SNFactory-SNIFS/02-004

Redefinition of the blue grating

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1 Grating blaze function

The transmission of a perfect transmission grating (neglecting any polarization effect) is given by the product of the grating function with the diffraction pattern of one groove of the grating :

$$I = \frac{\sin^2(N\Psi)}{\sin^2\Psi}\frac{\sin^2\Theta}{\Theta^2} \tag{1}$$

where

$$\Theta = \frac{\pi a(n\sin i - \sin r)}{\lambda}, \quad \Psi = \frac{\pi b(n\sin i - \sin r)}{\lambda} \tag{2}$$

with n being the index of the grating substrate, i the incidence angle, r the refracted angle, a the size of the grooves, b the grating step and N the number of grooves of the grating. The maximum of energy is sent in the 0 order, and the gratings are thus usually blazed to a given angle to shift the diffraction pattern of the grooves with respect to the grating function. If the blaze angle is γ, Θ is rewriten :

$$\Theta = \frac{\pi b\cos\gamma(n\sin i - \sin r)}{\lambda} \tag{3}$$

Note that i and r are no more the angle from the grating normal but to the grating groove normal, these two direction being no more aligned. The function $\frac{\sin^2\Theta}{\Theta^2}$ is then called the blaze function, and provides the theoretical transmission curve of the grating. If α and β are the incident and refracted angles from the grating normal, one have the following relations :

$$m\rho\lambda = n\sin\alpha - \sin\beta \tag{4}$$

whare m is the diffration order and $\rho = 1/b$ the lines density of the grating.

$$i = \alpha - \gamma,\ r = \beta - \gamma \tag{5}$$

It is an easy task to find the transmission curve as a function of the wavelength for a given incident angle.

2 The grism case

In a grism, the grating is a resin replica of a master, glued on a glass prism as shown in figure 1. The glass and resin have the refraction indexes n_g and n_r. The angles used in the following are defined on figure 1. The grating function gives the values of β at which the energy is diffracted for a given λ and a given incidence α. In the normal configuration, one have $\alpha = \Phi$ where Φ is the prism angle.

$$m\rho\lambda = n_r\sin\alpha' - \sin\beta = n_g\sin\alpha - \sin\beta$$

Where m is the diffraction order. The prism angle is determined by the wavelength λ_n at which one wants no deviation :

$$\lambda_n = \frac{(n_g - 1)\sin\Phi}{m\rho}$$

One can see that this relation is independant of the resin index.
On the other hand, the blaze function is given by the value of Θ (equation 2) which depends on n_r.

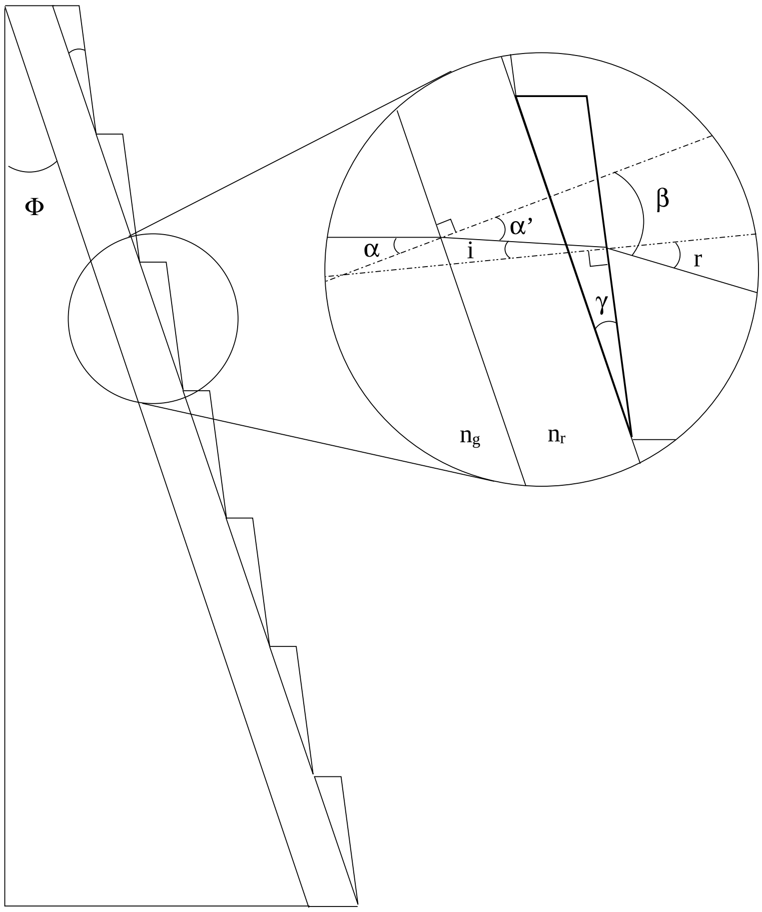

Fig. 1 – Grism configuration

The wavelength at which the blaze function reach its maximum is called the blaze wavelength (λ_b). It is straightforward to see that this occurs when $\Theta = 0$. One has the following relations :

$$n_r \sin i - \sin r = 0 \tag{6}$$

$$i = \alpha' - \gamma, \; r = \beta - \gamma \tag{7}$$

$$\alpha' = \arcsin\left(\frac{n_g}{n_r}\sin\alpha\right) \tag{8}$$

$$\beta = \arcsin(n_g \sin\alpha - m\rho\lambda) \tag{9}$$

Using the previous relations and the fact that $\alpha = \Phi$, equation 6 becomes :

$$n_r \sin\left[\arcsin\left(\frac{n_g}{n_r}\sin\Phi\right) - \gamma\right] = \sin\left(\arcsin(n_g \sin\Phi - m\rho\lambda_b) - \gamma\right) \tag{10}$$

This gives the expression of the blaze wavelength λ_b :

$$m\rho\lambda_b = n_g \sin\Phi - \sin\left[\arcsin\left[n_r \sin\left(\arcsin\left(\frac{n_g}{n_r}\sin\Phi\right) - \gamma\right)\right] + \gamma\right] \tag{11}$$

3 Problem of the SNIFS blue channel grism

When we calculated the SNIFS grism blaze functions, we made the assumption that the resin used for the grating replica had a refractive index close to the fused silica one. This gave for the blue channel the blaze function ploted in figure 2. Note that in this figure, the black area show the broadening of

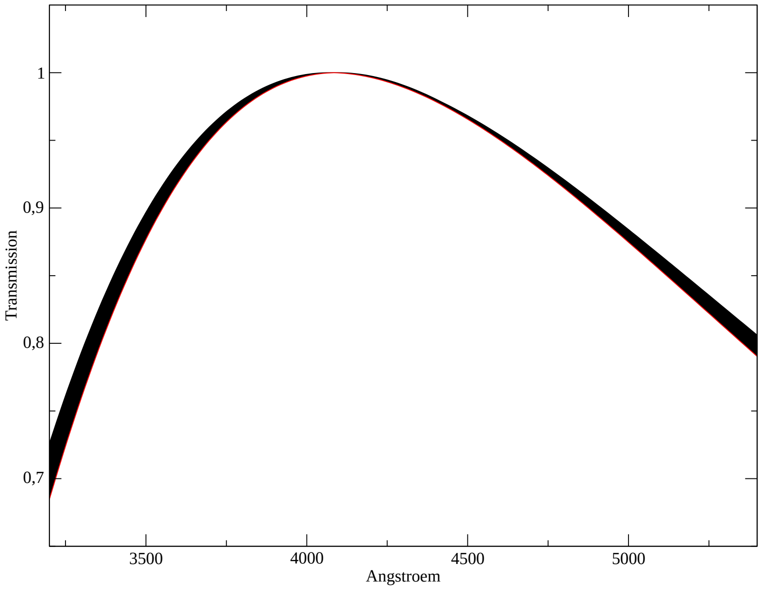

FIG. 2 – Expected transmission of the Richardson grating 360 lines/mm, $\gamma = 18.2^o$, on a fused silica prism with $\Phi = 19.35^o$. The broadening of the curve is due to the different incidence angle on the grism from one lens to another

the curve due to the different incidence angle on the grism from one lens to another. The blaze angle is 18.2^o, the prism angle 19.35 and the grating has 360 lines/mm. The choice of the grating was made on the Richardson catalog. Unfortunately, it appears that the epoxy resins used by Richardson for their replicas have a significantly higher index than fused silica. The comparison for the two extreme epoxy index curves with the fused silica one is displayed in figure 3. This difference of refraction indexes has a

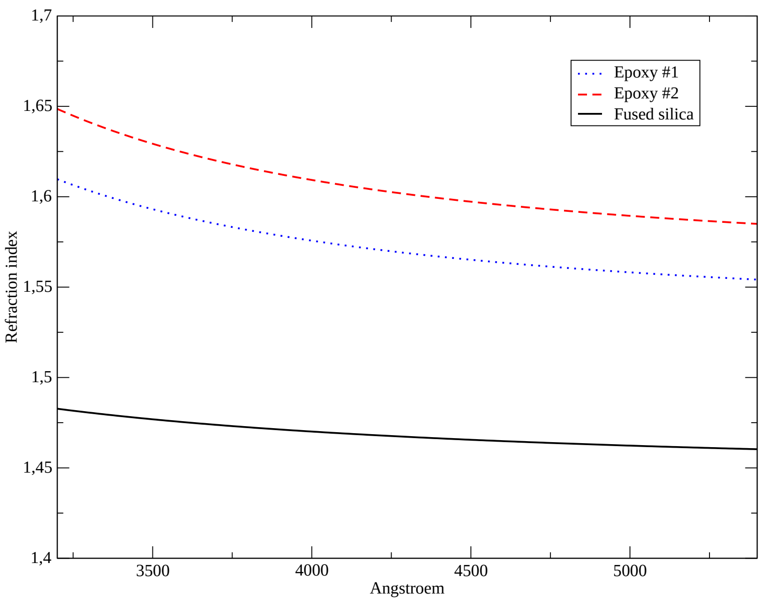

FIG. 3 – Comparison of the epoxy resin indexes with the fused silica one.

strong impact on the blaze function, shifting redward the blaze wavelength up to $\simeq 5000$Å. To solve the problem, one has to play with the two degree of freedom available : choice of the resin and of the blaze angle. If we want to keep a reasonable cost for the grating we have to chose it from the catalog. For the 360 lines/mm, we have the choice between the following blaze angles : 10.4^o, 18.2^o, 21^o, 31.3^o and 42^o. To shift blueward the blaze wavelength the blaze angle must be smaller, and we have only one choice. Figure 4 displays the transmission curves with the interface epoxy/air for the 18.2^o and 10.4^o gratings compared to the expected one if the interface was silica/air. It appears that the 10.4^o grating is neither

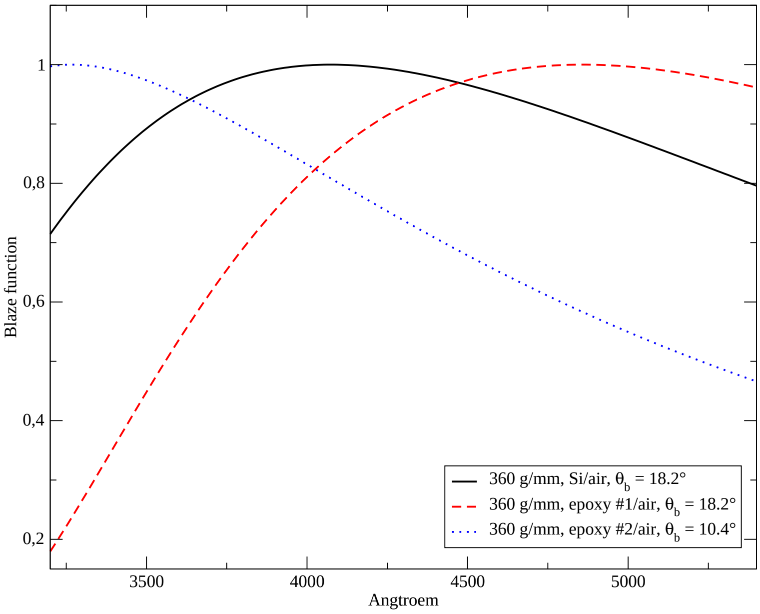

FIG. 4 – Blaze function for the 360 lines/mm gratings

well suited because its transmission curve is too blue. The only possibility is then to change the lines density, and thus the spectral resolution. In the Richardson catalog we can chose either 400 lines/mm or 300 lines/mm. The 400 lines/mm must be ruled out because the camera is not sized to accept the larger angle due to the higher dispersion. The only usable gratings in the 300 lines/mm are the 10.4^o and the 14.8^o. The corresponding blaze function are shown in figure 5 It appears that the only acceptable

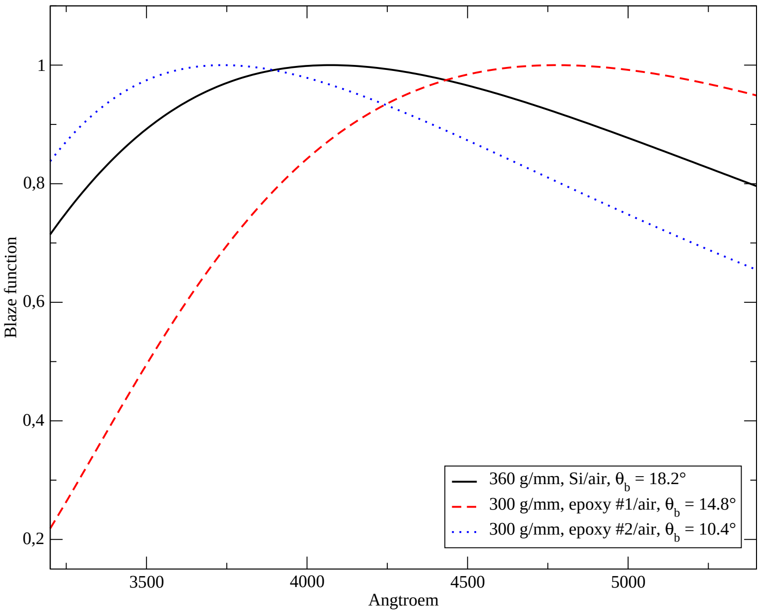

FIG. 5 – Blaze function for the 300 lines/mm gratings

grating is then the 300 lines/mm 10.4^o. With the 360 l/mm, the spectral sampling was between 1.71 Å and 2.14 Å . With a 300 l/mm one can estimate roughly that the sampling will be between 2.05 Å and 2.57 Å. I consider that this can be accepted for the scientific program. A little bit more worrying is the impact on the distorsion. In the blue channel, the lateral chromatism was not corrected, and in the edge of the field, some spectra were separated (at their extremity) by 5 pixels. This value will be now 4.5

pixels. Furthermore, there are some collision of 0 orders with first order spectra. These effect are shown in figure 6 and figure 7

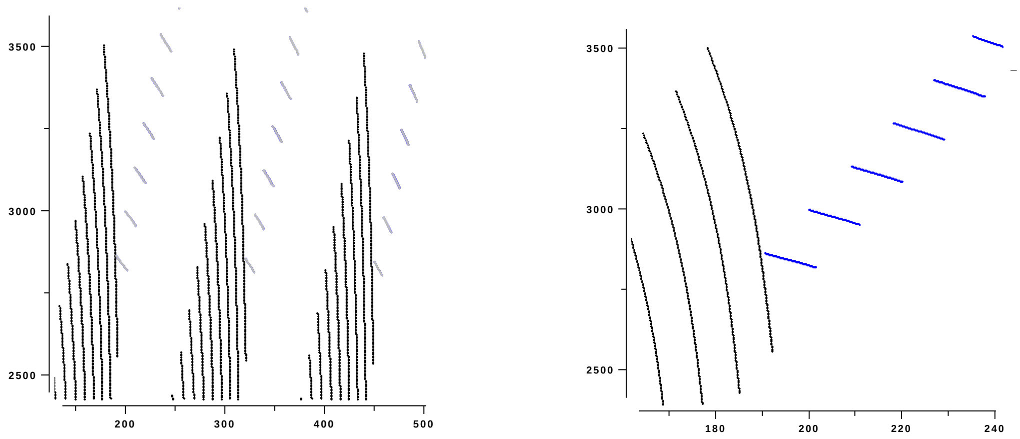

FIG. 6 – zero and first order collision in the edge spectra

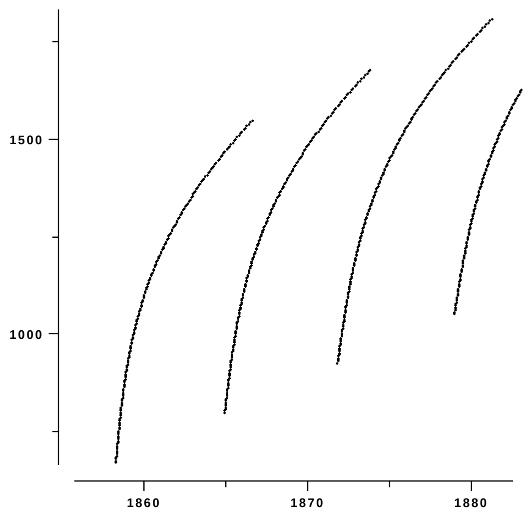

FIG. 7 – Effect of chromatic distorsion on the edge spectra