**References**

Flügge, S., 1967. 'Encyclopedia of Physics', XXIX, Optical Instruments.
Geyer, E.H. and Hoffmann, M., 1994. This Newsletter.
Hecht, E. and Zajac, A., 1974. 'Optics', Addison Wesley.
Scheiner, J., 1890. 'Spectralanalyse der Gestirne', Engelmann.

T. BAUER
Observatorium Hoher List der Universitätssternwarte Bonn
D-54550 Daun
Germany

## The Hoher List CCD Focal Reducer System: a Versatile Instrument for Fieldspectroscopy and Direct Imaging

With the introduction of CCD detectors in the astronomical observing technique about 10 years ago, dioptric focal reducer systems (FRS) became essential equipment for direct imaging, polarimetry, Fabry-Perot-interferometry and field spectroscopy (also named 'multi-object spectroscopy' [MOS]) at the larger telescopes of many observatories. The reason is that the 'field efficiency'

$$2\theta = d/(N_{ef} \cdot A) = d/F_t \text{ [rad]}$$

($d$ = linear diameter of the detector, $N_{ef}$, $A$, $F_t$ are the F-number, the aperture and focal length of the telescope, respectively) is very small for present day CCD sizes used in the direct focus of the telescope.

An 'afocal FRS' consists of a field lens collimator, similar to a Kellner ocular, and a camera lens, the entrance pupil of which has to be matched with the real exit pupil of the afocal telescope-collimator combination. The diameter of the exit pupil $\delta$ is given by

$$\delta = f_{coll}/N_{ef}$$

In an optically well designed FRS the collimator and camera should be de-coupled, so that camera optics of different f-ratio can be used. If the focal length of the camera lens is smaller than that of the collimator, a reduction of the telescope focal length by the factor

$$m = f_{coll}/f_{cam}$$

takes place. Therefore the field efficiency of the telescope is increased now by the factor m:

$$2\theta = d\, m/F_t$$

The advantages, principal techniques and possibilities of FRS have been shown and developed by us, about which we reported at several occasions already in the pre-CCD-times (Geyer 1979; Geyer 1981; Geyer, Hoffmann & Nelles 1979; Geyer & Nelles 1984).

The Hoher List Observatory Zeiss-FRS at the 1.06 m f/14.5 Cassegrain telescope has a field lens collimator of 720 mm focal length. The free distance between the telescope focus and the fieldlens system is 253 to 257 mm (longitudinal chromatic aberration!) and a relevant one of 150 mm between

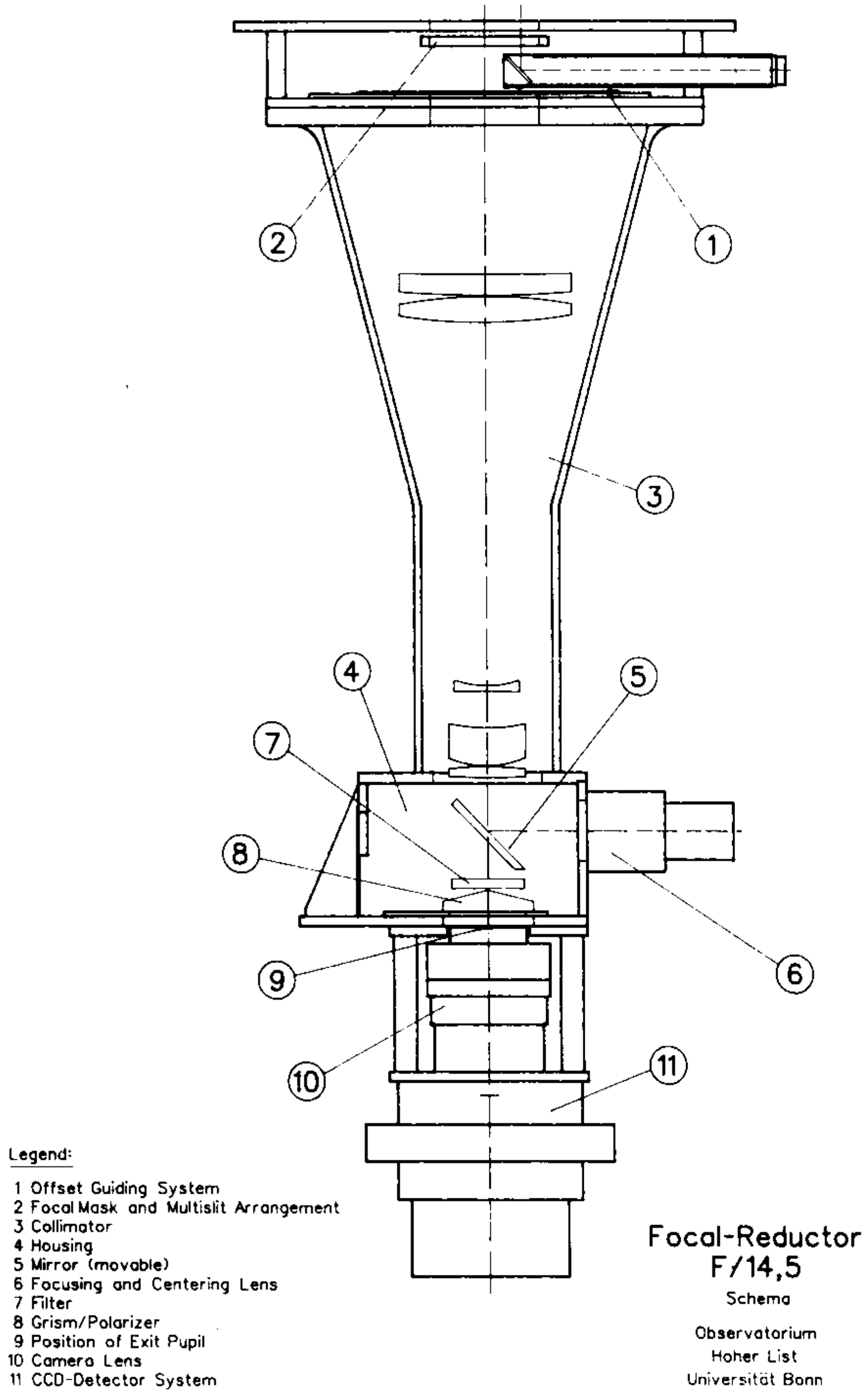


**Figure 1.** The schematically layout of the Hoher List Focal Reducer System.

the collimator lens and the exit pupil, which has a diameter of about 50 mm. The whole telescope field of 27 arcmin (given by the central hole at the primary mirror) yields a field angle of the parallel bundles of 5.6° in the exit pupil, which must be fully covered by the camera optics (Fig. 1).

For the past two years this FRS has been equipped with a CCD-detector system (CCDS) of the firm ASTROMED Ltd/Cambridge UK. The detector is a P8603 chip of EEV Ltd/England with 385 x 578 active pixels of 22 x 22 $\mu m^2$ size. It is thermo-electrically cooled with a 3-stage Peltier element in a high vacuum fully sealed dewar, allowing a minimum temperature of about 183° K at an ambient temperature of 283° K. Under these conditions the dark current is 8 e/pixel/hour with a readout noise of 6-8 e. This CCDS is under complete control of a 386 UNIX-RISC-PC.

The CCDS is optically coupled with the FRS-collimator via four camera lenses. Two of which are commercially available (Zeiss-Planar f=85 mm, f/1.5 and Zeiss Sonnar F=180 mm, f/2.8), having their entrance pupil within their lens system. They are quite well chromatically corrected in the wavelength range 480 nm - 660 nm. As their entrance pupil cannot be matched with the exit pupil of the FRS, field-silhouetting up to 30% (Planar) occurs.

The other two camera lenses are of special Zeiss design, having their entrance pupil 10 mm in front of their first lens. Thus they can be optimally matched with the FRS exit pupil. They are chromatically corrected for 365 nm - 436 nm (Z-B-lens), and 425 nm - 656 nm (Z-V-lens), respectively. These camera lenses are on loan from MPI-Aeronomie. The Table gives the optical data for the different FRS-CCDS combinations at the F/14.5-1.06 m Cassegrain telescope of the Hoher List Observatory. As with the reduction factor m also the chromatic aberration of the FRS-collimator is reduced, the camera lenses are optimally only usable within the limits of their best chromatic correction. This is essential for spectroscopy.

**Table 1.** Optical data of the F/14.5 HL-FRS

| Cam. lens | f [mm] | $F_{eff}$ [mm] | m | $N_{eff}$ | PixRes. [arcs] | CCD-Field [arcmin] |
|---|---|---|---|---|---|---|
| Planar | 85 | 1775 | 8.47 | 1.67 | 2.6 | 24.2 x 16.5 |
| Sonnar | 180 | 3750 | 4.00 | 3.53 | 1.2 | 12.5 x 7.8 |
| Z-B-lens | 140 | 2918 | 5.14 | 2.75 | 1.6 | 14.7 x 10.1 |
| Z-V-lens | 140 | 2918 | 5.14 | 2.75 | 1.6 | 14.7 x 10.1 |


**Figure 2.** A typical longslit spectrum of the Ring Nebulae M 57, showing its faint halo in the [OII]- and Hα-/[NII]-lines, and the night sky lines.

For direct imaging in the B-, G-, V-, R-colour system limiting magnitudes > 21 mag are reached within 5-10 min exposure time with the Sonnar- and Z-B/V- camera lenses. Very faint surface luminances are obtained (> 25 mag/arcs$^2$) with interference filters (5 - 10 nm HWFM) outside the night sky line wavelength regions.

For slit spectroscopy we use a longslit of 13.2 arcmin length and 3 arcs width as well as masking slits of 1 to 3 mm width for slitless spectroscopy. These slit arrangements are moveable over the telescope field, so that the different spectral ranges of grating prisms must not be separated by colour filters. With the 1 mm slit mask we observed in the red spectral range an asteroid of 17th mag with an S/N ≈ 10. The long slit spectroscopy is especially effective for faint extended emission objects (Fig. 2).

**Acknowledgements**

This investigation is supported by the Deutsche Forschungsgemeinschaft, Grant Ge 209/15.

**References**

Geyer, E.H., 1979. *Proc. IAU-Coll.*, **47**, 271.
Geyer, E.H., 1981. *Mitt.Astr.Ges.*, **54**, 156.
Geyer, E.H., Hoffmann, M. and Nelles, B., 1979. *Astron. Astrophys.*, **80**, 312.
Geyer, E.H. and Nelles, B., 1984. *Proc. IAU-Coll.*, **79**, 575.

E.H. GEYER and M. HOFFMANN
Observatorium Hoher List der Universität Bonn
D-54550 Daun
FR-Germany

## Wide-field CCD Astrometry at Hoher List Observatory — First Results

### 1. Introduction

Over the past twelve years CCDs have become more and more important for astrometric work. The first attempts demonstrated that parallaxes of stars can be measured more efficiently with this new technique (see Tinney 1993 and references herein). Later, also the measurement of angular separations of double star components with classical methods was nearly completely replaced by measurements with CCDs (e.g. Sinachopoulos 1988). Further applications of CCDs in astrometry are the determination of optical positions of extragalactic objects (Argue 1984; Wei et al. 1989) and of x-ray sources in the cores of globular clusters (Geffert et al. 1989, 1994).

At Hoher List observatory two new independent facilities with CCD detectors, which are also usable for astrometry, became available last year. We will present here the first results of the astrometric tests.