

HIGH RESOLUTION SPECTROSCOPY WITH A FIBER-LINKED ECHELLE-SPECTROGRAPH

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ABSTRACT. A compact fiber-linked echelle-spectrograph has been designed and constructed at the Landessternwarte Heidelberg-Königstuhl and was successfully tested during its first observation period in the end of May 1987. The optical design of the instrument is discussed in general terms and preliminary results of the first observations are presented. The reduction of several CCD frames has shown that the real properties of the spectrograph are within a few percent of the calculated ones.

1. Introduction

The concept to use single fused silica fibers for astronomical applications allows physical disjointment from the telescope and a simplified spectrograph design. One also eliminates telescope related flexure in the spectrograph while being capable of housing the instrument in a temperature and humidity controlled room. The light scrambling properties of the fiber results in a constant spectrograph illumination independent of guiding errors and seeing variations. To use the fiber technology, however, two important problems must be solved: the input beam focal ratio degradation and the signal attenuation. Therefore each new fiber must be tested carefully and only a few fibers are useful for astronomical observations.

For a given telescope the $\lambda/\Delta\lambda$ -resolution depends on the core-diameter of the fiber which represents the slit of the spectrograph. At the Cassegrain focus of the 0.75 m telescope of the Landessternwarte and slits between 1" and 5" diameter the $\lambda/\Delta\lambda$ -resolution changes between 70.000 and 15.000.

2. The optical system and its calculated properties

The major components of the spectrograph and the TV-guiding-system are shown in Fig. 1 and Fig. 2. Fig. 3 shows the calculated properties of the instrument as a function of the echelle-order number. All calculations are done with respect to a blaze angle of 65° and a separation between incident and diffracted beam of 12° (see references (1)-(5)).

In the TV-guiding-system the infalling $f/8$ beam from the telescope is reflected by several mirrors and focused on the photo-cathode of the TV-camera. The field of view using the 0.75 m telescope of the Landessternwarte is $440'' \times 330''$. A motor driven mirror and prism allows to change between starlight and light from the ArTh-comparison-lamp or the flat-field-lamp.

The fiber coupler is a mirror with a pinhole of 150 microns in it. The glued in fiber has an outer diameter of 140 microns and a core-diameter of 100 microns which represents the slit of the instrument. At variable seeing conditions it is possible to exchange the fiber in less than 10 minutes.

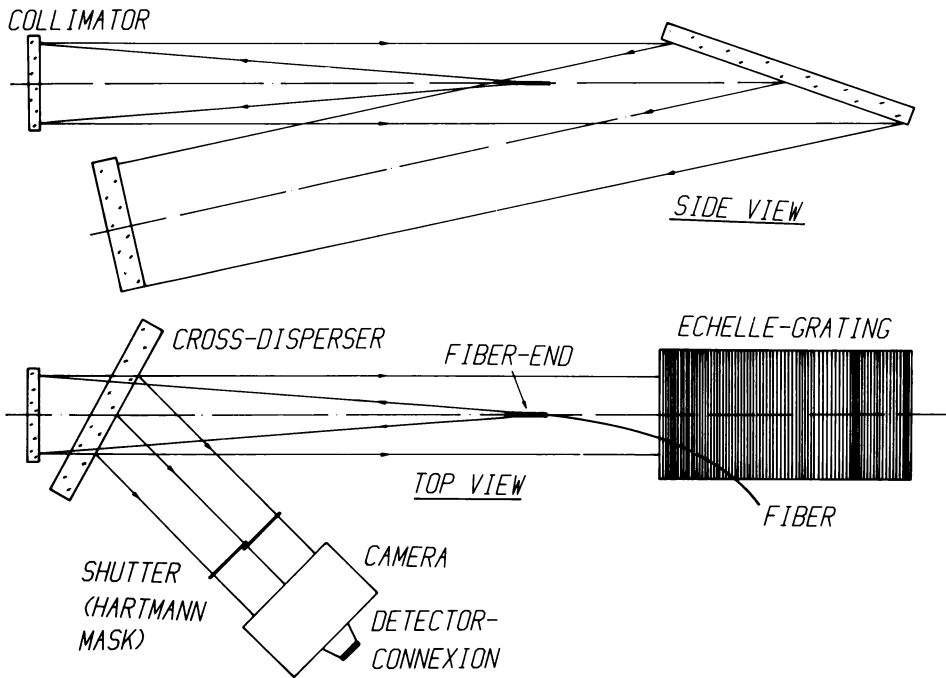


Figure 1. Optical lay-out of the echelle-spectrograph: collimator: $f/5$, $f=400$ mm; echelle-grating: 110×220 mm, 31.6 grooves/mm, blaze: 65° ; cross-disperser: 165×135 mm, 300 grooves/mm, blaze: 4.3° ; camera: $f/2.8$, $f=300$ mm.

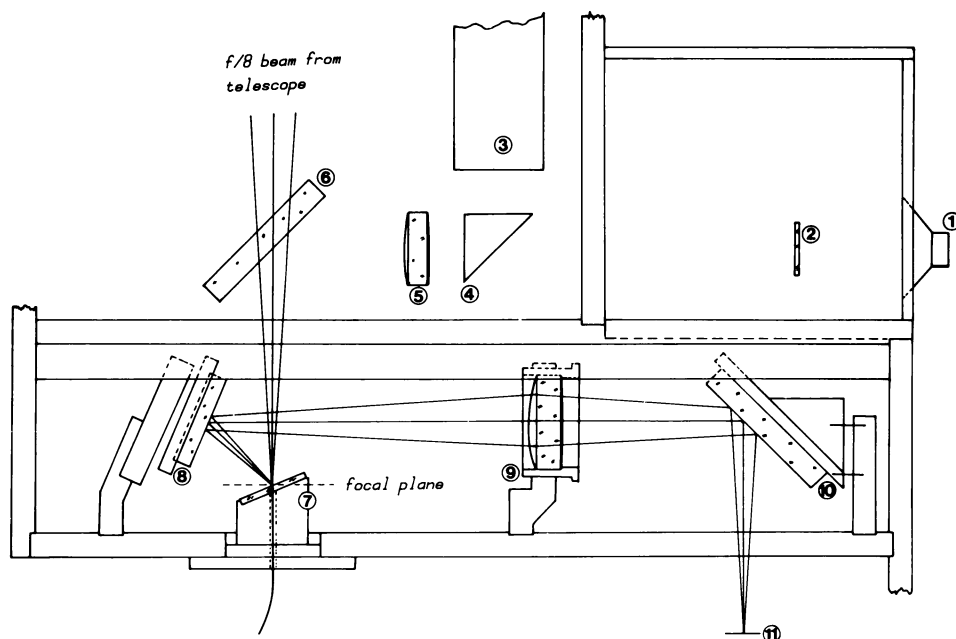


Figure 2. Optical lay-out of the TV-guiding-system: (1) flat-field-lamp; (2) ground glass screen; (3) comparison-lamp (ArTh); (4) motor driven prism to select the lamp; (5) lens $f/2.5$, $f=80$ mm; (6) motor driven mirror; (7) fiber coupler with fiber AS 140/100 from Quartz & Silice; (8) mirror; (9) lens $f/2.25$, $f=90$ mm; (10) mirror; (11) focal plane of the TV-camera.

3. Results

The spectrograph was tested at the 0.75 m Cassegrain telescope of the Landessternwarte. As detector a GEC chip type P8603/A was used. A 530 second exposure of α Boo (exposed through clouds) yielded a spectrum with a signal-to-noise ratio of 235 per pixel at $\lambda = 5500\text{\AA}$. The estimated overall efficiency (including air mass, telescope, spectrograph and detector) at the same wavelength is $\geq 0.6\%$. At better conditions the instrument reached 1.1%.

As an example the 96th echelle-order of an one hour exposure of P Cygni is shown in Fig. 4. In the continuum the signal-to-noise ratio differs between 50 and 90. At HeI-wavelength the signal-to-noise ratio is 160.

Figure 3. Calculated properties of the spectrograph.

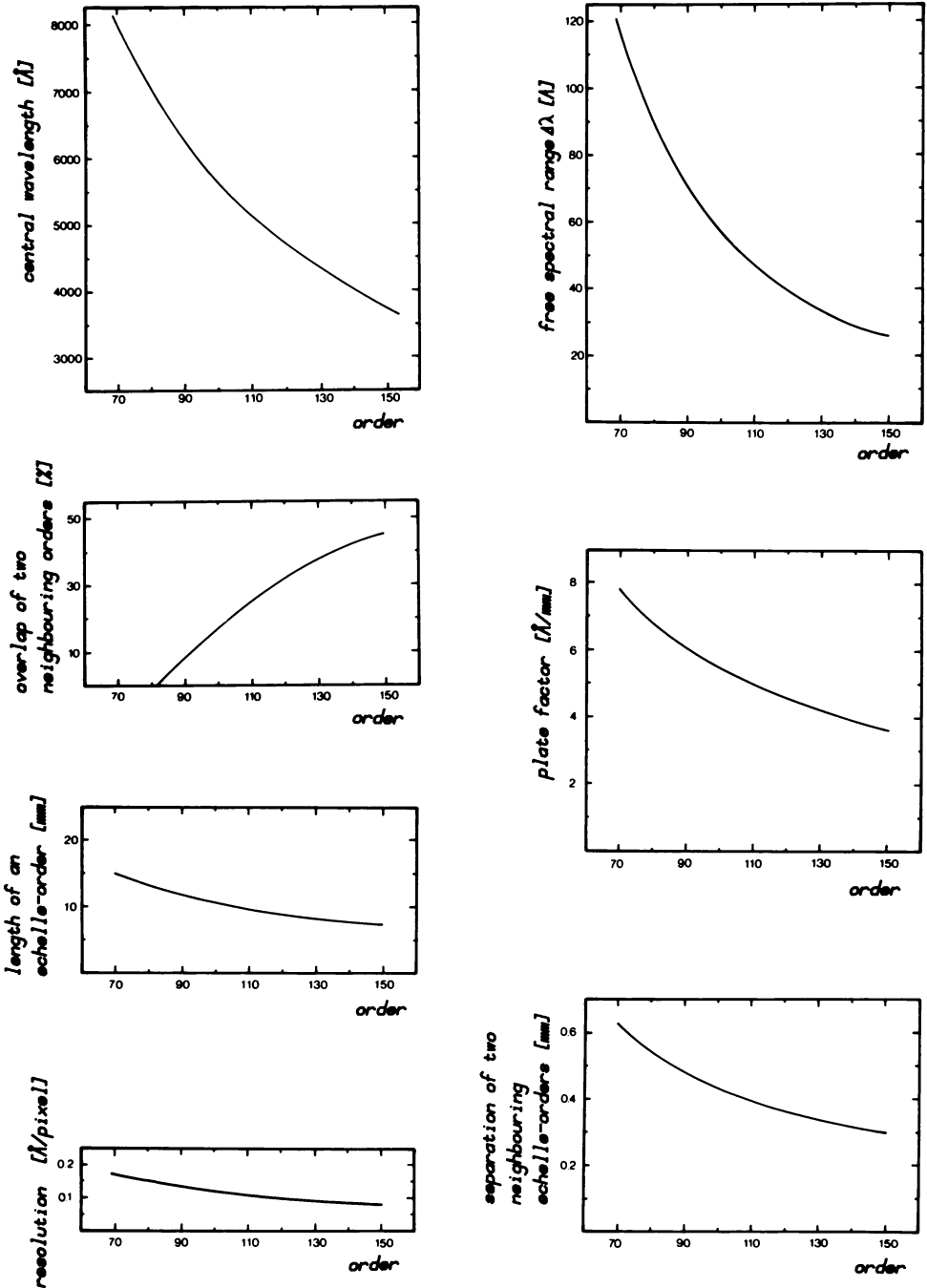
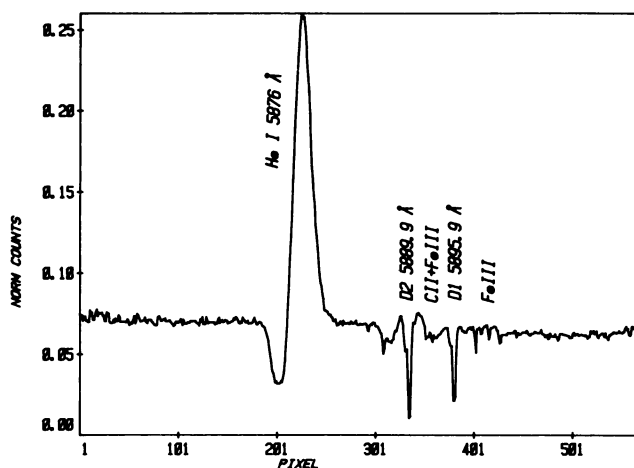


Figure 4.
Bias subtracted
and flat-fielded
echelle-order
Nr. 96 of an one
hour exposure of
P Cygni.



4. References

- (1) Bottema, M., 1981, *Applied Optics* 20, 528.
- (2) Chaffee, F.H., Schroeder, J.D., 1976,
Ann. Rev. Astr. a. Astrophys. 14, 23.
- (3) Harrison, G.R., 1949, *J. Opt. Soc. Am.* 44, 761.
- (4) Schroeder, J.D., 1967, *Applied Optics* 6, 1976.
- (5) Schroeder, J.D., 1970, *PASP* 82, 1253.

DISCUSSION

SODERBLOM What improvement in S/N has your optical fiber achieved? Does it significantly improve calibration?

MANDEL The illumination of the collimator is exactly the same by starlight, flat-field-light and ArTh-comparison-light. The only link to the telescope is a 5-10m long fiber. In fact of the possibility of housing the spectrograph temperature and humidity controlled you have no bending and temperature effects in the instrument and therefore no blurred spectral lines. The improvement in S/N has not been calculated, but if there is a pixel-shift of 0.5-1 pixel during long exposures for telescope mounted spectrographs you have an improvement in S/N of more than 10 %.

VOGT Do you know how much efficiency you are loosing from polarisation effects with your crossed grating geometry?

MANDEL No, these effects have not been calculated separately. The overall efficiency of the instrument at 5500Å was estimated to 1.1 %. If I calculate the efficiency with the optical elements I reach a value of 2.8%. The difference of 1.7% is due to guiding-errors, seeing variations and polarisation effects.

BAADE Is one of the advantages of using a fiber link that the internal flat-field lamp provides much better correction for fringing and low spatial frequencies distortions than a conventional coupling between telescope and spectrograph would do?

MANDEL Yes, it is.

LINSKY What is the maximum spectral resolution possible with your instrument setup?

MANDEL The maximum $\lambda/\Delta\lambda$ -resolution depends on the core-diameter of the fiber which represents the slit of the spectrograph. At best conditions I can reach a $\lambda/\Delta\lambda$ -resolution of ≈ 70.000 .