A dual-range diffraction grating for imaging hyperspectrometer based on the Offner scheme

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Abstract. The paper presents the results of a study of the feasibility of using a dual-range diffraction reflecting grating applied to a convex mirror in a imaging hyperspectrometer based on the Offner scheme. The parameters of a small diffraction grating are chosen and large for operation in the spectral ranges of visible and middle infrared regions. The results of modeling the work of the proposed configuration of the diffraction grating are presented, which showed a negligibly small effect of a large diffraction grating on the work of small and vice versa, and the negligibly small effect of a small grating on the work of a large grating. A method is proposed for increasing the diffraction efficiency of a dual-range grating for operation in the +1 order in the visible range and in the -1 near IR range. The results of modeling using the software package Zemax

1. Introduction

At the moment, for imaging remote sensing of the earth, imaging hyperspectral equipment is increasingly in demand, covering a wide spectral range [1-2]. To expand the spectral range in the hyperspectral equipment, a rotation of the diffraction grating can be used, which, turning at certain angles, allows parts to register the spectrum in a wide range. However, the rotation of the grating introduces significant delays when shooting. To eliminate this drawback, several matrices that simultaneously register the entire spectrum are often used. To separate the optical radiation into two photosensitive matrices, we can use beamsplitter platinum, the use of a separate lens for each spectral range, several slit diaphragms [3], or a reconfigurable input aperture based on a micromirror matrix [4]. In this paper, we propose the use of optical radiation for several matrices as a dispersing element of a diffraction grating of a complex configuration calculated for operation in two spectral ranges nah. The optical scheme uses the Offner scheme, which has minimal geometric aberrations. Earlier such a scheme with diffraction grating for the visible range was investigated in [5]. However, the diffraction efficiency of lattices with a simple binary profile is not high enough and, for the qualitative operation of the hyperspectrometer, the efficiency of the binary array may not be sufficient. To increase the diffraction efficiency, gratings with shine can be used [6]. In this connection, we consider a two-range diffraction grating, which is designed for two central wavelengths.

2. Simulation of a dual-range binary diffraction grating

The proposed diffraction grating for operation in a given optical system must have a profile in the form of a binary lattice of a large height (11 μm) on the protrusions and hollows of which a binary
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profile of a low height of the microrelief (0.55 μm) is formed. Schematically, such a lattice is shown in Fig. 1.

![Figure 1](image1.png)

**Figure 1.** An image of a microrelief of a two-range diffraction grating (a), the energy distribution by diffraction orders from simulation results for wavelengths of 0.7 μm and 1.3 μm, respectively (b).

Simulation of the grating was conducted in a software package for modeling Zemax optical systems for the two wavelengths (λ₁ = 0.7 μm and λ₂ = 1.3 μm). As a result of the simulation, the optimal lattice parameters for the given parameters of the optical system were selected. When using the above microrelief lattice parameters obtained that the point spread function (PSF) simulation results for λ₁ = 0.7 μm identical PSF for λ₂ = 1.3 μm and less than the approximately 2 times, as well as correlated wavelengths. The diameter of the Airy disk for λ₁ = 0.7 μm is 4.8 μm. The value of the PSF for the hyperspectrometer at a wavelength of 1.3 μm based on the simulation results was 8.4 μm. The diffraction efficiency for λ₁ = 0.7 μm was 32%, and for λ₂ = 1.3 μm, 34%, respectively.

### 3. Simulation of a dual-range diffraction grating with blaze

The proposed diffraction grating for working in the optical system of the hyperspectrometer according to the Offner scheme should have a complex profile, in the form of a lattice of high altitude, on the protrusions and hollows of which a low-height profile of the microrelief is formed. In addition, to better delineate the visible and near infrared optical range, it was decided to increase the efficiency by +1 for the visible range, for the near infrared range -1 order, making them operational for the corresponding photosensitive matrices. Schematically, such a lattice is shown in Fig. 1. Such a profile is formed if the inclined sections of the grating profile optimized for operation in the near-infrared range are filled with triangular elements with a period and height optimized for the visible optical range and having a slope in the opposite direction.

![Figure 2](image2.png)

**Figure 2.** Image of the profile cross-section of a dual-range diffraction grating.

As can be seen, optimizing the profile for a dual-range diffraction grating for the visible optical range with a central wavelength of 0.5 μm and a near-IR range with a central wavelength of 1.5 μm, the heights and periods of the so-called "small" and "large" profile details are related in this way the
same as their wavelengths. The slope of the sections of the profile, respectively, depends on the ratio of the lattice period and its height. Simulation of the grating operation in these ranges was carried out in a software package for simulation of Zemax optical systems for two wavelengths ($\lambda_1 = 0.5 \, \mu m$ and $\lambda_2 = 1.5 \, \mu m$). As a result of the simulation, the optimal lattice parameters for the given parameters of the optical system were selected. Based on the technological possibilities of fabricating such a complex profile grating on a curved surface, the height of the details for the "small" and "large" gratings, respectively, was 1 and 3 $\mu m$, respectively, 33 and 100 $\mu m$.

The optimized diffraction grating has shown an efficiency of about 80% in the visible and about 54% in the IR ranges. In Fig. 3 shows the distribution of power in order in the near infrared range.

![Figure 3](image1.png)

Figure 3. Image of the profile cross-section of a dual-range diffraction grating.

Figure 4 shows a similar distribution for the visible range for a wavelength of 0.5 $\mu m$.

![Figure 4](image2.png)

Figure 4. Power distribution by orders in the near visible range at a wavelength of 0.5 mkm.

This grating makes it possible to use two photosensitive matrices in the depicting hyperspectrometer due to work in different orders.

4. Conclusion
This paper presents the simulation results of a binary two-band diffraction grating and a two-range diffraction grating with a gloss for operation in the imaging hyperspectrometer. The simulation presented in this paper shows that the diffraction efficiency of the binary diffraction grating for $\lambda_1 = 0.7 \, \mu m$ was 32%, and for $\lambda_2 = 1.3 \, \mu m$, 34%, respectively. The optimized diffraction grating with blaze has shown an efficiency of about 80% in the visible and about 54% in the IR ranges. This makes it possible to use two photosensitive matrices in a hyperspectrometer operating in different orders.
5. References

[1] Vinogradov A, Egorov V, Kalinin A, Rodionov A and Rodionov I 2016 *Journal of Optical Technology* **83** 237

[2] Vinogradov A, Egorov V, Kalinin A, Rodionov A and Rodionov I 2017 *Journal of Optical Technology* **84** 683

[3] Golovin A and Demin A 2015 *Computer Optics* **39(4)** 521 DOI: 10.18287/0134-2452-2015-39-4-521-528

[4] Voropay E, Gulis I and Kupreev A2009 *Herald BSU* **1** 31

[5] Kazanskiy N, Kharitonov S, Karsakov A and Khonina S 2014 *Computer Optics* **38(2)** 271

[6] Rastorguev A, Kharitonov S and Kazanskiy N 2017 *Computer Optics* **41(3)** 399 DOI: 10.18287/2412-6179-2017-41-3-399-405

[7] Kazanskiy N, Kharitonov S, Doskolovich L and Pavelyev A 2015 *Computer Optics* **39(1)** 70 DOI: 10.18287/0134-2452-2015-39-1-70-76

[8] Karpeev S, Khonina S and Kharitonov S 2015 *Computer Optics* **39(2)** 211 DOI: 10.18287/0134-2452-2015-39-2-211-217

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