Pancharatnam in Mysore

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WHEN Mysore University was started, the post-graduate departments in various sciences were located in Central College, Bangalore and all the arts and humanities departments in Maharaja's College, Mysore, which was also the capital of the princely state. In 1960, post-graduate departments in the sciences including physics were also started in Mysore as a prelude to the subsequent bifurcation of Mysore and Bangalore universities. But it was only in May 1961 that the physics faculty was appointed with S. Chandrasekhar as the professor and head and D. Krishnamurti and S. Pancharatnam as readers.

By the time I joined as an M Sc student in the third batch somewhat late in 1962, the new department was practically 'established' in the sprawling Jayalakshmi Vilasa Mansion which was once the residence of a close relative of the Maharaja. It was the centre for the new Manasa Gangothri campus of the university which was being developed. The foundations of the new blocks of the various departments had already been laid and the buildings were slowly coming up. The department of physics was temporarily housed in the first floor of a not-so-glamorous 'backyard', part of the palace, which perhaps was used by the supporting staff in its non-academic phase.

I joined the course a little late during the year and the classes had already started sometime earlier. The seniors (six in number) and juniors (seven in number) were clubbed together during the lecture time as there was only one classroom. It was quite an unusual experience on the first day to start it with a prayer – a few *slokas* from the *Bhagavad Gita* – following a tradition started by the first batch of students two years earlier. Shortly after the prayer was over, a young man with a pleasant face and khaddar dress walked in and recognizing a new face asked me my name and advised me to catch up with the portions that I had missed by looking into the notes of my classmates. Pancharatnam was giving his course on classical mechanics. He started discussing some aspects of the mechanics of a rigid rotator in the form of a general triaxial ellipsoid. The lecture was delivered in a measured tone and illustrated with relatively neat diagrams drawn on the board. It lasted for two hours, at the end of which he took out a small piece of paper from his shirt pocket in which he had apparently noted the main points he intended to cover in that class. Having satisfied himself that he had indeed done so, he asked if there were any questions. There was none and he returned to his room, or rather to his desk in a room which he shared with other staff members.

As others had done before me, I quickly realized that Pancharatnam was indeed a unique person. He was rather serious about whatever he did. As a teacher of the theoretical physics course, he would start from simple physical arguments and develop the subject in a meticulous fashion. After the course on classical mechanics, he moved on to optics. He obviously enjoyed lecturing about this topic in which he had made many significant contributions. Electromagnetic theory, interference, diffraction, crystal optics – the subject was developed in great detail and with much gusto. I remember particularly the Poincaré sphere representation of the polarization of light, which was not described in the normal textbooks on optics. This representation is very useful to visualize the propagation of a polarized light beam through anisotropic media[1]. I recall that it became very useful for me later when I was trying to understand the propagation of light through a nematic liquid crystal medium having a weak twist distortion produced by an external field. As the birefringence of the medium is usually quite large ($\Delta n \simeq 0.1$–0.2), the twist angle per layer is much smaller than the optical phase difference between the ordinary and extraordinary waves. If we follow on the Poincaré sphere the propagation of a linearly polarized beam, incident with its polarization direction parallel to a principal axis at the front layer, it is easy to see that the trajectory remains close to the equator, i.e. the light remains linearly polarized. Further, its azimuth just follows that of the principal axis of the liquid crystal. This is known as the Mauguin criterion and follows from the adiabatic theorem. It is clear that if we have fixed boundary conditions, the twist distortion in the medium cannot be detected by an optical beam traversing the sample in this manner[2]. However, if the effective phase difference is lowered by viewing the sample at an appropriate oblique angle, this problem can be overcome. In the Poincaré sphere, the trajectory moves away from the equator, and the emergent light beam becomes elliptically polarized and hence the twist deformation can be detected optically. We devised a simple experimental technique of measuring the twist elastic constant using these ideas[2].

In the early sixties there were very few motor vehicles plying the streets of Mysore. One either used a bicycle or a whimsical public bus system. Pancharatnam had one of the few motor vehicles one saw on the campus – an 'army' motorcycle with its own distinctive sound. I remember that hearing it made us on more than one occasion to revise our thoughts about slipping off early in the afternoon, when we were supposed to be using the departmental library. Pancharatnam took a lot of interest in teaching his course. Occasionally he would set us some problem connected with his lectures and would expect us to work out the answer and show it to him. We were encouraged to ask questions after every class. I remember that after one of my seniors gave a seminar on zone plates, I asked if the aberrations in the image produced by such a plate were worked out. It appeared that they had not been. Pancharatnam asked me to work them out, which of course I did not attempt in spite of a couple of reminders by him. He was also very much interested in inculcating in us a healthy respect for the important contributors to the development of physics. When Niels Bohr died, Pancharatnam spent a considerable part of his class eulogizing him apart from asking us to stand in silence for a few minutes as a mark of customary respect to the departed soul.

At one stage in the academic year he was laid up with typhoid fever. When some of us went to his room to enquire about his health, we found him somewhat weak but busy reading some papers. He advised us to read books on optics and to finish some laboratory experiments. He started coming to the department after a while. On the first day he sent for two of us. We approached him with a sense of trepidation as both of us were responsible for breaking a minor piece of equipment while doing an experiment during his absence. In the event, it turned out that he had called us for seeking some help. Though the doctor had asked him not to strain himself, his dedication to his work was so strong that he had decided to resume teaching. He had written down all the required equations and figures on some sheets of paper and asked us to reproduce them on the black board so that he could sit in a chair and teach. We had to bring in an extra blackboard to write down all the equations and figures. This mode continued for a couple of weeks by which time he regained enough strength to take his usual two-hour class standing on his feet.

By the time I became a student, the general M Sc laboratory was fairly well established, though with relatively simple, often home-made equipment. (Some of the equipment had also been borrowed from other institutions.) We were supposed to set up experiments after consulting books on experimental physics. Spectroscopy was the only special subject being taught at that time. Krishnamurti had left the department in the meantime (he was to rejoin it after some years) and Pancharatnam would come to the laboratory once in a while to check if we were doing the right things. He had obviously put in considerable effort to set up the laboratory. I learnt that at first they had to use a pair of blades to form a slit, as the latter was missing from an old spectroscope which they could get. On several days when we went to the laboratory in the morning, we could see him taking readings on a torsional pendulum as he was trying to set up a new experiment.

Apart from his contributions to the establishment of the new post-graduate department, Pancharatnam continued his researches in optics while at Mysore and wrote two important papers[3,4]. In these he generalized his earlier work on partial polarization and partial coherence of monochromatic light to polychromatic light. He starts these papers by pointing out that in general the detector (like the eye for example) has a response which may vary rapidly with the frequency of light and as such the mean square of the total electric field is not an appropriate parameter to characterize the beam (for a discussion of the rapid variation of the characteristics of a light beam with frequency, see the article by V. Radhakrishnan, this issue). He emphasizes the need for developing the basic theory using the spectral representation. He then discusses the problem of partial polarization in his first paper[3], generalizing the statistical properties of light to incorporate the spectral distribution. In particular he shows that the macroscopic state of any polychromatic beam can be characterized by four Stokes *spectral functions*. He discusses the inadequacy of using the usual Stokes *parameters* to characterize quasi-monochromatic beams, and points out that parameters integrated over the spectral functions may be adequate in some situations. He also shows that it is possible to define a spectral coherency matrix whose elements are linear combinations of the Stokes spectral functions, and hence offer another scheme for characterizing polychromatic radiation.

In the next paper, he extends these arguments to a discussion of the interference of polarized polychromatic beams with large path retardations. A spectral coherence function is defined in terms of an appropriate ensemble average of the relevant parameters at the given Fourier component of the interfering beams. He then discusses the interference of quasi-monochromatic beams under large path retardation in both non-dispersive and dispersive media. In the latter case, the degree of coherence between the two interfering beams depends on the relative time retardation reckoned in terms of the group velocity. This fact is used to explain the early observations of R. W. Wood that the path difference for which two-beam interference can be observed can be increased considerably if one of the beams passes through a dispersive medium, as the group velocity is smaller than the phase velocity. In white light interference, a dispersive element in one arm allows one to see a large number of fringes for the same reason. He also discusses the occurrence and visibility of Talbot's bands which are seen when half of an entrance

Photograph taken in 1963 of the 1962–1964 batch of MSc students with the staff members of the Physics Department, University of Mysore. *Front row (from left to right)*: Venkatanarasimhiah, Pancharatnam, Chandrasekhar, Subrahmanyam, Sanjeeviah. *Middle row*: Appajigowda, Madhusudana, Narayanan, Krishnamurthy, Srinivas. *Back row*: Venkataram, Puttabasaviah, Subbaramiah, Hanumanthappa. Photograph courtesy of Prof. K. S. Krishnamurthy.

rectangular slit placed in front of a grating is covered by a phase plate like glass. It is also mentioned in the paper that these ideas can be extended for the general case of partially coherent interference of two polychromatic beams which are *not* completely polarized, and would be considered in a later paper. It does not seem that this generalized theory was written up.

Pancharatnam's dedication to his work, whether teaching in the classroom, or setting up experiments or conducting his research, coupled with his Gandhian simplicity of personal life made a deep impact on us. Hence it was indeed disappointing for us to learn that he would be leaving the Mysore University to pursue his research work in the UK: it meant that we would miss his whole theoretical physics course. Apart from the topics mentioned earlier, he had covered in this course given to our seniors classical and quantum statistics, quantum mechanics and thermodynamics.

It was customary those days to have 'class socials' near the end of the M Sc course in which the students and teachers would have a social get-together. Though the academic year was not yet half way through, we thought that we should have the 'social' event when Pancharatnam was still around. As we learnt that he would be leaving the department in just about a week or so, we approached him to fix a date. He casually said: 'I am getting married tomorrow. The day after tomorrow suits me.' In his brief speech at the socials, he advised us to be dedicated to our studies.

After our M Sc results were announced, we wrote him a letter thanking him for his efforts in teaching us. I also mentioned that I had become a demonstrator in a local college. He promptly replied, and wrote that he was setting up some experiments and asked me to think of taking up research work.

It was indeed shocking for all of us to learn about his untimely death in 1969. A gold medal has since been instituted in Pancharatnam's memory in the Mysore University to be awarded every year to the best physics student. I am indeed personally fortunate to have had the privilege of coming under the influence of a man of his stature at a crucial stage in my education.

1. For a detailed description of the Poincaré sphere, see Ramachandran, G. N. and Ramaseshan, S., *Crystal Optics, Handbuch der Physik*, Springer-Verlag, 1961, vol. XXV, p. 1.
2. Madhusudana, N. V., Karat, P. P. and Chandrasekhar, S., *Pramana*, Supplement **1**, 1973, 225.
3. Pancharatnam, S., *Proc. Indian Acad. Sci.*, 1963, **A57**, 218.
4. Pancharatnam, S., *Proc. Indian Acad. Sci.*, 1963, **A57**, 231.