Codiscoverer of the soft mode, a soft-hearted man

An obituary of T. M. K. Nedungadi

Thodukattil Meletil Kadingi Nedungadi was born on 15 July 1914 in Nilayankot near Pattambi in Kerala. He had his early schooling in Calicut and joined Annamalai University in 1933, where he took a B Sc Honours in 1936. He then joined the Department of Physics, Indian Institute of Science, Bangalore, to work with Professor Sir C. V. Raman. His work in Bangalore was mainly on scattering of light and the Raman effect in crystals. He obtained the D Sc degree from Annamalai University (the first to do so) in 1942 for his thesis 'Investigations on the Raman effect in single crystals'.

Nedungadi was one among many of Raman's students who joined the India Meteorological Department (IMD). Soon after he joined IMD in 1942, he won a scholarship for higher studies in meteorology at Imperial College, London. He obtained the DIC diploma in meteorology from Imperial College, working with Professor David Brunt and Professor P. A. Sheppard. On his return to India in 1947 he served in different forecasting and training divisions of IMD, in Bangalore, Poona and Bombay; at the Astrophysical Observatory, Kodaikanal; and in the Indian Institute of Tropical Meteorology, Pune. His last posting in the department was as Director, Regional Meteorological Centre, Bombay. In 1967 he was selected as UN Meteorological Expert in Weather Forecasting and Training in Kuwait, serving in this capacity for five years from 1968 to 1973. On his return he settled down in Bangalore, keeping active in various cultural activities. He passed away on 9 June 1991 after a brief illness.

Of a very cheerful and friendly disposition, extremely helpful to all those who came in contact with him, generous to a fault, Nedungadi will be sorely missed by his large circle of friends, relatives and colleagues.

Scientific work

Raman launched upon a programme of using the Raman effect (immediately after its discovery) to study single crystals of diamond, which produced some very valuable results. However, he was quite unhappy that, in solids, attention was mainly centred around measurement of the principal Raman frequency. He therefore suggested to young Nedungadi when he joined him that he start detailed studies of all aspects of the Raman spectra of single crystals. In recalling Nedungadi's achievements in this field one must remember that his work was done more than fifty years ago and what may be commonplace knowledge today was really path-breaking in those initial stages.

Nedungadi studied the Raman effect in crystals of different symmetries—$NaNO_3$ (rhombohedral); quartz (trigonal); KNO_3, Rochelle salt (potassium sodium tartrate), benzophenone (all orthorhombic); and naphthalene (monoclinic). He grew large single crystals from melts by Bridgman's method or by the evaporation technique; cut rectangular blocks with edges parallel to the axes of the optical ellipsoid; recorded the Raman spectrum for different orientations of the crystal with respect to the direction of the incident radiation and the scattered radiation; and studied the polarization characteristics of the Raman lines.

He was among the earliest to show: (a) that the low-frequency Raman lines are characteristic of the crystalline state and disappear when the substance passes to the fluid or amorphous states; (b) the validity of the Placzek rules; (c) that the appearance or non-appearance of both the low-frequency oscillation and the internal oscillation are determined by the symmetry of the crystal and not by that of the individual molecules or ions; (d) that, when the electric vector in the incident radiation is parallel to the plane of the molecule, the planar oscillations appear strongly in the spectra; (e) that rotational oscillations of ions or molecules present in the crystal lattice give rise to the strong scattering of light and correspondingly to intense Raman lines; (f) that with increasing temperature the low-frequency Raman lines broaden and shift towards the exciting radiation in an unsymmetrical manner, but the internal oscillations are generally less affected by temperature because of the strong valence forces that control them.

Perhaps the most outstanding work for which Nedungadi will be remembered is the discovery of the so-called soft mode in the alpha–beta transformation of quartz. This he did along with Raman. Here, one clearly sees the touch of the master revealing itself. In quartz, as the temperature is raised, the 220-cm^{-1} line behaves in an exceptional way, spreading out greatly towards the exciting line, and becoming a weak and diffuse band as the transition temperature is approached. However, the other intense lines, with smaller and larger frequency shifts, continue to be easily visible, though appreciably broadened and displaced.

To quote from the paper of Raman and Nedungadi (*Nature*, 1940, **145**, 147): 'The increasing excitation of this mode of vibration with rising temperature and the deformation of the atomic arrangement resulting therefrom are in a special measure responsible for the remarkable changes in the properties of the crystal. . . as well as for inducing the transformation [of quartz] from the α to the β form.'

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Edited and published by Prof. S. Ramaseshan, Current Science Association, Bangalore 560080.
Typeset by Book Makers (I) Pvt. Ltd., Bangalore 560009. Printed at Printek Printers, Bangalore 560079