Development of VPH Grism for Near Infrared Spectroscopy with the Subaru Telescope

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Abstract. We developed the VPH grism for NIR spectroscopy with the Subaru Telescope. After some cryogenic tests in the laboratory, we confirmed its on-sky performance.

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OBJECTIVE

To detect and explore the nature of GRBs, it is important to include appropriate observation functions on many telescopes and instruments around the world. Especially infrared observation is required for the identification of extremely distant GRBs. In addition, to measure their precise distance, abundance of heavy metals, and degree of ionization in the universe, NIR spectroscopy with large telescopes is crucial. This development is ongoing as part of a campaign of improvements in the infrastructure for GRB observations. We have developed VPH gratings for MOIRCS (Suzuki et al. [1]). MOIRCS is a wide-field multi-object NIR imager and spectrograph for the Subaru Telescope in Hawaii. MOIRCS has had some grisms with the resolving power of $\lambda/d\lambda \sim 500$ and efficiency of T $\sim$ 70 %. This research aims for the realization of VPH grisms with higher resolution ($\lambda/d\lambda > 2200$) and higher efficiency ($T_{peak} > 70$ %) in K band ($\lambda_c = 2.2\ \mu$m).

FABRICATION

Volume phase holographic (VPH) gratings are now being used extensively in astronomy because of their high intrinsic diffraction efficiencies. They are periodic phase structures, whose fundamental purpose is to diffract different wavelength of light from a common input path into different angular output paths. A VPH grating is made with a layer of transmissive material, usually a dichromated gelatin, which is sealed between two layers of clear fused silica glass. The phase of the incident light is modulated as it passes through the optically thick film which has a periodic differential value of refractive index. This is in contrast to a conventional grating, in which the depth of a surface

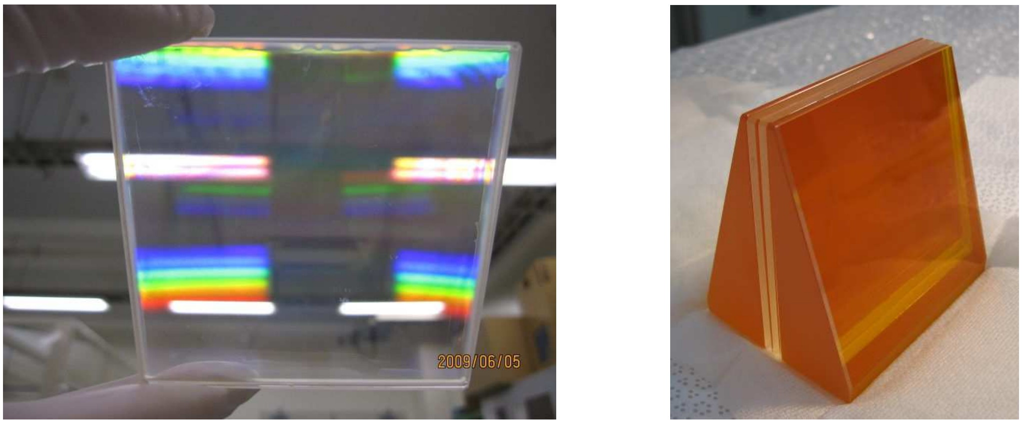

FIGURE 1. The grating alone (left) and completed grism (right).

relief pattern modulates the phase of the incident light.

We developed a VPH grism for MOIRCS. The VPH grating for the grism has been developed at JWU. They fabricated the gratings based on their own unique simulation program and fabrication system. The program can optimize the fabrication condition for the required optical specifications. This method overcomes the existing problem that VPH have narrow bandwidth compared to etched or ruled gratings (Nakajima et al. [2]). The effective area of our grating is 70 × 70 mm, and the active layers is 30 μm in thick, which is sandwiched between S-TIM35 (made by OHARA) glass substrates of 3 mm thickness (FIGURE 1 (left)). Then, the ZnSe prisms with 18.5 degree apex angles are glued on both sides of the grating to reduce beam deviation (FIGURE 1 (right)).

LABORATORY TESTS

We measured the transmission efficiencies of the grisms alone under cryogenic temperature (120K) with using a infrared spectrophotometer and our own small cryostat (FIGURE 2 (left)). As a result, we obtained a peak efficiency as high as 75 % at 2.2 μm with a FWHM of 0.46 nm, and the efficiency curve is almost consistent with that of room temperature (FIGURE 2 (right)). The results met our objectives.

ON INSTRUMENT TESTS

The VPH grism was installed on MOIRCS in late 2009, and a dome test and on-sky observation were carried out. For the dome test, dome flat spectra were obtained with using a multi-slit mask. From the test, we confirmed that the efficiency curves vary with the location of the slits because of the differences in the incident angles. We also confirmed its resolving power is not less than $\lambda/d\lambda$ 2200. The averaged dispersion is 1.94 Å/pix (FIGURE 3 (right)). For the on-sky observation, we obtained only one exposure with a spectroscopic standard star. From the test, we confirmed the total efficiency including the efficiency of telescope and instrument (FIGURE 3 (left)).

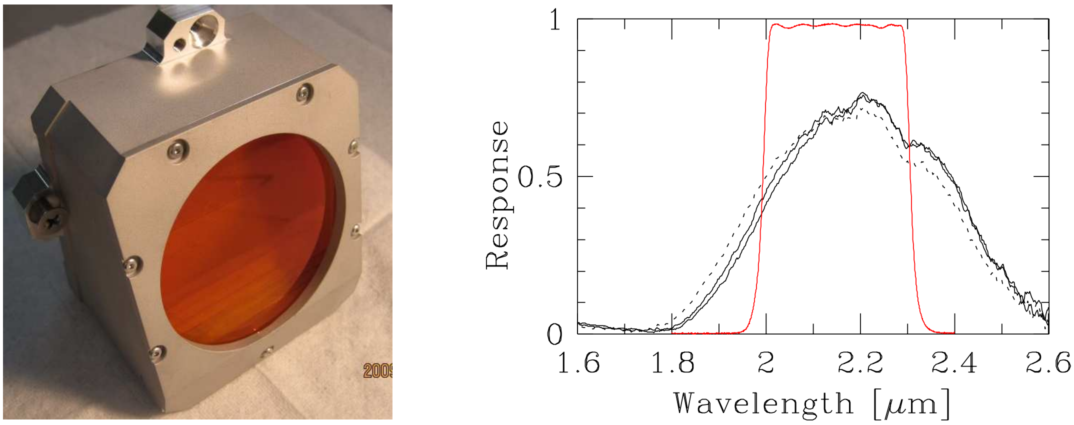

FIGURE 2. Mounted grism (left) and measured diffraction efficiency of the grism alone at 300 K and 120 K (right). Almost-overlapped two solid lines show the efficiency curves at 300 K before and after cooling. Dashed line shows that at 120K. Red line shows the *Ks* filter transmission curve for comparison.

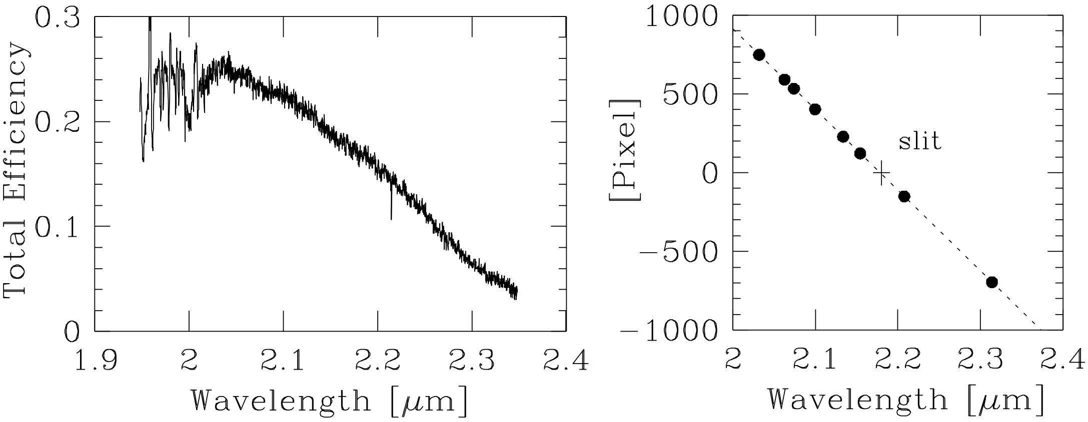

FIGURE 3. Total efficiency measured with using a spectroscopic standard star (left). It is including the atmospheric transmission, efficiency of the telescope and MOIRCS optics, and quantum efficiency of the detector. The peak wavelength is shifted to shorter wavelength because the object position was off from the center of the field. Spectral positions on the detector is shown in the right graph.

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REFERENCES

1. Suzuki, R., et al. *Publication of Astronomical Society of Japan*, PASJ, 2008, 60, pp.1347–1362.
2. Nakajima, K., et al. *Conference Proceedings*, SPIE, 2008, 7014, 1Q