partments between one subject and another and this was to be seen in his lectures drawing analogies from one discipline to another.

I do not remember a single occasion when Professor talked with me anything other than academic problems. When we were discussing some problem, he received the day's dak which contained a letter from Professor V. M. Goldtschmidt that he would accept an assignment in the Institute. A letter from a top scientist in the Siemens had also been received indicating that he too would accept an assignment in the Institute. Professor was perhaps in contact with a number of others also.

His encouragement to beginners was unsurpassed. One day when I told him that I had found the explanation of the Raman line in diamond which had been mentioned by him as an outstanding problem in his Nobel address, he asked me what it was. I said that the Raman line was to be attributed to the mutual vibration of the two face-centred lattices composing the diamond lattice ; he simply yelled out, "You are right, you are right," and insisted that the research paper should be immediately written up. He was in ecstasy over this work. I found myself elected to the Fellowship of the Indian Academy of Sciences at the age of 23 years of which Professor had given no inkling to me.

One day, Parthasarathy was to give an account of the determination of the velocity of sound in organic liquids by the method of diffraction of light by ultrasonic waves. Hardly had he finished the description of the experimental set-up, than Professor raised the query —What is the number of diffraction orders expected on the basis of Brillouin's theory ?— The reply was two first orders of weak intensity. What was the fact, was the next query. A number of diffraction orders not in agreement with the theory. Professor went to the board and said that the theory should be developed in a different way. A sound wave creates compressions and rarefactions. A light beam would be slowed in the region of compressions and it would move faster in the region of rarefactions, and so a plane wavefront would become a corrugated wavefront like a zinc sheet used for building purposes. Professor said that an analysis of this corrugated wavefront would explain the unexplained results. When I went to him next day giving an explanation of the results on the basis of his ideas, he said it was all correct and that started a series of papers by him and myself which has come to be known in literature as Raman-Nath Theory. Though his outlook was essentially that of an experimental physicist, he would insist on the physical significance of every theoretical result. He had a stock in trade of certain physical results and he would liberally draw on them to explain results in a different subject altogether. Once Professor Max Born exclaimed, "He leaps over Mathematics.'

In November 1969, he and Lady Lokasundari Raman were graciously pleased to attend the marriage reception of my daughter. Professor drew me aside outside the reception hall and told me for nearly half-an-hour that his latest problem was to give a proper theory of earthquakes. The present theories were based on models which were highly deficient as they did not properly take into account the shape of the earth and the wave nature of the disturbance.

The blue of the sky, the blue of the sea, the colours of shells, the colours of flowers, the music of pianoforte string, the music of the Indian musical drum, molecular vibrations, diamond and its properties, crystals, nature of vision, make a gamut of beautiful things which he pursued, and so long as these beautiful things are there, Professor's name will always be there to guide further work. Truly it can be said of his motto in life—

'Beauty is truth, truth beauty'—that is all
Ye know on earth and all ye need to know.
(KEATS).

THE RAMAN-NATH THEORY

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IT is scarcely possible in an article of this type to do full justice to Professor Raman's monumental contributions to Optics and Diffraction which extended over a period of six-and-a-half decades. We shall, therefore, confine our attention to an aspect of his work carried out in Bangalore between the years 1935-1937.

In 1932, Debye and Sears[1] in the United States and Lucas and Biquard[2] in France described some beautiful experiments on the diffraction of light by ultrasonic waves in a liquid. A parallel beam of monochromatic light is incident normally on a rectangular cell containing a liquid. If the liquid is traversed by ultrasonic waves generated by a quartz oscillator placed at the top of the cell, diffraction spectra are seen in the transmitted beam, similar to those produced by an ordinary ruled grating, the diffraction maxima satisfying the condition $\sin\theta = \pm n\lambda/\lambda^*$, where λ and λ^* are respectively the wavelengths of the incident light and the sound waves in the medium.

These experiments were suggested by a theory given earlier by Brillouin of the scattering of light by thermal waves in a homogeneous medium. The thermal waves give rise to periodic stratifications in the refractive index, so that the light scattering may be looked upon as a Bragg reflexion. The velocity of the waves produces a small Doppler shift in the frequency of the scattered light. In fact, Raman and his co-workers applied this technique to investigate the dispersion of hypersonic velocities in liquids at very high frequencies. Their measurements provided the first conclusive evidence of the existence of a rigidity modulus in *ordinary* liquids at these frequencies, a result which had an important bearing on molecular theories of the liquid state.[3]

The diffraction by artificially generated elastic waves, however, turned out to be a much more complex phenomenon, and it was clear that the elementary theory of the optical grating did not suffice to explain the observations. The intensities of the higher order spectra were considerably greater than expected from the simple theory. Furthermore, the intensity distribution in the different spectra varied in an irregular manner with the change of wavelength and direction of the incident light, as also with the change of amplitude of the sound wave. Debye and Sears[1] at first attempted to explain the higher orders as due to overtones in the quartz crystal. Theories were proposed by Debye,[4] Lucas and Biquard[2] and Brillouin,[5] but none of them accounted for the intensities of the higher orders and their variations under different experimental conditions.

In 1935, Raman and Nagendra Nath[6] put forward an elegant explanation of the phenomenon which at once proved to be a spectacular success. In his treatise on *Ultrasonics*,[7] Bergmann wrote of this theory: "It was a great achievement on the part of Raman and Nagendra Nath when they succeeded in clearing up the greater part of these phenomena, some of which are very complex, in several of their publications...." The basic idea underlying the Raman-Nath theory is that the sound wave acts as a pure *phase* grating so that the emergent optical wavefront is corrugated. This idea at once led to quantitatively satisfactory values of the intensity distribution of the spectra and of the Doppler shifts in the frequency of the diffracted light.

There has been continued interest in the theory because of the large number of applications of the effect in technology and industry. (A full list of references to such applications can be found in Section 10.2 of the annual indexes to the *Journal of the Acoustical Society of America*.) Various refinements of the theory have been developed in subsequent years. A notable contribution was that of Bhatia and Noble,[8] who derived a general and rigorous electromagnetic treatment of the phenomenon. Despite the formal rigour of these later treatments, it is clear from recent publications[9,10] that, in practice, the Raman-Nath equation still offers the best method of computing the intensities of the spectra.

The idea of the phase grating has been used in the theory of scattering of high energy particles by a central force (*see, e.g.*, ref. 11) and also in the interpretation of polarized diffraction patterns from cholesteric liquid crystals.[12]

1. Debye, P. and Sears, F. W., *Proc. Nat. Acad. Sci.* (Washington), 1932, 18, 409.
2. Lucas, R. and Biquard, P., *J. de Phys. et Rad.*, 1932, 3, 464.
3. Frenkel, J., *Kinetic Theory of Liquids*, Dover, New York, 1955.
4. Debye, P., *Phys. Z.*, 1932, 33, 849.
5. Brillouin, L., "La Diffraction de la Lumiere par des Ultrasons," *Act. Sci. et Ind.*, 1933.
6. Raman, C. V. and Nagendra Nath, N. S., *Proc. Ind. Acad. Sci.*, 1935, 2 A, 406, 413; 1936, 3 A, 75, 119, 495.
7. Bergmann, *Ultrasonics*, Bell (London), 1938.
8. Bhatia, A. and Noble, W. J., *Proc. Roy Soc.*, 1953, 220 A, 356.
9. Berry, M. V., *The Diffraction of Light by Ultrasound*, Academic Press, London and New York, 1966.
10. Leroy, O., *Proc. Ind. Acad. Sci.*, 1971, 73 A, 109.
11. Moliere, G., *Z. Naturf.*, 1947, 29, 133.
12. Chandrasekhar, S. and Shashidhara Prasad, J., In *Physics of the Solid State*, Academic Press, London and New York, 1969, p. 77.