Abstract

The spectacular night sky with its vibrant stars is our own Milky Way Galaxy. The observations for the Galaxy dates back to the time when Galileo first used a telescope (1608-10) to observe the night sky. His conclusion was that the Milky Way is a vast collection of stars. Subsequently, many astronomers have worked extensively to bring up our current understanding of the Milky Way as a spiral galaxy.

Polarisation has been seen in the light from the stars in the Galaxy - particularly those close to the plane. Stars, being spherically symmetric, one does not expect the light to be polarised and certainly not in a coordinated (aligned) manner, hence it was realized that this was due to the medium through which the light had travelled. This was the discovery of interstellar polarisation. The current understanding is that the asymmetric dust grains in the interstellar medium get aligned in the Galactic magnetic field giving rise to interstellar polarisation. Hence, measurement of polarisation is a way to measure the Galactic magnetic field - both strength and direction, in some conditions.

The inner regions of the galaxy have always been obscured from our view at optical wavelengths, because of the intervening clouds of dust. Therefore, our knowledge of the Milky Way structure and how the different components have been formed and put together can only be enhanced by surveying the galaxy at near and mid-infrared wavelengths. But most of these large scale surveys, until recently, were confined to imaging and spectroscopic studies, leaving behind the polarimetric observations which demands a thorough study in the regions of heavy dust presence. By studying the polarization distribution, one can get additional information about the magnetic field (its geometry & strength) and study the dust present in the region. One expects that there should be a correspondence of the distribution of molecular clouds in different

directions with the distribution of dust (which causes extinction and polarization). A polarimetric instrument in the near infrared is therefore a very valuable means to study the polarization distribution along the line of sight (in combination with distance determined using different techniques - e.g. red clump method, parallax etc).

The science part of the thesis has addressed the interstellar polarisation phenomena using the PRL 1.2 m telescope with the NICSPol instrument. The observations of a dark Lynds cloud L1340 have been undertaken and polarisation measurements for stars part of the cloud have been reported in the J, H & K_s bands. The plane of the sky magnetic field strength has also been estimated for the RNO 8 cluster and cloud core, which is a part of the L1340 cloud. The observations were taken using a wire-grid module (WGP) as analyzer on the near-IR camera & spectrograph (NICS) instrument. This work underlines a very promising scientific approach and impresses on the need for a more versatile instrument with improved accuracy in polarisation measurements, and negligible thermal contribution from the optics. This is one of the major scientific goals which led us to develop NISP (Near-IR Imager, Spectrometer & Polarimeter) as a new multi-function near-infrared instrument for PRL's upcoming 2.5 m telescope at Mount Abu.

The major part of the thesis covers the instrumentation part and includes the optical design of NISP which has been completed with optimization of the design at each step. The instrument offers multimode capabilities of imaging, spectroscopy and polarimetry in a single package. The different modes in the instrument have been realised using components whose designs were custom made to achieve the specifications required in the instrument. Several options were explored with the manufacturers since the components would be fabricated at room temperature but used at cryo temperatures at NIR wavelength (0.9 μm - 2.5 μm). This posed various challenges and constraints. With several constraints of meeting instrument specifications, instrument size limit, performance at cryo temperature etc., the optical design had been completed. The collimator optics design is a F/8 system with a collimated beam width of 38 mm, and the camera design necessary for our instrument specifications is F/5. The design has achieved a full unvignetted imaging field of view of 10′ x 10′, and a spectral resolving power ~ 2150

across all filters in the near-infrared. It implements single shot imaging polarimetry using wedged double Wollaston as an analyser. The dual beam polarimetry technique, will benefit many scientific projects with an improved precision in the observational data. The dual beam method helps in using the full light, by not wasting half of the orthogonal component of polarization. This also cancels the Earth atmosphere effects by the ratio of intensities taken amongst orthogonal components. Hence, this allows the observers to work on targets with low polarisation or sources with intrinsically variable polarisation behaviour on short time scales. Some example science programs are: polarisation study of the interstellar regions of the Milky Way, mainly involving polarisation study of larger molecular clouds, clusters, globules etc. & variability of AGN polarisation on short timescales, wherein polarisation variability has been noticed on short timescales (order of a few minutes) which need a simultaneous measurement mode, to obtain better polarisation accuracy. These will be addressed once the instrument is commissioned.

The thesis work illustrates the intricate details of the optical design of a near infrared multimode instrument and its fulfilment with robust attributes, in terms of the implementation of the various modules, in the NISP instrument for PRL's upcoming 2.5 m telescope.

Keywords : Optical design, multi-function infrared instrumentation, dual beam polarimetry, Interstellar polarisation, ISM, Lynds clouds