



DREAM 2047

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VP News

Inside

Recognition for Dream 2047

DREAM 2047, the monthly newsletter brought out by Vigyan Prasar has been awarded second prize for excellent production, instituted by the Federation of Indian Publishers, a body that represents all major Indian book publishers, recently. The award was received by Dr. V B Kamble, Acting Director, Vigyan Prasar, at the venue of the 15th World Book Fair at Pragati Maidan, New Delhi, on February 3, 2002. The eight-day World Book Fair commenced on January 28, 2002, and ended on February 4.

DREAM 2047 wants to share this accolade with all its readers, whose encouragement has been a constant source of inspiration for this young, 3-year-old publication. A number of letters that we receive every month indicate that the readers have found the magazine useful and informative. The continued support and regular feedback from readers, we hope, will go a long way in setting and achieving higher standards in terms of content and quality of production.

Vigyan Prasar also participated in the World Book Fair. Its popular science titles were well received with a large number of people visiting the Vigyan Prasar stall to buy the books.

EDITORIAL

Chandrasekhara Venkata Raman

A Legend of Modern Indian Science



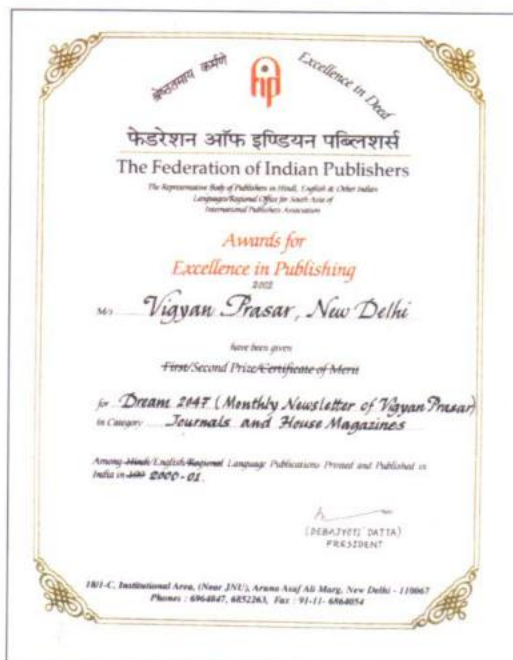
The Raman Effect



Indian Association for the Cultivation of Science



Raman Research Institute, Bangalore



Dr. V.B. Kamble, Acting Director, with Memento and Certificate

... think scientifically, act scientifically ... think scientifically, act scientifically ... think scientifically, act...

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Editor : Dr. V.B. Kamble

Attaining Criticality

The Science Policy Resolution of 1958 recognised the importance of "encouraging individual initiative for the acquisition and demonstration of knowledge, and for the discovery of new knowledge, in an atmosphere of academic freedom". Much later, a clause in the Article 51A of the Constitution of India was included that read, "it shall be the duty of every citizen of India to develop scientific temper, humanism and spirit of inquiry and reform". However, "the growing need to enhance public awareness of the importance of science and technology in the everyday life", and the special support of the Government "for programmes that seek to popularize and promote science and technology in all parts of the country" has been clearly spelt out only in the draft science and technology policy document 2001 (version 3). Indeed, this is highly encouraging!

During the pre-independence days, popularization of science was largely limited to a few motivated individuals with a missionary zeal - be it Ruchiram Sahni, Jagadis Chandra Bose or Sir C. V. Raman. They could electrify the audience with their remarkable gift of simplifying the complex phenomena interspersed with simple demonstrations, and attract the young to the world of science.

Not that the Government did not realize the need for scientific awareness soon after the independence. The Department of Education had set up in late fifties a few Vigyan Kendras especially in rural areas. In Gujarat there were two, and one was very close to Junagadh, which I used to frequent as a child. It used to be more a museum than an activity centre manned by a young science post-graduate. However, within a decade or so, the Vigyan Kendras mysteriously vanished! One wonders how and why!

In the sixties, the Kerala Sastra Sahitya Parishat took upon itself the mantle of science popularization as a social responsibility. It was around this time that a few voluntary organizations like Community Science Centre (later renamed Vikram A. Sarabhai Community Science Centre), Ahmedabad, came into being with the sole aim of popularizing science. Seventies marked the establishment of the National Council of Science Museums with its chain

of science museums, and was probably the first conscious effort at popularization of science in the country. A concerted, co-ordinated effort for science and technology popularization started when the National Council for Science and Technology Communication was established in 1984. Soon after, the level of S & T popularization activities in the country grew rapidly, and so did the number of voluntary organizations engaged in the field, a welcome sign indeed.

One is however, disappointed to find that, though the level of science popularization activities has significantly grown over the last one and a half decades, it still has continued to be at a sub-critical level. One reason is that most voluntary agencies engaged in S & T popularization find it difficult to make both ends meet. The new Science & Technology policy could come to their rescue in this regard. Further, there is no gainsaying the fact that the young graduates do not find the job lucrative. Next, after a few years of existence, an organization invariably falls into the trap of routine, stereo-typed activities and hence monotony, having exhausted ideas and initiatives. No longer does one find the job exciting and challenging. It is then that such organizations need a fresh breath of air. Who could provide it? Surely, the mantle falls on the established scientists and science communicators to offer them a fresh lease of life in terms of new ideas, new challenges, and new directions rather than keeping quiet or lamenting non-achievement of such organizations in fulfilling their stated goals. Encouragement and inspiration to old as well as up-coming organizations devoted to S & T popularization, and science activists would go a long way leading to national regeneration. It is then that our 'national reactor' will attain criticality.

This issue of Dream-2047 is dedicated to Sir C. V. Raman, a great scientist and a great teacher, who loved to talk to the young, discuss new ideas, inspire them to learn about nature, and explore hitherto unknown terrains.

□ V.B. Kamble

Editor : V.B. Kamble

Vigyan Prasas

Address for correspondence : C-24, Qutab Institutional Area, New Delhi-110 016
Tel. : 6967532; Fax : 6965986
e-mail : vigyan@hub.nic.in
website : <http://www.vigyanprasas.com>

Chandrasekhara Venkata Raman

A Legend of Modern Indian Science

□ Subodh Mahanti

All historical experience confirms the truth that man would not have attained the possible unless time and again he has reached for the impossible

Max Weber (1864-1920)

When the Nobel award was announced I saw it as a personal triumph, an achievement for me and my collaborators -- a recognition for a very remarkable discovery, for reaching the goal I had pursued for 7 years. But when I sat in that crowded hall and I saw the sea of western faces surrounding me, and I, the only Indian, in my turban and closed coat, it dawned on me that I was really representing my people and my country. I felt truly humble when I received the Prize from King Gustav; it was a moment of great emotion but I could restrain myself. Then I turned round and saw the British Union Jack under which I had been sitting and it was then that I realised that my poor country, India, did not even have a flag of her own - and it was this that triggered off my complete breakdown.

C.V. Raman

I have never seen anyone who enjoyed science so much. The sheer joy of seeing things and doing science filled him with exuberance and excitement. He had an incredible zest for life. He enjoyed his food, his jokes, his fights and quarrels. Yet the enjoyment he had for his science was something apart. In this pursuit it was as if his ego disappeared completely in the presence of effulgent Nature. Yes, he was truly lost in the wonder and beauty of what he was trying to comprehend.

S. Ramaseshan on C.V. Raman (quoted from C.V. Raman : A Pictorial Biography, Indian Academy of Sciences Bangalore)

Many people know Chandrasekhara Venkata Raman (more popularly known as C.V. Raman) because he was the first Indian Nobel Laureate in science. Till date Raman remains the only Indian to receive a Nobel Prize in science. There are two Indian-born scientists viz., Har Gobind Khorana and Subrahmanyam Chandrasekhar (who became US citizens) got Nobel Prizes in science. Raman was also the first Asian to get Nobel Prize in science.

Raman's celebrated discovery, the Raman Effect, experimentally demonstrated that the light-quanta and molecules do exchange energy which manifests itself as a change in the colour of the scattered light. However, this phenomenon was earlier predicted theoretically by Hendrik Anthony Kramers (1894-1952) and Werner Heisenberg (1901-76). It was the most convincing proof of quantum theory of light. This does not diminish the importance of Raman's discovery. As Albert Einstein (1879-1955) wrote : "C.V. Raman was the first to recognize and demonstrate that the energy of photon can undergo partial transformation within matter. I still recall vividly the deep impression that this discovery made on all of us...."

Raman's interests in science were wide, from astronomy and meteorology to physiology. 'Raman published 475 research papers and wrote five remarkable monographs on topics so varied that one's mind boggles'.

Raman made many major scientific discoveries in acoustics, ultrasonic, optics, magnetism and crystal physics. Raman's works on the musical drums of India was epoch-making and it revealed the acoustical knowledge of the ancient Hindus. It may be noted here that it was Pythagoras who first formulated what makes a sound musical to the human ear.

On the occasion of awarding the Hughes Medal of the Royal Society of London, Lord Rutherford (1871-1937) commented on Raman's scientific achievements as follows: "Sir Venkata Raman is one of the leading authorities in optics, in particular on the phenomenon of the scattering of light. In this connexion, about three years ago, he discovered that the light's colour could be changed by scattering. This had been predicted some time before, but in spite of search the change had not been found. The 'Raman effect' must rank among the best three or four discoveries in experimental physics in the last decade; it has proved and will prove (to be) an instrument of great power in the study of the theory of solids. In

addition to important contributions in many fields of knowledge, he (Raman) has developed an active school of research in physical sciences in the University of Calcutta".

Raman developed a vibrant and excellent school of physics. He established the Indian Academy of Sciences Bangalore (1934) and the Raman Research Institute (1948).



Sir Chandrasekhara Venkata Raman

Raman deserves to be remembered not only for his towering scientific accomplishment but also for his indomitable will. Raman was a staunch patriot and he had great faith in India's potential for progress. He excelled under the most adverse circumstances. Raman was a great populariser of science. "He was perhaps the greatest salesman science has ever had in this country", says S. Ramaseshan, a pioneer of X-ray crystallography in India and a nephew of Raman. During his popular science lectures (or 'performances' as Raman called them) Raman held his audience spellbound. His lectures were always accompanied by lively demonstrations. Raman had a deep sense of humour. According to Ramaseshan, the popular science lectures of Raman were so gripping because, "He talked only of those things about which he felt intensely or those things which he understood well or wanted to understand better. He brought out things in their simplest and their most basic elements. He made his audiences feel that they had seen it all too." Raman was a lecturer *par excellence*. Even his critics had to agree on this point. Throughout his life Raman lectured. He lectured to diverse audiences. However, he was at his best when he delivered popular science lectures. Raman also gave radio talks. The texts of his nineteen radio talks were brought out in a book form. The book was titled *The New Physics: Talks on Aspects of Sciences* and it was published by the Philosophical Library of New York. The topics covered by Raman ranged from the microscopic world of atoms to the universe itself. The quality of Raman's lectures can be guessed from what Francis Low, a distinguished theoretical physicist then working at the Institute for Advanced Studies, Princeton, wrote in the introduction to this book : "Physics by its very nature requires extreme specialization on the part of its students. Its conclusions, which must eventually predict numbers for the results of actual measurements, are best expressed in mathematical formulae. This has the disadvantage of making the subject well-nigh unintelligible to the layman. There are unfortunately few teachers who are able

to surmount this handicap. Professor Raman has written a book which avoids this pitfall and thus should give the lay reader an opportunity of penetrating at least part of the way into the mysteries of this interesting and important science".

Raman believed in excellence *per se*. He never compromised on quality and he firmly believed that if India was to make any economic advance it could only be based on such excellence. He had a great fascination for art and music. He was not confined to a particular narrow speciality. He believed that 'real fundamental progress is always due to those who had ignored the boundaries of science and who treated science as a whole.'

Raman was a very simple man. He was also a supreme egotist. But then in private conversation he often showed utmost humility. He was a man of emotion. He never bothered to suppress his feelings. He could get violently angry. He hurt many. He feared no authority. On some occasions he publicly wept like a child. Raman had "all-too-human" drawbacks in abundance. But then he was an excellent physicist and totally devoted to the pursuit of science.

C. V. Raman was born on 7 November 1888 in his maternal grandfather's house, in a small village of Thiruvanaikaval near Tiruchirapalli (Trichonopoly in those days), on the bank's of Kaveri in Tamil Nadu. Raman's maternal grandfather Saptarshi Sastri was a great Sanskrit scholar, who in his younger days travelled on foot to distant Bengal (over 2000 km away) to learn *navya nyaya* (modern logic).

Raman's parents were R. Chandrasekhar Iyer and Parvathi Ammal. Raman's father, who initially taught in a local school for many years and later became a lecturer in mathematics and physics in Mrs. A.V. Narasimha Rao College, Vishakapatnam (then Vizagapatnam) in Andhra Pradesh. Raman passed his matriculation examination at the age of 11 and he passed his F.A. examination (equivalent to today's Intermediate) with a scholarship at 13. In 1903 Raman joined the Presidency College in Chennai (then Madras) from where he passed the B.A. (1904) and M.A. (1907) examinations. He stood first both in B.A. and M.A. examinations and won all the prizes available. To get some idea we quote here Raman himself.

Raman wrote :

" I finished my school and college career and my university examination at the age of eighteen. In this short span of years had been compressed the study of four languages and of a great variety of diverse subjects, in several cases up to the highest university standards. A list of all the volumes I had to study would be terrifying length. Did these books influence me? Yes, in the narrow sense of making me tolerably familiar with subjects of so diverse as Ancient Greek and Roman History, Modern Indian and European History, Formal Logic, Economics, Monetary Theory and Public Finance, the late Sanskrit writers and minor English authors, to say nothing of physiography, chemistry and dozen branches of Pure and Applied Mathematics, and of Experimental and



R. Chandrasekhar Iyer
(Raman's father)



Parvathi Ammal
(Raman's mother)

Theoretical Physics. But out of this welter of subjects and books, can I pick out anything really to mould my mental and spiritual outlook and determine my chosen path in life? Yes I can and I shall mention three books.

A purposeful life needs an axis or hinge to which it is firmly fixed and yet around which it can freely revolve. As I see it, this axis or hinge has been, in my own case, strongly enough, not the love of science, not even the love of Nature but a certain abstract idealism or belief in the value of the human spirit and the virtue of human endeavour and achievement. The nearest point to which I can trace this source of idealism in my recollection of reading Edwin Arnold's great book, *The Light of Asia*. I remember being powerfully moved by the story of Siddharta's great renunciation, of his search for truth and of his final enlightenment.

The next set of books that I have to mention is one of the most remarkable works of all time, namely, *The Elements of Euclid*. Familiarity with some parts of Euclid and a certain dislike of its formalism have dethroned this great work from the apparently unassailable position which it occupied in the esteem of the learned world for an almost incredibly long period of time. Indeed, my own early reactions to the compulsory study of Euclid were anything but favourable... Not until many years later however, did I fully appreciate the central position of Geometry in relation to all natural knowledge. I can illustrate this relationship by a thousand examples but will content myself with remarking that every mineral found in Nature, every crystal made by man, every leaf, flower or fruit that we see growing, every living thing from the smallest to the largest that walks on earth, flies in the air or swims in the water or lives deep down on the ocean floor, speaks aloud of the fundamental role of geometry in Nature. The pages of Euclid are like the opening bars of the music of the Grand Opera of Nature's great drama. So to say, they lift the veil and show to our vision a glimpse of a vast world of natural knowledge awaiting study.

Of all the great names in the world of learning that have come down to us from the remote past, that of Archimedes, by common consent, occupies the foremost place. Speaking of the modern world, the supremest figure in my judgment is that of Hermann von Helmholtz. In the range and depth of his

knowledge, in the clearness and profundity of his scientific vision, he easily transcended all other names I could mention, even including Isaac Newton. Rightly he has been described as the intellectual colossus of the nineteenth century. It was my great good fortune, while I was still a student at College, to have possessed a copy of an English translation of his great work *The Sensations of Tone*. As is well-known, this was one of Helmholtz's masterpieces. It treats the subjects of music and musical instruments not only with profound knowledge and insight, but also with extreme clarity of language and expression."



Raman and S. Chandrasekhar. Lalitha
Chandrasekhar is partly seen

While Raman was a student, he independently undertook original investigations in acoustics and optics. Raman was the first student of the Madras Presidency College to get a research paper published, that too in a prestigious international journal. His first paper on 'unsymmetrical diffraction bands due to a rectangular aperture' was published in the *Philosophical Magazine (London)* in November 1906. This was the result of Raman's measuring the angles of a prism using an ordinary spectrometer in his college. This was followed by a note in the same journal on a new experimental method of measuring surface tension. Lord Rayleigh (1842-1919) took note of the papers published by Raman as a student. Rayleigh was an outstanding mathematical physicist and a good experimenter, who was awarded the Nobel Prize for the discovery of argon. Raman and Rayleigh exchanged some correspondence. It is interesting to note that Lord Rayleigh addressed Raman as Professor.



Raman showing diamonds to J.D. Bernal

Though Raman proved his brilliance in scientific investigations but as were the norms of those days he was not encouraged to take up science as a career. At the instance of his father Raman took the Financial Civil Service (FCS) examination. He stood first in the examination and in the middle of 1907 Raman proceeded to Kolkata (then Calcutta) to join the Indian Finance Department as Assistant Accountant General. He was then 18½ years old. His starting salary was Rs. 400 per month, a fabulous sum in those days. At that point of time perhaps nobody would have even dreamt that Raman would again venture into the pursuits of science. Raman's prospects in the Government service were too lucrative. And during those days opportunities for doing research were rare. But then one day while going to office Raman saw a signboard with the words "Indian Association for the Cultivation of Science" written on it. The address was 210, Bowbazar Street. On his way back he came to the Association where he first met an individual named Ashutosh Dey (Ashu Babu) who was to be Raman's assistant for 25 years. Ashu Babu took Raman to the Honorary Secretary of the Association, Amrit Lal Sircar, who was overjoyed when he came to know about Raman's intention -- to do research at the Association's laboratory. Amrit Lal had reason to be overjoyed because it was his father Mahendra Lal Sircar (1833-1904), a man of vision, who established the Association in 1876. This Association happened to be the first institute to be established in India solely for carrying out scientific investigations.

Mahendra Lal Sircar, who took the MD degree in 1863, was appointed a Fellow of the Calcutta University in 1870 and Sheriff of Calcutta in 1887. He was also a member of the Bengal Legislative Council from 1887 to 1893 and was associated with many learned societies of Kolkata. Mahendra Lal was a staunch patriot and his interest ranged beyond medicine. Being a visionary he had visualised that many problems faced by the country could only be solved by the application of modern science. Mahendra Lal had shown a great



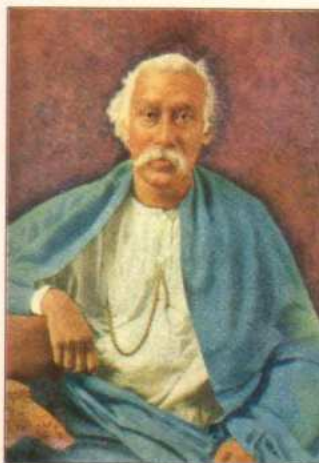
Amrit Lal Sircar



Raman and R. A. Millikan

foresight by realising that 'science would never strike a deep root in this country through the process of its introduction in the educational curriculum alone.' To realise his dreams Mahendra Lal founded the Association. Mahendra Lal stated the objective of the Association as follows: "The object of the Association is to enable the Natives of India to Cultivate Science in all its departments with a view to its advancement by original research and (as it will necessarily follow) with a view to its varied applications to arts and comforts of life." At the beginning the major activity of the Association was to organise popular science lectures by well-known scholars and scientists. The Association had built a Laboratory in 1891 with the generous donation by the Maharaja of Vizianagram. However, during Mahendra Lal's lifetime nobody came forward to do research under the aegis of the Association. Mahendra Lal was dismayed by the apathy of Indians towards the cultivation of science. A few weeks before his death Mahendra Lal had stated his wish in the following words: "Younger men must come and step into my place and make this into a great institution."

So when Amrit Lal Sircar saw Raman, perhaps he felt that he (Raman) would realise his father's dream. And as we know today Raman indeed realised Mahendra Lal Sircar's dream.



Mahendra Lal Sircar

It was not an easy task. Till 1917 Raman continued his research at the Association in his spare time. Doing research in his spare time and that too with very limited facilities Raman could publish his research findings in leading international journals like *Nature*, *The Philosophical Magazine* and *Physics Review*. During this period he published 30 original research papers. His research carried during this period mainly centred on areas of vibrations and acoustics. He studied a number of musical instruments viz., ectara, violin, tambura, veena, mridangam, tabla etc. He published a monograph on his extensive studies on the violin. The monograph was titled 'On the Mechanical Theory of Vibrations of

Musical Instruments of the Violin Family with Experimental Verifications of the Results Part- I'. During this period Ashu Babu, who never entered the portals of a university, was his only collaborator. This did not prevent Ashu Babu from becoming a joint author in many papers that Raman published. Even Ashu Babu was the sole author of a paper published in the *Proceedings of the Royal Society of London*. It was in 1919 Raman took research students for the first time.

There was an interruption to Raman's work at the Association. He was transferred to Rangoon (1909) and Nagpur (1910).

However, Raman's research work was not completely stopped. At both places he converted his home into a laboratory and continued his work. He came back to Calcutta in 1911.

In 1917 Raman was invited by Asutosh Mookerjee (1864-1924), to be a professor in the newly established Science College. Mookerjee, who was a judge of the Calcutta High Court for twenty years, was a great educationist and jurist of his time. On being appointed as the Vice-Chancellor of the



Ashutosh Dey

Calcutta University he not only started a post-graduate department for various disciplines of science but he also persuaded people to create endowment Professorships. Raman was offered the Palit Professorship in Physics. The salary for the professorship was about half the amount that Raman was getting in the Finance Department. Moreover, Raman was successful as a Finance Officer. In fact the Finance Department was reluctant to let him go. Thus the Member (Finance) of the Viceroy's Council wrote: "We find Vankataraman is most useful in the Finance Department being, in fact, one of our best men". However, Raman happily accepted the offer. He joined the Calcutta University as Palit Professor in July 1917. That Asutosh Mookerjee was touched by Raman's total devotion to science is obvious from his following remarks: "For the Chair of Physics created by Sir Taraknath Palit, we have been fortunate enough to secure the services of Mr. Chandrasekhara Venkata Raman, who has greatly distinguished himself and acquired a European fame by his brilliant research in the domain of Physical Science, assiduously carried on under the most adverse circumstances amidst the distraction of pressing official duties. I rejoice to think that many of these valuable researches have been carried on in the laboratory of the Indian Association for the Cultivation of Science, founded by our late illustrious colleague, Dr. Mahendra Lal Sircar, who devoted a lifetime to the foundation of an institution for the cultivation and advancement of science in this country. I should fail in my duty if I were to restrain myself in my expression of genuine admiration I feel for the courage and spirit of self-sacrifice with which Mr. Raman had decided to exchange a lucrative official appointment with attractive prospects, for a University Professorship, which, I regret to say, does not carry even liberal emoluments. This one instance encourages me to entertain the hope that there will be no lack of seeker after truth in the Temple of Knowledge which it is our ambition to erect."

Asutosh Mookerjee had to change the provision of the endowment before appointing Raman. Because one of the requirements, for appointment to the Palit Chair was to have been trained abroad. But Raman refused to go abroad to be 'trained'. The terms of Raman's appointment as the Palit Professor did not entail any teaching responsibilities. His duties were:

- i) to devote himself to original research in his subject to extend the bounds of knowledge;
- ii) to stimulate and guide research by students; and
- iii) to supervise the laboratory in the College of Science.

Though he was free from teaching responsibility but Raman, being a born-teacher, could not be away from the class room. He took a prominent part in MSc teaching. Here we quote L.A. Ramdas, one of his students: "Prof. Raman took 'Electricity and Magnetism' in the year 1920-21 and 'Physical optics' in 1921-22. Both sets of MSc students felt that they were indeed listening to a type of inspired teaching to which was brought all the original flavours and excitement of the past.... We shared with him much of excitement and superb thrill that Benjamin Franklin, Oersted, Arago, Gauss, Faraday, Maxwell, Hertz, Lord Kelvin and many others must have felt while they



Asutosh Mookerjee

were making their actual discoveries... Often he used to take the entire forenoon, for 2 and sometimes even 3 hours - such was his tremendous love of teaching.... And after each lecture we used spontaneously to look up original papers and treatises like Maxwell's *Electricity and Magnetism*, J.J. Thomson's *Conduction of Electricity*, Faraday's *Experimental Researches*, Lord Rayleigh's and Kelvin's *Collected Papers*, and so farther".

Even after joining the Calcutta University Raman was allowed to continue his work at the Association's Laboratories. In fact the Association became the research arm of the University. Following the death of Amrit Lal Sircar in 1919 Raman was elected as Honorary Secretary of the Association, the post he held till 1933, when he left Kolkata. It was not that Raman was very willing to leave Kolkata. His exit was the result of the clash between him and Meghnad Saha, another great personality of Indian Science. Raman was voted out of the Honorary Secretaryship of the

Association. It was certainly a moment of bitter humiliation for Raman and it was more so because he had a Himalayan ego. And so he decided to take up the pending invitation from the Indian Institute of Science (IISc), Bangalore, to become its Director. He was the first Indian to become its Director. Raman succeeded Sir Martin Forster, FRS. He served IISc both as its Director (1933-1937) and head of the Physics Department (1933-1948).

When Raman joined IISc its academic accomplishments were not very high. Its funding position was much better than Calcutta University where Raman was working. Raman brought out the following changes:

- i. A new physics department came into existence
- ii. Some of the existing departments were reorganised
- iii. Steps were initiated to establish a central workshop for fabricating precision instruments.
- iv. The surroundings were improved by planting beautiful flowering gardens.

For achieving academic excellence he himself gathered a team of talented students and started doing high quality research in many fields of physics. Raman also wanted to initiate basic research in fields like quantum mechanics, crystal chemistry and vitamins and enzyme chemistry by recruiting outstanding faculty. At that point of time many reputed scientists were forced to leave Germany because of Hitler's racist policy. Raman wanted to bring some of these scientists to IISc. Raman had many names on his list, both foreign and Indian. However, he was only successful in bringing Max Born, that too for a short time.

Some of the Raman's moves were opposed by the existing staff. In fact Raman's moves to reorganize some of the existing departments and the Institute's workshops led to the resignation of two professors - the Professor of Chemistry (Prof. Watson) and the Professor of Electrical Engineering (Prof. Modawalla). Raman's act of reapportioning the Institute's budget to aid the newly



Science College Calcutta



Niels Bohr and Raman



The Indian Institute of Science at Bangalore

established physics department invited charges of embezzlement. He was accused of patronizing the physics department at the cost of other departments. His attempt to keep Max Born in the institute was also not liked by many. As time passed Raman found himself increasingly in isolation. Seeing the growing turmoil in the campus, the Council, the body charged with overseeing the management of the Institute, recommended to the Visitor (then Viceroy of British India) in July 1935 to appoint a Review Committee to review the Institute's affairs. The Committee, the appointment of which was formally announced on January 19, 1936, consisted of Sir James Irvin, Principal and Vice-Chancellor of St. Andrews University, Dr. A. H. Mackenzie, Pro Vice-Chancellor, Osmania University and Dr. S.S. Bhatnagar, then Professor of Chemistry at the Punjab University at Lahore. Irvin was to head the Committee. The Committee in its Report to the Viceroy submitted in May 1936 more or less reaffirmed the accusations made against Raman. The Report stated: "Making full allowance for possible exaggeration, we greatly fear that there is much truth in these allegations. The resignations of Professor Watson and Professor Modawalla can now be readily understood". According to the Irvin Committee Report, Raman was guilty not only of administrative irregularities, but of financial lapses as well. The Committee branded Raman inimical to applied science. Besides castigating Raman, the Committee also proposed measures to curtail the powers of the Director. For example the Committee suggested that the budget be processed "through no fewer than four bodies in succession before it is finally sanctioned." Raman's warning that "it would place insuperable obstacles in the path of progressive administration such as is essential for success of a scientific institution" went unheeded. The Council endorsed the Report of Irvin Committee and the friction between the management of the Institute and Raman continued to grow. Finally the situation became such that there was no alternative for Raman other than to resign the Directorship of the Institute. In fact he was asked to resign or face action. However, he remained in IISc as Professor of Physics. Raman retired as Professor from the Institute in 1948.

After retirement from the Institute he concentrated his attention in building an institute of his own - the Raman Research Institute (RRI). Even before his retirement Raman had started to build an institute where he could retire and enjoy science. To quote Raman: "You know, I was to retire at 60. So two years before my retirement I started building this

institute so that on the day I retired I took my bag and walked right into this institute. I can not remain idle for a single day". Raman had to gather money for building the Institute. Raman had lost most of his life's savings including his Nobel Prize money in an investment. The Institute was built on a ten acre plot of land gifted by the Maharajah of Mysore way back in 1934 the land of given to

the Indian Academy of Sciences, and for its related activities. Raman traveled extensively for raising donation for constructing the building for housing the institute. When Raman moved to the institute the facilities were far from complete. Raman was opposed to the idea of taking grants from the government for running the institute. To earn money for the institute he started a few chemical industries (in association with one of his former students). The dividends from these industries were sufficient to support the institute to start with. He gifted away most of his personal properties to the

Academy for the benefit of the institute, as also the Lenin Peace Prize money. A museum was built to house Raman's collection of crystals, gems, minerals, rock specimens, shells, stuffed birds, butterflies and so on. Raman had fascination for colours and so he collected everything that had colours.

The Indian Academy of Sciences Bangalore, which now publishes some of the best science journals in the country, was established by Raman. The Academy was formed on April 27, 1934. It was registered in Bangalore under the Societies Registration Act. Besides Raman, there were 160 Foundation Fellows. The inaugural meeting of the Academy was held in the campus of Indian Institute of Science in August 1934. The best scientists from all over India were elected to the Raman's Academy. Commenting on the composition of the Academy Raman, in his address at the first annual meeting, observed: "Our list of Fellows is also representative of all parts of India. Bombay heads the list with 38 Fellows closely followed by Madras Presidency with 35, and Mysore State with 33. Other provinces are also well represented. We have 21 Fellows in the United Provinces, 13 from Punjab, 11 from Bengal, 8 from Central Provinces; Bihar, Orissa, Hyderabad, Travancore and Burma are also represented in our list."

The objectives of the Academy were: i) to hold meetings for discussing the results of research; ii) to hold symposia on special subjects and iii) to publish the proceedings.

Unlike in other countries India has three Science Academies. Raman formed the Academy on his own.



Raman with Rajendra Prasad



Raman with Jawaharlal Nehru

The need for an Academy was first highlighted by Raman in his editorial in *Current Science* published in May 1933. Raman wrote: "The conviction that research is civilization and determines the economic, social and political development of a nation has not yet been unreservedly accepted as part of the administrative policy of India, and we are disposed to ascribe the tardy and perhaps unwilling recognition of this fundamental fact to the absence of an all-India scientific organisation whose function would be to concentrate enlightened public opinion on the doctrine that science is material and spiritual wealth..... It seems to us that early establishment of a National Academy of Science would secure closer and better organised co-operation of activities among all research institutes in India and exercise through its official journal a wider influence for the consolidation and promotion of the best interests of science." Raman further wrote: "While the foundation of the scientific reputation of a country is established by the quality of work produced in its institutions the superstructure is reared by the national journals which proclaim their best achievements to the rest of the world". After writing the editorial Raman circulated a questionnaire among the Indian scientists to ascertain their views. The idea of an Academy proposed by Raman was discussed in the 1934 Session of Indian Science Congress presided over by M.N. Saha, who supported the idea and proposed Royal Society of London as a model. After discussing the matter in a General Committee, it was referred to an Academic Committee consisting of 25 members including Raman. However, when the Academic Committee could not take a quick decision Raman resigned from the Committee and formed an Academy on his own.

The National Institute of Sciences came into existence on January 3, 1935. Its inaugural meeting was held in Calcutta on January 7, 1935. It functioned in Calcutta till 1946 when it moved to New Delhi. Its name was changed to Indian National Science Academy in 1970. The idea behind establishing the National Institute of Sciences was not just to form just another Academy but to form a co-coordinating body. Thus in its inaugural meeting, Lewis L. Fermor, the first President of the National Institute of Sciences said:

"During the past year the word Academy has been much before us... It seems desirable, therefore, that we should first enquire what the word Academy means. It will surprise most of you to learn that the first Academy was a pleasure garden in Athens



Krishnaraja Wodeyar,
the Maharaja of Mysore

which is supposed to have belonged to an ancient Attic hero named Academus In this garden the Greek philosopher Plato taught for nearly 50 years; and the Academy thus started lasted from the days of Plato to those of Cicero, that is, for over 300 years.... While Academies, if we go to the original meaning, must, therefore, function locally or regionally in the most important portion of their activities, they can also legitimately make a wider appeal... When in 1933 the proposal was mooted to found an Indian Academy of Sciences, some of us overlooked the fact that there were already two such academies in existence -- one called the Asiatic Society of Bengal and the other of the United Provinces Academy of Sciences. The proposal, therefore, to found a third Indian Academy...logically meant either the creation of a fresh garden in another part of India, or of a body to co-ordinate the already existing gardens. Our friends in Bangalore knew all the time that they needed a Society of Academy status with its headquarters in Bangalore. Had they boldly said so at the beginning, the confusion that has arisen in scientific circles during the past year would have been avoided, because it is obviously correct that southern India should have its own philosopher's garden. However, Bangalore did not do this ...Object as we may to the manner in which our Bangalore friends cut adrift...we... welcome the Indian Academy of Sciences found at Bangalore....But we still need a co-ordination body and that is why it is necessary to found the National Institute". The National Institute of Sciences had 125 Foundation Fellows including Raman.

The United Provinces Academy of Sciences was founded at Allahabad in 1930. It has now been renamed National Academy of Sciences Allahabad.

The journal *Current Science*, the most visible journal of the Indian Academy of Science Bangalore was launched even before the formation of the Academy. It was founded as a result of resolution passed at a special meeting held during the Session of the Indian Science Congress in Bangalore in 1931. The *Proceedings of the Indian Academy of Sciences* also started in 1934. Its objective was "to provide all scientific men with an opportunity of obtaining at least a general idea of what is being done in India in fields of knowledge other than their own specialty. However, as the amount of published matter grew rapidly the *Proceedings* was separated into a number of theme journals - viz., *Proceedings - Chemical Sciences*, *Earth and Planetary Sciences*,



Raman with some of his associates

Sitting (left to right) : V.S. Tamma, S.K. Banerji, C.V. Raman, N.K. Sur and N.K. Sethi. Standing (left to right) : K. Seshagiri Rao, Bidhubhushan Roy, Lala Govardhan Lal Dutta, Durgadas Banerjee, Y. Venkatramayya, Panchanan Das and Ashutosh Dey. Squatting on the lawn (left to right) L.A. Ramdas and Sunderaraman



Raman with some of his associates

Sitting (left to right) : A.S. Ganesan, L.A. Ramdas, K.S. Krishnan, C.V. Raman, K.R. Ramanathan, S. Venkateswaran, S.S. Moorthy Rao. Standing (left to right) : C. Ramaswamy, S. Bhagavantam, S. Paramasivan, Sreenivasa Rao, N.S. Nagendranath, R. Ananthakrishnan and C.S. Venkateswaran

Mathematical Sciences, Animal Sciences, Plant Sciences and Engineering Sciences (later renamed as Sadhana). The other journals published by the Academy are : *Pramanan-Journal of Physics*, *Bulletin of Materials Science*, *Journal of Biosciences*, *Journal of Astronomy and Astrophysics*, *Journal of Genetics and Resonance* : *Journal of Science Education*. It may be noted here that the *Journal of Genetics* was founded by William Bateson in 1910 in England. Subsequently the journal was brought to India by J.B.S Haldane. However, the journal ceased its publication in 1977. Later it was revived by the Academy.

The Academy has instituted a prestigious Raman Professorship. It has started a scheme of Young Associateship to provide opportunity for outstanding young scientists to be associated with the Fellows of the Academy. Since the days of Raman, the Academy continues to sponsor symposia and discussions.

Raman was of the view that science alone could solve India's problems. He said: "There is only one solution for India's economic problems and that is science and more science." But then Raman insisted that India should not be dependent on others for ideas. India is capable of tackling her own problems. He said: "In the past, India had shown her greatness in the fields of scholarship, philosophy and science but today, we are helplessly dependent on Western countries for knowledge of science. India should not be a camp-follower but a leader in science. It is no use getting our ideas from the west. We have to think out our problems and find the solutions to them."

However, Indians need to be convinced of their strength. While once addressing young people Raman said : "I would like to tell the young men and women before me not to lose hope and courage. Success can only come to you by courageous devotion to the task lying in front of you and there is nothing worth in this world that can come without the sweat of our brow. I can assert without fear of contradiction that the quality of the Indian mind is equal to the quality of any Teutonic, Nordic or Anglo-saxon mind. What we lack is perhaps courage, what we lack is perhaps driving force which takes one anywhere. We have, I think, developed an inferiority complex. I think what is needed in India today is the destruction of that defeatist spirit. We need a spirit of victory, a spirit that would carry us to our rightful place under the sun, a spirit which will recognize that we, as inheritors of a proud civilization,



Raman with Wolfgang Pauli



Raman and Werner Heisenberg(right)

physical activity."

Raman had a holistic view of science. He thought nature is the best teacher. He said: "What is science in the last analysis but the study and the love of nature, displayed not in the form of abstract worship but in the practical form of seeking to understand nature?" Further he said: "One aspect of Indian culture was its profound understanding of Nature. Much of India's philosophy related itself to the understanding of the rationale and the meaning of the phenomena of Nature."



Raman with Zakir Hussain

Raman had displayed great faith in Mahatma Gandhi's ideas. He remarked: "Each textbook must contain as frontispiece a portrait of Gandhiji and there must be lessons containing the sermons of Gandhiji from Sabarmati to Birla House. This would be the best and the most potent way of offering homage to the memory of the world's greatest man and the Father of the Indian Nation, and is better than building memorials and erecting statues." Further he said: "His (Gandhiji's) teachings stressed the supreme virtue of the human spirit, utterly indestructible and unconquerable. India can never hope to find a place in the sun, unless it upholds the value of the human spirit." In the honour

of Gandhiji he instituted the Gandhi Memorial Lecture in the Raman Research Institute. Till his death Raman never failed to deliver this lecture. Raman's wife Lokasundari was well-known to Kasturba Gandhi.

Raman strongly espoused the cause of women. He once said: "I have a feeling that if the women of India take to science and interest themselves in the progress and advance of science as well, they will achieve what even men have failed to do. Women have one quality--the quality of devotion. It is one of the most important passports to success in science. Let us therefore not imagine that intellect is a sole prerogative of males only in science."



Raman with Mahatma Gandhi and Mahadeo Desai



Lokasundari with Kasturba Gandhi



Raman and AH Compton (centre)

Raman had displayed his great leadership in institution building and training students. Raman made both the Indian Association for the Cultivation of Science and the Physics Department of the Calcutta University vibrant and excellent centres of learning. His reputation attracted students from all corners of the country. Raman was among the founders of the Indian Science Congress, which was established in 1914 and served as its Secretary for several years and also became its President. He established the *Indian Journal of Physics*. During his stay for over fifteen years in the Indian Institute of Science, Bangalore, he established an excellent school of Physics and trained a band of first-rate physicists. As mentioned earlier in 1934 Raman established the Indian Academy of Science. Raman was elected Founder President of the Academy and remained so till his death.

He wanted that the scientists should not be concerned with their own research alone, they should also try to develop the scientific institutions, the edifice on which the superstructure of science can be built. He remarked: "While the foundation of the scientific reputation of a country is established by the quality of work produced in its institutions, the superstructure is reared by the national journals which proclaim their best achievements to the rest of the world. Manifestly the edifice of science in India is incomplete...It is true that the spirit of science and its service are international, but is it not also true that every nation has its own Academies, learned societies, magazines and journals? India will have to organize and develop her national scientific institutions before she can enter into the comity of international scientists."

He emphasised the importance of strengthening our universities. He said: "Let us try to make our universities the best - we should not be satisfied with anything less than the best. What will be the result? Instead of a great many of our young men going out of the country, they will remain here and strive to advance our reputation and that will make us strive for more and more good things."

Raman was elected as a Fellow of the Royal Society of London in 1924 in recognition of his outstanding researches in physical optics, molecular diffraction of light, X-ray scattering by liquids and a molecular anisotropy. It may be noted that Raman had resigned the Fellowship of the Royal Society. He was conferred a Knighthood by the British Government in 1929. He received the Nobel Prize for Physics in 1930. The Government of India awarded him the title of "Bharat Ratna" in 1954. The erstwhile Soviet Union honoured him with the International Lenin Prize in 1957. Some of the other awards/honours, received by Raman were: Matteucci Medal of the

C V Raman with
Hideki YukawaThe tree planted on the
site at the campus of
Raman Research
Institute where Raman
was cremated

'Societe Italiana della Scienza of Rome (1928); Hughes Medal of the Royal Society of London (1930) and Franklin Model of the Franklin Institute of Philadelphia (1941).

Raman loved children and he derived immense pleasure in showing them his museum and the laboratories of the Raman Research Institute. He believed that "The true wealth of a Nation consists not in the stored-up gold in its coffers and banks, not in the factories, but in the intellectual and physical strength of its men, women and children."

Towards the end of his life Raman chose to make himself a recluse. He not only built high walls around the Raman Research Institute but also put up a prominent signboard announcing that visitors were not welcome. He was not at all happy the way the Government was trying to build up science and technology in the country. "To Raman, scientific activity was the fulfillment of an inner need. His approach to science was one of passion, curiosity and simplicity. It was an attempt to understand. To him science was based on independent thought. Combined with hard work, science was a personal endeavour, an aesthetic pursuit and above all a joyous experience." Raman believed that science can be promoted only by doing it. He did not see any role for professional organizers of science. "For such people" Raman thought "The So-called organization of science becomes more important than science itself or its values".

Raman died on November 21, 1970. As per his desire he was cremated in the gardens of his institute.

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Some of the photograph reproduce in the article are taken from the publication listed at 1 and 9.

The Raman Effect

□ V.B. Kamble

The colour of the sea

Nobel prize was conferred on Sir C. V. Raman on December 11, 1930 for his work on the scattering of light and for the discovery of the effect named after him. This is how he began his Nobel Lecture:

In the history of science, we often find that the study of some natural phenomenon has been the starting point in the development of a new branch of knowledge. We have an instance of this in the colour of skylight, which has inspired numerous optical investigations, and the explanation of which, proposed by the late Lord Rayleigh, and subsequently verified by observation, forms the beginning of our knowledge of the subject of this lecture. Even more striking, though not so familiar to all, is the colour exhibited by oceanic waters. A voyage to Europe in the summer of 1921 gave me the first opportunity of observing the wonderful blue opalescence of the Mediterranean Sea. It seemed not unlikely that the phenomenon owed its origin to the scattering of sunlight by the molecules of the water. To test this explanation, it appeared desirable to ascertain the laws governing the diffusion of light in liquids, and experiments with this object were started immediately on my return to Calcutta in September 1921. It soon became evident, however, that the subject possessed a significance extending far beyond the special purpose for which the work was undertaken, and that it offered unlimited scope for research. It seemed indeed that the study of light-scattering might carry one into the deepest problems of physics and chemistry, and it was this belief which led to the subject becoming the main theme of our activities at Calcutta from that time onwards.

- Sir C.V. Raman

A voyage to Europe in the summer of 1921 and the curiosity to explain the blue of the sea, as described in the passage above, was the beginning of a seven year pursuit that ultimately culminated in the discovery of the Raman Effect in 1928. From the work of the first few months, it became clear to Chandrasekhar Venkat Raman (1888-1970) and his collaborators that the molecular scattering of light was a very general phenomenon, which could be studied not only in gases and vapours, but also in liquids and in crystalline and amorphous solids. It was essentially an effect arising from molecular disarray in the medium causing local fluctuations in the density. Apparently, such molecular disarray could be ascribed to thermal agitation – except in amorphous solids. It was found that the anisotropy of molecules (that is not having the same properties in all directions) and because they can align freely in liquids gave rise to additional type of scattering, which could be distinguished from the scattering due to fluctuations in density. The former is polarized, while the latter is unpolarized. The state of polarization of the light scattered

in fluids is connected with the optical anisotropy of the molecules. Much of the work done at Calcutta during the period 1922-1927 was intended to obtain data concerning this property and to establish its relations with various optical phenomena. The interpretation of observations led to a development of a molecular theory of light scattering in dense media by Raman, K.S.Krishnan (1898-1961), and K.R.Ramanathan (1893-1985).

A puzzling observation



Sir Chandrasekhara Venkata Raman

The investigations described above were guided by the classical electromagnetic theory of light, the application of which to the problems of light scattering is chiefly associated with the names John William Strutt Baron Rayleigh (1842-1919) and Albert Einstein (1879-1955). While the experiments appeared to support the electromagnetic theory of light, evidence came to hand at a very early stage of the investigations of the existence of a phenomenon which seemed to stand **outside** the classical scheme of thought. The scattering of light in transparent fluids observed was extremely feeble. It was experimentally discovered that associated with the Rayleigh-Einstein type of molecular scattering was another and still feebler type of **secondary radiation**, the intensity of which was of the order of magnitude of a few hundredths of the classical scattering, and differed from it in **not having the same wavelength as the primary of incident radiation**. The

first observation of this phenomenon was made at Calcutta in April 1923 by Ramanathan who was led to it in attempting to explain why in certain liquids (water, ether, methyl and ethyl alcohols), the depolarization of scattered light varied with the wavelength of the incident radiation. Ramanathan found that after exhaustive chemical purification and repeated slow distillation of the liquid in vacuum, the new radiation persisted undiminished in intensity, showing that it was a characteristic property of the substance studied and not due to any fluorescent impurity (fluorescence is explained later in the article). Krishnan observed a similar effect in many other liquids in 1924, and a somewhat more conspicuous phenomenon was observed by Raman himself in ice and in optical glasses.

The origin of this puzzling phenomenon naturally interested the group. In the summer of 1925, attempts were made to investigate it by photographing the spectrum of the scattered light from liquids, using sunlight filtered through colour screens, but no decisive results could be obtained. Attempts were made in 1926 and 1927 to look for a similar phenomenon in gases and vapours, but, without success.

A new phenomenon

Krishnan took up the challenge once again towards the

end of 1927. However, the first indication of the true nature of the phenomenon came from a different quarter! One of the problems of interest then was the behaviour in light scattering of highly viscous organic liquids. S. Venkateswaran, a collaborator of Raman, undertook to study this problem. One day, he reported the interesting result that colour of the sunlight scattered in a highly purified sample of glycerin was a brilliant green instead of the usual blue. The phenomenon appeared to be similar to that discovered by Ramanathan in water and the alcohols earlier, but of much greater intensity, and therefore, could be studied more easily. No time was lost in following up the matter. Tests were made with a series of filters transmitting narrow regions of the solar spectrum and placed in the path of the incident beam, which showed that in every case the colour of the scattered light was different from that of the incident light, and was displaced from it towards the red. The radiations were also strongly polarized. These facts indicated a clear analogy between the empirical characters of the phenomenon and the Compton effect. The work of Compton had made familiar the idea that the wavelength of radiation could be reduced in the process of scattering, and the observations with glycerin suggested that the puzzling phenomenon since 1923 was in fact the optical analogue of the Compton effect.

The greatest difficulty in the study of the new phenomenon was the extreme feebleness of the observed radiation, whose intensity was only about 10^{-6} to 10^{-7} that of the incident radiation. How did Raman overcome this difficulty? This difficulty was overcome by using a 7-inch reflecting telescope in combination with a short focal length eye-piece to condense sunlight into a pencil of very great intensity. How did he isolate the modified radiation? He used complementary light filters in the path of the incident and the scattered beams, as was done by Ramanathan in 1923. This was ingenious indeed, and probably this was one reason why nobody could observe it earlier. Krishnan assisted Raman in these investigations and found that the phenomenon could be observed in several organic vapours, and even succeeded in visually determining the state of polarization of the modified radiations from them. Compressed gases such as CO and N_2O , crystalline ice, and optical glasses also were found to exhibit the modified radiations. **These observations left little doubt that the phenomenon was really a kind of light scattering analogous to the Compton effect.** The new effect was conclusively observed on February 28, 1928. Krishnan has made the following observations in his diary:

February 28, 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 that the modified scattering was separated from the

The initial paragraph of the historic paper of Raman and Krishnan announcing the discovery of the Raman effect, which appeared in Nature (C. V. Raman and K.S. Krishnan, Nature, 121(3048), 501, March 31, 1928) is reproduced below.

A New Type of Secondary Radiation

If we assume that the X-ray scattering of the 'unmodified' type observed by Prof. Compton corresponds to the normal or average state of the atoms and molecules, while the 'modified' scattering of altered wavelength corresponds to their fluctuations from that state, it would follow that we should expect also in the case of ordinary light two types of scattering, one determined by the normal optical properties of the atoms or molecules, and another representing the effect of their fluctuations from their normal state. It accordingly becomes necessary to test whether this is actually the case. The experiments we have made have confirmed this anticipation, and showed that in every case in which light is scattered by the molecules in dust-free liquids or gases, the diffuse radiation of the ordinary kind, having the same wavelength as the incident beam, is accompanied by a modified scattered radiation of degraded frequency.

The new type of light scattering discovered by us naturally requires very powerful illumination for its observation. In our experiments, a beam of sunlight was converged successively by a telescope objective of 18 cm. aperture and 230 cm. focal length, and by a second lens was placed the scattering material, which is either a liquid (carefully purified by repeated distillation in vacuo) or its dust free vapour. To detect the presence of a modified scattered radiation, the method of complementary light filters was used. A blue-violet filter, when coupled with a yellow-green filter and placed in the incident light, completely extinguished the track of the light through the liquid or vapour. The reappearance of the track when the yellow filter is transferred to a place between it and the observer's eye is proof of the existence of a modified scattered radiation. Spectroscopic confirmation is also available.

Some sixty different common liquids have been examined in this way, and everyone of them showed the effect in greater or lesser degree. That the effect is a true scattering, and secondly by its polarization, which is in many cases quite strong and comparable with the polarisation of the ordinary scattering. The investigation is naturally much more difficult in the case of gases and vapour, owing to the excessive feebleness of the effect. Nevertheless when the vapours is of sufficient density, for example with ether or amylene, the modified scattering is readily demonstrable.

scattering corresponding to the incident light by a dark region.

The Raman effect had been discovered! A newspaper announcement was made the following day, i.e. February 29 (1928 was a leap year!).

The Raman Effect : Mechanism

At a very early stage in our investigations, we came across a new and entirely unexpected phenomenon. As early as 1923, it was noticed that when sunlight filtered through a violet glass passes through certain liquids and solids e.g., water or ice, the scattered rays emerging from the track of the incident beam through the substance contained certain rays not present in the incident beam. The observations were made with colour filters (see Figure 1). A green glass filter was used which cut off all light if placed between the violet filter and the substance. On transferring the



The first Raman Spectrum was obtained with this Spectrograph in 1928

glass to a place between the substance and the observer's eye, the track continued to be visible though feebly. This is a clear proof of a real transformation of light from a violet into a green ray. The most careful chemical purification of the substance failed to eliminate the phenomenon.

-C.V.Raman in Presidential Address to the Indian Science Congress 1929.



Lord John William Strutt Rayleigh



Arthur Holly Compton

When light passes through a "transparent" substance, solid, liquid or gaseous, a certain part of light is scattered in all directions. This is called the Tyndall effect. The most familiar example is the light from a clear sky. Rayleigh ascribed it to the scattering by the individual molecules, or by groups of molecules much smaller in linear dimension than the wavelength of light. What is more, the intensity of light scattered is proportional inversely to the fourth power of wavelength. This is why the sky appears blue, all other longer wavelengths being scattered away by the molecules or groups of molecules in the atmosphere. However, if the incident light is monochromatic, the scattered light is ordinarily observed to be unchanged in frequency, in accordance with Rayleigh's theory.

It was shown in 1925 by Kramers and Heisenberg that, according to classical electromagnetic theory, if the scattering electrons in an atom or molecule are in motion, the scattered light should contain other frequencies in addition to that of the incident light. Failure to notice this implication of classical theory has been due to the common assumption that the radiating particles were at rest except as disturbed by radiation. In 1928, as we have noted earlier, independently of the theoretical prediction, Raman and Krishnan discovered the phenomenon experimentally in the course of an extensive study of scattering by liquids and solids.

The scattering of light with a change in its frequency has been studied extensively since then. To observe it, the incident light should be monochromatic and very intense. The scattered light is then seen to contain, besides a line of the same frequency as the incident light, several weak lines of other frequencies. If the incident frequency ν is varied, these other lines move along the frequency axis at the same rate, maintaining constant frequency differences from ν and not changing greatly in intensity. In these respects the Raman lines

differ sharply in behaviour from fluorescent lines, the frequencies of which are fixed by the scattering substance and which flash out only when the incident frequency falls upon an absorption line of the substance. In the Raman effect it is frequency shifts in the scattered spectrum that are determined by the nature of the scatterer rather than the frequencies themselves.

The explanation of Raman effect in terms of quantum theory is very simple. When a photon of frequency ν is "scattered" by an atom or molecule whose quantum state is not altered in the process, the scattered photon has the same frequency as had the incident photon. But it may happen that the atom or molecule is changed in the process from a state in which its energy is W_1 to a state of different energy W_2 . Conservation of energy then requires that the frequency ν' of the scattered photon be modified so that $h\nu' + W_2 = h\nu + W_1$; hence, $\nu' = \nu + (W_1 - W_2) / h$. In terms of such ideas the Raman effect had been predicted, tentatively, at a much earlier date by a V. Smekal in 1923.

In the expression just written, the term $(W_1 - W_2) / h$ can be interpreted as a frequency ν_{12} that the atom might conceivably emit or absorb in the usual way, in jumping from the first state to the second. Thus for the Raman line we may write

$$\nu' = \nu \pm \nu_{12}$$

The difference between the frequency of each Raman line and the frequency of the incident light is thus equal to the frequency of some conceivable emission or absorption line of the scattering atom or molecule.

The intensity of a Raman line has nothing to do, however, with the intensity of the emission or absorption line that is thus correlated with it.

Accordingly to wave mechanics, a Raman jump is possible between two atomic or molecular levels A and B only when there exists at least one third level, C, such that ordinary radiative transitions are allowed between A and C and between B and C (Figure 2). It is almost as if the atom or molecule actually jumped first from A to C and then from C to B. The relative probabilities of the various processes do not correspond to this simple picture, however, nor can it be said that the atom or molecule exists for any definite

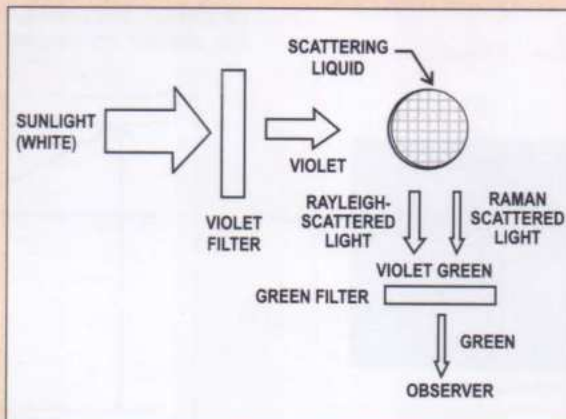


Figure 1 :System of complementary filters devised by Raman to detect light scattering with a change of frequency. The observation is made visually, the advantage being that a number of scattering substances can be studied rapidly. For quantitative studies Raman used a mercury arc as the source of light and a quartz spectrograph for recording the spectra.

(Source : Journey into Light by G. Venkataraman)

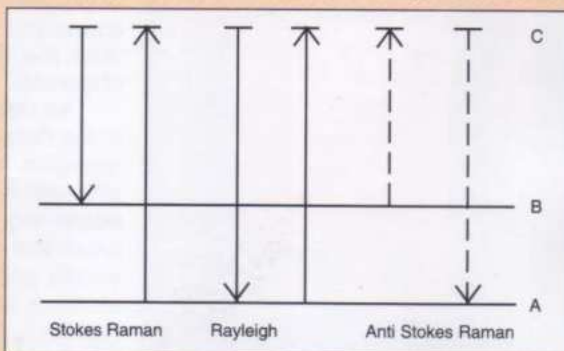


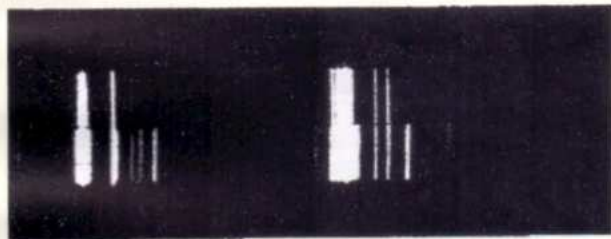
Figure 2: In Raman Scattering, the atom changes its state, the transition occurring via an intermediate state C. The diagram also shows the origin of stokes and anti-stokes lines.

How Raman succeeded in isolating the new radiation

Sir C.V. Raman describes in his Nobel lecture how he succeeded in isolating the new radiation in the most ingenious way. Here is an excerpt.

Thanks to the vastly more powerful illumination made available by the 7-inch refractor, the spectroscopic examination of the effect, which had been abandoned in 1925 as indecisive, now came within the reach of direct visual study. With a Zeiss cobalt glass filter placed in the path of the incident beam and one or other of a series of organic liquid as the scattering substance, a band in the blue-green region was observed by me in the spectrum of the scattered light, separated by a dark interval from the indigo-violet region transmitted by the filter. Both of these regions in the spectrum became sharper when the region of transmission was narrowed by the insertion of an additional filter in the incident beam. This suggested the employment, instead of sunlight, of the highly monochromatic radiations given by a mercury arc in combination with a condenser of large aperture and a cobalt glass filter. With these arrangements the spectrum of the scattered light from a variety of liquids and solids was visually examined, and the starting observation was made that the spectrum generally included a number of sharp lines or bands on a diffuse background which were not present in the light of the mercury arc.

— Sir C.V. Raman, Nobel Lecture, 11 December, 1930



Raman spectrum of carbon tetrachloride

time in state C, as it does in the production of fluorescence (Figure 3).

In light scattered by polyatomic molecules, for example, there may be Raman lines correlated in this manner with energetically possible lines in either the rotational or the vibration - rotational or the electronic spectra of the molecule.



The Nobel Diploma



Nicolaas Bloembergen



Arthur Leonard Schawlow

When irradiated with an intense source of monochromatic light, and the scattered radiation is examined spectroscopically, not only is light of the exciting frequency, ν_0 observed (Rayleigh scattering), but also some weaker bands of shifted frequency are detected. Moreover, while most of the shifted bands are of lower frequency $\nu_0 - \nu_1$, there are

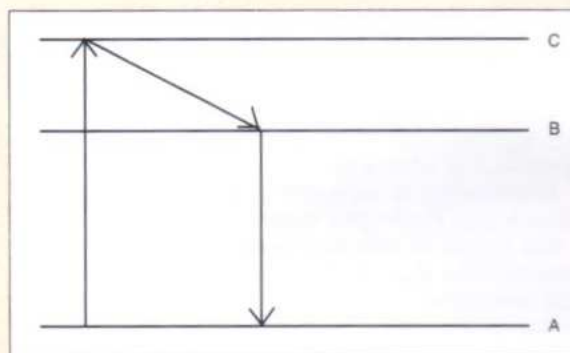


Figure3: What is fluorescence? The absorption of the incident light causes the atom to be raised to a higher level C from the state A. The atom makes a transition from C to B through a non-radiative process. Finally the atom makes a transition B to A, emitting light which appears as the fluorescent radiation.

some at higher frequency, $\nu_0 + \nu_1$. By analogy to fluorescence spectrometry, the former are called Stokes bands and the latter anti-Stokes bands. The Stokes and anti-Stokes bands are equally displaced about the Rayleigh band; however, the intensity of the anti-Stokes bands is much weaker than the Stokes bands and they are seldom observed.

As stated earlier, the energies corresponding to the Raman frequency shifts are found to be the energies associated with transitions between different rotational and vibrational states of the scattering molecule. Pure rotational shifts are small and difficult to observe, except for those of simple gaseous molecules. In liquids, rotational motions are hindered, and discrete rotational Raman lines are not found. Most Raman work is concerned with vibrational transitions, which give larger shifts observable for gases, liquids, and solids. Gases have low molecular concentration at ordinary pressures and therefore produce very

Nobel Prizes awarded for research related to Raman Scattering of Light and Spectroscopy

Here is a list of Nobel Prizes awarded for research on scattering of light and spectroscopy.

1904	Lord (John William Strutt) Rayleigh	Great Britain	in Physics for his investigations of the densities of the most important gases and for his discovery of argon in connection with these studies.
1927	Arthur Holly Compton	USA	in Physics for his discovery of the effect named after him.
1930	Sir Chandrasekhara Venkata Raman	India	in Physics for his work on the scattering of light and for the discovery of the effect named after him.
1981	Nicolaas Bloembergen Arthur Leonard Schawlow	USA USA	in Physics for his contribution to the development of laser spectroscopy. -do-



With visitors at the Raman Research Institute

faint Raman effects; thus liquids and solids are more frequently studied.

Raman Spectroscopy Today

A field that evolved soon after the Raman effect was discovered was the Raman microscopy. In Raman microscopy, the Raman frequency shift is analyzed at different points in the sample. Raman microscopy can resolve parts with different chemical composition in a sample, and, together with infrared microscopy, is sometimes referred to as chemical imaging. It has been applied to the study of thin films, coatings, microelectronic integrated circuits, mineral inclusions, pigments in art works, identification of narcotics and plastic explosives, biological tissues, and others.

Raman spectroscopy became an increasingly important tool for study of molecules with a large number of applications when lasers became available. The laser is basically a highly monochromatic and coherent light source capable of high intensity. Of course, from a technical point of view, the Raman spectroscopy does not require any new principles of light scattering beyond what was already known in the pre-laser era. The advent of laser led not only to the discovery of processes far beyond what Raman did, but to the emergence of several new techniques and devices as well.

Raman spectroscopy can characterize minerals, detect trace amounts of organic substances and identify biological substances such as proteins, DNA, amino acids and plant pigments. The method often is used in medicine for tasks that range from analyzing genes to detecting microbes! A planetary Raman spectroscope can press a probe against a sample, or perhaps plunge a fibre optic cable into the soil,

then fire the laser repeatedly on the probe and scan the sample. A special filter would remove scattered light that had not changed colour. Raman shifted light would pass through the filter, then pass through a grating and bend according to wavelength. In not too distant a future, perhaps in 2008, a rover on Mars will carry a compact Raman spectrometer along with a microscopically thin laser beam, press its Robotic arm against a rock and look for the sign of any organic life and any sign of life that might have existed there. In the more distant future, a space craft hardened to withstand Jupiter's intense radiation may land on the icy moon Europa.

To commemorate the legacy of Sir C.V. Raman, 28 February has been designated as the National Science Day, the day when Raman Effect was discovered at the initiative of the National Council for Science and Technology Communication, Department of Science and Technology, Govt. of India.

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A wonderful narration of circumstances and events that eventually led to the discovery of Raman effect, told by the great master himself. The present article partly draws on it.
2. Introduction to Modern Physics
F.K. Richtmyer, E.H. Kennard, and T. Lauritsen
McGraw Hill Book Co. 1955
A classic reference book for historical development of Modern Physics.
3. Dictionary of scientific Biography
Editor-in-Chief Charles Coulston Gillispie,
Charles Scribner's Sons, New York 1975
A wonderful resource in 14 volumes.
4. The Raman Effect
<http://www.le.ac.uk/geology/mjb29/raman.html>
A good article describing basic theory of Raman Effect and recent published studies on its application.
5. Journey into Light
G. Venkataraman
Indian Academy of Sciences (in co-operation with Indian National Science Academy), Bangalore 1988
All about the life and work of Sir C.V. Raman, A great piece of work.
6. C.V. Raman - A pictorial biography
Indian Academy of Sciences, Bangalore, 1988
This book is wonderful. You will find some rare pictures of Sir C.V. Raman in it.
7. Seeking Life's Chemical Fingerprints with the Raman Effect
Lee Siegel, NASA Astrobiology Institute
<http://www.space.com/searchforlife/raman-010425.html>
A beautiful article on applications of Laser Raman Spectroscopy in obtaining signatures of life using Raman probes.
8. <http://www.nobel.se>
The website of Nobel Foundation. A great resource on Nobel Laureates - their work and lives.

The Raman Effect : Glossary

Important terms used in connection with research work on Scattering of Light and Raman Spectroscopy are given below. The terms given do not necessarily appear in the present article.

Anisotropic : Showing different properties as to velocity of light transmission, conductivity of heat or electricity, compressibility, and so on, in different directions. Also known as aeolotropic.

Anti-Stokes lines : Lines of radiated frequencies which are higher than the frequency of the exciting incident light.

Brillouin scattering : Light scattering by acoustic phonons (a phonon is a quantum of sound energy).

Compton effect : The increase in wavelength of (that is, decrease in frequency) electromagnetic radiation in the x-ray and gamma-ray region on being scattered by material objects; the scattering is due to the interaction of the photons with electrons that are effectively free.

Compton scattering : The elastic scattering of photons by electrons. Also known as Compton process.

Compton shift : The change in wavelength of scattered radiation due to the Compton effect.

Fluorescence : Emission of electromagnetic radiation that is caused by the flow of some form of energy into the emitting body and which ceases abruptly when the excitation ceases.

Laser : A device that uses the maser principle of amplification of electromagnetic waves by stimulated emission of radiation and operates in the optical or infrared regions. Derived from light amplification by stimulated emission of radiation. Also known as optical maser.

Laser beam : A narrow beam of coherent, powerful, and nearly monochromatic electromagnetic radiation emitted by a laser.

Laser spectroscopy : The use of lasers for spectroscopic analysis, particularly in Raman spectroscopy.

Light quantum : A massless particle, the quantum of the electromagnetic field, carrying energy, momentum, and angular momentum. Also known as photon.

Maser : A device for coherent amplification or generation of electromagnetic waves in which an ensemble of atoms or molecules, raised to an unstable energy state, is stimulated by an electromagnetic wave to radiate excess energy at the same frequency and phase as the stimulating wave. Derived from microwave amplification by stimulated emission of radiation.

Photon : A massless particle, the quantum of the electromagnetic field, carrying energy, momentum, and angular momentum. Also known as Light quantum.

Polarization : Phenomenon exhibited by certain electromagnetic waves and other transverse waves in which the direction of the electric field or the displacement direction of the vibrations is constant or varies in some definite way.

Polarized light : Polarized electromagnetic radiation whose frequency is in the optical region.

Raman Effect : A phenomenon observed in the scattering of light as it passes through a transparent medium; the light undergoes a change in frequency and random alteration in phase due to a change in rotational or vibrational energy of the scattering molecules. Also known as Raman scattering.

Raman spectroscopy : Analysis of the intensity of Raman scattering of monochromatic light as a function of frequency of the scattered light.

Raman spectrum : A display, record, or graph of the intensity of Raman scattering of monochromatic light as a function of frequency of the scattered light.

Rayleigh line : Spectrum line in scattered radiation which has the same frequency as the corresponding incident radiation.

Rayleigh scattering : Scattering of electromagnetic radiation by

independent particles which are much smaller than the wavelength of the radiation.

Rotational spectrum : The molecular spectrum resulting from transitions between rotational levels of a molecule which behaves as the quantum-mechanical analogue of a rotating rigid body.

Rotation-vibration spectrum : Absorption-spectrum (absorbed electromagnetic energy) wavelengths produced when both the energy of vibration and energy of rotation of a molecule are affected by excitation.

Spectral line : A discrete value of a quantity, such as frequency, wavelength, energy, or mass, whose spectrum is being investigated. Also known as line, spectrum line.

Spectrometer : A spectroscopy that is provided with a calibrated scale either for measurement of wavelength or for measurement of refractive indices of transparent prism materials.

Spectroscope : An optical instrument consisting of a slit, collimator lens, prism or grating, and a telescope or objective lens which produces a spectrum for visual observation.

Spectroscopy : The branch of physics concerned with the production, measurement, and interpretation of electromagnetic spectra arising from either emission or absorption of radiant energy by various substances.

Spectrum : The set of frequencies, wavelengths, or related quantities, involved in some process; for example, each element has a characteristic discrete spectrum for emission and absorption of light.

Stokes line : A spectrum line in luminescent radiation whose wavelength is greater than that of the radiation which excited the luminescence.

Tyndall effect : Visible scattering of light along the path of a beam of light as it passes through a system containing discontinuities, such as the surfaces of colloidal particles in a colloidal solution.

Vibrational spectrum : The molecular spectrum resulting from transitions between vibrational levels of a molecule which behaves like the quantum-mechanical harmonic oscillator.

Form IV-E

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I, Subodh Mahanti do hereby declare that to the best of my knowledge and belief, facts mentioned above are true.

(Sd) Subodh Mahanti

(Signature of the Publisher)

Indian Association for the Cultivation of Science

The Indian Association for the Cultivation of Science (IACS) is the oldest institution in India devoted to the pursuit of research in basic sciences. The Association owes its origin to the vision and initiative of Dr. Mahendra Lal Sircar, who was a pioneer in recognizing the important role science can play in the regeneration of modern India. Trained as a doctor of medicine, he visualized an institution for spreading the message of science to the people. Through his sustained efforts the Association was established with "the object of enabling the natives of India to cultivate science in all its departments by original research and to its varied application to the art and comforts of life". The Association was inaugurated at 210, Bowbazar Street on Saturday, July 29, 1876 and Mahendra Lal became its first Honorary Secretary. Besides Dr. Sircar himself, a galaxy of men taught at IACS in the early years - the Rev. Father F. Lafont, Jagadish Chandra Bose, Asutosh Mookerjee and Chunilal Bose, to name a few. Also associated closely with IACS were eminent persons like Pandit Iswar Chandra Vidyasagar and Keshub Chandra Sen, who were among the members of the first Trustee Board, Gurudass Banerjee, Surendranath Banerjee, Raja Peary Mohan Mookherjee, the first Indian President of IACS, Nilratan Sircar, Jnan Chandra Ghosh, Satyendra Nath Bose, etc.



The building at 210 Bowbazar Street, Kolkata, where IACS was originally housed

However, despite Mahendra Lal Sircar's persistent efforts, no one came forward to undertake research at the Association till his death in 1904. After Dr. Sircar's death, his son Amrita Lal Sircar took over as Honorary Secretary. Three years later in 1907, aroused by curiosity at the nameplate, young Chandrasekhara Venkata Raman, walked into the Association premises one August evening on his way back from work at the Accountant General's office, and changed the future of the Association and the pursuit of science in India. The basic research actually started at the Association with the enrollment of C. V. Raman as a member in 1907. He began carrying out researches in his spare time. The rest is history. Discovery of Raman effect in 1928 was followed by the Nobel Prize two years later. This firmly established a position for India in the scientific research map of the world.

In 1933 Raman left Calcutta for Bangalore. In 1988 the American Chemical Society eulogized the discovery of Raman Effect by installing an International Historic Chemical Landmark plaque at IACS. Visitors can view this plaque on the first floor of the main building. Raman's celebrated disciple K. S. Krishnan, joined IACS as the first Mahendra Lal Sircar Professor and carried out his much acclaimed work on magnetic anisotropy. He was succeeded by K. Banerjee, a pioneer of the direct method in crystallography.

In 1951, the Association moved to its present campus at Jadavpur and two years later started functioning as a full-fledged research institute under M. N. Saha, who became its first wholtime Director. This was in keeping with the growing activities of IACS. In less than a decade four departments each in physics and in chemistry were established and research activities began to flourish and make impact internationally. Some of the leading researchers of the time were S. C. Sircar, B. N. Srivastava, A. Bose, P. Ray, S. R. Palit, Sadhan Basu and P. C. Dutta. In the next two decades these departments had produced more than 2,000 research papers and more than 300 doctorates in science.

The completion of a 100 years in 1976 marked the celebration of a heritage, heralding a new beginning into its next century. The centenary celebrations were inaugurated by the then Prime Minister Smt. Indira Gandhi on July 29, 1976 and were marked by major national and international symposia and conferences. Raman's historic works setting the stage, the research activities during the first century of the Association spanned various fields in physics and chemistry. Some of the areas covered included magnetic anisotropy of graphite and rare earth compounds, early work on direct methods in crystallography, first electronic observation of dinuclear metal compounds, early work on



New IACS campus

liquefaction of air, structure phase transition at low temperatures, transport properties of gases in fractional distillation of petroleum, variational methods for ion-atom collision problems etc. The two decades old activities in chemical sciences also had made notable contributions, comprising kinetics and mechanism of free radical polymerization reactions, end group analysis of polymers by dye techniques, chemistry of rubber vulcanization, new strategies in reactions of general applicability, synthesis, stereochemistry and reactions of new species in coordination chemistry, new analytical reagents, isolation and chemistry of new carbohydrates from nature, immunochemistry of capsular and cell-free polysaccharides from pathogenic bacteria etc.

The centenary celebrations brought about an upswing and improved visibility in the activities of IACS. The next 25 years have seen the Association diversifying into several frontier areas with technological potential. Availability of increased funding and the desire to instill a fresh scientific look induced IACS to search for scientists who were relatively young but already eminent and those who could provide leadership and open up new areas of research. This resulted in the appointment of a number of distinguished physicists and chemists and they along with other scientists contributed significantly in keeping IACS at the frontier of research, primarily basic but with forays into fields having technological and social relevance. National and international

Contd. on page... 22

Raman Research Institute, Bangalore

□ T.V. Jayan

From a research institution privately owned by the greatest-ever Indian scientist to a national centre of repute in basic sciences, the Raman Research Institute (RRI), Bangalore, has come a long way during its existence over half a century.

Founded by Prof. Raman, the only Nobel Prize winner in science from India, in 1948, RRI is located in a sprawling campus very close to the Indian Institute of Science (IISc). The campus, lined with a large number of flowering and non-flowering trees planted by none other than Raman in the early years of the institution, even today is a secluded place of peace and tranquility as it was in Raman's days, despite being located in one of the busiest parts of Bangalore city.

Run on a grant received from the Department of Science and Technology (DST) since 1972, RRI has been carrying out first-rate original research in several areas of fundamental science. These areas are theoretical physics, optics, liquid crystals and astronomy and astrophysics. It must be said here that Raman, during his days at the institute, refused to accept any funds from the Government and other sources as he believed that no funds could come without any attached strings.

"Raman who was an experimental scientist par excellence hated writing project reports and for that matter giving periodic status reports to those who fund projects. He was of the firm belief that science could not be done that way," said Prof. N V Madhusudana, Dean of Research at RRI and a leading liquid crystal scientist.

Raman had planned the institute much before he retired from IISc as the head of its Physics Department. As he had abhorred being idle even for a single day, his idea had been to walk straight into his newly-founded institute when he retired from IISc.

Much before he thought about founding an institute of his own, Raman had approached the then Maharaja of Mysore for land for building an office for the Indian Academy of sciences (IAS), which was again a brainchild of Raman. The Maharaja readily acceded to his request and a 10-acre plot was gifted to the academy in 1934. The decision to build a research institution on this land was subsequently taken when there was a danger of this piece of land being retrieved by the Government of Mysore as the academy failed to utilise it till the end of 1941.

Subsequently, Raman put forward a proposal to build a research institute to the academy at an extraordinary meeting and this was accepted by the meeting. Raman who raised the funds for the institute, was clear that it should have a distinct identity from the academy.

According to A Jayaraman, one of his students in the initial days of the institute, RRI was under the umbrella of the Indian Academy of Sciences. But Raman gradually changed this, for he thought conflicts could arise if the institute was not made into a statutory body. During his time, the presidency of the academy and the directorship of the institute rested in him. He was the supreme authority as far as the Institute was concerned. This highly personal style suited the temperament

of the founder. Just before his death, however, Raman chartered out a framework for running the institute, giving it a separate status and autonomy. The Institute adopted the change in 1971 and stepped into a new era.

"Till Raman's death, this was his private research institute. He had a very small group of research students working with him and a very few administrative staff. When he moved into the institute, the work on the building was incomplete and there was no electricity. This forced him to conduct several optics-related experiments using sunlight," Prof. Madhusudana said.

Despite its budgetary and infrastructural constraints, scientists working under Raman did some path-breaking work. For instance, S. Pancharatnam, who joined the institute in 1954, discovered a fundamental quantum optic effect, independent of Raman. This work, according to Jayaraman, was "the most outstanding original piece of research that came out of RRI at that time."

This discovery proved for the first time that geometric phase exists in optics. But this phenomenal work wasn't known to the world till similar discovery was made by scientists elsewhere about two decades later. Subsequently, RRI could convincingly prove that Pancharatnam discovered this long ago and today "this phase is called Pancharatnam Phase world over," said Madhusudana. Pancharatnam unfortunately did not live long enough and his brilliant career was cut short when he died in 1969 while in Oxford.

The institute also houses Raman's prized collection of gems, crystals, minerals, and rock specimens from all over the world.

Raman, who was fascinated by the colours of the biological kingdom, also had a veritable collection of stuffed birds, beetles, and butterflies in his museum. It is said that Raman used to take a lot of pride in showing off his precious collections to distinguished visitors to the institute. During Raman's time, many celebrated scientists from other countries paid a visit to the institute. Among them were: J. D. Bernal, E. C. Bullard, P. M. S. Blackett, C. G. Darwin, P. A. M. Dirac, G. Gamow, J. B. S. Haldane, Linus Pauling, C. F. Powell, L. Rosenfeld, G. Wentzel and Norbert Wiener.

One of the current research priority areas of the institute is liquid crystals. This has been an active area of research at the Raman Research Institute for nearly three decades. The research programme covers a broad spectrum of activities ranging from the synthesis of new liquid crystalline materials to display electronics. Discoveries of the columnar phase formed by disc-like molecules and pressure induced mesomorphism are two of the early significant contributions made by the liquid crystal group. "Out of 36 liquid crystal materials discovered world over three were from this institute," said Prof. Madhusudana. Among them are two new liquid crystalline phases, namely the undulating twist grain boundary C phase and the biaxial smectic A phase.

Techniques developed for driving passive matrix liquid



Raman Research Institute, Bangalore

crystal displays at the institute are now being widely used. In recent years the liquid crystal group has been working on electrochemical aspects of surface science and on other soft materials like surfactants, polymers, and on the physics of biological systems

Astronomy and astrophysics has been another strong area of research for RRI. According to Prof. Madhusudana, this division accounts for the maximum number of faculty and research students of the institute. Over the last 20 years, it has been carrying out observational programmes in radio astronomy, covering almost the entire radio spectrum. Besides having a millimetrewave telescope of 10.4 metre diameter on the campus, RRI has set up a decametrewave Radio telescope at Gauribidanur, about 80 kilometres away from Bangalore, jointly with the Indian Institute of Astrophysics (IIA), Bangalore. This is one of the few largest telescopes that operate at the wavelength of 10 metre and is being used by RRI scientists to study radio emission from various types of celestial objects such as the Sun, Jupiter and similar radio sources in Milky Way and other galaxies. Other radio telescopes that are being used by RRI scientists for observations are Ooty Radio Telescope, at Ooty, and Giant Metre wavelength Radio telescope (GMRT), near Pune, both set up by the Tata Institute of Fundamental Research (TIFR). RRI also played an active role in building a low-frequency radio telescope in Mauritius jointly with the University of Mauritius and IIA.

The major astronomical investigations pursued at the Institute can be broadly classified into the following categories: (i) Neutron Stars and Pulsars; (ii) cosmology; (iii) Diffuse matter in space; and (iv) Radio Sky Surveys.

The theoretical physics activity in the institute has centred around relativity and gravity, quantum theory, and optics. The current activity in gravitation centres around two themes, gravitational radiation and quantum gravity. Gravitation is known to be the weakest of all known forces of nature, but it dominates all structure and motion on the astronomical scale because of its attractive universality, its long range and the fact that matter on the large scale is essentially neutral. The correct theory of gravitation is now believed to be Einstein's General Theory of Relativity. One of the fundamental predictions of General Theory of Relativity is that of gravitational waves -- waves of distortion of spacetime itself - propagating at a finite speed of light. This replaces the Newtonian gravitations forces which was instantaneous. Such waves are expected to be emitted when, for example, two massive inspiralling stars tend to coalesce under their mutual gravitations attraction. Accurate calculation of this gravitational radiation - its waveform - has been one of the major research programmes of the theoretical physics group at the institute. Their work is expected to be a crucial input towards its eventual detection.

Another major activity of the theoretical physics group has been in studying propagation of light waves in certain types of liquid crystals and minerals and their associated polarization phenomenon. RRI has been a pioneer in the this field of study which was actually initiated by one of Raman's research students, Pancharatnam.

Errata

In the English version of the article titled "Kariamanikkam Srinivasa Krishnan" appeared in January 2002 issue of Dream 2047, the photograph of John Milton was inadvertently used in place of George Bernard Shaw. In the same article, it was written that 'KSK was the first recipient of the Bhatnagar Memorial Award in 1961. While the award was indeed presented in 1961, but it was for the year 1958. We regret these errors.

- Editor

Contd. from page... 24

recognition, major prizes and medals, fellowships of distinguished scientific academies subsequently followed.

In the very early years, activities at the Association were supported by generous public donations. But with the tools of research becoming increasingly expensive, such support alone proved insufficient. Today the Association receives aid from the Department of Science and Technology, Govt. of India. A matching grant is provided by the Govt. of West Bengal. Individual scientists also receive grants from funding agencies like CSIR, DAE, DNES, ICMR, NSF, UNDP etc. for specific projects.

Currently there are eight departments comprising the physical and chemical sciences. These are 1. Materials Science 2. Solid State Physics 3. Spectroscopy 4. Theoretical Physics 5. Biological Chemistry 6. Inorganic Chemistry 7. Organic Chemistry 8. Physical Chemistry. Three units which have taken shape during the last two decades are 1. Energy Research 2. Mahendra Lal Sircar Professor 3. Polymer Science. Many of the activities of the departments and units are interlinked and interdisciplinary in nature. Hence, the contributions from various fields can be broadly categorized into 1. Molecular Sciences 2. Physics and Chemistry of Solids 3. Biosciences and 4. Theoretical Sciences.

The highlights of activities in these areas comprise development of a-Si solar cell leading to setting up of a pilot plant by BHEL, scientific and technological studies on glass-metal and glass semiconductor nanocomposites, preparation of thin films for fundamental studies and device fabrication, studies relating to atomic and molecular collision processes, immunochemistry of plant and bacterial sources, biochemistry of tumour cells, new and increased comprehension on the chemistry of transition metals, synthesis of bioactive natural products, new aspects of polymer blends, development of a microbial BOD sensor, theoretical studies on the structure and dynamics of molecules etc.

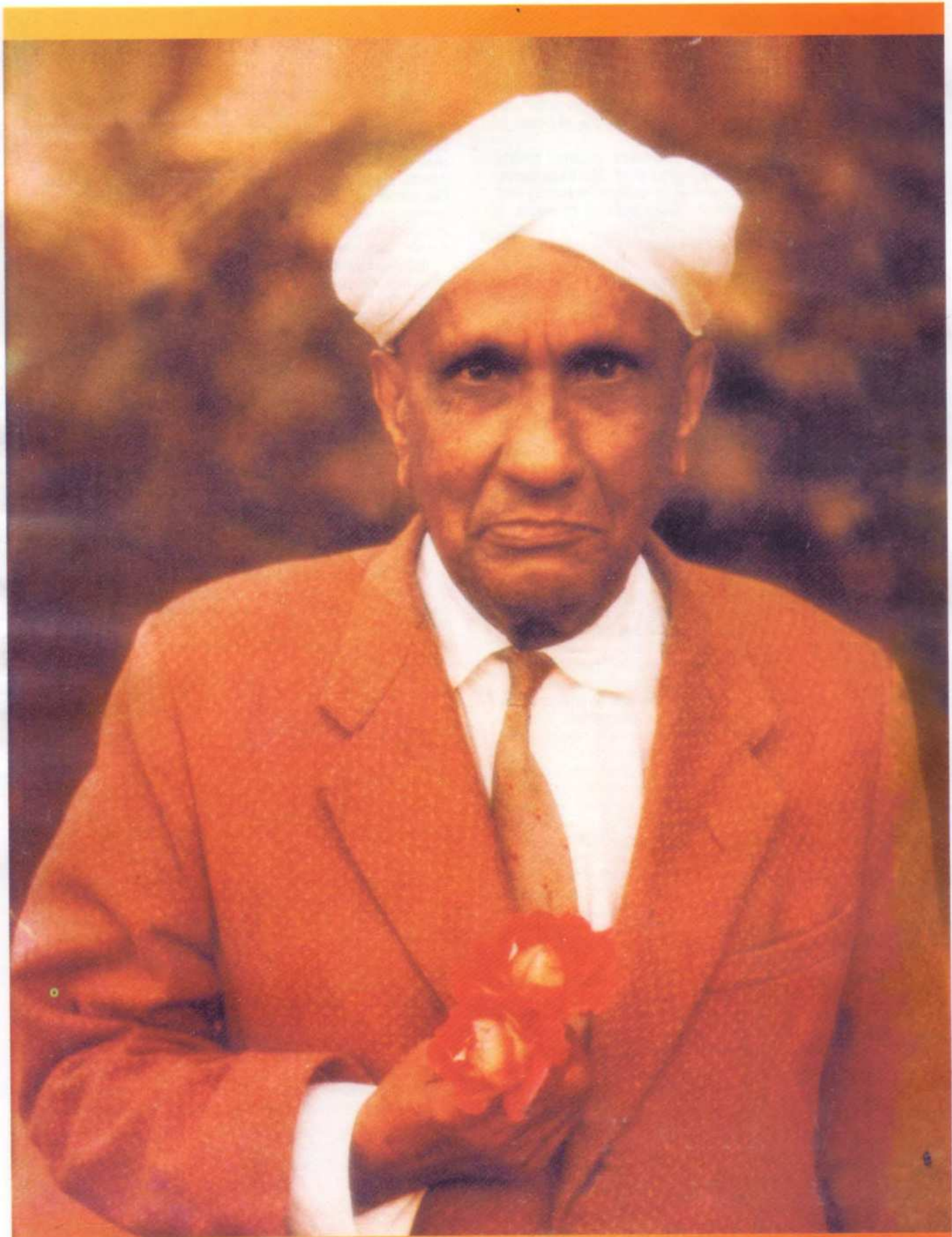
A well appointed library is the heart and soul of any sustained research activity. The IACS library is the oldest research library in India, offering bibliographical facilities to a wide class of scholars. It has a vast collection of very old scientific journals of immense historical and archival value, a collection that has no parallel in any other library of a research institute. The first volume of the first scientific journal - *The Philosophical Transaction of the Royal Society*, published in May 1665 is available in this library.

The Association publishes the Indian Journal of Physics, the oldest journal in Physics from India which was founded by C. V. Raman. This year it will complete the 75th year of continuous publication. The Nobel Prize winning work of C. V. Raman was first published in this journal. Apart from C. V. Raman's contributions, the journal published many important papers of M. N. Saha, K. S. Krishnan, K. Banerjee, S. K. Mitra, S. Bhagvantam and others. The journal, with its uninterrupted publication, has grown into an international journal, publishing papers in two sections A and B covering almost all branches of physics. Special issues commemorating Golden Jubilee, birth centenaries of C. V. Raman, M. N. Saha and K. S. Krishnan have been published.

The research activities pursued at the Association continue to receive national and international recognition. With the background experience of 125 years, IACS is in a fit position to scale new and emerging frontiers in research. The Association is poised to initiate research in the multidisciplinary areas such as advanced designed materials and biology-inspired sciences.

We would like to thank Prof. Devashish Mukherjee, Director, Indian Association for the Cultivation of Science, Kolkata, for promptly providing the information we requested for preparing this write-up.

Editor



Sir Chandrasekhara Venkata Raman

(7.11.1888 - 21.11.1970)

सर चंद्रशेखर वेंकट रामन

Recent Development of Science and Technology

Smart Fluid Developed

A liquid polymer "Smart Fluid", which gets solidified in the presence of a magnetic field and changes back into liquid within seconds after the magnetic field is removed, has been developed by a scientist of the National Physical Oceanography Laboratory in Kochi.

The Smart Fluid has many applications including those for making automobiles brakes, clutches, moulds, vibration damping and safety valves. Dr. Reji John who developed the Fluid said in presence of the magnetic field there is an increase in the viscosity in the fluid. The initial viscosity of the fluid is around 500 cps (cetri poise). If magnetic field of one gauss is applied, viscosity becomes 1.5 lakh cps within 0.2 sec and as soon as the magnetic field is removed the initial viscosity of fluid become 500 cps immediately. He also said this fluid called "Magnetrorheological" was developed six months ago and can have wide defence applications. The institute has applied for patenting US, UK, France, Japan besides in India.

Source: PTI News

Fifth State of matter

Cool a gas of rubidium atoms to one-hundred-millionth of a degree above absolute zero or less and something strange happens. The atoms lose their individuality and merge into a single quantum state, forming what is known as a Bose-Einstein Condensate (BEC). In this condensate atoms flow without friction, endowing the ultra-cold gas with the property of super-fluidity. Scientists have known that much since 1995, when Eric A. Cornell of the National Institute of Standards and Technology and his colleagues created the first BEC in the laboratory - an achievement that earned them the 2001 Nobel Prize in Physics. Now new research has taken the work one step further, revealing a surprising BEC behaviour. It appears that under certain conditions, the condensate undergoes a reversible quantum phase transition, switching from a superfluid to a patterned fluid - a new type of matter.

Physicist Henk T. Stoof of Utrecht University in the Netherlands notes that the ideal array of single atoms created in the insulating phase lends itself to quantum computing. "Every rubidium has a magnetic movement and so has two internal states that may serve as the 0 and 1 of a quantum bit". Given the large number of rubidium atoms in the optical lattice, he says, they could provide the memory for a quantum computer. Moreover, "if there are two such memories that can be moved relative to each other, we can even make use of the interactions between atoms to perform a quantum computation.

Source: Nature, Jan 2002

compiled by:kapiltripathi

Letters to the Editor

I happened to read your thought provoking scientific journal "Dream 2047". We all at our school read it. We were so much excited that we got together and decided to write to you, requesting you to send us a free journal every month. I am sure, it will be a priceless asset to the school's collection. I will be a good reference book also to us.

Aathira Ari

Class-8, Kendriya Vidyalaya, Palappuyam, Ottappalam, Palakkad-distt KERALA

Your article on Riding on Radio Waves (Part-1) in the Oct. 2001 issue received and read by us all. We celebrated the 100th year of Trans Atlantic wireless communication on 13th December as a day of honouring Dr. J.C. Bose who contributed in no small measure, than other scientist to the development of Radio Technology, by conducting a live demonstration to school children from the Ham Station of VU2IR Om Satya. Incidentally that day was devoted to enrolling young enthusiasts for the Ham Radio Training in the Academy also.

Organiser, Academy of Radio Sports

No. 39, Theypperumanallur Radd, Kumbakonam - 612001, Tamil Nadu

श्री मा. वि. पंचा. प्रयोग, प्रयोग-प्रयोग, विद्या प्रयोग (म.प.)

(கனடா) உகாந் ஸாஹீ ப-ஸா

[illegible]

କାହାଣୀର ଲକ୍ଷଣ ଓ ଲକ୍ଷଣର ଲକ୍ଷଣ

‘இந்தக் கல் தாது

संज्ञांक, दिनांक 17/01/2002

1. பெரிய கூரை மேல் நிலை

विज्ञान प्रसार की मासिक पत्रिका "विज्ञान 2047" (वि.सं. 2001, खण्ड 4, अंक 3) में प्रकाशित हुई। पत्रिका में विज्ञान के बारे में रोचक जानकारी दी गयी है। पत्रिका पत्रिका हिन्दी और अंग्रेजी दोनों में है इसलिए इसका

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[\[2/5/6\]](#) [\[2/5/6\]](#) [\[1-2/5/6\]](#)

ଶିଳ୍ପ : ଶିଳ୍ପ ଶାସ୍ତ୍ର 2002

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ନୌ-ସାକ୍ଷାତ : ୧୫

[illegible]

स्मात् पृथक् देवेभ्यः ताम्

विज्ञान एवं भूगोलिकी के प्रमुख विभागों में