

Astronomical Applications of Volume-Phase Holographic Gratings

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ABSTRACT

Volume-Phase Holographic (VPH) gratings provide unique capabilities over classical surface gratings which can be exploited in modern astronomical spectrographs. The peak diffraction efficiency of a VPH grating is tunable due to the nature of Bragg diffraction. This allows a single dispersing element to serve the function of several classical gratings. Additionally, VPH grating structures can be stacked to produce complex gratings capable of directing the diffracted light in ways that classical gratings can not.

INTRODUCTION

A VPH grating diffracts light through the mechanism of Bragg diffraction inside a volume in which periodic modulation of the refractive index forms the grating structure. The intersection of these modulations with the surface of the element form a surface grating that disperses the light according to the classical grating equation. The energy envelope of the diffracted light is, however, controlled by the fringe modulation frequency and its orientation within the grating medium and provides peak diffraction efficiency at the wavelength that meets the Bragg condition. For a grating with fringes normal to its surface, the Bragg condition is given by

$$mv\lambda = 2n \sin(\alpha) \quad (1)$$

where m is the Bragg order, v is the fringe frequency, λ is the wavelength of light, n is the refractive index of the grating medium, and α is the diffraction angle within the grating medium.

TUNABLE SPECTROGRAPHS

As discussed by Barden, Colburn, and Arns¹, the peak efficiency of VPH gratings can be shifted in wavelength by tilting the grating with respect to the incident light, changing the wavelength that satisfies the Bragg condition. A tunable spectrograph, in which both the grating and camera angles can be adjusted, can take advantage of this characteristic to minimize the number of separate dispersing elements required to cover potential observing modes of the instrument. Classical surface relief gratings (both ruled and holographically generated) have fixed blaze profiles in which the diffraction efficiency is relatively unchanged as the grating is tilted with respect to the incident light. Although classical gratings provide flexibility in the design of a spectrograph since the camera and collimator angle do not significantly change the energy distribution of the grating, it becomes necessary to have several gratings with different blaze angles to cover the useful range of the spectrograph.

Barden, Colburn, and Arns¹ also showed that decent efficiency can be obtained when the grating is tuned for diffraction into higher than the first order of diffraction. Hence, not only can the blaze function of the grating be adjusted, but the dispersion of the grating can be varied as well, further

reducing the number of individual gratings required for the spectrograph. Good diffraction efficiency has been seen in diffraction orders as high as $m=3$ for a 300 l/mm VPH grating¹.

COMPLEX GRATING STRUCTURES

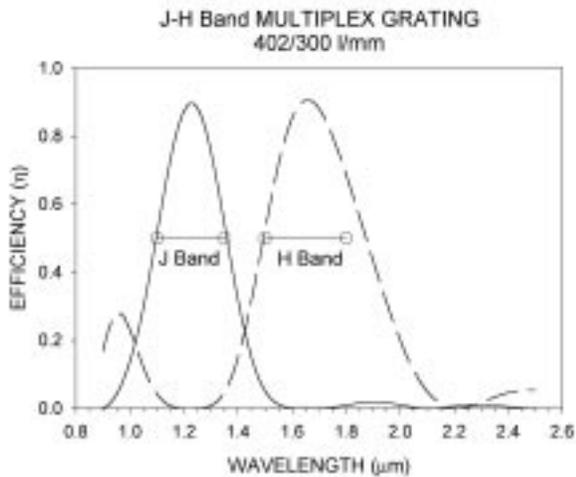


figure shows the theoretical efficiency of such a grating pair (402 l/mm and 300 l/mm) designed to superimpose the wavelengths of the J and H bands. A slight rotational tilt of the fringes in one grating with respect to the other grating will separate the spectra so that additional cross-dispersion elements are not required.

SUMMARY

Volume-Phase Holographic gratings show great potential as an alternative grating technology for astronomical spectrographs. Their tunable nature allows more versatility with a single dispersing element than can be achieved with classical gratings, both in terms of the desired wavelength being observed and in the dispersion desired. Tunable spectrographs will allow both a tilt of the grating and a means to adjust the camera-to-collimator angle by either mechanical adjustment of the angle or by introducing prism sets in front of the camera.

The ability to make complex grating structures will simplify spectrograph design by minimizing the number of optical elements required to make a classical instrument perform in a comparable manner.

REFERENCES

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