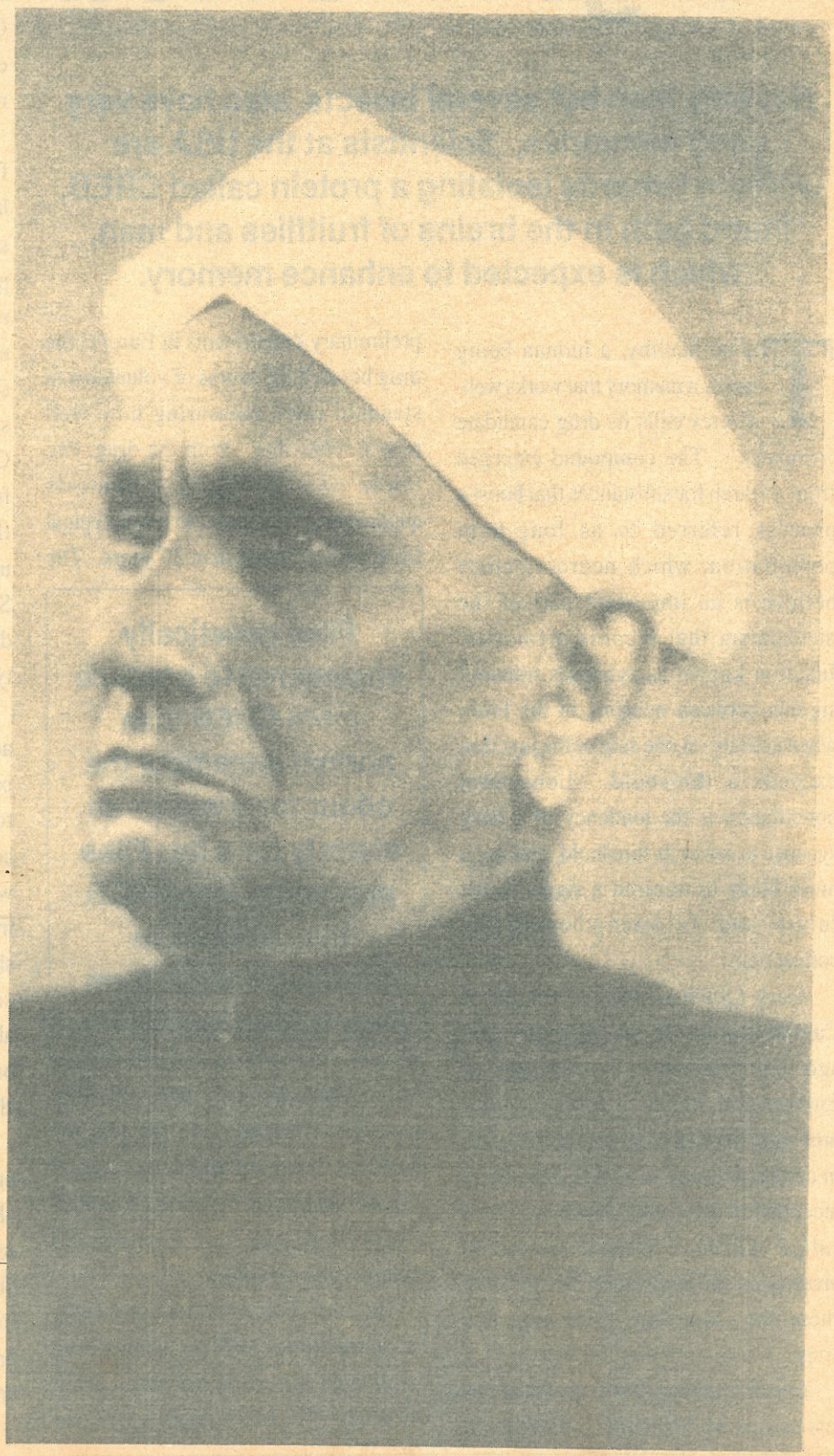
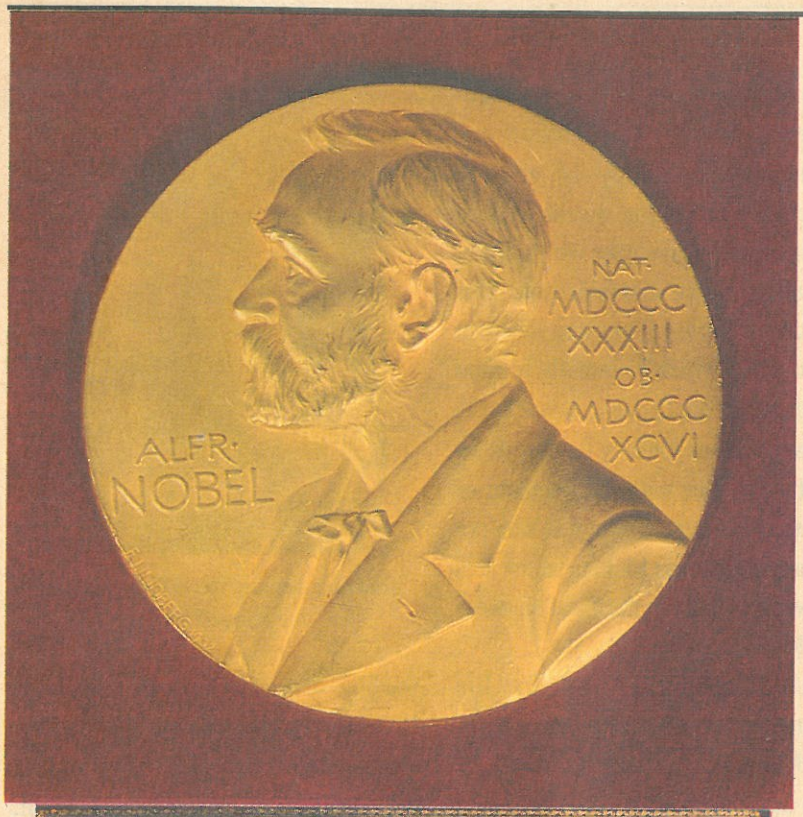
The Raman Effect

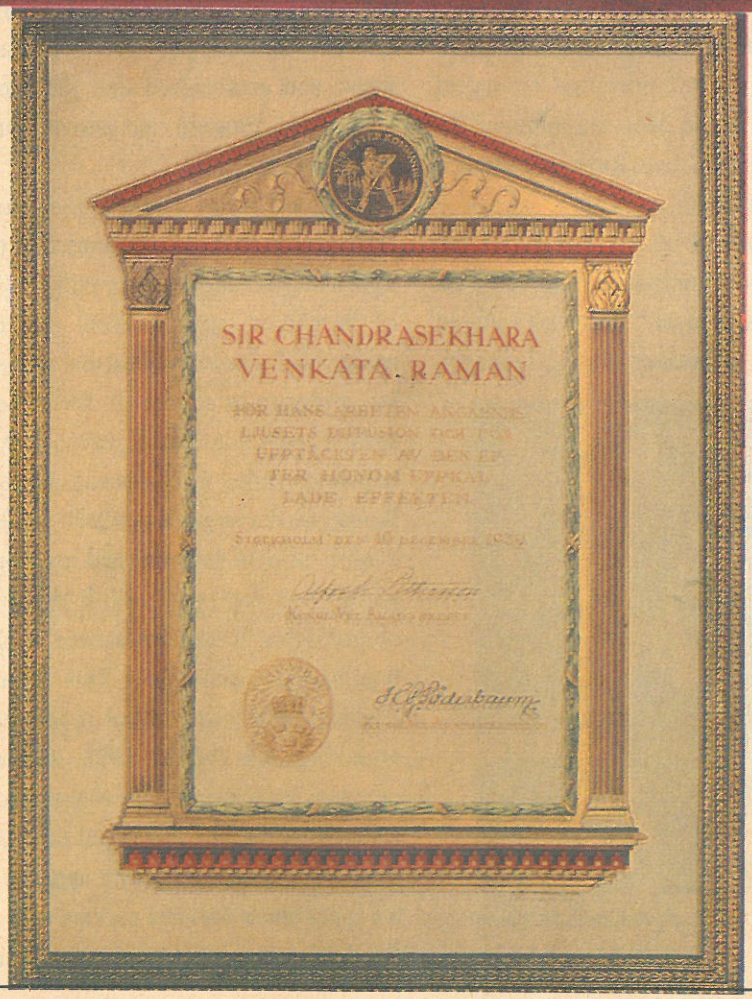
The 'Raman effect' of molecular scattering of light was not restricted to the world of Physics alone but had a resounding effect on the minds of crores of Indians about their own country's scientific capabilities. Every year the 28th of February - the day on which Sir. C.V. Raman discovered 'Raman effect' is most appropriately celebrated as the 'National Science Day'. A tribute to this great Indian scientist on the 79th year of his famous discovery.



■ G.P. Vinayababu



The Nobel Medal



The Nobel Diploma

NEW THEORY OF RADIATION

PROF. RAMAN'S DISCOVERY

(ASSOCIATED PRESS OF INDIA)

CALCUTTA. Feb 29

Prof. C.V. Raman, F.R.S., of the Calcutta University, has made a discovery which promises to be a fundamental significance of physics. It will be remembered that Prof. A.H. Compton of the Chicago University was recently rewarded the Nobel Prize for his discovery of the remarkable transformation which X-rays undergo when they are scattered by atoms. Shortly after the publication of Prof. Compton's discovery, other experimenters sought to find out whether a similar transformation occurs when ordinary light is scattered by matter, but reported definitely negative results. Prof. Raman with his research associates took up this question afresh, and his experiments have disclosed a new kind of radiation from atoms excited by light.

The new phenomenon exhibits features even more startling than those discovered by Prof. Compton with X-rays. The principal feature observed is that when matter is excited by light of one colour, the atoms contained in it emit light of two colours, one of which is different from the exciting colour and is lower down the spectrum. The astonishing thing is that the altered colour is independent of the nature of the substance used. It changes however with the colour of the exciting radiation, and if the latter gives a sharp line in the spectrum, the second colour also appears as a second sharp line. There is, in addition, a diffuse radiation spread over a considerable range of the spectrum. He will deliver a lecture demonstrating these phenomena first at Bangalore on the 16th March.

First Newspaper announcement of the Discovery of the Raman Effect made on 28th Feb. 1928

On the evening of the 27th February 1928, Raman decided to view the 'fluorescent track' emanating from the light passing through a liquid through a direct vision spectroscope, but by the time Ashu Babu (Raman's associate in all experiments) set it up, the sun had set. Next morning the first observation was made of what is now known as Raman effect. The spectroscope showed that the track contained not only the incident colour but at least another colour separated by a dark space. Using a filter in the incident light which cuts off all the visible light longer than the indigo 4358 AU line, the direct vision spectroscope showed not one but two sharp lines in the blue green region. The announcement of the discovery was made to the associated press the following day, the 29th of February 1928. For his efforts Raman was given the Nobel Prize first for any Indian in Science in the year 1930.

Raman was a great admirer of nature. He always appreciated the beauty of forests, majesty of mountains, vast expanse of seas, the lovable tunes of birds and in fact everything that nature offered. Raman was not stopping only at appreciating nature but would go deep into the scientific principles which makes the fruits of nature so wonderous. This is exactly what led Raman to discover Raman effect which eventually fetched India its first Nobel prize in science. On his first overseas journey to Europe he came face to face with the grandeur of Mediterranean sea. Though it was not the first time he was looking at the sea, he grew curious about the vivid blueness of the Mediterranean.

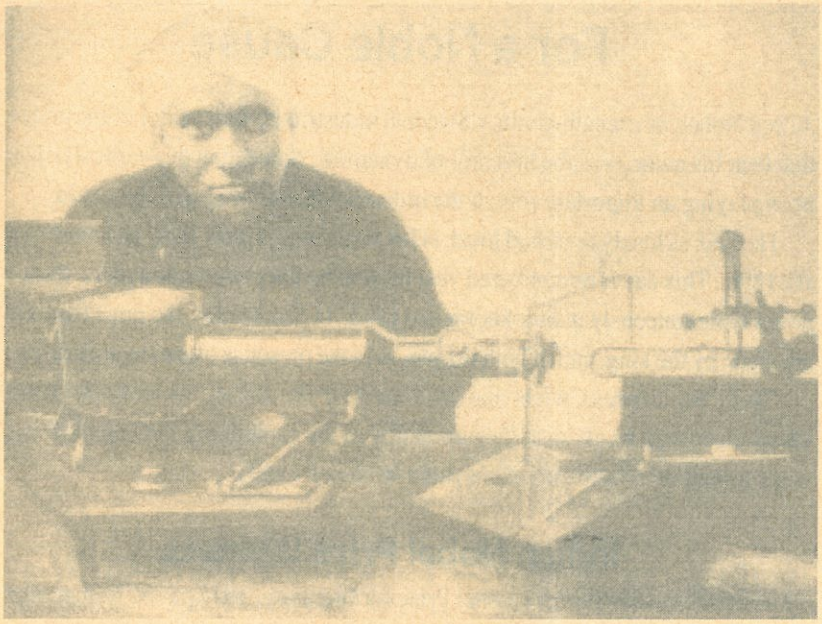
This formed the basis for his experiments on the scattering of light through liquids.

Immediately on his return from Europe he presented a research paper questioning the accepted theory of blueness of the deep sea proposed by Lord Rayleigh. Lord Rayleigh, who had explained the blueness of the sky as due to scattering of molecules in the atmosphere, dismissed the blue of the sea with the statement "The much admired dark blue of the deep sea..... is simply, the blue of the sky seen by reflection". Raman demolished this idea with a simple experiment which showed that the blue colour of sea was due to the molecular scattering of light through sea water and established that the Smo luchowshi - Einstein fluctuations were its basic cause.

Raman receiving the Nobel Prize from the King of Sweden

Raman later continued his experiments on molecular scattering of light and concluded that the interaction of the photon (small packets of light energy) with a molecule must reveal itself by a change in colour. In December 1927, a 'weak florescence' was observed in pure glycerine with greater intensity. Raman used a larger lens which would double incident intensity and used the winter sun for light. With this he observed this 'weak fluorescence' in all liquids, gases and solids. This 'weak fluorescence' was called modified scattering. On Feb 28, 1928, Raman examined the scattered track with a direct vision spectroscope and found that the classical modified scattering appear in the spectrum as separate regions with a distinct dark region between them, a clear

C.V. Raman and other Noble Prize winners of 1930 (Hans Fischer, Karl Landsteiner and Sinclair Lewis)



Raman with spectrograph and Raman tube

demonstration of a change of wavelength in scattering which was later called the 'Raman effect'.

The Nobel Confidence

Raman, all along his early career had dreamt of and had firmly believed that he would get the Nobel prize one day. There are several incidents which various people have narrated which explain the confidence he had in getting a nobel prize.

However Raman getting the nobel prize was not an accident nor was it a surprise because he had supreme confidence in himself and an intense desire to get the prize. We all know that Raman is one of the very few Indians who have got Nobel Prize.

An European scientist visiting the California Institute of Technology recalled that he met a scientist from India who imagined that he was going to discover a quantum effect in light scattering which would win for India the Noble prize. "I thought he was crazy. The incredible thing is that this man does make the discovery and does get the Nobel Prize six years later!"

In 1925 Raman writes to G.D. Birla, the industrialist and friend of Gandhi, that he needs money for an instrument called a spectrograph: "If I have it, I think I can get the Nobel Prize for India."

Yet another incident which talks about the supreme confidence of Prof. Raman was the incident at Royal society in 1924. Raman was elected a fellow of the Royal society and at the meeting to felicitate him, he is known to have said that while he appreciated the honour done to him, he did not consider it the

Raman in his lab

ultimate and that he would get the Nobel Prize for India within 5 years!

Nobel Prizes are announced in the second and third week of November. The meeting of the Nobel Committee are held in the highest secrecy and the awards are announced in November about a month before the prize giving ceremony in mid December. It is surprising how Raman could leave by steam ship after receiving the news by telegram to be in time for the ceremony. It is now a historical fact however that Raman had booked 2 tickets for himself and his wife in July that year to enable them to reach Stockholm in early December!

But one would wonder why and how he had such an intense desire to get the Nobel Prize. Prof. Ramasesan one of the close associates of Raman feels that this was because it was first instituted when he was at the impressionable age of 13 and because of so many of his heroes in science like Roentgen, Lorentz, Zeeman, Becquerel, Pierre and Marie Curie, his own Guru in absentia Ray Leigh, Leonard, J.J. Thomson and Michelson were its recipients during his college career. Apart from that, winning Nobel Prize is one of the best ways scientists can establish the supremacy of their works and Prof. Raman also believed that.

In 1930 Raman was awarded the Nobel Prize. Amongst those who nominated him were Lord Rutherford, Niels Bohr, Louis de Broglie, Charles Fabuy, Jean Perrin, Eugene Bloch, CTR Wilson and Russian scientist Choweson all great physicists.

A letter written by the charge d'affaires of the US in Sweden to the US secretary of state in Washington reporting on the Nobel prize ceremony of 1930 in which two US citizens were awarded prizes, described the momentous occasion thus.

.... of the prize winners, the day was easily carried however by Sir Venkata Raman the Indian prize winner, who upon returning to his seat on the platform after receiving his prize from the hand of the King was visibly moved by his emotion and sat with the tears streaming down his face.

Raman later confirmed this by saying "when the nobel award was announced,

For a Noble Cause

Alfred Nobel, nineteenth-century Swedish industrialist and creator of the prizes that bear his name, was the inventor of dynamite. Since then this explosive has been playing an important role in the industrial development of the world.

He died, as lonely as he had lived, in his home in Sanremo, Italy, on December 10, 1896. This day is remembered year by year by the presentation of the Nobel prizes simultaneously in Stockholm and Oslo. In Stockholm, the presentations are made by the king, and in both the places in the presence of the royal families.

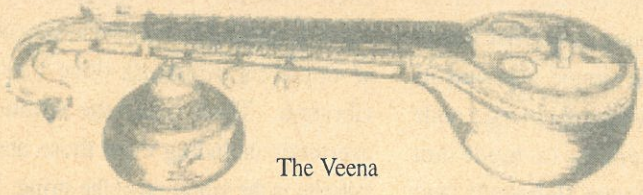
"It is my express wish that in awarding the prizes no consideration whatsoever shall be given to the nationality of the candidates, but that the most worthy shall receive the prize" (written in Nobel's will).

Indian Nobel Prize Winners

After Rabindranath Tagore (Nobel Prize for literature, 1913), C.V. Raman (for Physics, 1930), and H.G. Khorana (orig. Indian, later US, for Physiology/

Mother Teresa

Medicine, 1968), Mother Teresa was the last Indian to receive a Nobel Prize, and the first Indian to receive the Nobel Peace Prize in 1979. Mother Teresa, born on August 27, 1910 in Skopje (Balkan region), received the Nobel Peace Prize in recognition of her selfless efforts on behalf of the poor and for founding the "Society of the Missionaries of Charity" in Calcutta, which by now has branches in many towns of India.



The Veena

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 people of my country. I felt truly humble when I received the prize from King Gustar, it was a 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."

Multifaceted Personality

Raman was not just a great scientist but a multifaceted personality.

Not many people know that he was not allowed to resign from his Asst. Accountant General's post in the Finance department where he began his career, saying that he was one of the departments best men and they couldn't afford to lose him. But his obsession with science was so intense that he entered into science research even under immense pressure to stay back. Born as the second son to his parents in 7th November 1888 in Tamil Nadu, he went through the preliminary education exercise very soon. He matriculated at eleven, completed PUC at thirteen, passed BA at fifteen in the first class winning gold medals in English and Physics and completed his M.A. at an young age of eighteen years.

In 1906 after his M.A. he appeared for the competitive exams which chose civil servants for finance department which he topped.

He married Lokasundari and took her to Calcutta where he had to discharge his duty as Asst. Accountant General. Even as an official of finance department he wouldn't leave science. He started scientific research in the 'Indian Association for cultivation of science', whose laboratories were later to house the experiments on Raman effect.

In the year 1933 he was offered the Directorship of Indian Institute of Science at Bangalore. A significant move which Raman did during his tenure as a director is remembered even today. He proposed to provide facilities for many scientists for research who were fleeing from Germany under the tyranny of Hitler. He was not successful in attracting many great scientists like Schrodinger (the originator of wave mechanics) as they got settlements in various other countries by the time he proposed this. However Max Bohr was appointed to an extraordinary chair in physics in the institute. The reason Raman invited the German scientists to India was simple. He didn't want Indian science students to go abroad for scientific research but wanted them to stay on in India and work with the best scientists of the world. This act of his also forced him to resign from the directorship of Institute but he continued as its professor.

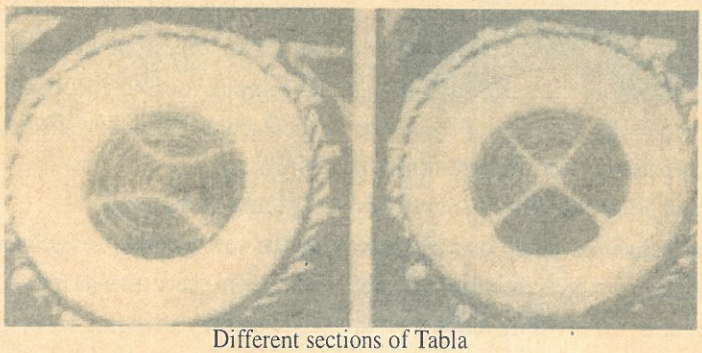
In 1934 Raman started Indian Academy of sciences to encourage scientific activity in India. He also built his own institute - The Raman Research Institute to work on subjects of great interest to him.

Raman's other researches

Raman worked on such delectable things as the plumage of birds, the colour of shells, the hues of old iridescent glass, and soap bubbles. He also worked on the acoustics. Earlier on in his career he had published a paper on the acoustic knowledge of the ancient Hindus, which fascinated him a lot.

Musical Research

In the *soirees* held in his father's house in Vishakapatnam and in public concerts Raman heard South Indian music at its best - for those were the days of the great



Different sections of Tabla

vidwans (maestros). He was particularly fascinated by the *mridanga* or the concert drum played with the hand and fingers by experienced drummers, using a highly developed technique. He marvelled at the manner of striking the drum head, and the regulation of the region of contact between hand and skin which elicited the requisite tone quality, intensity and duration of the sound.

His keen ear recognised that certain strokes appeared to bring out the first, second or even the third harmonic. Therefore he was somewhat surprised when he read in the *Theory of sound* that the natural vibrations of a circular stretched membrane (of uniform thickness) do not give rise to any harmonic sequence and so it is not simple to ascribe any particular pitch to them. Raman would not believe that the *mridanga* was in any sense musically defective as normal drums were. So he went on to demonstrate that the Indian musical drum produced as many as five harmonic overtones having the same relation of pitch to the fundamental tone as in a stringed instrument. He also showed that this was due to the central loading of the stretched membrane, and its behaviour presented a remarkable analogy to the law of vibrations of the homogeneous string.

The study by Raman of the string instruments, the *veena* and the *tanpura* (tambura), which are of undoubted antiquity, disclosed to him a remarkable appreciation of acoustical principles on the part of their ancient designers. Raman had noticed (probably when his wife played the veena) that the overtones did not die away as fast as the fundamental mode, but they seemed to steadily increase in volume. When he investigated the causes a surprise was in store for him. His simple experiments showed that the overtones having a node at the plucked points (a mode not permitted by the Young-Helmholtz law) sing out powerfully and that the position of plucking hardly appeared to make any difference in the intensity of overtones thus appearing to violate known acoustical principles. Raman traced this peculiar behaviour to the curved shape of the bridge in which the strings do not come clear off a sharp edge (as in European stringed instruments). The forces exerted by the string on the bridge near this grazing contact are in the nature of impulses occurring once in each vibration. These cause the retinue of overtones including even those absent initially in the vibration of the string. The woollen or silken thread traditionally slipped between the string and the bridge when adjusted properly enhances these effects making the sound very pleasing to the ear.

"I felt truly humble when I received the prize from King Gustar, it was a 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."

The plumage of birds

Colour, the striking feature of the plumage of birds, which fascinated Raman no end, was the subject of many of his studies. The interest was all the more as the optical characters and distribution of colours were so different in different parts of the same bird, in different specimens and in different species that no single explanation would suffice. Every phenomenon known to the optical scientist - interference, diffraction and scattering of light - and more had to be invoked. Interference due to thin films on the surface, selective spectral reflection from stratified films, the diffraction of light by discontinuities not small compared to the wavelength of light, the Tyndall effect due to minute air cavities, the anisotropic scattering due to elongated holes and particles, all contribute to these colours. Further Raman appreciated the delicate interplay of these physical effects with the chemical colours enhancing the spectacular chromatic display seen in birds.

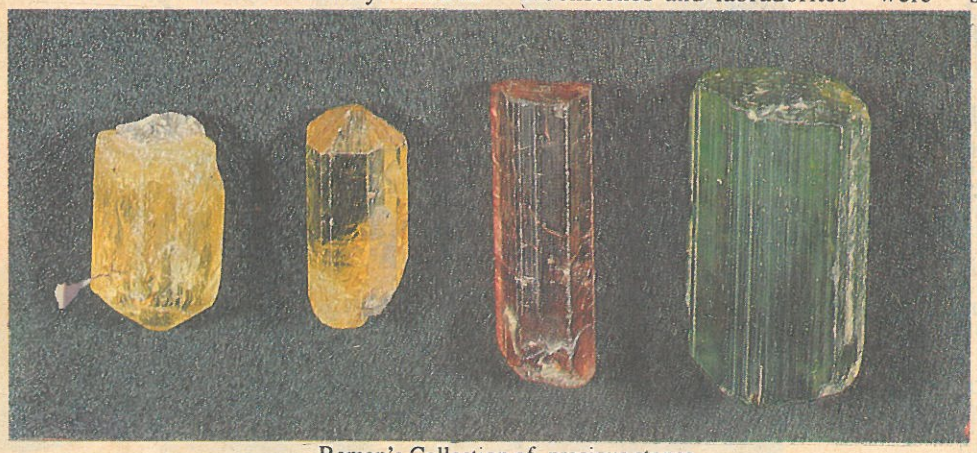
Colours of minerals

In the new Institute he built for himself to work in peace after he formally retired, he started by arranging his magnificient, now famous, collection of minerals,

The Peacock

specimens he had gathered from all over the world for the extraordinary optical phenomena they exhibited - limestones, marbles, alabasters, gypsums, tourmalines, agates, quartzites, jades, amethysts, fluorites, micas and serpentines, iolites malachites, lapis lazuli and feldspars.

Feldspars were truly intriguing - labrodorite, a special variety, displayed brilliant colours; another group, moonstones, found use in jewellery because of their beautiful optical effect called *schiller*. He continually leaned on his old experiences with scattering of light in liquids. For example he compared the blue *schiller* from the best moonstones he had with the blue opalescence in binary liquid mixtures as the critical temperature is approached; or the spectacular blue colour exhibited by many labradorites with the blue opalascence when water is added to methanol containing benzene in solution (when benzene tends to separate). He concluded that although in a common macroscopic sense these substances - moonstones and labradorites - were monocrystals, they had optical heterogeneities in them.



Raman's Collection of precious stones

Pearls

The gemstone which does not need the services of a lapidary to enhance its natural beauty. The precise understanding of the optics behind its loveliness was a matter of more than ordinary interest to Raman. He (and D. Krishnamurti) discovered that light falling normally on the rear surface does not travel through the pearl but around it (as does sound in a whispering gallery- a subject in which he had done much research), following the lamination of its structure. The beauty of the pearl is to be found in this effect, together with the superposition of the chromatic diffusion halo and also the reflected light. All these research efforts show Raman's inquisitiveness about his surroundings. He would understand the principles governing a phenomenon the hard way and present them in a way easily understood by everyone. He was a great influence on many young scientists who went on to become world renowned scientists later on.

His scientific endeavors were of the highest order and provided answers to some of the most important aspects of physics. He gave a great boost to the growth of Indian Science and continues to do so. On the 79th year of the discovery of Raman effect our younger generation should rededicate themselves to the great vision envisioned by Raman.

Picture courtesy:

C.V. Raman - A Pictorial Biography

Material Source - Prof. Ramasesan's Speeches during Raman centenary celebrations.