical of Raman. I think this should go into the records of the Academy.

TVR: Dr. Jayaraman, I also want to tell you that C.V. Raman was a visiting Professor at BHU. This was a time when such things were possible, in the sense that Sri Madan Mohan Malavya wanted some very distinguished people to oversee research and Raman was one of them. They had no restricting responsibilities. If they wanted to come and spend time they could; if they did not want, they need not. But Raman took it fairly seriously, at least in the early years, 20s and 30s, and visit BHU often and give talks. In one book about the University I have seen excerpts from his talks. One of the things I still remember his saying; "Malavya had made the University by collecting a lot of money from people who gave both large and small amounts. Out of that he created the University, the Departments, and the Chairs and so on.. The greatest thing that Malavya could do was create positions for young people, so that they could devote themselves to research, to furthering their own professional interests and growth

without pressures.” he also said that a University or a higher educational Institution in which the primary occupation of its faculty was with administration is no better than a school.

AJ: Yes.

TVR: So obviously this was the view he not only held but he practiced . He was a great teacher and explorer of the world of Nature.

AJ: Correct.

AJ: it would be of interest to add here some of the personal habits in daily life. Raman was a strict vegetarian and ate simple food . He would have a small breakfast, bread and banana and drink butter milk. He would work until lunch time and go home to have whatever Lady Raman had prepared for lunch.

TVR:And come back to the Institute again?

AJ: Yes. He would return to the Institute around 2.30 pm and go on until 5.30. He would take long walks in his garden whenever he felt like doing so. Sometimes he would go to Cubbon Park or even Lalbag for a walk. I have gone with him many times on these walks, which again would be a learning experience for me, and his views on many matters. He knew quite a bit about the Flora and Fauna of the Bangalore region, and was fascinated with flowering trees. During the decade of seventy he got interested in the physiology of vision and investigated the sensitivity of the eye for colours. He wrote many papers and monographs on the subject.

IC: He wore a turban?

AJ: Yes. It was more or less a custom in India of men wearing turbans. In the Mysore state the Maharaja was always seen with a turban when in procession or Durbar.

IC: What clothes he would wear?

AJ:He would always be in trouser and jacket and tie. When at home he will wear a dhotie in the south Indian style.

IC: That is interesting. Thank you.