A New High-Resolution Holographic Grating for the Blue Arm of EMMI

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1. Introduction

A high-resolution capability for the blue arm of EMMI has been high on the list of wishes of many astronomers. As cross-dispersion is not possible in the blue arm, S. D'Odorico and H. Dekker explored the possibilities and found that the best solution would be a holographic grating with a very high groove density. Previously the highest groove density grating was Grating #3 with 1200 g/mm, but the new grating (hereinafter Grating #11) with 3000 g/mm pushes the resolution limit down from 0.1 nm to 0.03 nm entering the domain of the echelle in the red arm.

Grating #11 is produced with holographic techniques: i.e. the grating grooves are not manufactured with the conventional process of diamond ruling, but with the chemical treatment of a blank coated with photoresist and impressed by interference fringes from a stabilized laser (Hutley 1976). The advantages of holographic gratings with respect to the conventional ones can be summarized in two main points (Dravins 1978):

(1) The holographic process permits a higher density of grooves with respect to the conventional ruling, therefore allowing a higher spectral resolution for a given slit width and beam dimensions.

(2) The ruling process is extremely clean. The surface of each groove does not present the (even small) imperfections (microroughness) present in the conventional gratings. These imperfections are the main source of grating scattered light. Also, the very precise groove spacing eliminates the possible periodical errors in the inter-groove spacing, which is the major cause of ghosts.

As a consequence, holographic gratings produce very pure instrumental profiles and a very low level of stray light (see for example Dravins 1978, Gilliotte and Mendes de Oliveira 1994).

On the other hand, low groove density holographic gratings have a lower efficiency than blazed ruled gratings due to the fact that their symmetrical groove profiles diffract light in the + and − orders with about equal efficiency. Only recently has it become possible to obtain blazed holographic gratings by the combination of ion etching and interferometric techniques.

However, if the grating is used at a high angle of incidence the grating equation $\sin\alpha + \sin\beta = m\lambda n$ [1] permits only diffraction in the zeroth and first order as the other orders have $|\sin\beta| = |m\lambda n - \sin\alpha| > 1$. For a 3000 g/mm grating in the 300–500 nm range, the value of λn ranges from 0.9 to 1.5. In this domain the diffraction efficiency of a holographic grating reaches acceptable values whereas stray light is much better than that of ruled gratings.

Many spectral lines of astrophysical interest are located in the spectral region from 300 to 520 nm covered by EMMI blue, and it is important to have the capability to study these lines in detail. Grating #11 will therefore provide the ESO user community with a configuration with a resolution intermediate between that of the low-resolution spectrographs present at La Silla (Boller & Chivens, EFOSC's, and EMMI) and that of the high-resolution spectrographs (CASPEC, CES, EMMI Echelle). Thanks to the absence of a cross-dispersing element, it is possible to approach high-resolution capabilities with an efficiency close to that of low-resolution spectrographs.

[1] α and β are the angles of incidence and exit, respectively, with respect to the grating normal, m is the order number, λ the wavelength and n the number of grooves per mm.

The Grating

The grating characteristics are summarized in Table 1 and the efficiency curve is shown in Figure 1.

Although the efficiency curve strongly depends on the polarization of the light, the average efficiency is quite good, as it may be deduced by comparing Figure 1 with the efficiency of the classical gratings available at the NTT (Giraud 1994). This comparison is even more favourable considering that the groove density is more than doubled with respect to the conventional gratings.

Grating #11 is mounted on a standard EMMI support, and the central wavelength can be changed by the user using the standard EMMI user interface software.

TABLE 1.

Grating #11 specifications	
Type	Holographic plane grating
Grooves/mm	3000
Wavelength range	300–500 nm
Stray light	1×10^{-10} (measured by Jobin-Yvon)
Size	180 × 135 × 30 mm
Blank Material	Silica
Manufacturer	Jobin-Yvon

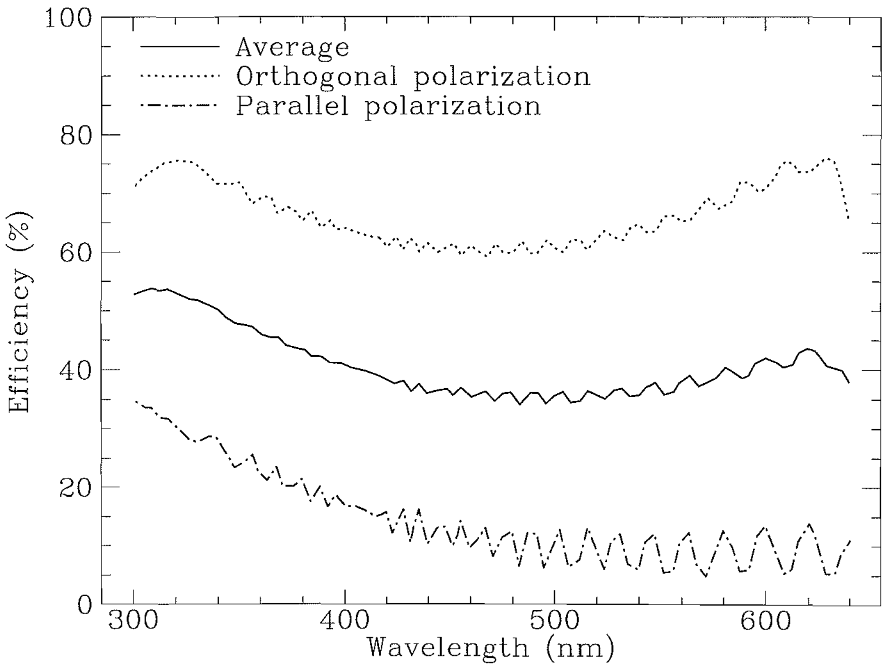

Figure 1: *The efficiency of Grating #11 as measured in the laboratory by B. Buzzoni. Note the very strong dependence on polarization, especially towards the red.*

Results of the Tests

After some small modifications to its original housing, Grating #11 was successfully mounted for the first time in November 1993. The first astronomical tests were performed in December 1993.

The dispersion, as measured directly on Th-Ar spectra, is 0.64 nm/mm at 390 nm. Considering the pixel size (24 μm) of the Tektronix CCD mounted on the blue arm of EMMI and the non-cross-dispersed format, this translates into a spectral range of 15 nm. The slit resolving power product R_s is about 9000 at 400 nm (1" slit) but the maximum resolving power (considering two pixels FWHM) is almost 13,000 at 400 nm. This resolving power can only be realized with a 0.7" slit but it is not at all unreasonable to use such a narrow slit at the NTT. Tests with the internal Th-Ar lamp have shown that two pixels FWHM can also be obtained in practice with this grating, if the instrument focus is kept under very good control. These tests also showed that the resolution was uniform within $\pm$ 0.2 pixels over the covered spectral range without any obvious trends with wavelength.

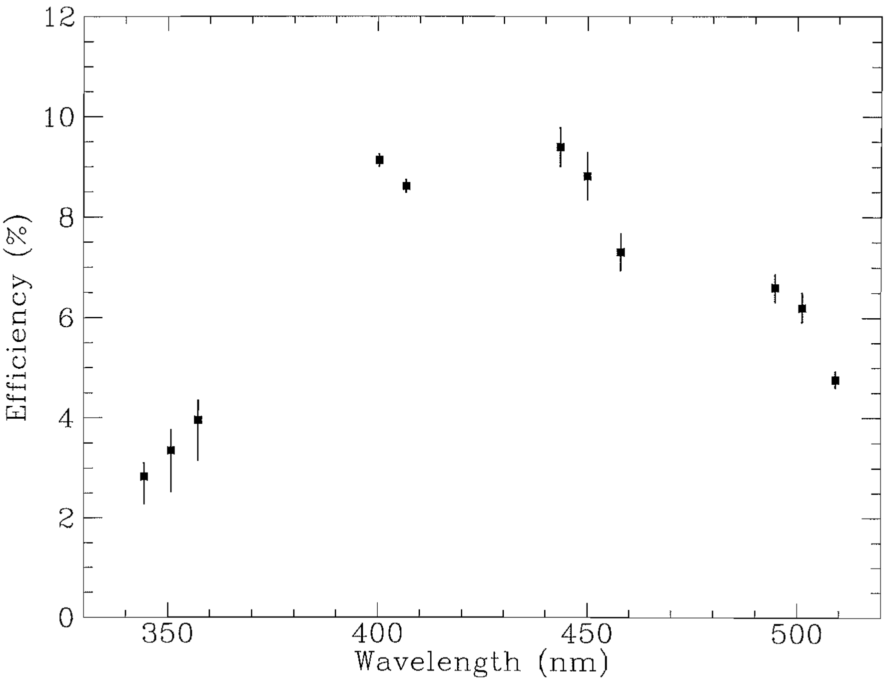

Figure 2: *The total efficiency of the NTT, EMMI blue with Grating #11 and CCD#31 as a function of wavelength. The error bars indicate the actually measured values for the two stars observed.*

No ghosts were found, even in very high S/N observations. Note here that ghosts are quite common with high-density groove conventional gratings.

The efficiency of the whole system (NTT + EMMI + Grating #11 + CCD #31) was measured with 4 different wavelength settings, observing two high-resolution spectrophotometric standard stars (Hamuy et al. 1992). One star was observed at low and one at high airmass. The results are summarized in Figure 2, where the measured efficiency is given as a function of wavelength. The error bars indicate the position of the individual measurements for the two stars. For the wavelengths shorter than 390 nm the high airmass measurements were only given half weight as mean extinction coefficients were used for the reduction.

The curve matches very well the efficiency expected from the grating efficiency curve of Figure 1, together with the CCD #31 response and the transmission of the EMMI blue optics (Giraud 1994).

The efficiency peaks at more than 9% in the B pass band, a value which compares very well with state-of-the-art high-resolution spectrographs in this spectral region.

An obvious use of the grating will be in the dichroic mode (DIMD) with one of the echelle gratings mounted in the red arm of EMMI. In this configuration the new grating will, simultaneously, provide a complementary blue spectrum at a comparable resolution to the one achieved in the red arm. The light loss due to the dichroic beamsplitter in the wavelength range 385 to 400 nm ranges from about 15 to 25% but this should be considered an upper limit as the dichroic prism and the wide-band mirror are performing better at bluer wavelengths.

Grating #11 is offered to the users starting the next period.

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New Holographic Grating for the B&C on the ESO 1.52-m Telescope

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There are 31 ruled gratings currently available for the Boller and Chivens spectrograph (B&C) on the ESO 1.52-m telescope. These have dispersions ranging from 3.2 to 51 nm/mm. Recently, a new holographic blazed grating has become available from the Jobin-Yvon manufacturer and successfully tested at La Silla. This grating is designated #32. Its main characteristics are given in Table 1.

In first order, grating #32 gives the