2.5 Characteristics of the gratings

The VPH gratings are not too expensive, and we can think in terms of a reasonable number of gratings that can be simultaneously installed in the bench spectrograph and remotely interchanged. From our study of efficiency and resolution as a function of wavelength, we consider that 6 gratings would be ideal to reach the specifications of the spectrograph. The observations could start with a smaller number, if we have difficulties to obtain the complete set in a short time.

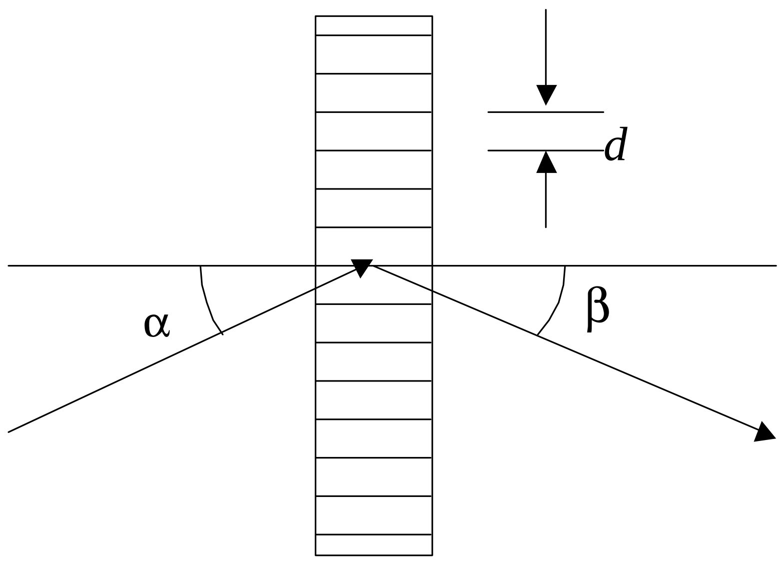
We present here the set of 6 VPH gratings. The studies were made with the software *G-solver*, which is based on *Rigourous Coupled Wave Analysis*. The angle of the grating and of the camera must be tuned independently to get maximum efficiency at a given wavelength. We always use first order, and do not consider using the gratings at efficiency lower than 50%.

2.5.1 Details of the calculations

We considered that:

- The grating will always operates near the Bragg, regime, in which the deflection angle β is equal to the angle of incidence α as shown in the figure below.
- We consider the resolution associated with 2 pixels, since the image of the output of a fibers corresponds to 2 pixels of the CCD. The resolution is related to β, as follows:

Fig 2.11



$$R = \frac{\lambda}{\Delta\beta * \frac{d\cos\beta}{m} * \frac{1}{2000}}$$

N° of pixels of CCD/2

(angular dispersion)$^{-1}$

“camera FOV”

$\Delta\beta = 10{,}41^{o} = 0{,}181688$ radians

Using:
$\beta = \alpha$
$m\lambda = 2\, d \sin\alpha$ (2)
Equation (1) can also be wrtten as:

$$R = \frac{4000 * \tan(\alpha)}{\Delta\beta} \qquad (3)$$

A resolution R= 30 000 is reached at $\alpha = \beta = 53.72^{0}$. Interestingly, this does not depends on *d* or λ. The grating must be sufficiently wide to intercept the beam without vignetting; for a 100 mm beam this implies a 100 x 169 mm grating.

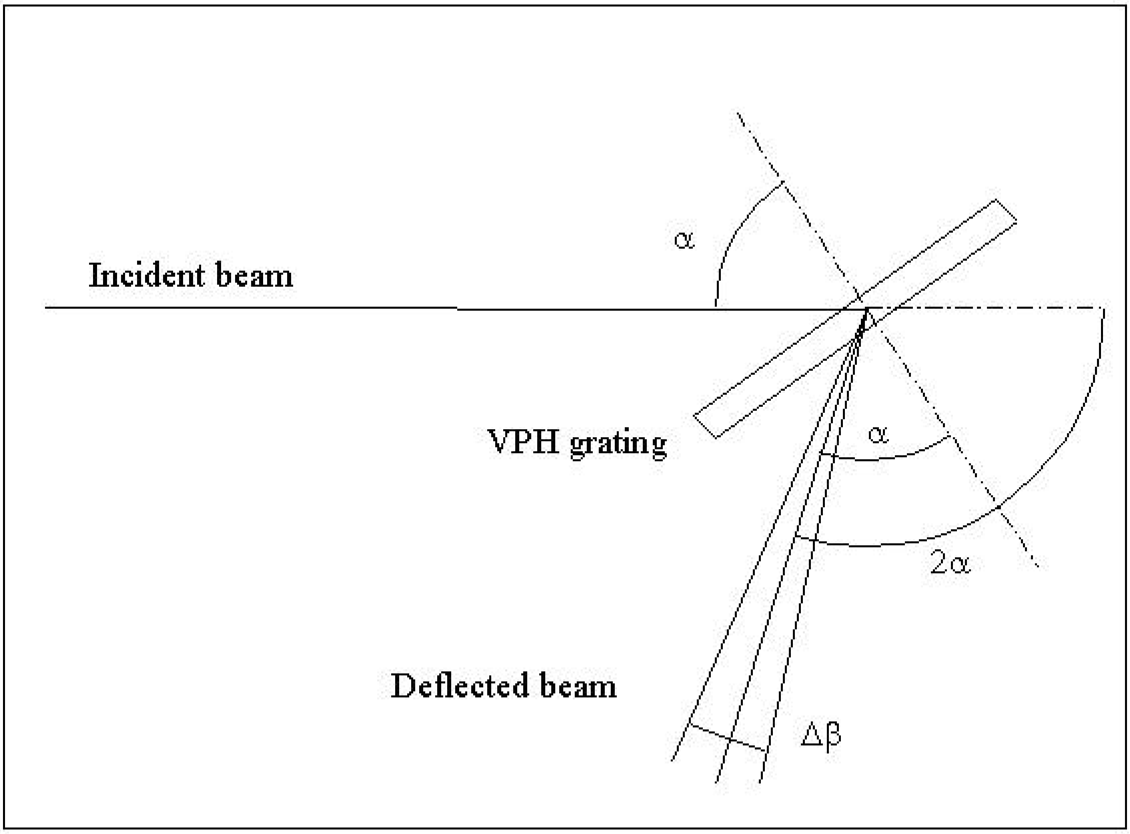


Figure 2.12

The set of gratings that we propose is presented in Table 1. The parameters are the density of grooves, the amplitude of modulation *Dn* of the index of refraction, the thickness *d* of the gel layer. In our simulations we optimized *Dn* and *d*.

Frequency (gr/mm)	Δn (for n=1,5)	d (μm)
500	0,040	9,1
1300	0,075	4,0
1800	0,075	4,0
2200	0,07	5,0
2600	0,05	5,5
3600	0,04375	4

Table 1 - Parameters for the set of 4 gratings.

2.5.2 Description of the gratings

In all cases, we considered a maximum angle of incidence of 65^{O}, which limits the resolution to ~45000.

500 g/mm

Figure 2.13 shows the efficiency curve for the two ranges of wavelengths, from 350 to 700 nm, and from 700 to 1100 nm. With two position angles of the camera, the entire wavelength range can be covered with efficiency greater than about 70%. The resolution as a function of wavelength is presented in Figure 2.19.

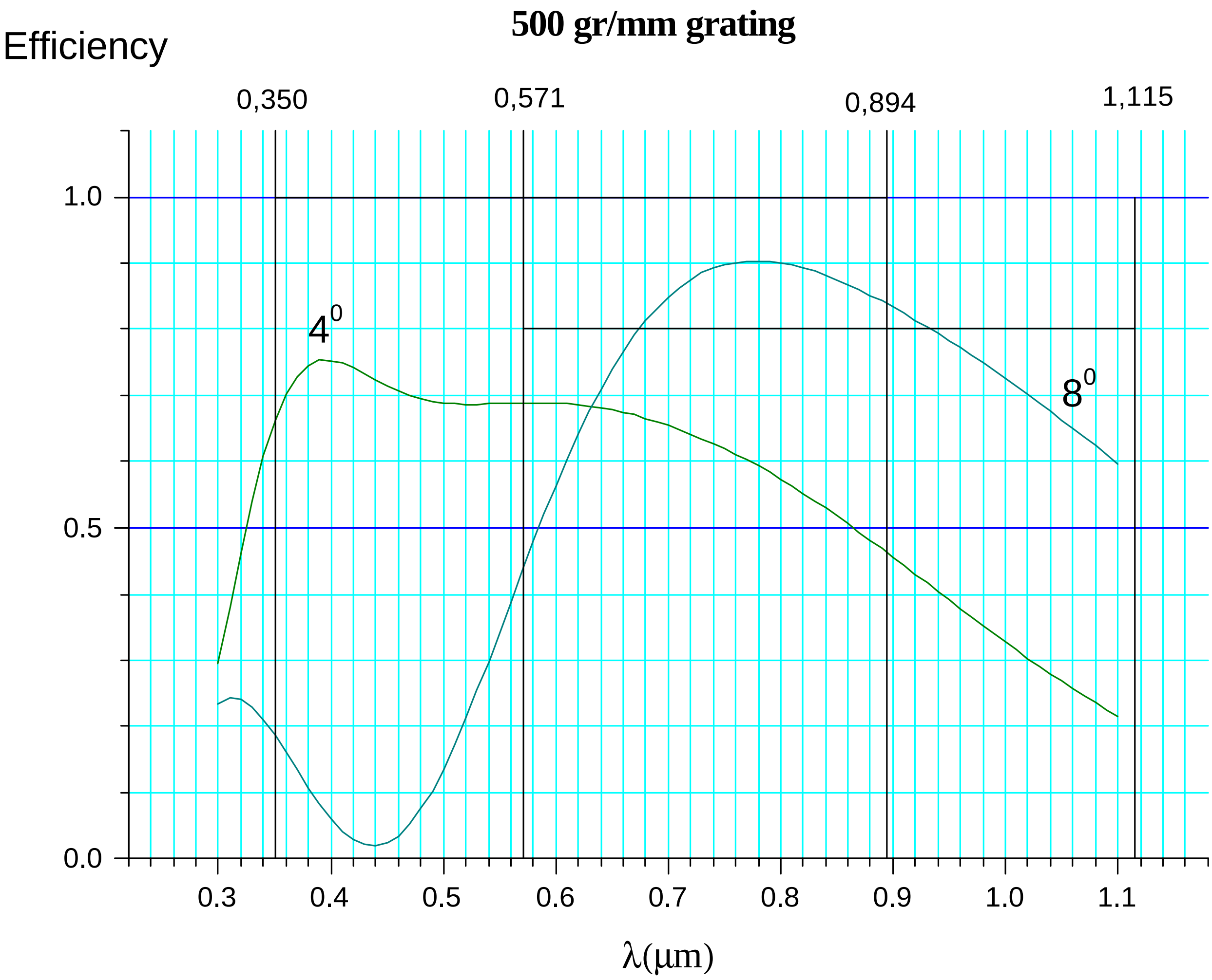


Fig. 2.13

1300 gr/mm

Figure 2.14 shows efficiency curves for different values of α, in the range of 534 to 1112 nm. Below 534 nm the efficiency falls down quickly, but this region is well covered by the other gratings. There is a peak of 93% efficiency at 600 nm. The separation between the vertical lines indicates the CCD coverage in one observation.

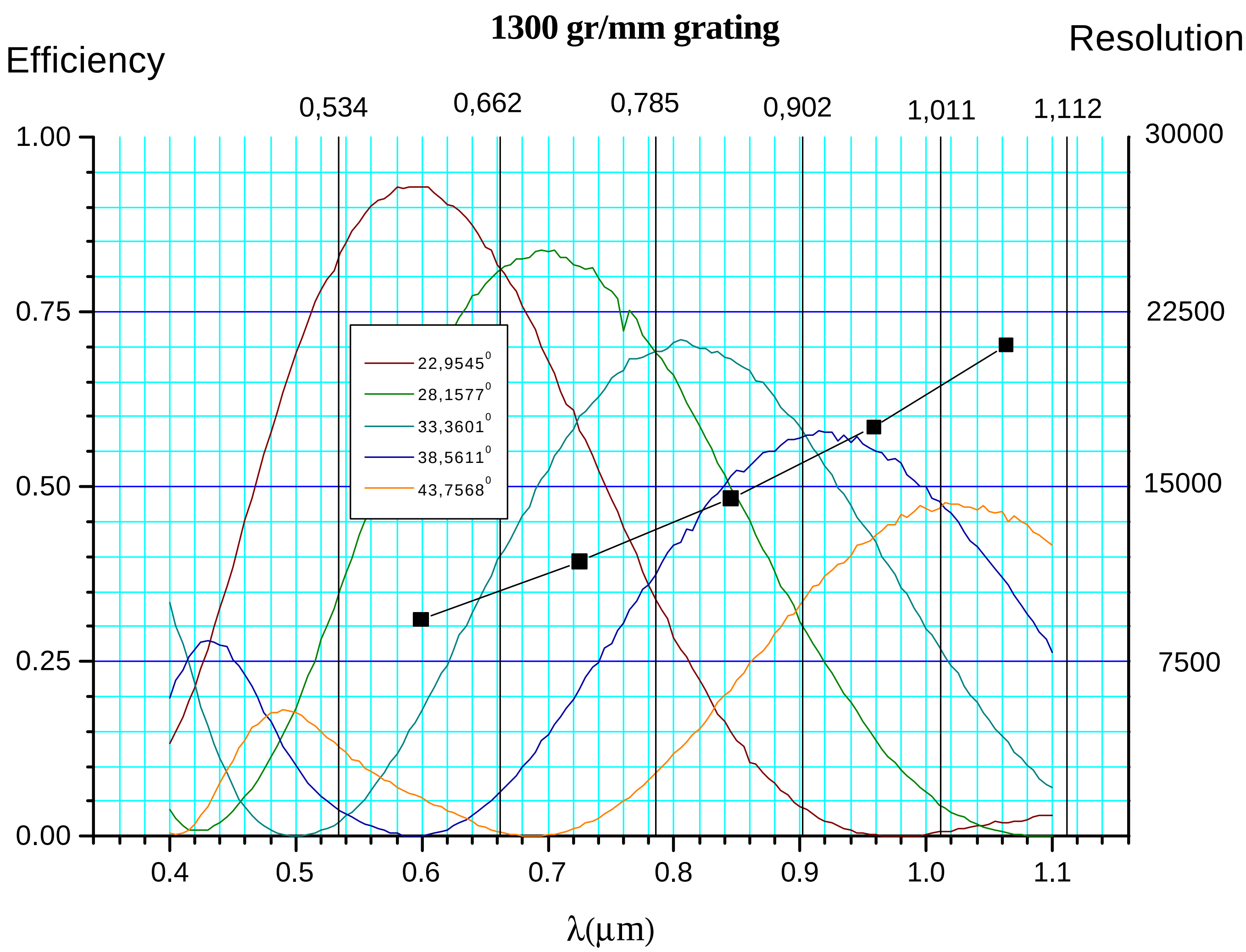


Fig 2.14

1800 g/mm

This grating is designed for use between 500 and 1050 nm. In this range, the resolution varies from 11000 to 55600 . An efficiency of 93% is reached at α = 33,0520° (Figure 2.15)

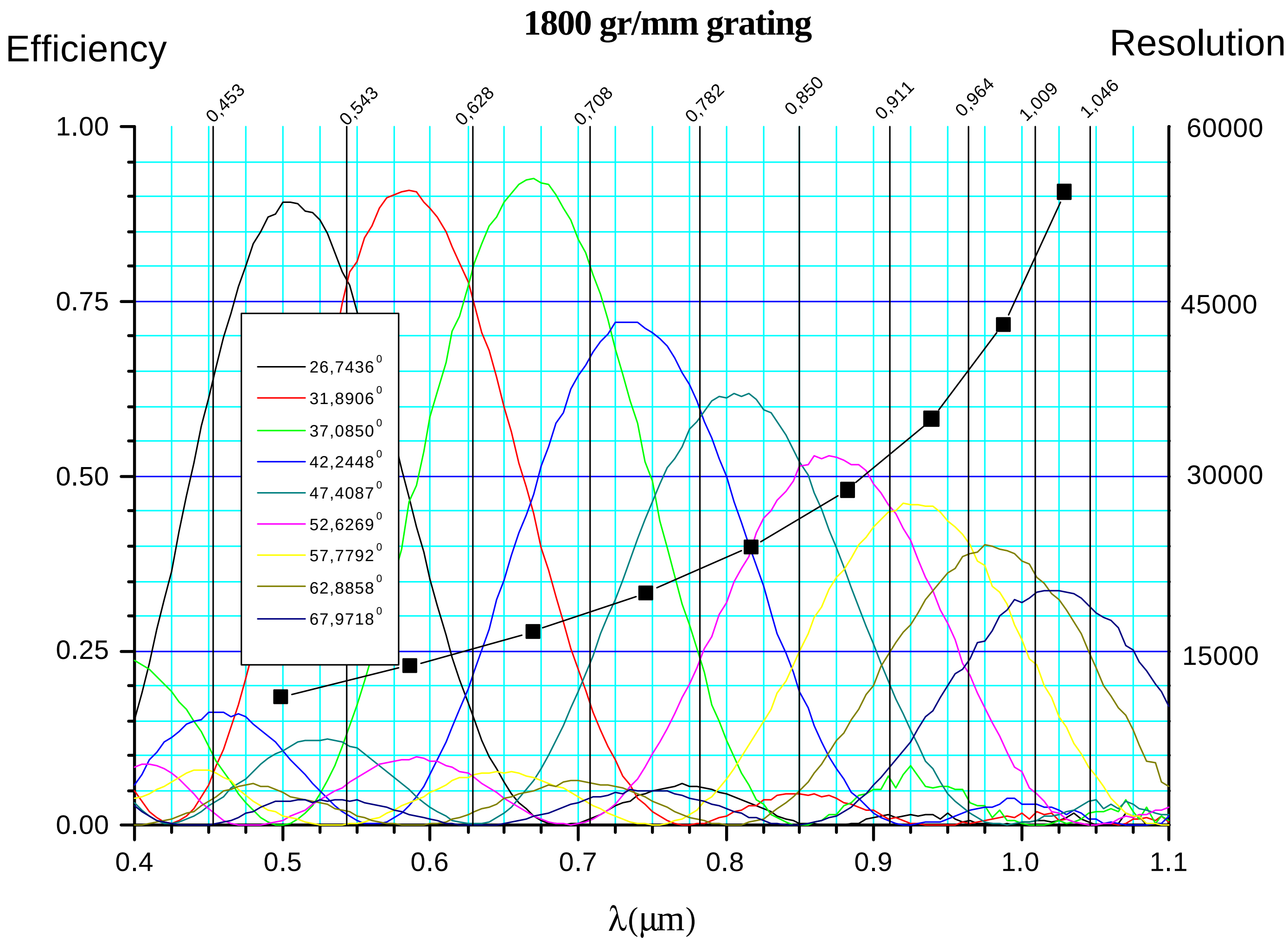


Fig. 2.15

2200 gr/mm

This grating offers a resolution ranging from about 15 000 to 40 000, between 500 and 800 nm.

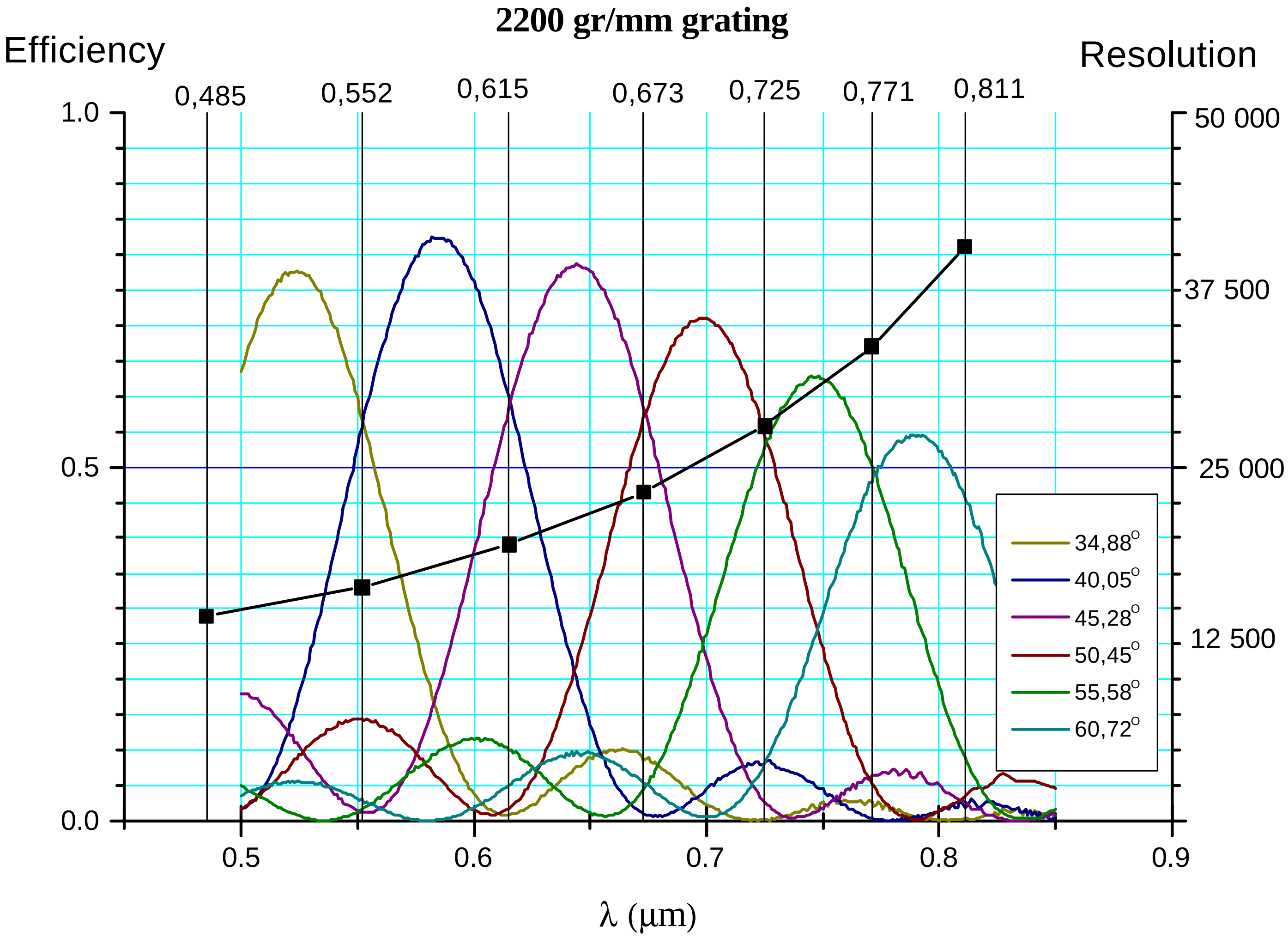


Fig. 2.16

2600 l/mm

This grating is designed to be used mostly between 350 and 700 nm. An efficiency of 85% is reached at $\alpha = 47^o$.

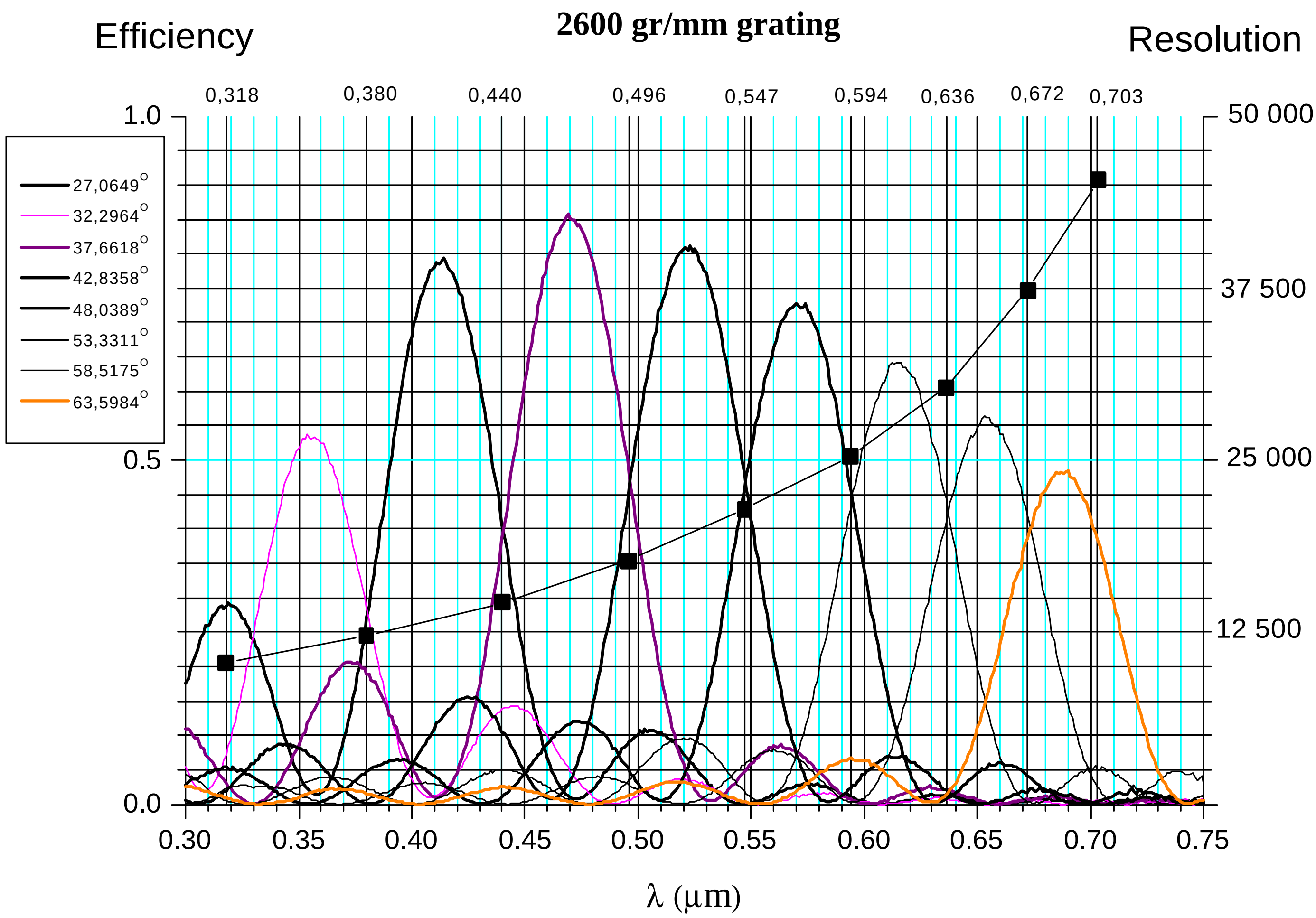


Fig. 2.17

3600 gr/mm

This grating is only usefull over the wavelength range 350 nm- 500 nm. Its efficiency at 350 nm is 85%, so that it plays an important role to guarantee a good overall efficiency at 350 nm.

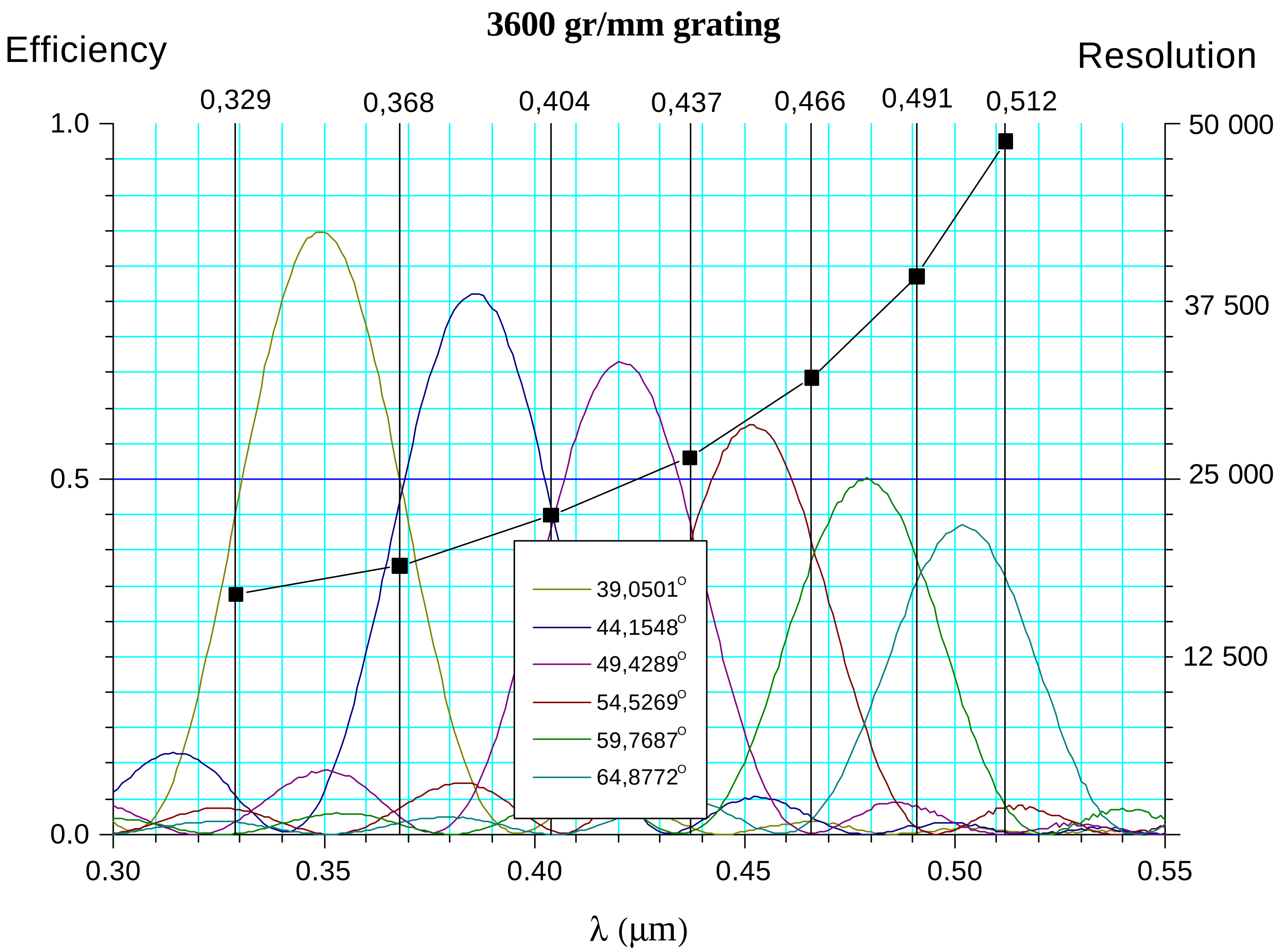


Fig. 2.18

The resolution obtained from expression 1, is shown for the 6 gratings in Figure 2.19

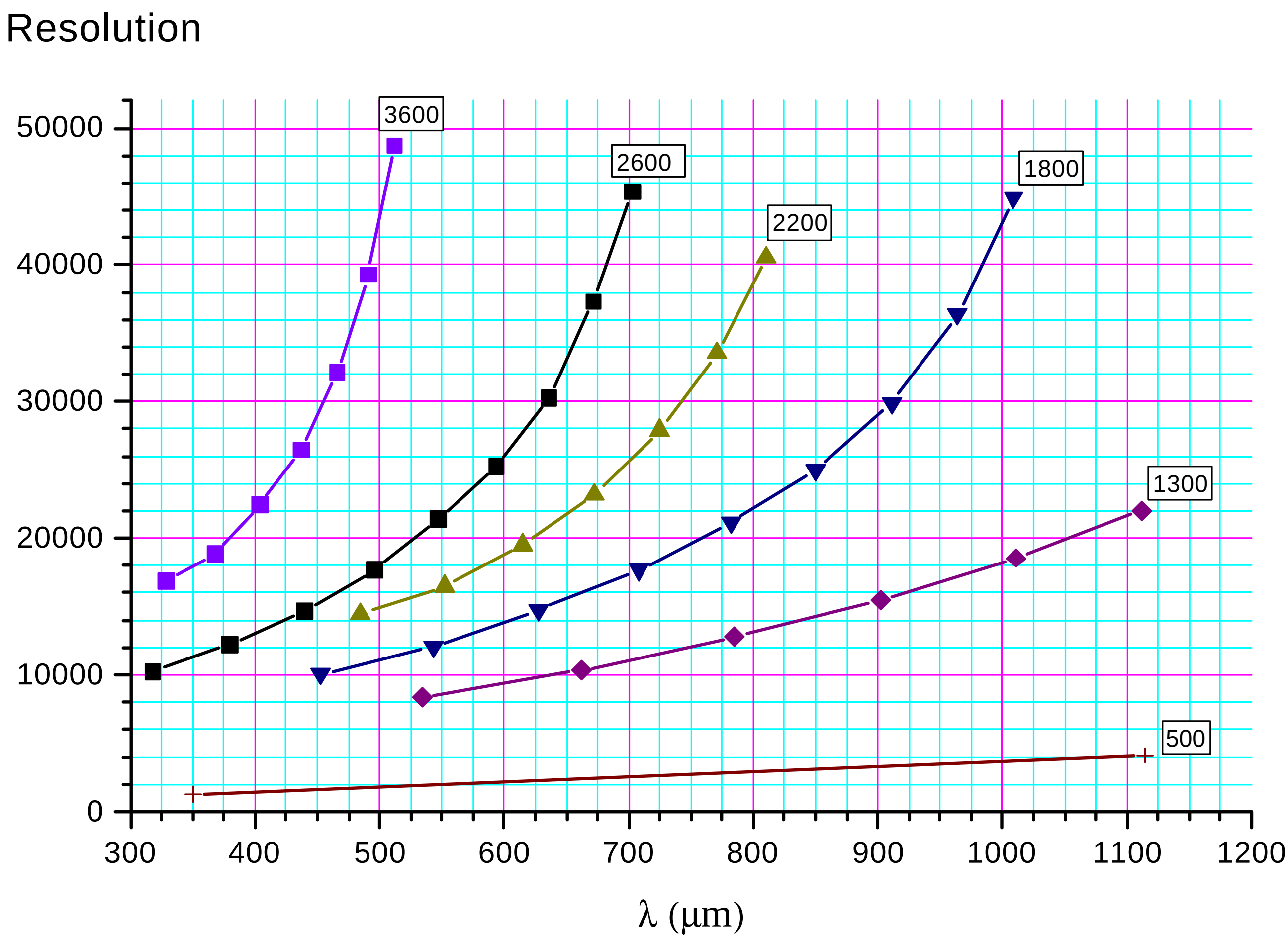


Figure 2.19

Conclusion

The proposed set of gratings enables us to reach resolution higher than 20 000 over a large fraction of the 350-1000nm range, and at the same time to provides a wide range of resolutions. The lowest resolution allows us to cover the whole wavelength range in two steps, and the highest resolution reaches about 50 000 at Hα, which is convenient for velocity measurements.