Frontline

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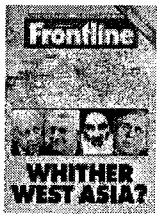

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TRIBUTE

Lasting effect

T.V. VENKATESWARAN

The 75th anniversary of the Nobel Prize of Sir C.V. Raman, the first and only Indian citizen to win a Nobel in science, is being celebrated this year.

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Sir C.V. Raman (second left) with other Nobel Laureates of 1930, (back row) M. Svedberg, M. Euller, M. Dahlein, Hans Fischer, (front row) Sir Clair Lewis, S. Lagerlof, Karl Landsteiner and M. Barany, after the presentation of the prizes in Stockholm.

IT is said that in 1930, anticipating the Nobel Prize, C.V. Raman bought two tickets to Stockholm, one for himself and the other for his wife, as early as September though the prizes were to be announced formally only in November. Indeed, his conviction was not misplaced; he was decorated with the Nobel Prize for Physics that year for his path-breaking work and the discovery of the Raman effect. The first `Indian Nobel' for science is thus 75 years old. And Raman remains the only Indian to receive a Nobel Prize in science. Two Indian-born scientists, Har Gobind Khorana and Subrahmanyan Chandrasekhar, won Nobel Prizes, but they had become U.S. citizens. February 28, the date on which Raman's discovery was reported, is observed as National Science Day in India.

ONE day in 1903, Professor Eliot of Presidency College, Madras (now Chennai), saw a little boy in his B.A. class. Thinking that he might have strayed into the room, the Professor asked,

"Hi, boy... there... why are you here?"

"Mm... Sir," the boy stammered.

"Are you a student of the B.A. class?"

"Yes Sir," the boy answered.

"Your name?"

"C. Venkata Raman."

Yes, he was a genius right from his childhood. Chandrasekhar Venkata Raman, popularly known as C.V. Raman, was born in Tiruchirapalli, Tamil Nadu, on November 7, 1888. He was the second child of Chandrasekhar Iyer and Parvathi Ammal. Raman's education commenced at Visakhapatnam, where his father was then a Professor of Mathematics at the Mrs. A.V.N. College. Raman's academic brilliance was perceptible at a very young age. At 11, he finished his matriculation. He completed his F.A. at the age of 13, and then moved to the prestigious Presidency College in Madras. At 15 years of age, he finished his B.A. at the head of the class, winning the first place and gold medal for physics. He was barely 17 when he received his M.A. degree in 1907, as the class topper.

Though Raman proved his talent in scientific investigations, he followed in the footsteps of his elder brother C.S. Iyer and appeared for the Financial Civil Service (FCS) examination in 1907. He was offered the post of Assistant Accountant General in Calcutta (now Kolkota) at a princely salary of Rs.400 a month.

His marriage, like his whole life ahead, was full of drama. While visiting his relatives at their house, he chanced upon young Lokasundari, just 13, and was immediately attracted to her. In a revolution of sorts for those days, he arranged his own marriage; apparently she was singing a Carnatic composition, `*Rama Ni Samanam Evaro*'(Rama, who is your equal?), when he first saw her!

Though he joined the Finance Department, his interest in physics did not wane; he used his spare time for research by establishing a rudimentary laboratory at his house. Soon he found a more facilitating environment for research. In yet another dramatic turn in his life, one day, while on his way to the office, he chanced upon a signboard `Indian Association for Cultivation of Science' (IACS) at Bowbazar. Legend has it that he jumped out of the moving tram and rushed to the IACS, where he was received warmly by Amrit Lal Sircar, honorary secretary of the Association. Amrit Lal was elated on hearing Raman's intention to do research using the facilities at the IACS, which his father Mahendra Lal Sircar (1833-1904), a man of vision, established in 1876. The IACS is the first institution to be established in India solely for carrying out scientific investigations.

By 1917 Raman was so well known that Asutosh Mookerji (the first Indian Vice-Chancellor of Calcutta University) offered him the Sir Taraknath Palit Professorship in Physics at Calcutta University. Raman stayed for the next 15 years in this university. But rules and regulations required that the incumbent have training in Europe. Of course, Raman stubbornly refused to oblige. So, to meet the

requirement, he was sent as a delegate of Calcutta University to the International Universities Congress of 1921. This was the first foreign trip he undertook.

Influenced by the German scientist Hermann L.F. von Helmholtz (1821-1894) and the English scientist Lord Rayleigh (1842-1919) right from his college days, Raman developed an immense interest in the study of sound (acoustics) and light (optics), the two fields of investigation to which he dedicated his career. When he was 18 years of age, he observed diffraction bands by using an ordinary spectrometer in his college. He reported the observation in the *Philosophical Magazine* (London) in 1906.

He followed this up with a note in the same journal on a new experimental method of measuring surface tension. Later, Raman published another paper in the scientific journal *Nature*. Lord Rayleigh took note of the papers and there was an exchange of correspondence. Interestingly, Lord Rayleigh addressed Raman as `Professor', not realising that he was corresponding with a `student'.

C.V. RAMAN, while returning from Europe aboard a ship in 1921, was perplexed as to why the ocean is blue. The received wisdom of those days was that of Lord Rayleigh's conjecture - that the blueness of the ocean was because of the reflection of the sky on its surface. Raman, who undertook a quick study during his long voyage, was convinced that the `reflection theory' could not adequately explain the phenomenon. Furthermore, Raman, who had travelled in the northern latitudes, had observed a pale blue opalescence in the icebergs. He had also observed this opalescence in deep sea and large lakes. What causes this opalescence? Why the deep ocean is blue? Raman set out to investigate this phenomenon. From then on C.V. Raman was preoccupied with the `scattering question'. In 1922, along with one of his students, K.R. Ramanathan, he produced a monograph explaining the change in colour due to scattering. But he attributed the change to weak fluorescence. S. Venkateswaran, another student of Raman, noted in 1927 that this weak fluorescence was strongly polarised.

Raman and his students, especially K.S. Krishnan, began studying the phenomena. Krishnan attempted to record the effect of scattering of light in various mediums throughout February in 1928. On February 27, he observed a definite, faint greenish glow in glycerine and reported it. Raman set out to study the "mysterious" greenish glow on the morning of February 28. But he had to leave the IACS laboratory for his university. He returned in the evening and continued the investigations, and was able to discover the "new secondary radiation". He found out that the opalescence of the icebergs or the deep sea was not just because of reflection or scattered rays, but that there was a small component of "induced secondary radiation". This effect, called "Raman effect", earned him the Nobel Prize.

According to Krishnan, he explained his discovery to a group of school children by using an analogy from cricket. Assume that a batsman is wagging his bat forward and backward incessantly, and the

ball is bowled at him. If the bat is moving backward at the instant of contact between the ball and the bat, there will be a small incremental loss in the velocity of the deflected ball. On the other hand, if the bat is moving forward at the instant of contact, there will be an incremental increase in the velocity.

In a like manner, one can "picture" that when the light particle, photon, hits the "revolving" electron, there will be an incremental increase or loss in energy depending upon whether at the moment of contact the electron moves along the direction of movement of the photon or in the opposite direction. As the colour of light reflects nothing but the energy of the particle, the incremental increase or decrease of energy would result in new "induced radiation" very different from the incident and scattered light.

When light is scattered from a molecule, most photons are elastically scattered. The scattered photons have the same energy (frequency) and, therefore, wavelength, as the incident photons. A molecule may undergo a vibrational transition (not an electronic shift) at exactly the same time as the scattering occurs. This results in the emission of a photon with energy different from that of the incident photon by an incremental additional amount. However, only a small fraction of the scattered light - only one in one million photons - is shifted in wavelength by the molecular vibrations and rotations of the molecule in the sample. The shifts in wavelength depend upon the chemical structure of the molecule that is responsible for the scattering - this is Raman scattering. The process leading to this inelastic scattering is termed the `Raman effect' and the resultant spectrum of this wavelength-shifted light is called a Raman spectrum.

Raman was not alone in the quest. This phenomenon was predicted theoretically by A. Smekal, Hendrik Anthony Kramers and Werner Heisenberg. Since 1913, two Russians, Mendelsram and Landsberg, were carrying out studies in the same direction. From 1925 such studies converged on pure quartz. However, cheated by shopkeepers who sold low-quality quartz (impure quartz does not show the light scattering as expected), they failed miserably. At last, in 1928, they did get pure quartz, and on February 21 they did observe for the first time the phenomenon similar to that observed by Raman. However, owing to a lack of self-confidence they did not publish the result. When Raman published his result the Russians realised that they also had observed same phenomenon.

C.V. Raman's discovery of the effect that light scattered by any medium contains frequencies different from the incident ones by amounts that are characteristic of the scattering medium was a beneficial and significant one. `Raman effect' was the most convincing proof of the quantum theory of light. It not only satisfied theoretical expectation but had potential commercial uses in petroleum and chemical industries.

Raman spectroscopy is now applied in the study of thin films and coatings, micro-electronic integrated circuits, pigments in art works,

and biological tissues and in the identification of narcotics and plastic explosives. Raman spectroscopy is preferred for reasons such as it is non-destructive of samples, it makes higher temperature studies possible and readily achieves the examining of low-wave-number regions. X-ray Raman effect is used to study the molecular structure, viscosity and polymer lattice structure of chemical substances.

THOUGH Raman is renowned for his work in optics and to a lesser extent on musical instruments, his interest in science was wide - it extended from astronomy and meteorology to physiology. Raman published 475 research papers and wrote five remarkable monographs.

Some of the other important investigations carried out by Raman were experimental and theoretical studies on the diffraction of light by acoustic waves of ultrasonic and hypersonic frequencies (published in 1934-1942) and those on the effects produced by X-rays on infrared vibrations in crystals exposed to ordinary light.

In 1948, Raman, through his studies of the spectroscopic behaviour of crystals, approached fundamental problems of crystal dynamics in a new manner. He was also fascinated by the structure and properties of diamond and the structure and optical behaviour of numerous iridescent substances (labradorite, pearly felspar, agate, opal and pearls).

Raman received worldwide recognition for his work in optics and the scattering of light. He was elected to the Royal Society of London in 1924 and was made a knight of the British Empire in 1929. The following year he was honoured with the prestigious Hughes Medal by the Royal Society. And in 1930, he became the first Indian scholar educated entirely in India to receive the Nobel Prize.

In 1934, Raman became the director of the newly established Tata Institute for Science (currently the Indian Institute of Science) in Bangalore, where two years later he continued as a Professor of physics. In 1947 he was appointed the first National Professor by the new government of independent India. He retired from the IISc in 1948, and a year later he established the Raman Research Institute in Bangalore. He served as its director and remained active there until his death on November 21, 1970, at the age of 82.

Raman was a delightful speaker. Sprinkled with good humour, his talks were simple yet profound. During his popular science lectures (or `performances' as Raman called them) Raman held his audience spellbound. His lectures were accompanied by lively demonstrations. Raman had a deep sense of humour. He used to say that the colour of the sea interested him more than the fish that lived in it.

According to Ramaseshan, the Editor of *Current Science* and a nephew of Raman, 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."

His talk to children on 'Why the sky is blue' is a veritable primer in communicating the scientific sprit and scientific methods. Science is presented not as mere facts or formulas to be learnt by rote, but by way of step-by-step questioning. And by methodical reasoning, the working of nature is explained. Firmly holding that "research is civilisation and determines the economic, social and political development of a nation", C.V. Raman rebuffed all pseudo-scientific claims such as those of astrology.

This year is being celebrated as the International Year of Physics to commemorate 100 years of the path-breaking papers of Albert Einstein (1879-1955). Indeed as Einstein wrote: "C.V. Raman was the first to recognise 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... ."

It is only proper that Raman is remembered in this year not only for the 75th anniversary of his Nobel Prize but also for his contribution to physics.

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