A MICROCOMPUTER CONTROLLED CCD H-ALPHA SPECTROMETER

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ABSTRACT. A miniaturized spectrometer designed for mounting at the Cassegrain focus of a 40 cm telescope has been built and laboratory tested with promising results. The optical system consists of a slit, spherical mirror, and reflection grating in a Littrow configuration. The detector is a 128 element linear CCD cooled by an evacuated microminiature nitrogen refrigerator and interfaced to a microcomputer using direct memory access. Laboratory spectra of a mercury vapor discharge tube have been obtained and demonstrate 1 Angstrom resolution with low noise. The spectral coverage of about 100 Angstroms is suitable for measurement of stellar H-alpha line profiles, and it is anticipated that the instrument can be used to monitor bright Be stars.

1. OPTICS

Since compactness and light weight are necessary for an instrument to be carried by a small telescope, a Littrow mount, in which a single mirror is used as both collimator and camera, was chosen. A spherical mirror of 60 mm diameter and 200 mm focal length accepts the full f/12 beam of the 40 cm Cassegrain telescope and brings the full diffracted beam to focus at the detector. A plane reflection grating 30 mm square with 600 lines/mm and 650 nm blaze wavelength is used at an angle of about 11 degrees to give a reciprocal linear dispersion of approximately 80 Angstroms/mm. The entrance slit is 13 microns wide on aluminum coated glass, tilted slightly so that a diagonal mirror can reflect an image by way of a relay lens to the guide eyepiece mounted at the side of the chassis. The slit width was chosen to cover one pixel width at the detector, resulting in 1 Angstrom resolution. It subtends about 0.5 arcsec on the sky. All of the optical elements are held in place by adjustable brackets machined from quarter inch aluminum plate. The spectrometer chassis is a box 12" long, 7" wide, and 5" deep with a 10" x 12" telescope mounting flange, also made from quarter inch aluminum plate.

J. B. Hearnshaw and P. L. Cottrell (eds.), Instrumentation and Research Programmes for Small Telescopes, 457–458.

2. ELECTRONICS

A Texas Instruments virtual phase 128 element CCD linear array is used as a detector. The pixels are 12.7 microns square, so a spectral interval of about 128 Angstroms is covered. Operation of the chip is supported by a factory supplied driver board mounted on one inside wall of the chassis. An onboard interface card designed around a National Semiconductor ADC 0820 8 bit half flash A/D converter digitizes and transfers the data to a Compaq microcomputer at 250 kHz through a parallel port using direct memory access. Memory refresh is suspended during the transfer so that no pixel values are lost. Exposure timing is done by a programmable interval timer chip connected to the clock output provided on the TI driver board. The TTL power supply is taken from the computer bus, and the driver board is powered by a 16 volt dual power supply mounted in the spectrometer chassis.

3. REFRIGERATION

To eliminate thermal noise, the CCD is cooled to -100 degrees Celsius by a microminiature refrigerator from MMR Technologies. This consists of a small vacuum chamber containing a glass strip on which the chip is mounted. Pressurized nitrogen gas expands through capillaries in the glass and liquefies beneath the chip, after which it recirculates to cool the incoming gas before venting at atmospheric pressure. The temperature can be controlled by a resistive heater embedded in the glass strip. The chamber is continuously evacuated while the instrument is on the telescope, requiring a high capacity vacuum pump because of the length of the connecting hose.

4. PRELIMINARY TEST RESULTS

In the laboratory, the spectrometer very cleanly resolved the 577-579 nm mercury doublet from a vapor discharge tube through a foil pinhole focused on the entrance slit, demonstrating the estimated resolution of 1 Angstrom per pixel. It was only recently adjusted for the H-alpha line and mounted on the telescope, and the results have been very discouraging. The electronics and refrigeration systems work perfectly well, but attempts to locate the sensitive point on the slit using Jupiter, the Moon, and even the bright star Sirius have failed completely. At the deadline time for this writing, the original slit has been replaced by a much wider one (150 microns, or about 6 arcsec) in a compromise of resolution for illumination. Regardless of slit width, photometric accuracy will be difficult because the linear detector array is so narrow. One solution to this problem might be running the star up and down along the length of the slit during exposure. Such a motion could be made quite regular since the telescope itself is computer controlled. Unfortunately, testing has been impossible because of a long period of cloudy weather.