Indian Institute of Astrophysics

FACILITIES

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Indian Institute of Astrophysics

The research and supporting facilities of the Institute are spread over four centres; Bangalore, Kavalur, Kodaikanal, and Gauribidanur. The optics and electronics laboratories, mechanical workshop, and the administrative offices are at Bangalore. Solar research facilities are at Kodaikanal, and the decametre wave radio telescope (run jointly with Raman Research Institute) is located at Gauribidanur. The Institute's main research facility is the Vainu Bappu Observatory at Kavalur.

Vainu Bappu Observatory, Kavalur

Situated in the Javadi hills in the North Arcot district of Tamil Nadu, Vainu Bappu Observatory houses a number of optical telescopes, of apertures 2.3m, 1.0m, 0.75m, 0.45m (Schmidt), and 0.38m. Kavalur has a VAX 11/780 computer system for the eventual control of the 2.3m telescope and for data acquisition.

Supporting facilities at Kavalur include electronics and mechanical workshops, and two aluminizing chambers which can handle mirrors of up to 2.4m aperture. There is also a small library which provides reference material when the skies are clear and reading material when they are not. Two 144 KW diesel generators, and a few smaller ones, keep the vital installations in operation in the event of power failure.

A few small-aperture telescopes and a small museum cater to an ever-increasing number of school and college students and visitors to the observatory.

1. THE 2.3m VAINU BAPPU TELESCOPE

The F/3.25 paraboloid primary of the 2.3m telescope saw its first light of the night sky in the autumn of 1985.

The equatorially mounted horse-shoe-yoke structure of the 2.3m telescope is ideally suited for low latitudes and permits easy observation near the north celestial pole. The prime focus with an image scale of 29 arcsec mm^{-1} is now available for direct photography and photoelectric photometry. A CCD camera is under construction.

The Cassegrain secondary has been ground in the Institute laboratories and is being figured. At an F-ratio of 13 and a consequent image scale of 6.6 arcsec mm^{-1}, the focus is well-suited for medium and high-resolution spectroscopy, spectro-photometry, and photometry.

The 10m diameter observing platform is divided into three sectors which can be independently moved up and down hydraulically, during observations at the Cassegrain focus.

1.1. Photography

The manual cage at the prime focus of the 2.3m telescope is optimized between the constraints of easy positioning and movement of the observer on the one hand, and the upper limit of 15% on the obstruction of the incoming beam, on the other. Consequently, it is not possible to mount large sized instruments.

The three element Wynne corrector system provides an aberration-free field of diameter 40 arcmin. The plate holder has been designed to capture the entire field using a 10cm × 10cm filter and 8cm × 8cm photographic plate. The guiding is achieved by acquiring a star near the edge of the field, with the help of a mirror attached to a movable arm. The arm can move in only one direction, but the plate-holder can be rotated to access any star in an annular area located at the periphery of the field. The star image is guided through a fibre optic bundle of 10mm × 8mm cross-section and 1m length, to a convenient position, thus enabling an easy access by the observer.

1.2. *Photoelectric photometry*

A prime-focus photoelectric photometer, designed and fabricated in the laboratories of the Institute, is available for *UBVRI* photometry.

The design of this photometer differs from that of the Cassegrain photometers because the F-ratio of the prime-focus beam is low. A field lens collimates the beam coming from the telescope focus, and the primary is imaged on to the photocathode by a second lens. An optically flat, nickel mirror with a series of diaphragm holes (350, 500, 800, 1000 μm), placed at 45° to the focal plane is used for field viewing and guiding during observations. A retractable flat mirror is brought in the path of the collimated beam and directs the light to a lens that images the diaphragm and the star.

A fibrescope mounted on a slide in the common focal plane of the wide-angle eyepiece and diaphragm viewing lens brings in view either the field, or the star image in the diaphragm, by a proper choice of a retractable mirror. The eye-end of the fibrescope provides viewing at a position convenient for the observer. With the present arrangement, viewing and guiding can be done comfortably up to the 15th magnitude in moderate seeing. The filter assembly consists of the following *UBVRI* filters.

U : UG2 (2mm) + BG 18 (2mm)
B : BG12 (2mm) + BG 18 (2mm) + GG 4 (1mm)
V : GG14 (2mm) + BG 18 (2mm)
R : OG550 (2mm) + RG6 (1mm)
I : BG3 (1mm) + RG1 (2mm)

2. THE 1m TELESCOPE

The 1m telescope by Carl Zeiss Jena was installed in 1972 and has been in continuous use since then. The equatorial 2-pier (German mount) of the telescope obstructs the north celestial pole only slightly. In fact, the star Polaris itself can be observed for several hours when it transits at midnight.

The telescope is of Ritchey-Chretien design with a coma-free field of 40 arcmin diameter at the F/13 Cassegrain focus. The versatile Cassegrain focus can be used for photography and photometry as also for low and medium resolution spectroscopy and spectrophotometry. The F/30 coude focus contains an instrumentation platform which extends from the observing floor to the ground 12m below. One may place here larger sized and heavier high-resolution spectrographs which cannot be mounted at the Cassegrain focus.

Some photographic equipment came with the telescope. Other instruments of interest were developed at the Institute. To these has now been added a spectrograph by Carl Zeiss.

2.1. *Photography and objective-prism/grating spectroscopy*

The entire 40 arcmin diameter coma-free field of the Cassegrain focus can be covered by the Zeiss plate-holder at the F/13 focus, using a 16cm × 16cm photographic plate and a same size filter. Guiding is achieved by directing a star from the edge of the field to the guide eye-piece. The mirror which selects the star can move in only one dimension, but the entire plate holder can be rotated to access any star situated in an annular region around the periphery of the field. Attachments are available for employing smaller-sized plates if entire field is not required to be photographed.

Two focal reducers are available at the Cassegrain focus to collimate the beam to a smaller beam diameter. A faster camera of smaller aperture may then be employed to photograph the field. These Zeiss focal reducers are coupled respectively to an F/6 and an F/2 camera with resultant image scales of 33 and 100 arcsec mm^{-1}, respectively. Experiments have successfully been made to attach a Zeiss F/3.5 camera coupled to an image intensifier. Though the system is not in regular use, it can easily be assembled when required.

Excepting the F/13 plate-holder, other cameras have provisions for mounting interference filters for narrowband photography, and prisms/transmission gratings for low-resolution and ultra-low resolution spectroscopy. An objective grating attachment has been developed for employment at the converging F/13 focus. The set-up has proved useful in crowded fields such as galactic open clusters.

2.2. *Photoelectric photometry*

Two dry-ice-cooled and one thermoelectrically-cooled photoelectric photometers are in regular use. These may either be used with a chart recorder in dc mode or coupled to one of the three microprocessor-controlled photon counting units designed, fabricated, and programmed in the Institute laboratories. Two of these are versatile photon counting systems, and are described later. Third one, developed earlier, provides just continuous count-and-print facility over preassigned integration times ranging between 1 s and 99 s (in integral numbers).

Various filters, apertures, and photomultipliers are available for *UBVRI* and *uvby* photometry observations. Interference filters may be fitted into the filterholders if narrow-band photometry is desired.

2.3. *Infrared photometry*

An InSb infrared detector system is available for infrared photometry. The basic system was acquired from the Infrared Laboratories, Inc., Tucson. The image acquisition and focal-plane sky-chopping unit was made in the Institute laboratories. The liquid nitrogen-cooled system consists of a set of *JHKLM* filters and two circular variable filters (1.2–1.6 micron, 1.5–3.9 micron) driven by a stepper motor. At present, only a chart recorder is available for recording the data.

2.4. *Universal astronomical grating spectrograph (UAGS)*

A spectrograph manufactured by Carl Zeiss is available for spectroscopic observations at the F/13 Cassegrain focus. The catadioptric collimator system and the folding of collimated beam before the grating is illuminated make the spectrograph fairly compact. Two gratings are available at present: one with 651 grooves mm^{-1} at a blaze angle of 8° and an efficiency of over 40% between 3000 and 7000 Å peaking at 4000 Å (85%); and the other with 1800 grooves mm^{-1} at a blaze angle of 26°45′ and a peak efficiency of 81% at 5086 Å. Two Schmidt-type cameras of focal length 110 mm and 175 mm respectively may be used interchangeably for photographic observations. The resultant reciprocal dispersions are 136 and 86 Å mm^{-1} respectively, with the 651 grooves mm^{-1} grating in the first order.

For observations with a single-stage image intensifier, a Schmidt-Cassegrain camera of 150mm focal length is available (dispersion : 100 Å mm^{-1}). The Varo 8605 electrostatically-focused single-stage image intensifier may be coupled to the camera. The intensifier has input and output fibre-optic windows of 40mm diameter. The fibre-optics cuts off the wavelengths shorter than 4000 Å. The advantage lies however in the S-20 photocathode which helps extend observations up to 8600 Å, and with some difficulty, up to 8900 Å. However, note that the present gratings are inefficient in the near-IR region. The P-20 green output phosphor and the resolution of 64 line pairs per mm are ideally suited for the employment of Kodak IIa-D emulsion.

The spectrograph has a field viewing arrangement which helps in acquiring visually objects as faint as 15 mag on the 1m reflector. The diameter of this field is 8 arcmin. The slit-jaws are made up of hardened chromium-nickel steel with vapour-deposited aluminium coating. The slit-viewing microscope allows a 15 mag object to be seen off the slit by a fully dark-adapted eye. A star as faint as 13 mag can be centred easily on the slit and guided using the light reflected from the slit jaws. The maximum unvignetted slit length is 10mm, corresponding to 160 arcsec at the F/13 focus of the 1m reflector.

Point objects can be trailed along the slit for up to 3 mm using a rocker prism. The period for one cycle is 30s. The comparison spectrum can be recorded on either side of the spectrum of the object at any separation between 0.2 and 10mm. An intensity calibration spectrum can be obtained on a separate plate. To affect this, the wavelength calibration source is replaced by the continuum source and a neutral density stepwedge of transmissivities 0.10, 0.16, 0.25, 0.40, 0.63, and 1.00 inserted in the light path.

A filter wheel following the slit allows a choice of filters for order separation and also for matching the colour of intensity calibration source with the spectral type of object. A neutral density filter can be inserted while observing bright stars.

2.5. The Cassegrain image-tube spectrograph

A Cassegrain image-tube spectrograph made at the Institute has been in regular use for the past several years. The spectrograph is of conventional design and can be mounted on an offset guide device. The offset guide and the mirror slit together have the capability of acquiring and guiding a star as faint as 15 mag, though the slit-viewing microscope and the available wavelength comparison sources are not fully optimized for faint object spectroscopy. A number of gratings of ruled area 76 mm × 65 mm and cameras of various focal lengths are available yielding dispersions ranging from 22 Å mm^{-1} to 1000 Å mm^{-1} in the visible and image-tube IR parts of the spectrum. Varo 8605 image intensifier is fixed at the output of the camera. The most efficient use of the spectrograph is with objects of intermediate brightness, at medium-low resolution, in a spectral region extending from green to near-infrared.

2.6. Photoelectric spectrophotometry

The single-channel photoelectric spectrum scanner has undergone continuous upgrading since its installation in 1972. It can be mounted on the Cassegrain offset guide, is provided with a set of entrance apertures and order-separation filters, and can be used in conjuction with a range of photomultipliers in the available cooled housings. The basic spectrograph conforms to the Ebert-Fastie design using two separate identical mirrors as collimator and camera. A grating with 600 grooves mm^{-1} blazed for 7600 Å in the first order yields a reciprocal dispersion of 25 Å mm^{-1} in the first order.

The grating is driven by a stepper motor coupled through a wormwheel and a gear. One step of the motor corresponds to a step of 10 Å in wavelength in the first order and 5 Å in the second order. The data acquisition as also the control of the stepper motor is through a microprocessor controlled photon counting unit, with a spare unit standing by.

It is possible to replace the grating with another of 1800 grooves mm^{-1} and achieve a better resolution of 3Å in the first order.

2.7. Microprocessor-controlled photon-counting system

A microprocessor-based photon-counting system is available for the following tasks : (i) Control of the photoelectric spectrum scanner, and data acquisition. (ii) Data acquisition in filter photometry. (iii) Data acquisition during continuous photometric monitoring of an object. (iv) Data acquisition in fast photometric mode (such as lunar occultation records). (v) On-line folding and co-adding fast photometric data, useful for period-search of optical pulsars.

The system is based on the Intel 8085 8-bit microprocessor board and includes a 16-bit timer; 16K of read-only memory; 4K of random access memory; a

24-bit counter; 24 input/output lines; an interrupt controller; an I/O expander with control circuits; two digital-to-analog converters; display units to display the minimum and maximum of the counts stored in the memory as well as the number of scans; and a printer with key board, an optional oscilloscope for display of spectrum scans. The system was developed in the Institute laboratories; a spare unit has also been assembled.

2.8. Coude B spectrograph

The highest available spectral resolution with the 1m reflector is with the Coude B spectrograph. The spectrograph has a collimator of focal length 6m and a camera of focal length 3m, resulting in a reduction factor of only two from the slit to the detector. A grating of 400 grooves mm^{-1}, blazed at 1.2μm in the first order, and of ruled area 206 mm $\times$ 154 mm yields a dispersion of 2.8 Å mm^{-1} in the third order blue. The F/30 beam at coude focus has an image scale of 6 arcsec mm^{-1}. This, coupled with the small reduction factor of the spectrograph, means that only a small fraction of the stellar image goes through the slit. Hence the typical exposure for a fourth magnitude star runs into several hours on Kodak IIaO emulsion. It requires an equally long exposure to hit the circumstellar cores of Ca II H and K lines in a star of about first magnitude.

2.9. Coude echelle spectrograph

In the echelle spectrograph higher resolution is achieved by going to a high order of diffraction, a short focus camera can therefore be employed resulting in a larger reduction factor from the slit to the detector. The echelle spectrograph at the coude focus of the 1m reflector has a collimator of 1.4m focal length. Several cameras are available (focal lengths 150 mm, 175 mm, 250 mm, 500 mm). The 250mm camera results in a reduction factor of 5.6. Thus the slit can be widened to let in most of the star light in good seeing. An echelle grating of 79 grooves mm^{-1} blazed at 5461 Å of 42nd order, and ruled area of 128mm $\times$ 56 mm yields a dispersion of 7 Å mm^{-1} with the 250mm cameras in the 34th order of the spectrum. Gratings of 80, 150, or 300 grooves mm^{-1} may be used as cross dispersors to separate orders. Typical exposure times in the red region using Kodak 098-02 are several hours for a fourth magnitude star. There is provision to use Varo 8605 single stage image intensifiers which reduces the exposure times by a factor of about 10.

2.10. Calibration spectrographs

There are two instruments that can help in registration of calibration steps for the photographic emulsion. One is to use the UAGS in the calibration mode. The other one is to use the auxiliary calibration spectrograph, whose basic unit is a quartz prism spectrograph by Adams Hilger. The slit is widened and illuminated by a uniform diffuse source. A sector rotating in front of the slit obstructs light for different durations as a function of slit height. The sector is cut such that the logarithmic exposure time difference from one step to the next is close to 0.1. The width of each step is 0.1 mm and 13 steps are accomodated by the slit. The reduction factor of the spectrograph is unity.

3. THE 0.75m TELESCOPE

The 0.75m telescope is a Cassegrain reflector designed and built at the Institute. The mouting ring is similar to the Cassegrain mounting ring of the 1m reflector. Hence, in principle, any of the spectrographs or photometers used with the 1m reflector can be used with the 0.75m reflector. However, in practice, only the photoelectric photometer is transported. A spectrograph is permanently available with the telescope.

3.1. Bhavnagar spectrograph

The first stellar spectrograph to be built in the Institute, the Bhavnagar spectrograph is named after the 0.5m reflector with which it was first used. This reflector had been purchased from a grant by Maharaja Takhtasinghji of Bhavnagar for Poona and was sent to Kodaikanal in 1912.

The spectrograph was later attached to the 1m telescope, and then finally to the 0.75m reflector. The spectrograph has a collimator lens of 4cm aperture and 36.5 cm focal length. The camera is mounted at an angle of 45° to the slit-collimator line. Two cameras are available with focal lengths of 125mm and 50mm. A range of gratings from 80 grooves mm^{-1} to 1800 grooves mm^{-1}, of ruled area of 76mm × 65mm, allows a range of dispersions, the best resolution possible being 17 Å mm^{-1} in the red and 30 Å mm^{-1} in the blue.

4. THE 0.38m TELESCOPE

The home made 0.38m Cassegrain reflector was installed in Kavalur in 1968 when the site survey was in progress. Though some spectroscopic observations have been secured with it in the early days, the telescope is now dedicated to photoelectric photometry. A *UBVRI* photometer is available for observations.

5. THE 0.45m SCHMIDT TELESCOPE

The 0.45m Schmidt telescope was fabricated in the Institute to coincide with the return of the comet Halley. The telescope consists of 60cm F/2.245 primary and a 45cm corrector plate. A field flattener of 100mm × 125mm is placed in front of the focal plane so that a flat photographic plate can be employed. The entire corrected field of the telescope is 6° in diameter. The unvignetted field has a diameter of little over 3°. The field flattener yields a flat field of 4° × 5°. The image scale is about 2.5 arcmin mm^{-1}.

6. PHOTOGRAPHY LABORATORY

All the telescope buildings, excluding the one for the 0.38m telescope are equipped with independent photography laboratories for processing the photographic plates.

The 1m telescope building is also equipped with facilities for obtaining enlarged and contact prints. An oven with thermostat control and air-tight containers, and dry nitrogen cylinders are available for nitrogen-baking hypersensitization of emulsions.

7. VACUUM-COATING FACILITIES

The 2.8m vacuum coating plant commissioned in 1984 and 1.5m vacuum coating plant commissioned in 1978 form an in-house facility for periodic aluminizing of the telescope mirrors and other optics. High quality surfaces up to 2.4m diameter can be coated using these plants, which were designed, fabricated and commissioned with the help of Bhabha Atomic Research Centre (BARC), Bombay.

The 2.8m vacuum coating plants was used for the first aluminizing of the primary mirror of the Vainu Bappu telescope in 1985 August. It has been used for other applications requiring metal coatings by the vaccum evaporation technique.

The 1.5m plant has been used to periodically aluminize many astronomical mirrors including the 1.2m primary mirror of Japal Rangapur Observatory and the 1.02m primary mirror of the 1m telescope.

A 30cm coating plant at Bangalore is used for experiments on different types of coating and coating materials, and for aluminizing small mirrors.

8. VAX 11/780 SYSTEM

VAX 11/780 computing system is installed in the Vainu Bappu telescope building for eventual telescope control, and data acquisition and processing.

8.1. Hardware

Word length	32 bits
Main memory	3 Mbytes
Disc drive	RM80 : 1 × 124 Mbytes RM05 : 2 × 300 Mbytes
9 track tape drives	TU77 : 800/1600 bpi TU78 : 1600/6250 bpi
Card reader	200 cards per min
Printer/plotter	Printronix 600
Terminals	2 × VT 100 1 × VT 125 2 × VT 240
Graphics terminal	Tektronix 4115B
Colour copier	Tektronix 4691
Image processor	COMTAL Vision One/20
Interface	CAMAC LPA 11K
Operating system	VMS Version 3.5

8.2. Software

Languages	Macro assembler Digital command VMS Fortran (superset of Fortran 77)
Graphic packages	PLXY (on Printronix) IGL (Tektronix) ReGis (VT 125, 240)
Mathematical package	Scientific subroutine package (SSP)
Spectroscopic reduction package	RESPECT

9. MECHANICAL WORKSHOP

The mechanical workshop at Kavalur is equipped for the maintenance and fabrication of light-duty instrumentation. The equipment includes two milling machines, two lathes, a shaping machine, a plate-bending machine, a band saw machine and a bench drilling machine. Though these equipments cannot handle all the precision work needed in astronomical instrumentation, instruments have been fabricated in the past using them. Cranes are available at various locations for assembling instruments/parts of telescopes.

10. LIBRARY

Though there is no full fledged library at Kavalur, the copies of essential books, catalogues and atlases are available in the 1m reflector building. Recent volumes of main journals in the field are also available.

11. TELESCOPES FOR THE VISITORS

Two small telescopes of 0.15 apertures are available for visitors and students to look through. The 0.15m reflector is of Maksutov type fabricated by the Carl Zeiss Jena. The 0.15m refractor was gifted to Kavalur by Mrs Yemuna Bappu, whose husband Dr M. K. Vainu Bappu had got it from Mr R. G. Chandra of Jessore who in turn had received it from the American association of variable star observers.

Kodaikanal Observatory

Located in the Palani Hills, Kodaikanal Observatory has been devoted to solar research since the beginning of the century. The principal facility—in regular use since 1962—is the solar tunnel telescope which provides high image resolution and high spectrographic dispersion.

1. THE TUNNEL TELESCOPE

The 11m high tower houses a two-mirror, fused quartz coelostat of 61cm diameter, which reflects light onto a third quartz flat. The flat mirror directs the horizontal beam into a 60m long underground tunnel, where an achromatic objective of 38 cm aperture and 36m focus forms a solar image, 34cm in diameter, and on a scale of 5.5 arcsec mm^{-1}. The telescope has been made by Grubb Parsons. The solar image feeds light to a Littrow-type spectroheliograph which utilizes a 20cm aperture, 18.3m focus Hilger achromat in conjunction with a 600 lines per mm Babcock grating of ruled area 200mm × 135mm and blazed in the fifth order at 5000 Å.

2. SPECTROHELIOGRAPHS

Kodaikanal has three spectroheliographs. A Foucault siderostat with a 46cm diameter mirror reflects sunlight onto a 30cm Cooke photovisual triplet lens which forms a 60mm solar image. This image then feeds light to the two spectroheliographs. The K-spectroheliograph is a two-prism instrument with a dispersion of 7 Å mm^{-1} near 3930 Å. Its exit slit admits 0.5 Å about K_{232}. In use since 1904, the K-spectroheliograph produces daily spectroheliograms of the solar disc and prominences. The other, hydrogen-alpha spectroheliograph uses a Littrow grating. Its exit slit isolates 0.35 Å about hydrogen alpha. This instrument has been taking daily pictures of the sun since 1911.

The third spectroheliograph, made by K. C. A. Raheem in the 1960s is used with the tunnel telescope. Meant for specialized work, it is a Littrow arrangement of 4.3m focus with a 1200 lines per mm grating blazed at 7500Å.

3. SPECTROHELIOSCOPE

The Hale spectrohelioscope along with a 13cm coelostat was received as a gift from Mount Wilson Observatory. Set up in 1934, the spectrohelioscope daily monitors the solar chromospheric activity.

4. PHOTOHELIOGRAPH

The photoheliograph made out of a 15cm aperture telescope by Lerebours and Secretan of 1850 vintage produces white-light photographs 20cm in diameter.

Kodaikanal has also a 20cm equatorial by Troughton and Simms which was acquired in 1866 at Madras.

5. SOLAR-TERRESTRIAL RELATIONSHIP

Kodaikanal's proximity to the magnetic equator makes it an ideal field station for solar-terrestrial relationships. A C3 ionosphere recorder has been in use at Kodaikanal since 1952. A Lacour magnetometer and a Watson magnetometer are available for geomagnetic recordings. Since 1983 a high frequency phase path sounder set up is in operation for monitoring small scale dynamics of the equatorial ionosphere.

Decametre-Wave Radio Telescope, Gauribidanur

Operated jointly with Raman Research Institute, the Gauribidanur telescope is a T-shaped array of 1000 broad-band dipoles, 640 in the east-west arm and 360 in the south arm. All dipoles accept east-west polarization. A fully reflecting screen, 60,000 m^2 in area, is mounted 1.5m below the dipoles. The entire structure is supported on a grid of 3500 wooden poles of varying heights. The east-west arm is 1.4 km long, and the south arm 0.45 km.

In the east-west arm, the elements are arranged in four rows, placed 5m apart. Each row has ten groups of 16 broad-band dipoles; each group has its own feeder system to permit phasing in the north-south direction. To preserve the bandwidth of the system a binary branching feeder network is used throughout.

The south arm of the T consists of 90 rows placed 5m apart, each with four broad-band dipoles. The four dipoles are coupled together in a branched feeder system and each row is connected into the main north-south feeder system. The outputs of the east, west and south arms are carried by coaxial cables to the centre of each arm and from there to the main observatory building. The signals are amplified and the sum of the east and west signals is correlated with that of the south arm. In this way a beam of about 26 arcmin $\times$ 40 arcmin at the zenith is produced at a frequency of 34.5 MHz.

The beam of the south arm can be pointed anywhere within $\pm$ 60° of the zenith on the meridian. This is accomplished by adjusting the phase gradient across the aperture using remotely-controlled diode phase shifters. The phase shifters are designed to introduce phase variation in binary steps of 22°.5 from 0° to 360°. The phase variations are achieved by switching calibrated lengths of coaxial cables in the circuit path with the aid of diodes. A special purpose digital control system supplies the switching voltages to set the beam to the required position. The digital control system also cycles the beam through several declinations sequentially. The time required to change the beam from one position to another is of the order of a few milliseconds. The number of declinations through which the beam is cycled can be varied from one to 16. The beam of the east-west array can be tilted in hour angle to $\pm$5° of the meridian. This tilting is also accomplished by remotely-operated diode phase shifters, controlled by another special purpose digital system. It is thus possible to track a source for about 45 minutes around meridian transit.

The receiving system extracts the in-phase (cosine) and the quadrature (sine) correlations between the two arms for each one of the beam positions. Predetection band-widths of 30 and 200 KHz, and postdetection time constants ranging from 1 to 30 s are available. The output of the receiving system is recorded in both analog and digital forms.

The effective area of this instrument is about 25,000 m^2. At 34.5 MHz, the mean sky brightness is of the order of 10,000 K. Therefore the collecting area is sufficient for the detection of sources whose flux densities are in the range of 10 to 15 Jy (1 Jy $= 10^{-26}$ W m^{-2} Hz^{-1}).

T. P. Prabhu & R. K. Kochhar