

RAMAN RESEARCH INSTITUTE

BANGALORE

ANNUAL REPORT-1982-83

Introduction

The Raman Research Institute founded by Prof. C. V. Raman in the late forties was reorganised, after his death in 1970, as a national Institute for research in basic science and it has been receiving generous grants from the Department of Science and Technology of the Government of India since 1972. The main fields of research are Liquid Crystals, Astronomy and Astrophysics.

1. Liquid Crystals

Liquid Crystals are states of matter intermediate between the liquid and crystalline states. Many organic compounds whose molecules have pronounced shape anisotropy exhibit such phases. The unique combination of fluidity and anisotropic properties of liquid crystals has led to many applications of these materials. The Liquid Crystals Laboratory of the Raman Research Institute has contributed significantly to the development of the field over the past decade.

The laboratory has been organised to undertake studies on most of the fundamental properties of liquid crystals. Theoretical and experimental work on liquid crystals is continuing along the lines indicated in the previous year's report.

The Ninth International Liquid Crystals Conference was held during December 6-10, 1982 and about 300 scientists from 30 countries participated in the conference and over 350 papers were presented.

2. Astronomy and Astrophysics

Astronomy which is one of the oldest sciences is concerned with the study of heavenly bodies by investigating the radiation received on earth from them. Optical astronomy deals with the "visible" part (wavelength 3000 Angstroms to 6500 Angstroms, 1 Angstrom = 10^{-8} centimeter) of the electromagnetic spectrum. Radio Astronomy, which had its beginnings in 1932 also deals with the study of these heavenly bodies, but the radiation received by radio telescopes on earth is in the radio wavelength part (30 metres to 1 millimeter) of the same electromagnetic spectrum. The lower and upper limits in wavelength of the radio spectrum are set by the earth's atmosphere and ionosphere respectively. In spite of these limitations, the radio window is very wide (30,000 to 1 compared to the 2:1 wavelength ratio in the visible part) and studies within it over the years have yielded information leading to some exciting discoveries such as the 3°K cosmic background radiation, quasars, pulsars, etc.

The Institute has set up a Decameter Wave Radio Telescope at Gauribidanur jointly with the Indian Institute of Astrophysics. It is among the largest telescopes in the world. It consists of two long antenna arrays; one oriented in the E-W and the other in the N-S direction of lengths 1.5 KM and 0.5 KM respectively. Operating at a wavelength of ten meters, the telescope can resolve objects whose angular separation is about 25 arc minutes in the sky. It is being used to study radio

emissions from various types of celestial objects such as the Sun, Jupiter, our galaxy and external galaxies. The Sun emits intense radio bursts very frequently. Observations of the characteristics of these radio bursts give valuable information on the structure of the solar corona. Moving further out in our galaxy, we have the so-called ionised hydrogen regions, which are the birth places of stars. The Decameter Wave Radio Telescope is a very sensitive instrument for detection and study of such ionized hydrogen regions. These are just two examples of the kind of studies carried out with this telescope.

During the past decade, millimeter wave astronomy has assumed great importance because of the discovery of several molecules (combinations of Hydrogen, Carbon, Nitrogen, and Oxygen atoms) by their emitted line radiations in the millimeter wave part of the electromagnetic spectrum. These molecules are generally found in dense molecular clouds in our Galaxy where star formation is thought to be taking place. Hence, studies of the radiation from them should lead to an understanding of the nature and mechanism of star formation.

The Raman Research Institute is currently engaged in constructing a telescope to do advanced research in millimeterwave astronomy. The wavelength of operation will be a few millimeters. This puts a stringent requirement on the accuracy of the surface of the reflector which forms a major part of the radio telescope and will be of diameter 10.4 meters. The Institute is also engaged in building very sensitive receivers to operate in this wavelength band. This whole effort will help in the generation of technological know-how which has not been available in India hitherto.

The Ooty Radio Telescope operated by the Tata Institute of Fundamental Research was used for pulsar observations, recombination line observations, etc., by members of the Institute's staff.

As reported last year, there are also theoretical research programmes in the fields of ionic crystals, maximum entropy method, pulsars, supernova remnants, general relativity and gravitation.

A somewhat more technical account of the research carried out in the past year by the various groups in the Institute is given in the following.

Liquid Crystals

Theoretical and experimental work on liquid crystals is continuing along the lines indicated in the previous year's report. Some of the more important results obtained during the current year are summarized below.

I. Theoretical Studies

Theory of defects in cholesterics and nematics.

The structure of defects in cholesterics has been reexamined from the view point of the coarse-grained' approximation. The theory indicates that the smectic A-type edge dislocations are energetically more favourable than the so far proposed nematic type twist disclinations. The clustering of defects, which is frequently observed, follows as a natural consequence of the theory. The problem of slow motion of defects in nematics has also been studied in the linear approximation and it has been found that single disclination motion is affected greatly by the motion of other disclinations.

Homogeneous instability under free convection in a nematic.

Homogeneous instability (HI) under free convection in a flow aligning nematic (such as MBBA) has been solved exactly, including the effect of secondary flow. It is also shown that HI may be observable in a non-flow aligning nematic (such as HBAB) under the joint action of a stabilising shear and a destabilising magnetic field of strength greater than the Freedericksz threshold, the magnetic field being applied normal to the initial orientation of the nematic director.

Molecular statistical theory of nematics.

The scaled particle theory of a system of spherocylinders with a superposed attractive interaction has been extended to derive various thermodynamic properties of nematics at high pressures. The experimental results are reproduced reasonably well by the theory.

Field induced nematic-paranematic critical point.

This is a problem that has attracted several experimental and theoretical investigations in recent times: it has been suggested by us that the only feasible method of attaining such a critical point may be to subject a material with strongly polar end groups to electric fields. Calculations have been made using the constant coupling approximation and taking into account the antiparallel correlations between neighbouring molecules.

Local field in a skew-cybotactic nematic.

A model has been developed to calculate the tilt angle dependence of the anisotropic local field of a nematic liquid crystal with a skew cybotactic type of short range order. It explains the unusual result, discovered in our laboratory, that the ordinary refractive index n_0 in such a material, decreases with decrease of temperature. The model is now being extended to calculate the dielectric properties of such materials: experimentally it is found that the dielectric anisotropy of such a system reverses sign, becoming negative at high temperatures, a result which is contrary to usual experience.

II. Experimental Studies

The smectic A-nematic transition.

It is now well known that there is a formal analogy between the smectic A-nematic (AN) transition and the superconductor-normal metal transition. One of the remarkable consequences of this analogy is that a *curl n* type of distortion (which is equivalent to a magnetic field in the superconductor case) should depress the AN transition point. A quantitative measurement of this effect has been made by us for the first time.

Bilayer smectics.

About a decade ago the idea was put forward by us that molecules with strongly polar end groups should have antiferro-electric short range order. This idea is now

well established and it is recognized that such correlations lead to many interesting effects such as reentrance, smectic A polymorphism, etc. We have now found unusual new compounds with cyano and nitro end groups synthesized in our laboratory, *viz.*, a very strong ($\sim 25\%$) thermal contraction of the layer spacing, a reversal of dielectric anisotropy as a function of temperature and in two cases a smectic A-smectic A transition in which the layer spacing changes discontinuously.

High strength disclinations in nematics.

Ever since the discovery of liquid crystals, only disclinations of strength $\pm 1/2$ and ± 1 have been observed in nematics, since defects of higher strength cost higher energy. We have recently found stable defects of strength $\pm 3/2$ and ± 2 in nematic mixtures containing plate-like molecules. Detailed investigations of these high strength defects are in progress.

High pressure studies.

Of late, multicritical points in liquid crystalline systems are of considerable interest. Our pressure studies have led to the discovery of a new kind of multicritical point, *viz.*, the reentrant nematic-smectic C-smectic A (RN-C-A) point. A high precision study has shown that the topology of this multicritical point is quite different from that of the NAC multicritical point which has been observed in the temperature-concentration diagram of some binary liquid crystal systems.

Pressure studies on compounds exhibiting the reentrant nematic phase is being continued. The results show clearly that the maximum pressure of smectic stability (P_m) is related to the nematic range (R) at atmospheric pressure by the relation $P_m = P_0 \exp(-mR)$, where P_0 and m are constants which depend on the molecular structure.

Effect of pressure on monolayer as well as partially bilayer smectic A phases has been studied. It is found that the behaviour of the two types of A phases is very different showing thereby that the pressure behaviour of the A phase depends on the extent of the interdigitation of the molecules.

Dielectric studies.

Dielectric measurements are being continued as they serve as a powerful tool for studying molecular associations in the different phases. Two interesting results that have emerged are that (a) the reversal of the sign of the dielectric anisotropy from positive to negative with decreasing temperature can occur in pure nematogens, and is not a consequence of the appearance of the smectic phase at lower temperatures as has been claimed previously by some authors; (b) the dielectric properties of mixtures exhibiting the reentrant nematic phase are strongly influenced by the smectic-like short range order in the nematic, the effect being more pronounced close to the critical concentration at which the smectic phase makes its appearance.

The crystal and molecular structures have been determined for two important compounds, one a re-entrant nematogen and the other a cyanobiphenyl compound. In each case the molecular packing gives an indication of the characteristic mesomorphic behaviour of the compound.

III. Applications

Several recipes have been developed in liquid crystalline mixtures which can be used with multiplexed displays. A compact 32 character multiplexed alphanumeric display with the necessary addressing circuits has been fabricated. A new hybrid addressing scheme has been proposed which combines features of the usual Alt and Pleshko scheme and the binary addressing scheme proposed by us some time ago.

NMR Work

The fact that in mixtures of liquid crystals of opposite diamagnetic anisotropy two spectra coexist at a critical concentration and temperature has been used for various investigations. The couplings (indirect and direct) between ^1H and ^{77}Se in phenylselenyl halides could be obtained thus enabling the deduction of the molecular structure. Using the example of 2,6-dichlorophenol, it has been shown that in certain cases more reliable spectral parameters can be obtained if both the spectra at coexistence are analysed simultaneously. An attempt is being made to understand and rationalise the discrepancies that arise in the measurements of chemical shift anisotropies using different methods.

A Landau type theory for the switching transition observed in the NMR experiments using two liquid crystals of opposite diamagnetic anisotropy has been developed. It gives a very satisfactory description of the transition as a function of the relative concentrations of the liquid crystals.

The molecular structures of pyridine-*N*-oxide, halofluorobenzenes and several bicyclic compounds have been obtained. It has been demonstrated that the polarization of the C-H and C-halogen bonds plays an important role in determining the internuclear distances in halofluorobenzenes.

Theoretical Physics and Astrophysics

1. *Variable polarisability in ionic crystals:*

It has been shown that the refractive index data on families of simple ionic crystals are not consistent with constant polarisabilities (α) for the individual ions. A model with constant α_+ for cations and variable α_- for anions, of the form $\alpha_-^\infty \gamma \eta$ where γ is the nearest neighbour distance and η is a parameter, gives significantly better agreement. We find $\eta = 0.26$ for halogen ions and $\eta = 0.9$ for chalcogen ions.

2. *Theory of ionic crystals:*

The semi-empirical theory of repulsion developed earlier by Narayan and Ramaseshan has been simplified to facilitate routine applications to a variety of ionic crystals. The repulsion parameters of a number of ions, notably divalent cations and anions, have been refined from crystal data. The relative stability of AB_2 crystals in the competing fluorite, rutile and cadmium iodide (chloride) structures, is being investigated. It appears that a fully ionic theory could explain the occurrence of AB_2 halides in the layered cadmium iodide structure.

3. *Rare gas crystals:*

Repulsion parameters of rare gas atoms have been deduced from the properties

of neighbouring monovalent and divalent ions in the periodic table. These parameters fit the experimental lattice spacings and compressibilities of rare gas crystals. Using a simple quantum theory of thermal effects (Einstein approximation), the temperature variations have also been calculated and are in good agreement. The theory predicts certain instabilities at high temperatures which might be relevant for a theory of melting.

4. Molten ionic salts:

A theory of molten ionic salts was attempted in analogy with ionic crystals. The Coulomb, van der Waals and repulsion interactions in molten NaCl were computed in terms of the experimental partial radial distribution functions. A thermal term was also included and the free energy was minimised as a function of density. The calculated equilibrium density is encouragingly close to the experimental value.

5. Maximum entropy method for polarised brightness:

In the maximum entropy method of reconstructing a brightness distribution \mathbf{B} , we recently showed that a whole family of functions $f(\mathbf{B})$ can be used in place of the usual choices $f = \ln \mathbf{B}$ and $f = -\mathbf{B} \ln \mathbf{B}$. We have now shown that for polarised brightness distributions \mathbf{B} , the integral of the trace of $f(\mathbf{B})$ is the "entropy" that should be maximised. We have derived an expression for the gradient of the entropy which can be used in numerical iterative schemes. We have also proved that the solution is unique when $f'' < 0$.

6. Relative orientations of rotation axis $\vec{\Omega}$, Magnetic axis $\vec{\mu}$ and line of sight \vec{L} in pulsars:

Accurate polarization observations on sixteen pulsars obtained by Backer and Rankin have been analysed within the framework of the Radhakrishnan-Cooke model to determine the angles α (between $\vec{\Omega}$ and $\vec{\mu}$) and β (between $\vec{\mu}$ and \vec{L}). The angles are estimated for various groups of pulsars using (a) the shape of the linear polarization position angle curve within the pulse, (b) the maximum gradient of the position angle in the pulse, and (c) the magnitude and sign of the maximum gradient within the interpulse. We find that the line of sight is as likely to lie between $\vec{\mu}$ and $\vec{\Omega}$ as beyond $\vec{\mu}$. This is contrary to certain pulsar theories which predict that \vec{L} should always lie between $\vec{\Omega}$ and $\vec{\mu}$.

7. Evidence for evolving elongated pulsar beams:

Analysis of the Backer-Rankin polarization observations on sixteen pulsars within the RC model framework shows that pulsar radio beams are on the average 3.0 ± 0.4 times longer in the North-South direction than in the East-West direction. By including previous polarization observations on other pulsars we find that the elongation evolves with period approximately as $P^{-0.65}$, and appears to have little relation to the period derivative \dot{P} . An independent analysis incorporating the inherent spherical effects confirms these results. The evolution of beam elongation explains the observed variation of interpulse occurrence with P . It also modifies the "beaming fraction" to 0.53 and consequently affects estimates of pulsar birth rate.

8. *A model for PSR 0950 + 08:*

A model has been proposed for PSR 0950 + 08 in which the radio beam is highly elongated. The angular separation between the magnetic and rotation axis is small, so that the "northern" part of the beam straddles the rotation axis and extends beyond it on the other side. In this model, the main and inter-pulse arise from the same beam and this helps to resolve many of the puzzling features observed in PSR 0950 + 08.

9. *The millisecond pulsar:*

It has been proposed that the very recently discovered millisecond pulsar may have been born and processed in a mass transfer binary. This scenario predicted an extremely low value for the period derivative $\dot{P} < 6 \times 10^{-19} \text{ ss}^{-1}$, in excellent agreement with the recently measured value of $\dot{P} \approx 2 \times 10^{-19} \text{ ss}^{-1}$.

10. *Interpulse in the millisecond pulsar:*

The prominent interpulse of the new millisecond pulsar is consistent with very short period pulsars having fan-like beams, as suggested by an earlier and independent study. It is shown that all the available data on interpulse statistics support this picture, and also indicate that pulsars with perpendicular rotation and magnetic axes are absent at long periods.

11. *Pulsars and supernova remnants:*

The implications of the recently discovered x-ray and radio pulsar in the supernova remnant MSH 15-52 were explored. The luminosity of the x-ray nebula surrounding this pulsar, and the absence of any radio emission, was found to be consistent with a rather long initial-period for the pulsar ~ 70 ms. This gave further support to the long line of arguments which suggest that most pulsars may be born spinning slowly, contrary to conventional wisdom.

12. *Multiple scattering by gravitational lenses:*

The unusually large angular separations in the three known cases of gravitational lensing coupled with the non-detection of any lensing galaxy in two of the cases suggest that multiple lenses may be involved. We have considered the case when lenses are strongly clustered and have developed a statistical theory to treat the distribution of images. In this multiple scattering limit, we automatically obtain large separations and asymmetric image configurations; the absence of a single, dominant lens is also natural. However, the observed degree of galaxy clustering does not seem to be as strong as this picture would require.

13. *Particle beam luminosity in thick accretion discs:*

We have investigated the interaction of the radiation produced in thick highly luminous accretion disc funnels with the material in the surface layers of these funnels, including the effect of turbulent mixing and using an improved treatment

of radiative acceleration and drag. We find, for a specific funnel geometry studied, that the particle luminosity (L_p) can range from ~ 0 to ~ 0.2 times the photon luminosity (L_γ) depending on the value of the sound speed in the funnel, and upon the exact strength of the instability induced turbulent shear stress. The terminal Lorentz factor of the particles is quite modest.

14. *Magnetic fields and accretion disks around Kerr black holes:*

Accretion onto a rotating black hole immersed in a weak uniform magnetic field was studied. For motion in the equatorial plane, the Keplerian angular momentum distribution and the marginally bound and stable orbits were obtained and used to compute the efficiency of mass-to-energy conversion. Though the magnetic field can significantly increase the efficiency for test particles, its effects on hydrodynamic accretion are found to be quite small.

15. *The gravitational analogue of the magnetic monopole field:*

This study concerns the concept of rotation in Einstein's theory of gravitation. The analogy that exists between rotation and magnetic fields was pursued and led to an exact solution of Einstein's equations which was the gravitational analogue of the field due to a magnetic monopole. It became apparent subsequently that this recovered the Newman-Unti-Tamburino metric from another viewpoint.

16. *Induced rotation in general relativity:*

The phenomenon of induced rotation of inertial frames within the framework of general relativity was considered. Employing the exact solution corresponding to a rotating cylindrical shell, it was shown that such an effect in fact exists giving rise to induced centrifugal and Coriolis forces.

17. *Symmetries of constrained systems:*

This problem deals with the geometrical analysis of symmetry properties of singular Lagrangian systems. The investigation was a successor to some earlier work on the geometric analysis of the dynamics in singular systems. It showed that the symmetries of singular systems respect all the constraints that are demanded by the dynamics.

Radio Astronomy

Decameter Wave Radio Astronomy at Gauribidanur. A joint programme with the Indian Institute of Astrophysics, Bangalore.

Sun

Observations of the slowly varying component of the solar radio emission were continued whenever there was no transient burst activity on the sun. The maps of radio emission obtained thus are being compared with K-Coronameter data of Mauna Loa Solar Observatory, Hawaii. Preliminary results indicate that the centroids of decameter radio emission coincide with the positions of coronal streamers.

High sensitivity observations on the fine structure of noise storm radiation are being made with a sixteen channel receiver having time and frequency resolutions of 100 milliseconds and 50 KHz respectively. Some interesting fine structures such as slow drifting spike bursts have been detected. Theoretical models to interpret these fine structures are being constructed.

Jupiter and Saturn

Observations of the decametric radio bursts from Jupiter are being made to study the time and frequency structure and also the long term correlations between solar activity and radio emission from Jupiter.

In a joint effort with the Observatoire de Paris at Meudon, the decameter radio telescope was used to search for weak radio emission from electrostatic discharges on Saturn. The data obtained at Gauribidanur are now being analysed at Meudon.

The Galaxy

A radio survey of the galactic plane at decameter wavelengths is being carried out using the Gauribidanur telescope. The limits of the survey are 0 to 10 Hr in R.A. and $+74^\circ$ to -45° in Declination. A map of the galactic centre region within the limits 17 to 18.5 Hr in R. A. and -35° to -5° in Declination has already been made and analysis is in progress. The spectra of many interesting emission and absorption features detected on this map are being determined.

A radio map of the Rosette Nebula an H II region, in continuum absorption has been made. These observations were combined with those at high radio frequencies where the nebula is optically thin to derive the electron temperature distribution across the nebula. It is found that the electron temperatures in the south-eastern parts of the nebula are around 5000 to 6000 K and increase upto 8500 K in the north-western regions. This effect is attributed to the presence of more dust in the south-eastern region which changes the spectrum of the ionising radiation.

Extragalactic radio sources

A radio map of the diffuse halo source in the Coma cluster of galaxies was made using the decameter wave radio telescope. The size of the halo is found to be 54 arc min, and the integrated flux is 60 ± 11 Jy. An extended source to the south of Coma A was also detected. The measured flux is about 15 Jy and the spectral index in the frequency range 408 to 34.5 MHz is found to be -1.0 . It is suggested that this source also belongs to Coma cluster.

Instrumentation: 1-Hardware

A digital control system for scanning the antenna beam in the North-South direction was installed and is in regular operation. It is now possible to scan upto 16 declinations sequentially. Diode phase shifters were also installed in the East-West array to tilt the beam in hour angle. A special purpose digital system controls these phase shifters and provides the following modes of operation:

1. Tracking in East-West direction for about 42 min.
2. Slew mode for fast scanning in East-West direction.
3. Scan while tract: a 4×4 sequential beam matrix tracks a source. This will be used for locating transient bursts on the Sun.

An on-line interference remover has been developed to remove impulsive interference.

2. Software

Software necessary for processing data from the magnetic tapes has been improved and standardised. Problems connected with the adaptation of the CLEAN algorithm to data obtained with the Gauribidanur telescope are being studied.

Meterwave Astronomy using the Ooty Radio Telescope

Pulsar observations:

The Ooty radio telescope which has a half power beamwidth $\sim 3'$ in the North-South direction has been used to improve the declination positions for 40 pulsars whose quoted declinations were uncertain by $\sim 5' - 15'$. Each of these pulsars was observed by pointing 8 simultaneous beams at the quoted position. Given a knowledge of the beam shapes, it was thus possible to determine the declinations to an uncertainty of only $0.5'$. The improved positions help to improve the period for ~ 25 pulsars. The new positions for PSR 1926 + 18 and 1922 + 20 clearly show that these are not associated with any known continuum sources.

Recombination Line Observations

The survey of radio recombination lines of hydrogen and carbon towards about 50 directions in the galactic plane using the Ooty Radio Telescope is now completed. These directions include HII regions, Supernova Remnants and regions of continuum minimum. Interpretation of these lines in terms of the distribution and physical condition of gas responsible for them is in progress. To facilitate this interpretation, radio continuum measurements were made with the Ooty Radio Telescope to obtain the full beam brightness temperature towards these 50 directions.

Further, a computer code developed by Brocklehurst and Salem of the University College, London to calculate the departures from local thermodynamic equilibrium necessary for interpretation of these lines, has been successfully installed on "PRIME COMPUTER" at the TIFR Centre, IISc., Bangalore. This code is now being used for the analysis of the observed recombination lines. Preliminary results of the analysis indicate the following:

- a) Within 7 kiloparsec of the galactic centre and in the galactic plane, the lines have similar intensities with respect to the adjacent continuum irrespective of whether the direction of observation corresponds to that of an HII region or an SNR or a region of continuum minimum.
- b) The HII regions themselves, because of their high densities and consequent effects of pressure broadening and optical depth, are unlikely to contribute to the observed line intensities.

c) Therefore, it appears that these observed lines arise from a nearly uniformly distributed low density ionised gas in the inner parts of the galaxy. Preliminary indications are that this gas has a density of $1-10 \text{ cm}^{-3}$ and a temperature of $3000-5000^\circ\text{K}$.

Millimeter Wave Telescope Project

Considerable progress has been achieved on the assembly and testing of the telescope mount in the hangar of the National Aeronautical Laboratory, Bangalore. A new hardened Azimuth ring was fabricated and tested over a period of three months under continuous dynamic loading conditions. Additional features such as (i) a receiver cabin on one side of the elevation axis and (ii) new counter-weights which facilitate the erection of this cabin are under design. The current guide rail from which the reflector surface has to be machined was resurveyed and adjusted to a repeatable accuracy of better than 40 microns (r.m.s.). The error pattern is very stable with time and hence is a reliable indication of the accuracy of the guide rail and the measurement technique. The rotation axis of the reflector has been adjusted to coincide with the focal axis to within 200 microns. The concentricity of rotation and the wobble in the rotation have also been determined. Springback errors on the honeycomb panels are also being redetermined. The final cutting of the reflector surface will be undertaken as soon as all the above errors have been minimised.

A room temperature receiver operating in the 80–115 GHz band has been assembled into the front-end box to be located at the focus of the radio telescope. It contains a low-noise millimeter wave mixer, a klystron local oscillator source with its stabilisation circuits and a low-noise GaAs FET amplifier at 1.4 GHz which acts as the first IF amplifier. Several tests have been performed on the receiver and the results show that it has a receiver noise temperature (DSB) of 750K at 113.6 GHz, with a slightly better performance at the low end of the band. The room temperature operation of this receiver compares favourably with those reported by other groups across the world in the same frequency band.

Other important developments which have taken place are (i) design and fabrication of Gunn oscillator sources in the 33–55 GHz and 75–110 GHz bands and (ii) development of scalar feed horns and quasi-optical components in the 75–110 GHz band. In the 33–55 GHz band, the Gunn oscillator gave a maximum power output of the 60 mW and a mechanical tuning range in excess of 10 GHz. In the 75–110 GHz band, the Gunn oscillator gave a maximum power output of 30 mW and a mechanical tuning range of about 10 GHz.

Corrugated conical horn feeds were designed and fabricated by electroforming technique to operate in the 75–115 GHz band. Gain, input VSWR and radiation patterns in both E and H planes were measured and found to be in good agreement with the predicted values over the whole band. The input power reflection coefficient was found to be better than 18dB over the whole band and better than 25dB over the most of the band. The side-lobe levels are less than 20dB and the ratio of the E-plan to H-plan beam widths is less than 1.1 over most of the band. Lens-corrected corrugated conical horns were also designed and fabricated. Preliminary results show comparable performance with an additional loss of about 1dB due to the lens.

Advanced training in research was offered to the following teachers from other organisations:

Name	Topic of Study	
A. N. Kalkura Vijaya College Mulki, S. K.	High Pressure Optical Studies on on Liquid Crystals.	UGC Faculty Improvement Programme
B. S. Srikanta AES National College Gauribidanur	Order and Elasticity in Liquid Crystals	
M. Subramanya Raj Urs Sahyadri College Shimoga	Synthesis of some new mesogenic compounds	
<i>Ph.D. (Awarded/submitted)</i>		
G. Venkatesh	High pressure studies of liquid crystals Bangalore University	Awarded
K. L. Savithramma	Theoretical Studies on Order & phase transitions in liquid crystals, Mysore University	Awarded
K. Venkatachala Rao	Experimental studies of the Re- entrant phenomenon in liquid crystals, Bangalore University	} Reports awaited
A. N. Kalkura	High Pressure optical studies in liquid crystals Mysore University	
S. N. Prasad	Vibrational Spectra of Liquid Crystals Mysore University	

Publications

The research work done by the staff of the Institute has been published in a number of journals. A list of publications that have already appeared and those submitted and in press is given at Annexure I (Page 16).

Conference/Seminars and Meetings.

The staff of the Institute visited various institutions in India and abroad and attended 12 conferences and presented papers. In addition 19 lectures were given by them elsewhere.

The Ninth International Liquid Crystal Conference (December 6-10, 1982) was organized in Bangalore under the chairmanship of Professor S. Chandrasekhar. About 300 persons from 30 countries participated in the conference and over 350 papers were presented.

Colloquia

During the year the scientists of the Institute and the visiting scientists both from

within and outside the country gave 15 colloquia at the Institute on different topics. In addition 4 discussion meetings were held on topics in theoretical physics.

Journal Club and Neighbourhood Astronomy Meetings

The Journal club meetings started last year was continued during the year and twenty meetings were held on various topics relating to the scientific activities of the Institute. The scientists of the Institute participated in the second Neighbourhood Astronomy Meeting held at the Indian Institute of Astrophysics, Bangalore during April 1982.

Visiting Scientists

A number of scientists from Institutions within the country and outside visited the Institute during the year. Their names are listed following those of the scientific and technical staff of the Institute given towards the end of the report.

Library

During the year three hundred and eighty eight new books were added to the library bringing the total collection to 12,919. The library is subscribing to one hundred and forty current periodicals and has 15,371 bound volumes.

General

I. The following grants were received from the Department of Science & Technology during the year:

Recurring Non-Plan	Rs. 20.53 lakhs	
Recurring Plan	Rs. 30.68 lakhs	
	<hr/>	Rs. 51.21 lakhs
Non Recurring Plan		Rs. 58.09 lakhs
		<hr/>
	Grand Total	Rs. 109.30 lakhs

II. In addition to the above, a sum of Rs. 3,30,000/- was received from the Electronics Commission for the Project "Development of Multiplexed Liquid Crystal Display Systems".

III. The Audited Statement of Accounts with the auditor's report is given in Annexure II (Page 23).

Staff

The Scientific and Technical staff of the Institute is given below. Additions during the year are marked with an asterisk.

- | | |
|-----------------------------------|------------------------------|
| 1. V. Radhakrishnan | 43. G. Rengarajan |
| 2. S. Chandrasekhar | 44. A. Deshpande |
| 3. S. Krishnan | 45. Vijay Gopalaratnam |
| 4. N. V. G. Sarma | 46. K. Sukumaran |
| 5. C. V. Vishveshwara | 47. S. Chanthrasekharan |
| 6. C. L. Khetrapal | 48. B. Sudhindra |
| 7. N. V. Madhusudana | 49. K. G. Girish |
| 8. A. Krishnan @ | 50. K. Chandrasekhar |
| 9. G. Srinivasan | 51. P. G. Ananthasubramaniam |
| 10. R. Shashidhar | 52. R. Vijayalakshmi |
| 11. G. S. Ranganath | 53. Elizabeth Vincent |
| 12. A. C. Kunwar | 54. V. Lakshminarayan |
| 13. V. Surendranath | 55. Mohamed Ateequlla |
| 14. Rajendra Bhandari | 56. M. N. Ramanuja |
| 15. C. S. Shukre ⁺ | 57. B. R. Ratna |
| 16. Rajaram Nityananda | 58. M. Vivekanand |
| 17. Ramesh Narayanan | 59. B. R. Iyer |
| 18. U. Devappa Kini | 60. K. S. Dwarakanath |
| 19. K. A. Suresh | 61. T. S. Ravishankar* |
| 20. B. K. Sadashiva ⁺⁺ | 62. G. Jayakumar* |
| 21. J. Padmanabhan | 63. C. J. Pasupathy* |
| 22. K. T. Balakrishnan | 64. K. Srinivasa Prasad* |
| 23. D. K. Ravindra | 65. C. Ramachandra Rao* |
| 24. R. S. Arora | |
| 25. K. R. Anantharamaiah | <i>Visiting Positions</i> |
| 26. Jayanthi Ramachandran | 1. S. Ramaseshan |
| 27. M. O. Modgekar | 2. G. S. R. Subba Rao |
| 28. M. R. Subramanyam | 3. R. Srinivasan |
| 29. P. N. Ramachandra | 4. S. Panchapakesan |
| 30. R. Nandakumar | <i>Medical Consultant</i> |
| 31. K. Subramanya | A. R. Pai |
| 32. T. Ramachandran | <i>Research Fellows</i> |
| 33. K. Smiles Mascarenhas | 1. G. V. Vani |
| 34. N. Udayashankar | 2. K. L. Savithramma |
| 35. M. Selvamani | 3. M. Subramanya Raj Urs |
| 36. T. N. Ruckmongathan | 4. B. S. Srikanta |
| 37. P. A. Johnson | 5. H. K. Jayaram |
| 38. G. Sarabagopalan | 6. S. Krishna Prasad |
| 39. B. V. Nataraja | 7. R. Pratibha |
| 40. R. Ganesan | 8. K. R. Sumathy* |
| 41. H. Subramaniam | 9. S. K. Srinivasan* |
| 42. Antony Joseph | 10. Joseph Samuel* |
| | <i>Resignations</i> |
| | R. Sivaramakrishnan |

++ on leave with University College, Cardiff, Wales, U. K.

+ on leave with Radio Physics Division, CSIRO, Australia

@ on deputation from National Aeronautical Laboratory, Bangalore.

List of Visitors

1. Dr. Salil Gupta April 25 – 29, 1982
Patrice Lumumba Univ.
Moscow, USSR
2. Dr. A. R. P. Rau, Louisiana State Univ. June 28 – July 24, 1982
Univ. Baton Rouge Campus, USA
3. Paul J. Wiita, University of June 28 – Aug. 2, 1982
Pennsylvania, Philadelphia, USA
4. Varun Sahni, Moscow Aug. 19 – 24, 1982
State University, Moscow, USSR
5. Dr. David Malin, Anglo-Australian Oct. 17 – 21, 1982
Observatory, Epping, NSW Australia
6. Dr. Raghavendra Sahai, California Oct. 20 – 24, 1982
Institute of Technology, USA
7. Prof. G. W. Series, Visiting Raman Nov. 5 – Feb. 4, 1983
Professor, J. J. Thomson Physical
Laboratory, Reading, UK
8. Prof. J. P. Ostriker, Princeton Univ. Nov. 28 – Dec. 5, 1982
Observatory, New Jersey, USA
9. Dr. Suketu P. Bhavasar, Dec. 22 - Dec. 24, 1982
University of Sussex, Sussex, UK.
10. Dr. Max Komesaroff, Dec. 14, 1982 – Jan. 1, 1983.
CSIRO Division of Radiophysics
Epping, NSW Australia

Publications

1. Liquid crystals of disc-like molecules. (S. Chandrasekhar) Review article-Advances in Liquid Crystals, Vol. 5, Academic Press (1982).
2. Instabilities in low molecular weight nematic and cholesteric liquid crystals. (S. Chandrasekhar and U. D. Kini)-review article-International Seminar on Polymer Liquid Crystals, Santa Margherita Ligure, Italy, May 1981, Academic Press (1982) p. 201-245.
3. X-ray scattering by columnar liquid crystals. (G. S. Ranganath and S. Chandrasekhar)-Curr. Sci. **51**, 605 (1982).
4. Twist disclinations in elastically anisotropic nematic liquid crystals. (G. S. Ranganath)-Molecular Crystals and Liquid Crystals, **87**, 187 (1982).
5. Near neighbour correlations and the dielectric properties of liquid crystals. (S. Chandrasekhar and B. R. Ratna)-Molecular Crystals and Liquid Crystals, **82**, 193 (1982).
6. Scaled particle theory of a system of right circular cylinders subjected to an attractive potential. (K. L. Savithamma and N. V. Madhusudana)-Molecular Crystals and Liquid Crystals, **90**, 35 (1982).
7. Some unusual properties of 4-n-decylphenyl-3'-methyl-4'-(4''-nitrobenzoyloxy) benzoate. (N. V. Madhusudana, B. S. Srikanta and M. Subramanya Raj Urs)-Molecular Crystals and Liquid Crystals Letters, **82**, 25 (1982).
8. High strength defects in nematic liquid crystals. (N. V. Madhusudana and R. Pratibha)-Current Science, **51**, 877 (1982).
9. S_A-S_A transition in 4-n-decylphenyl-3'-methyl-4'-(4''-cyanobenzoyloxy) benzoate. (N. V. Madhusudana, B. S. Srikanta and M. Subramanya Raj Urs)-Molecular Crystals and Liquid Crystals, **82**, 317, (1982).
10. Elasticity and orientational order in some cyanobiphenyls Part IV. Reanalysis of the data. (N. V. Madhusudana and R. Pratibha)-Molecular Crystals and Liquid Crystals, **89**, 249 (1982).
11. Ratio of the bend to splay constants of some binary mixtures exhibiting the induced smectic A phase. (N. V. Madhusudana and K. P. L. Moodithaya)-Molecular Crystals and Liquid Crystals, **90**, 357, (1983).
12. High pressure studies on polymorphic liquid crystals. (A. L. Kalkura, R. Shashidhar, G. Venkatesh, D. Demus and W. Weissflog)-Molecular Crystals and Liquid Crystals, **84**, 275 (1982).
13. High pressure studies on liquid crystals. (R. Shashidhar)-Eighth AIRAPT and 19 EHPRG Conference, Uppsala, Sweden, August 1981; in 'High Pressure in Research & Industry', Eds. C. M. Backman, T. Johannisson and L. Tegner, Proceedings of the Conference, p. 597 (1982).
14. Influence of ordering on the pressure behaviour of the nematic-isotropic transition. (H. D. Kleinhan, R. Shashidhar and G. M. Schneider) Molecular Crystals and Liquid Crystals Letters, **82**, 19 (1982).
15. Pressure studies on reentrant nematogens. (A. N. Kalkura; R. Shashidhar and M. Subramanya Raj Urs)-Journal de Physique, **44**, 51 (1983).
16. A new multicritical point in a single component liquid crystal: High pressure study of DOBBCA. (R. Shashidhar, A. N. Kalkura and S. Chandrasekhar)-Molecular Crystals and Liquid Crystals, **82**, 311 (1982).

17. Two-dimensional films of discotic molecules at an air-water interface. (F. Rondelez, D. Koppel and B. K. Sadashiva)-*Journal de Physique*, **43**, 1371 (1982)
18. NMR Spectrum of benzo (b) furan in a nematic phase. (S. Arumugam, A. C. Kunwar and C. L. Khetrapal)-*Organic Magnetic Resonance*, **18**, 157 (1982).
19. Oriented molecules. (C. L. Khetrapal and A. C. Kunwar) -*Specialist Periodical Reports, NMR*, Vol. 11, p. 248 (1982)-The Royal Society of Chemistry, London.
20. NMR Spectrum of pyridine-N-oxide in a nematic phase. (N. Suryaprakash, S. Arumugam, A. C. Kunwar and C. L. Khetrapal)-*Journal of Magnetic Resonance*, **47**, 507 (1982).
21. NMR spectra of oriented biologically important molecules. The structure of and the internal rotation in N:N-dimethyl uracil. (C. L. Khetrapal and A. C. Kunwar)-*Journal of Physical Chemistry*, **86**, 4815 (1982).
22. An NMR study of the interaction of cytosine and lysozyme. (Geeta Datta, S. Surunani, N. Suryaprakash, K. V. Ramanathan and C. L. Khetrapal)-*FEBS Letters*, **148**, 276 (1982).
23. Luminosity limits for funnels in thick accretion discs, (R. Nityananda and R. Narayan), *Mon. Not. R. Astr. Soc.* **201**, 697 (1982),
24. Maximum luminosity of an accretion disc around a black hole. (R. Narayan and R. Nityananda), *Invited Talks Volume of the Proceedings of the VII Annual Meeting of the Astronomical Society of India and Symposium on Variable Stars, Roorkee, 1981*, p. 55 (1982).
25. Simple variational approach to the thermal properties of ionic crystals. (R. Nityananda and R. Narayan), *Pramana* **19**, 367 (1982).
26. Geometry of pulsar beams: Relative orientations of rotation axis, magnetic axis & line of sight. (R. Narayan and M. Vivekanand), *Astronomy and Astrophysics*, **113**, L3-L6, 1982.
27. On selection effects in pulsar searches. (M. Vivekanand, R. Narayan and V. Radhakrishnan), *J. Astrophys. Astron.*, **3**, 237, 1982.
28. Elongated beams, interpulses and the new millisecond pulsar. (R. Narayan and V. Radhakrishnan), *Curr. Sci.*, **52**, 46 (1983).
29. On the origin of the recently discovered ultra-rapid pulsar. (V. Radhakrishnan and G. Srinivasan), *Curr. Sci.*, **51**, 1906 (1982).
30. On the implications of the radio and x-ray pulsar in the supernova remnant MSH 15-52. (G. Srinivasan, K. S. Dwarkanath and V. Radhakrishnan) *Curr. Sci.* **51**, 596, (1982).
31. A new look at the birth rate of supernova remnants (G. Srinivasan and K. S. Dwarkanath) *J. Astrophys. Astron.*, **3**, 351 (1982).
32. Observations of the supernova remnants HB 9 and IC 443 at 34.5 MHz (K. S. Dwarkanath, R. K. Shevgaonkar and Ch. V. Sastry) *J. Astrophys. Astron.* **3**, 207 (1982).
33. Neutrinos in the Kerr and Robertson-Walker geometries. (S. V. Dhurandhar, C. V. Vishveshwara and J. M. Cohen) *Journal of Physics, 'A'* **15**, 1643, (1982).
34. Neutrinos in perfect fluid spacetimes with local rotational symmetries (S. V. Dhurandhar and C. V. Vishveshwara) *Phys. Rev. D.*, **26**, 2598, (1982).
35. Neutrinos in gravitational collapse: The Dirac formalism (B. R. Iyer, S. V. Dhurandhar and C. V. Vishveshwara) *Phys. Rev. D.*, **25**, 2053, (1982).
36. An example of induced centrifugal force in general relativity. (J. M. Cohen,

- W. J. Sarill and C. V. Vishveshwara) *Nature* **298**, 829, (1982).
37. The diffuse gamma-ray background and the pulsar magnetic window. (V. Radhakrishnan and C. S. Shukre), *Astrophysical Journal*, **258**, 121, (1982).
 38. On the nature of Pulsars (V. Radhakrishnan) *Contemporary Physics*, **23**, 207, (1982).
 39. Absorption bursts in the radio emission from the sun at decameter wavelengths. (Ch. V. Sastry, V. Krishan & K. R. Subramanyam), *Astrophys. Lett.* **23**, 95, (1983).
 40. Observations on the HII region W51 at decameter wavelengths. (A Deshpande and Ch. V. Sastry) *Bull. Astron. Soc. India.* **10**, 50, (1982).
 41. Time structure of solar decameter type III radio bursts (G. Thejappa and Ch. V. Sastry) *J. Astrophys. Astron.* **3**, 151. (1982).

Papers in press

1. Liquid crystals of disc-like molecules (S. Chandrasekhar)-Royal Society Discussion Meeting on the Physics, Chemistry and Applications of Thermotropic Liquid Crystals, October 27-28, 1982-Philosophical Transactions of the Royal Society.
2. Molecular interactions and dynamics in liquid crystals. (S. Chandrasekhar & N. V. Madhusudana)-Review article-Molecular Interactions. Vol. 4, Ed. W. J. Orville-Thomas (Wiley).
3. Physics of liquid crystals. (S. Chandrasekhar)-A course of 10 lectures delivered at the Spring College on the Physics of Polymers, Liquid Crystals and Low-dimensional Solids. International Centre for Theoretical Physics, Trieste, Italy, April-June 1980 (Plenum).
4. Energetics of disclinations in liquid crystals. (G. S. Ranganath)-Invited talk-Ninth International Liquid Crystal Conference, Bangalore, 1982. *Molecular Crystals and Liquid Crystals*.
5. Thermomechanical effect in cholesteric liquid crystals. (H. K. Jayaram, U. D. Kini, G. S. Ranganath and S. Chandrasekhar)-Ninth International Liquid Crystal Conference, Bangalore, 1982-*Molecular Crystals & Liquid Crystals*.
6. On dislocations in cholesteric liquid crystals (G. S. Ranganath)-*Molecular Crystals and Liquid Crystals*.
7. Extension of McMillan's model to liquid crystals of disc-like molecules (S. Chandrasekhar, K. L. Savithramma and N. V. Madhusudana)-Invited lecture, Fourth International Symposium on Liquid Crystals and Ordered Fluids, Las Vegas, USA, 1982-*Liquid Crystals and Ordered Fluids*, Vol. 4.
8. New addressing techniques for multiplexed liquid crystal displays. (T. N. Ruckmangathan and N. V. Madhusudana)-Society for Information Display Proceedings.
9. High pressure studies on liquid crystals. (R. Shashidhar)-invited lecture National Symposium on Instrumentation, Bangalore, July 1982-*Proceedings of the Symposium*.
10. Pressure studies on liquid crystalline mixtures. (H. D. Kleinmans and R. Shashidhar)-*Angewandte Chemie*.

11. Effects of magnetic field and boundary conditions on homogeneous instabilities of shear flow of nematics. (U. D. Kini)-Molecular Crystals and Liquid Crystals.
12. Pressure variation of the smectic C layer spacing in HOAB. (R. Shashidhar and S. Chandrasekhar)-Ninth International Liquid Crystals Conference Bangalore, 1982, Molecular Crystals and Liquid Crystals.
13. Effect of pressure on the stability of smectic C phase. (R. Shashidhar, A. N. Kalkura, G. Venkatesh, Mary Neubert and J. P. Ferraro)-Ninth International Liquid Crystals Conference, Bangalore 1982-Molecular Crystals and Liquid Crystals.
14. Pressure studies of liquid crystalline transitions. (R Shashidhar)-Ninth International Liquid Crystal Conference, Bangalore, 1982-Molecular Crystals and Liquid Crystals.
15. Pressure studies on $\bar{7}.S.5$, $\bar{8}.S.5$ and their mixtures. (A. N. Kalkura and R. Shashidhar)-Ninth International Liquid Crystal Conference, Bangalore, 1982-Molecular Crystals and Liquid Crystals.
16. Effect of pressure on monolayer and bilayer smectics. (S. Krishna Prasad, R. Shashidhar, A. N. Kalkura, K. A. Suresh, G. Heppke and R. Hopf)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
17. Temperature variation of the layer spacing in A_d , reentrant nematic and A_1 phases of 4-nonyloxybenzoyloxy-4'-cyanoazobenzene. (K. A. Suresh, R. Shashidhar, G. Heppke and R. Hopf)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
18. Effect of smectic ordering on the dielectric properties of reentrant nematic mixtures. (B. R. Ratna, R. Shashidhar, M. Bock, A. Gobl-Wunsch and G. Heppke)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
19. Dielectric studies of nOBCAB in the smectic A, reentrant nematic and reentrant smectic A phases. (B. R. Ratna and R. Shashidhar)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
20. High Pressure studies on reentrant nematogens. (R. Shashidhar, and A. N. Kalkura)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
21. Effect of molecular ordering on the pressure behaviour of nematic-isotropic transition in binary reentrant nematic mixtures. (H. D. Kleinhans, G. M. Schneider and R. Shashidhar) Molecular Crystals and Liquid Crystals.
22. The topology of the P-T diagram of DOBBCA in the vicinity of the reentrant nematic-smectic C-smectic A multicritical point. (R. Shashidhar, S. Krishna Prasad and S. Chandrasekhar)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
23. Studies on some smectogenic compounds with large bilayer spacings. (N. V. Madhusudana, B. S. Srikanta and M. Subramanya Raj Urs)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
24. Scaled particle theory of a system of spherocylinders: Extension of calculations to high pressures. (K. L. Savithramma and N. V. Madhusudana)-Ninth

- International Liquid Crystal Conference Bangalore, 1982. Molecular Crystals and Liquid Crystals.
25. Experimental determination of the curvature-induced reduction in the smectic A-nematic transition point. (N. V. Madhusudana and B. S. Srikanta)-Ninth International Liquid Crystal Conference Bangalore 1982. Molecular Crystals and Liquid Crystals.
 26. Effect of electric field on the nematic-isotropic phase transition of compounds with strongly polar molecules. (K. L. Savithramma and N. V. Madhusudana)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
 27. Studies on binary mixtures of systems which exhibit a maximum as well as a minimum in the S_a -N transition boundary. (B. S. Srikanta and N. V. Madhusudana)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
 28. Dielectric and conductivity studies on 2-cyano-4-heptylphenyl-4'-pentyl-4-biphenyl carboxylate and its mixtures with 4-n-heptyl-4'-cyanophenyl. (B. S. Srikanta and N. V. Madhusudana)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
 29. Studies on high strength defects in nematic liquid crystals. (N. V. Madhusudana and R. Pratibha)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
 30. Induced smectic mesomorphism in binary mixtures of cholesteryl chloride and 4,4'-di-heptyloxyazoxybenzene. (K. A. Suresh)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
 31. Effect of skew cybotactic structure on the optical properties of a nematogen with a lateral cyano substituent. (N. V. Madhusudana, K. P. L. Moodithaya and K. A. Suresh)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
 32. Homogeneous instability under free convection in a tilted nematic sample. (U. D. Kini)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
 33. Phenyl 4-benzoyloxybenzoates with lateral methoxyl substituent. (M. Subramanya Raj Urs and V. Surendranath)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
 34. The crystal and molecular structure of a reentrant nematogen: 4-cyanophenyl-3-methyl-4'-(4"-n-undecyloxy-cinnamoyloxy) benzoate. (G. V. Vani)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
 35. Crystal and molecular structure of nematogenic 4'-n-butyl-4-cyanobiphenyl (4CB). (G. V. Vani)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
 36. Synthesis and miscibility studies of some phenyl cinnamoyloxy benzoate derivatives. (M. Subramanya Raj Urs, B. K. Sadashiva, K. A. Suresh and S. Krishna Prasad)-Ninth International Liquid Crystal Conference, Bangalore, 1982. Molecular Crystals and Liquid Crystals.
 37. NMR spectroscopy of oriented molecules. (C. L. Khetrpal and A. C. Kunwar) *Advances in Liquid Crystals*, Academic Press, N. Y.
 38. NMR studies of molecules oriented in mixed thermotropic liquid crystals of

- opposite diamagnetic anisotropies. (C. L. Khetrapal, A. C. Kunwar and M. R. Lakshminarayana)-Proceedings of the International Symposium on Liquid crystals and Ordered Fluids, Las Vegas, USA, 1982-Liquid crystals and Ordered Fluids, Vol.4.
39. The influence of bond polarizations on the molecular structures of halofluorobenzenes. (N. Suryaprakash, A. C. Kunwar and C. L. Khetrapal)-Journal of Molecular Structure.
 40. Determination of indirect spin-spin couplings between hetero-nuclei from NMR spectra of oriented molecules. The spectrum of phenyl-selenyl chloride (N. Suryaprakash, A. C. Kunwar and C. L. Khetrapal)-Journal of Magnetic Resonance.
 41. A theory of concentration dependent switching transition in mixed liquid crystals of opposite diamagnetic anisotropies. (K. P. Sinha, R. Subburam and C. L. Khetrapal)-Molecular Crystals and Liquid Crystals.
 42. Landau type theory as applied to mixtures of liquid crystals of opposite diamagnetic anisotropies. (K. P. Sinha, R. Subburam and C. L. Khetrapal)-Chem. Physics Letters.
 43. Application of NMR in agriculture, foodstuffs, soil sciences and allied fields. (C. L. Khetrapal and M. R. Lakshminarayana)-Quarterly Reviews of Indian Council of Chemistry.
 44. The structures of ammonium halides. (G. Raghurama and R. Narayan) J. Phys. Chem. Solids.
 45. Variable anion polarisability in ionic crystals. (G. Raghurama and R. Narayan) Curr. Sci.
 46. The maximum entropy method of image reconstruction-a non-information theoretic practical approach. (R. Nityananda and R. Narayan) J. Astrophys. Astr.
 47. Reconstruction of a polarized brightness distribution by the maximum entropy method. (R. Nityananda and R. Narayan). Astron. Astrophys.
 48. Thick accretion disks-luminosity limits and mass outflow. (R. Nityananda and R. Narayan) to appear in the proceedings of the Winter School on Energetic Extragalactic Sources, Bangalore, 1983.
 49. Gravitational lenses-the multiple scattering limit. (R. Narayan and R. Nityananda) to appear in the proceedings of the Winter School on Energetic Extragalactic Sources, Bangalore, 1983.
 50. The luminosity of particle beams from thick accretion discs. (R. Narayan, R. Nityananda and P. J. Wiita) Mon. Not. R. Astr. Soc.
 51. Evidence for evolving elongated pulsar beams. (R. Narayan and M. Vivekanand). Astronomy and Astrophysics.
 52. Interstellar electron density. (M. Vivekanand and R. Narayan) J. Astrophys. Astron.
 53. A new model for the Emission geometry in PSR 0950 + 08. (R. Narayan and M. Vivekanand) Astrophysical Journal.
 54. Magnetic fields and accretion disks around Kerr black holes. (P. J. Wiita, C. V. Vishveshwara, M. J. Siah and B. R. Iyer) J. Phys. 'A'.
 55. Magnetization of all stationary cylindrically symmetric vacuum fields. (B. R. Iyer and C. V. Vishveshwara) Journ. Math. Phys.
 56. Dynamics and symmetry for constrained systems. (G. Mamo, N. Mukunda and J. Samuel) Rivista del Nuovo Cimento.

57. Core-envelope models of collapsed objects. (B. R. Iyer) Proceedings of the Workshop on Gravitation and Relativistic Astrophysics. Ahmedabad, 1982.
58. Some general relativistic aspects of gravitational collapse. (C. V. Vishvesh-wara). Proceedings of the workshop on Gravitation and Relativistic Astrophysics. Ahmedabad, 1982.
59. Diffuse radio emission from the coma cluster of galaxies at decameter wave-lengths. (Ch. V. Sastry and R. K. Shevgaonkar) J. Astrophys. Astron.
60. Observations on the slowly varying components of solar radio emission at decameter wavelengths. (Ch. V. Sastry, R. K. Shevgaonkar and M N. Rama-nuja) Sol. Physics.
61. On the association between pulsars and supernova remnants (V. Radhakrish-nan and G. Srinivasan) Proceedings of the IAU Symposium NO. 101. Super-nova Remnants and their x-ray Emission, Venice, August 30- Sept. 2, 1982.