FIES: A high resolution FIber fed Echelle Spectrograph for NOT

S. Frandsen[1] *and B. Lindberg*[2]
[1]*Institute for Physics and Astronomy, Aarhus University, Denmark*
[2]*LensTech AB, Skellefteå, Sweden*

Abstract. A few words are presented about the FIES design and tests. Plans for the future of FIES are outlined. More documentation is found elsewhere.

1. Introduction

In the time after the Nordic Telescope became operational, ideas for instrumentation have been discussed. One of the instruments considered was a bench mounted, high resolution spectrograph, coupled to the telescope by an optical fiber. Due to financial problems and change of the responsible group for the construction, an instrument has only seen 'first light' now 7 years after the concept was first defined. The instrument: FIES (FIber coupled Echelle Spectrograph) now exists in a laboratory setup at LensTech AB in Sweden and various tests have been carried out. This article describes the performance and a plan for the installation at NOT.

The targets addressed by such an instrument are mainly stars. Among the topics will be variable star research (seismic studies), active stars, stellar dynamics and abundances, binaries and much more.

2. Specifications

The design of the spectrograph took place in collaboration with ESO (B. Delabre) and the FOCES (for the Calo Alto telescope) group at Munich. Lately, we have had discussions with the FEROS (for the ESO 1.5m) responsible A. Kaufer at Heidelberg.

FIES is a cross dispersed (large prism) Echelle spectrograph with a large format detector. The spectrograph is mounted on a 600 kg optical table with dimensions 1.25m$\times$3m. The design is of the white pupil type with two off axis parabolic collimators (see Fig. 1).

The following list is a specifications of the elements on the table along the optical axis.

1. A fiber unit containing a focal extender and a slit that feeds the light into the instrument. This unit is being redesigned to make it simpler and easy to modify. Details follow later.

2. Two off-axis collimators with focal length f=1524mm and aperture A=250mm. The first one is passed twice by the beam of light before and after the Echelle grating.

3. Echelle grating, 31.6 gr/mm, 63.5 deg., 154mm$\times$306mm ruled area.

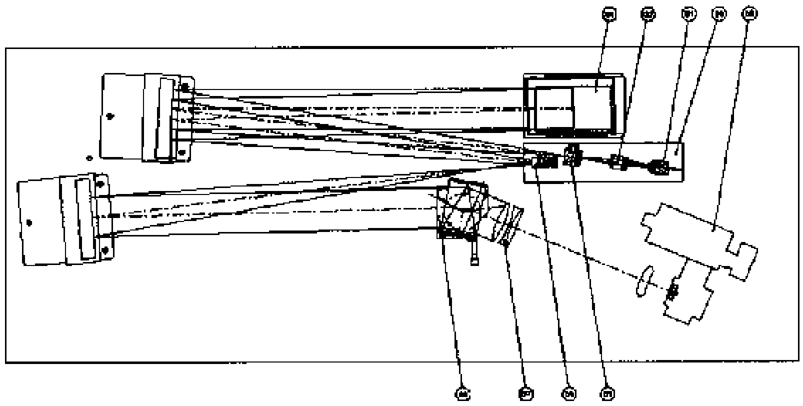

Figure 1. *Layout of the optical table (from Dybdal & Frandsen, 1992)*

4. A small folding mirror close to the fiber entrance.
5. A large cross disperser prism with wedge angle 48 deg., h=160mm, Schott LF5 glass
6. Camera with several lenses, f=520mm, A=170mm, F/3.0
7. CCD detector, Loral 2k×2k chip with pixel size 15μm, Brocam controller. The CCD is cooled with liquid nitrogen.

With a slit size of 88μm (transmitting 75% of the light imaged onto the fiber), the average resolution is R$\sim$60,000. The wavelength coverage is from 350–820nm. Estimated efficiency at this resolution of telescope and spectrograph about 10%, but see later.

3. Tests

In order to assess that the design criteria has been met, tests have been carried out in the laboratory of transmission, spectral resolution, order separation and stability. Some of the results can be found in a report prepared by Lindberg (1998).

3.1. Resolution

According to theoretical aberration curves the resolution should not be affected at the nominal resolution by the optics. The Loral CCD chip installed unfortunately suffer from charge smearing to the extent that the effective pixel size becomes 30μm. A smaller 11μm pixel size CCD has therefore been used to measure the spectral resolution.

In Fig. 2 a tiny part of the spectrum with two lines separated by 0.24Å is shown obtained with a slit width around 30μm to the left and a slit of 90μm at the right. Analyzing these spectra we obtain a resolution of 79,000 with the narrow slit and 63,000 with the wide slit.

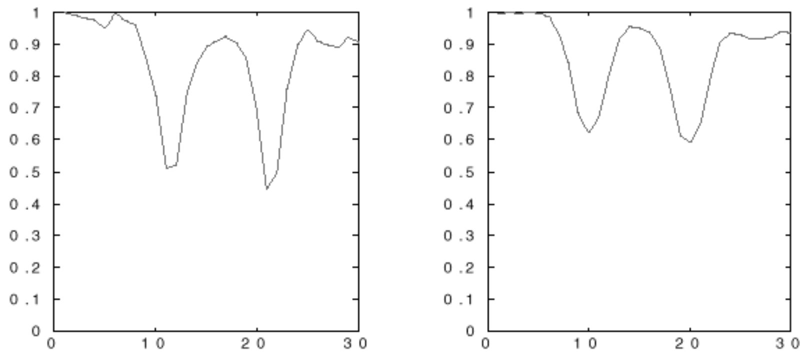

Figure 2. *Spectra with a narrow slit (left) and wide slit (right)*

The specified resolution with the wide slit varies from 54,000 to 65,000 depending on wavelength. The specifications are thus fulfilled.

Due to lack of a proper light source, a detailed study as function of wavelength has not taken place yet. Since the first tests a Thorium Argon hollow cathode lamp has been acquired, which permit more extensive tests to take place.

3.2. Transmission

We have measured the transmission through the optics on the table and verified that the assumptions going into a full simulation are correct. As the final fiber unit is not yet available, we can not test the transmission from the light enters the fiber unit through the fiber and slit to the detector. The expected performance is shown in the Fig. 4.

It is possible to have a second fiber unit optimized for R=30,000 with a higher transmission increasing the maximum transmission to close to 20% (Lindberg 1988). The instrument can be supplied with both units, and then one is selected which fits the requirements of a particular observing program best.

3.3. Stability

The lab setup is not really suited for tests of stability. The table is an open table in a thermally varying room. But, we did make a test of the stability from one day to the next day of the position on the CCD of a spectral line. The change was about 0.05 pixel, which corresponds to a change of 70 m/s in velocity. When the spectrograph has been properly enclosed in a thermally stable box, more detailed tests will be initiated.

Finally, studies of the scattered light level experimenting with internal baffles indicate that a low level can be achieved with FIES.

4. Installation plan

The preparation for installation at NOT is described in detail by Lindberg and Frandsen (1998). The remaining work can be split in a few independent parts

1. Construction of a double thermal enclosure, the inner protecting the optics

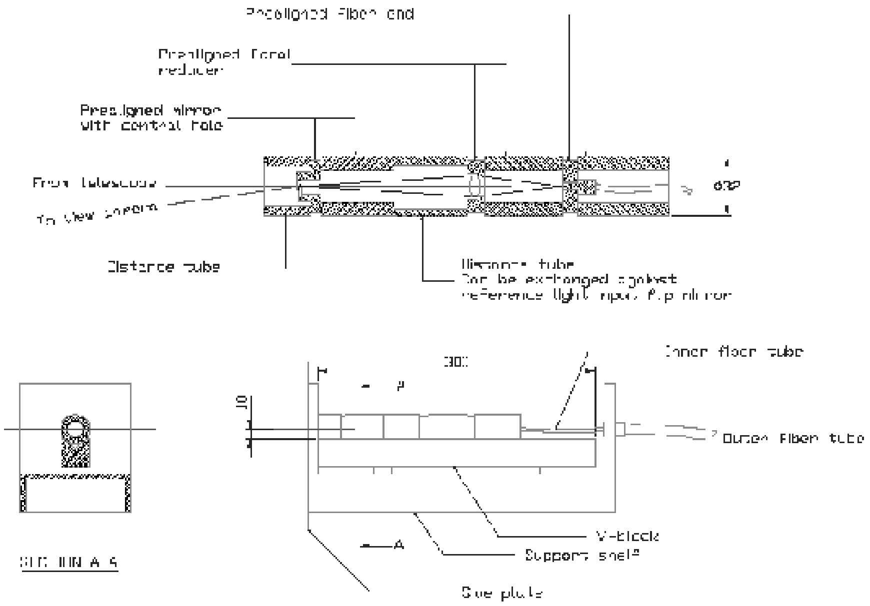

Figure 3. *A model fiber unit. Only one fiber end of such a fiber assembly is shown*

against dust and light, the outer providing thermal control and access to items like the Dewar and the fiber unit.

2. Automatisation of the calibration unit and the focus of the optical camera.

3. Construction of a fiber unit feeding the spectrograph with light in an optimum way. This fiber unit has been extensively redesigned in order to maximize transmission and provide greater flexibility and reconfiguration possibilities. An example using small optics placed in a V-groove is shown in Fig. 3.

4. Documentation: a technical manual and a Users Guide.

The work has started on the completion of the laboratory instrument into a field version. Before shipping the instrument a number of test will take place to ensure that no serious problems will occur in attaching the spectrograph to the telescope. We foresee two possibilities for feeding FIES: from the HiRAC II unit and from a position in the adaptor. A special fiber unit must be constructed for each position.

The instrument is easily reconfigured for installation at any telescope providing access for a fiber unit. There are also several simple routes for upgrades giving higher resolution, better resolution or higher transmission. They are discussed in Lindberg and Frandsen (1998).

5. Recommendation

FIES as an online facility at NOT is a very attractive instrument. It is an efficient instrument for many stellar studies and a good backup when weather conditions do

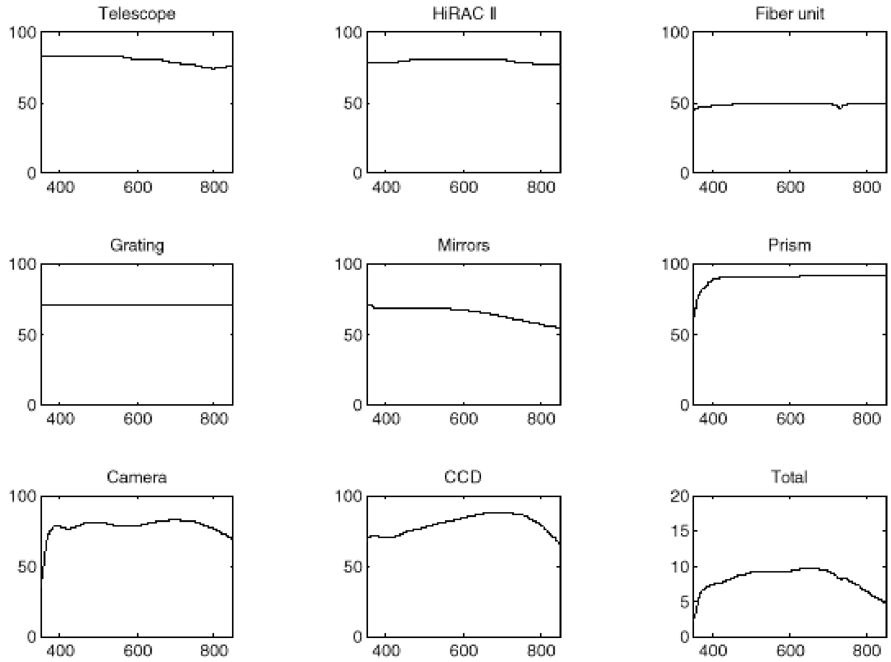

Figure 4. *Estimates of transmission of nominal design at R=60,000*

not permit high quality imaging. It provides a platform that permit further upgrades to take place without interfering too much with the operation of the telescope, which makes it possible to keep the instrument at a competitive level with other similar instruments. We strongly recommends that FIES is installed and evaluated at NOT as soon as possible.

Acknowledgments. We have had great pleasure discussing design aspects and possible improvements with Michael Andersen.

References

Andersen, M. & Sørensen, A.N. 1998, www.astro.ku.dk/~ijaf/reports.html, "HiRAC II, a 5-mode adaptive optics system for the NOT"

Dybdal, S. & Frandsen, S. 1992, NOTSA Report, "Progress report for the VELUX spectrograph for the Nordic Telescope"

Lindberg, B. 1998, LensTech AB, Fäbogatan 26, S-931 56 Skellefteå, "The FIES Spectrograph for NOT"

Lindberg, B. & Frandsen, S. 1998, www.obs.aau.dk/~srf/papers/STC_report.ps.gz, "FIES: A high resolution FIber fed Echelle Spectrograph for NOT"