# SIXTH INTERNATIONAL CONFERENCE ON RAMAN SPECTROSCOPY AT BANGALORE—4-9 SEPTEMBER 1978

BANGALORE witnessed an occasion of historic importance to Indian Science when the Sixth International Conference on Raman Spectroscopy was held from 4th to 9th of September 1978. The five previous conferences in this series had been held at various centres in Europe and America. [The first conference was organised at Ottawa in 1969, the second at Oxford in 1970, the third at Reims (France) in 1972, the fourth at Brunswick (U.S.A.) in 1974 and the fifth at Freiburg (West Germany) in 1976.] To the scientific community throughout the world and particularly to us in India, this sixth Conference was of special significance for two reasons. First, it commemorated the Golden Jubilee of the discovery of the Raman Effect for which Professor C. V. Raman won the Nobel Prize in Physics in the year 1930. Secondly, the Conference was held at Bangalore where Raman himself had lived and worked for nearly 40 years. It was thus a fitting tribute to Raman and his lasting contributions to science that distinguished scientists from all over the world chose to meet at Bangalore this year for the sixth Conference.

On an occasion like this, it is not out of place to refresh our memory with the historical aspect of the discovery of Raman Effect. It was on the 28th of February 1928 that Prof. C. V. Raman carried out the crucial experiment which established the new phenomenon that now bears his name. This was the culmination of seven years of intensive effort by him and his students on the study of light scattering in the laboratories of the Indian Association for the Cultivation of Science, Calcutta. Raman discovered that the scattered light has a very weak component whose wavelength is slightly different from that of the incident light and that this change of wavelength is directly related to the vibrational energy of the molecules constituting the scattering material. Thus it provided another direct confirmation of the quantum nature of light and opened up a new and simple technique of studying the energy levels of molecules and crystals. The first complete scientific account of the experiments that led to the discovery was presented by Raman in a lecture entitled ' A New Radiation ' delivered at Central College, Bangalore, on 16th March 1928. Within a few weeks, the discovery was hailed all over the world. A number of papers dealing with Raman's observation were read at the French Academy of Sciences, the earliest of these being that of Y. Rocard who presented a paper on April 23, 1928 discussing several aspects of the new effect and suggesting amongst other things that the diffuseness of the lines found in the spectrum of benzene might be due to intermolecular fields. Soon afterwards, the American Physicist R. W. Wood sent a cable to ' Nature ', " I have verified Prof. Raman's brilliant and surprising discovery in every particular. It appears to me that this is a very beautiful discovery, which resulted from Raman's long and patient study of the phenomenon of light scattering ". The same year, Landsberg and Mandelstam in Moscow submitted a paper to ' Naturwissenschaften ' in which they described the Raman spectrum of crystalline quartz. The work of Landsberg and Mandelstam was probably independent of that of the Calcutta School, but, it must be said to their credit that these authors acknowledged that they had seen the report of Raman and Krishnan in ' Nature '. In August, Pringsheim in Berlin made a critical analysis of the processes involved ' in the new light scattering phenomenon ' and named it the Raman Effect. Raman was awarded the Nobel Prize for Physics in 1930.

Schools of Raman Spectroscopy were soon established at various centres throughout the

world. Until the early sixties, nearly all Raman spectroscopic studies were limited to the vibrational and rotational spectra of molecules and crystals. However, with the advent of the laser in 1960, an ideal and powerful source of light, highly monochromatic and well collimated, became available for Raman Spectroscopy. Consequently, it is now possible to study even very weak scattering phenomenon from minute samples, with the result that during the last fifteen years there has been a renaissance in this field.

Studies of excitations and phase transitions in crystalline solids, structural investigations of organic and inorganic substances, quantitative analyses of ionic equilibria and interactions, the elucidation of the conformational and environmental behaviour of macromolecules and their relationship to biological and living systems, detection and control of pollution are just a few examples of the recent wave of activity in this field.

In addition to these studies, which require only relatively low power lasers, many fascinating new Raman scattering processes have been discovered using intense laser sources. Above a certain threshold intensity of the laser, the stimulated Raman scattering may take place. In this case, the Raman scattered light also behaves as an intense, coherent, laser-like source whose frequency can be varied over a wide range by a suitable choice of scattering materials. Thus, the Raman Effect, in turn, has provided the new laser sources. Coherent anti-stokes Raman scattering (CARS) is another exciting and new development which promises to have many interesting and widespread applications. The inverse and hyper Raman effects are further unusual examples of non-linear Raman processes.

With the tremendous resurgence of interest in this field, it is not surprising that the need was felt to have a conference to exchange ideas and information, and therefore in 1969, the first International Conference was organised in Ottawa. However, unlike the previous conferences, the Bangalore Conference is a rather special one in that it is being held in the Golden Jubilee year of the Raman Effect. Partly because of this, an International Organisation Committee was formed with Prof. James R. Durig of U.S.A. as the Chairman and with members from six other countries, including India; and a National Organising Committee was constituted by the Government of India with Prof. M. G. K. Menon as the Chairman. The Conference had the generous support of the Government of India and also the sponsorship of the Indian Academy of Sciences, the Indian National Science Academy, the Indian Association for the Cultivation of Science, Calcutta, the Indian Institute of Science and a number of other organisations in the country. At international level the Conference was sponsored by the Royal Society, of which Raman was a Fellow and a Hughes medallist, the French Academy of Sciences of which Raman was an honorary fellow, the US National Science Foundation, three International Unions belonging to the International Council of Scientific Unions, namely, those of Physics, Chemistry and the Biological Sciences.

The meeting was attended by more than 300 participants from 26 countries, including U.S.A., U.S.S.R., U.K., France, Poland, West Germany and India. In addition, all the old students and colleagues of Raman were specially invited to attend the Conference. Nearly 45 invited talks and 260 contributed papers were presented at the Conference and these were grouped together into thirteen broad categories as follows:

1 Chemical applications
2 Applications in biochemistry and biology
3 Resonance Raman scattering
4 Intensities and depolarization ratios
5 Time dependent processes, reorientation and relaxation
6 Gases, flames and environmental analysis
7 Melts, liquids and solutions
8 Matrix isolation
9 Polymers.

10 Molecular and liquid crystals
11 Ionic crystals, metals and semi-conductors
12 Non-linear effects including stimulated and coherent anti-stokes scattering, and
13 New techniques.

The large variety of topics dealt with at this Conference and the depth of their coverage bear clear testimony to the current importance of Raman spectroscopy in the different branches of science and technology.

The Proceedings of the Conference, edited by Schmid, Krishnan, Kiefer and Shroetter runs to about 1,000 pages and is divided into two volumes. The proceedings were made available during the Conference.

The high standard of the deliberations and the rich scientific fare at this meeting were recognised by all the participants. To quote Professor James Durig, the Chairman of the Conference, " It was the finest meeting so far on Raman spectroscopy. The excellent arrangements and standards set here would be indeed hard to meet in future conferences elsewhere ".

The Conference opened with a welcome address by Prof. M. G. K. Menon and Dr. J. R. Durig and the historical session traced the history and development of Raman spectroscopy during the past fifty years. Dr. K. R. Ramanathan, a distinguished scientist and one of the earliest associates of Raman, reminisced about Raman's indefatigable zeal and enthusiasm for his scientific pursuits. He noted that the discovery of the Raman effect was the culmination of seven years of intensive efforts by Raman and his students in the study of various aspects of light scattering.

Dr. S. Bhagavantam, another distinguished student of Raman, vividly recalled his association with Raman for over four decades and presented a graphic portrait of Raman's scientific as well as human spirit. Dr. D. A. Long of the University of Bradford emphasized in his talk that the fundamental significance of Raman's discovery so excited the enthusiasm of scientists in France and elsewhere in Europe that even within the first few weeks after Raman's announcement of his discovery, several detailed investigations were carried out on a variety of systems using the Raman Effect. The fourth historical paper was by Dr. R. C. Lord, a distinguished Raman spectroscopist from U.S.A., who was unable to come. His paper, presented by Dr. F. A. Miller, described the early contributions of R. W. Wood and other scientists in U.S.A. in the field of Raman spectroscopy, and touched upon the developments of the post-laser era which have revolutionized this area of research in all its aspects.

Finally Dr. R. S. Krishnan, another associate of Raman, dwelt upon the recent progress in our understanding of the Raman spectra with particular reference to alkali halide crystals.

The historical session was followed by the presentation of invited and contributed papers devoted to the discussion of new results obtained using Raman spectroscopy in the different areas mentioned already. It is obviously impossible to summarise here the detailed findings of all of these papers. Only a few of the recent techniques and applications of Raman spectroscopy, that were highlighted at the Conference are mentioned here. Dr. C. K. N. Patel of the Bell Telephone Laboratories in U.S.A. described the development of the spin-flip Raman laser which has emerged as a very sensitive tool for high resolution spectroscopy. It is also applied in the detection and monitoring of atmospheric and stratospheric pollution. Dr. Bridoux from France described the recent advances in pulsed Raman spectroscopy which is another promising new technique. Used in conjunction with signal averaging and multichannel detection, it allows time and space resolved studies of samples even in trace quantities. The Raman microprobe technique is yet another new development which permits *in-situ*, non-destructive analysis of the spatial distribution of particles of microscopic size. Finally, the use of optical fibres and evanescent wave excitation, render it

possible to study samples which might otherwise suffer decomposition when illuminated by the direct laser beam. These developments have also been applied in several important areas of research, such as medical diagnosis and treatment, cancer cell metabolism, nucleic acids, structure of proteins, peptide conformations and biomembranes. Tranquilizers as well as other compounds of therapeutic interest have also been examined. The resonance Raman effect has been used to determine the oxygen saturation in whole human blood *in vitro*. Pulmonary function testing, intra and post operative monitoring, intensive care, determination of cardiovascular parameters, and occupational and sports medicine are some of the other areas, where new applications are being evolved. The petroleum industry is yet another area where Raman spectroscopy is finding new applications in determining the structure of liquid alkanes, polyethylene and paraffinic compounds. The flow properties as well as the constituents in gaseous flames are also investigated by Raman spectroscopy. The above developments are clearly indicative of the increasing importance of Raman spectroscopy in diverse areas of basic and applied research.

It is interesting to recall here Raman's own assessment of the importance of his discovery. To quote from his Nobel Prize lecture, "The Universality of the phenomenon, the convenience of the experimental technique, and the simplicity of the spectra obtained, enable the effect to be used as an experimental aid to the solution of a wide range of problems in physics and chemistry. Indeed, it may be said that it is this fact which constitutes, the principal significance of the effect. The frequency differences determined from the spectra, the width and character of the lines appearing in them and the intensity and state of polarization of the scattered radiations enable us to obtain an insight into the ultimate structure of the scattering substance".

It is thus an appropriate tribute to the prescient vision of this great Indian scientist that all his expectations are being realized now in ever greater measure.

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## INVITED LECTURES DELIVERED AT THE CONFERENCE

1 Stimulated Raman Effect and Coherent Raman Scattering by N. Bloembergen.
2 Spontaneous Raman, Coherent Raman and Infrared Spectroscopy in the Study of High Temperature Systems by I. Beattie.
3 Spin Flip Raman Laser and High Resolution Spectroscopy by C. K. N. Patel.
4 Application of Raman Spectroscopy to the Study of the Orientational Motion of the Molecules in the Liquids by J. Lascombe.
5 Raman Spectra of Matrix Isolated Materials by W. J. Orville-Thomas.
6 Progress in High Resolution Raman Spectroscopy by B. P. Stoicheff.
7 Polymers or Biological Molecules by W. L. Peticolas.
8 Applications of Normal Coordinate Calculations to the Study of Chain Molecules and Polymers by T. Shimanouchi.
9 The Theory of Resonance Raman Spectroscopy by W. Siebrand.
10 Raman Intensities of Charge Transfer Crystals by M. Ito.
11 Raman Scattering in Semiconductors by W. Richter.
12 Resonance Raman Spectra of Biological Materials: Approaches to Interpretation by P. R. Carey.
13 Determination of Acceptor *g*-values by Raman Spectroscopy by J. F. Scott.
14 Raman Spectra of Molecular Crystals formed of Simple Molecules by R. M. Pick.
15 Raman Spectra of Solid Inorganic Halide Complexes by J. Shamir.
16 Raman Spectral Studies of Ion-Ion and Ion-Solvent Interactions by D. E. Irish.
17 Raman Spectroscopy of Organic Compounds by B. Schrader.
18 The Application Possibilities of 3rd Order Non-linear Raman Effects as a Spectroscopic Tool for Chemistry by A. Lau.
19 Experimental Problems and Results in the Raman Spectra of Polymers by J. L. Koenig.