Development of Novel High-Efficiency & Wideband Medium-Dispersion Grisms for MOIRCS at Subaru Telescope

Ichi Tanaka[(1)(*)], Noboru Ebizuka[(2)], Chihiro Tokoku[(3)], Takashi Hattori[(1)], Yusei Koyama[(1)], Kentaro Motohara[(3,4)], Michael Lemmen[(1)], Brian Elms[(1)], Koji Omata[(3)], Yosuke Minowa[(1)], Tadayuki Kodama[(5)], et al.

(1) Subaru Telescope, NAOJ (2) Riken (3) Advance Technology Center, NAOJ (4) Institute of Astronomy, Univ. of Tokyo (5) Tohoku Univ. (*) Contact Address: ichi@naoj.org

Acknowledgement: This work was supported by Kakenhi Kiban-A 18H03717 (PI: T. Kodama), Director's Contingency Budget for Subaru 2018 & 2022, Ultimate-Subaru Fund, and NAOJ Leadership fund 2022.

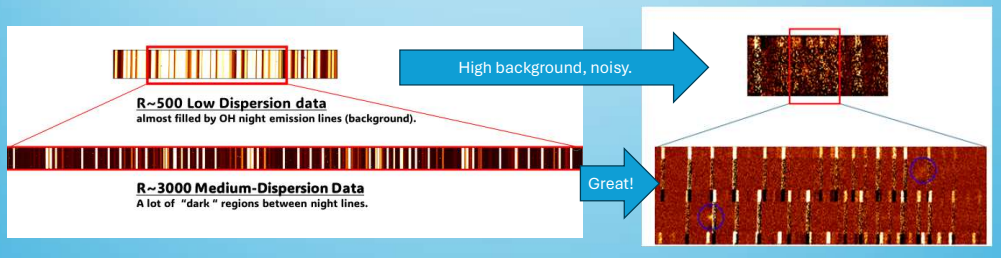
Abstract

In order to improve the performance of the medium-dispersion spectroscopy for MOIRCS, we have been developing new grisms: in 2020, we successfully commissioned high-performance grisms for the J- and H-bands using a novel high-efficiency and wide spectral coverage grating from LightSmyth ("LightSmyth J & H grisms"). Encouraged by the success, we started developing a new K-band medium-dispersion grism ("VB-K grism") using our own Volume-Binary grating in 2022, which was successfully completed by summer 2023. We are currently awaiting the 1st on-sky testing this spring.

1. Introduction:

MOIRCS is Multi-Object Near-Infrared (NIR) Camera and Spectrograph for Subaru. Its spectroscopy mode has low dispersion (R~500) and medium-dispersion (R~3000) modes. We have been working on updating its medium-dispersion mode since 2018.

Medium-dispersion is important for the NIR spectroscopy, because the sky in NIR is dominated by the OH night background emission.



We used to use the VPH grisms (YJHK) for medium-resolution mode. Though the VPH gratings gave high sensitivity at peak, their peaky transmission curve made the efficient use difficult. But a new novel grating by LightSmyth Tecnologies changed the situation.

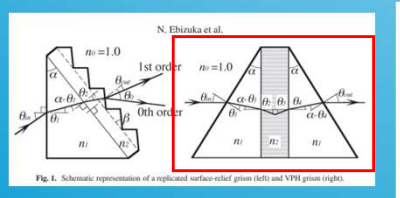
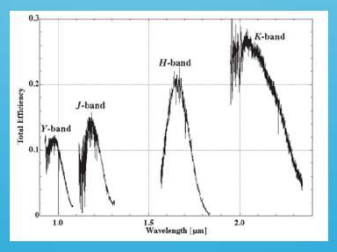
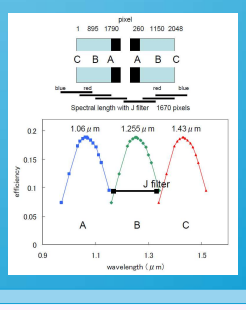


Fig. 1. Schematic representation of a replicated surface-relief grism (left) and VPH grism (right).

Ebizuka et al (2011, PASJ, 63, S605)

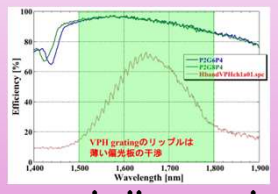




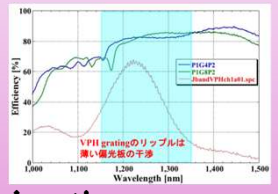
2. LightSmyth Grisms

LightSmyth grating has an amazing characteristics of highest throughput and wide spectral coverage. We decided to make grisms using the LightSmyth grating as the first astronomical application.

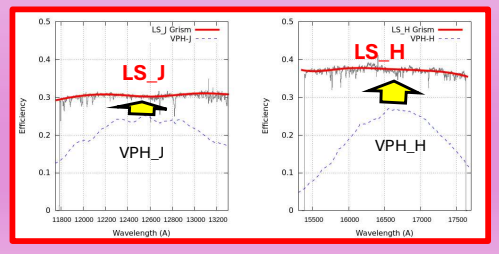
VPH_H grating: Custom-Made



VPH_J grating: Cataloged Item



Despite some challenges during the assembly (thinness of gratings), stability tests of the fabricated grisms with cooling cycle went well. The first-light were achieved in July 2020, and <u>we confirmed the great performance of LightSmyth Grisms. It's a great success!</u>



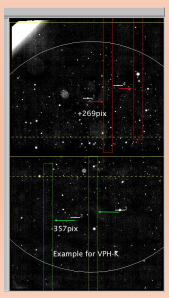
Tanaka et al. (2020) Proc. SPIE, Vol. 11451, id. 114515 for more.

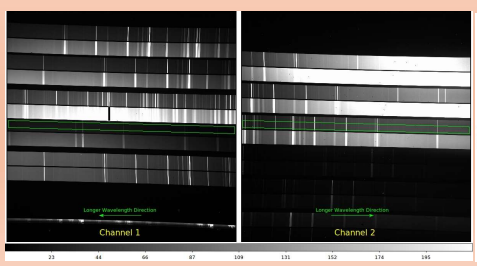
3. K-band Medium-Dispersion Grism

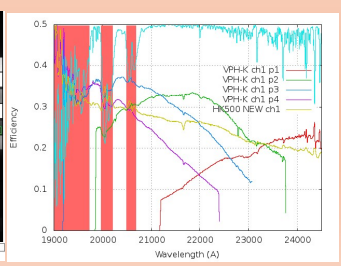
Encouraged by the success of the LightSmyth Grisms, we started developing a new K-band medium-dispersion grism ("VB-K grism") using our own Volume-Binary Grating in 2022.

3.1. Why?

Current VPH-K Grism has three issues: 1) Peaky transmission curve which has a dependence of AoI (=Slit Position). 2) Large shift of the spectra in spatial direction, and 3) ~1.5 deg tilt, causing significant loss of the detector area for science.

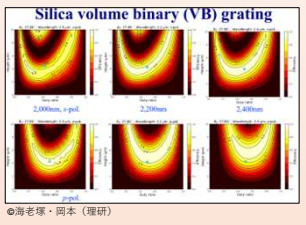


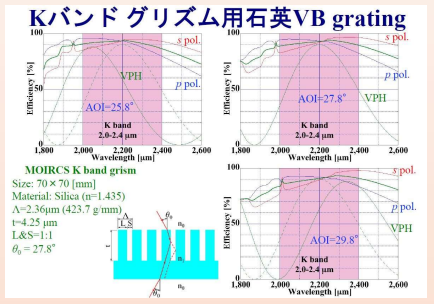




3.2. "VB-K" Grism Project

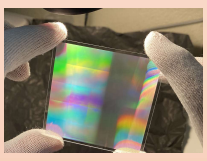
The Volume-Binary ("VB") grating, which has been developed by one of our CoI (see also the Poster P22 by N. Ebizuka), has high diffraction efficiency and wide spectral coverage. The simulation shows >85% efficiency across the whole K-band window.

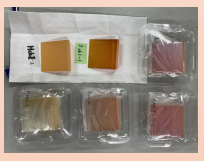


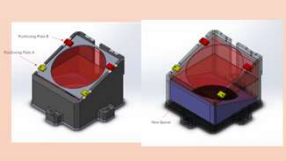


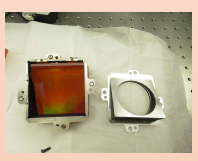
3.3. Fabrication

After the successful test fabrication of the VB-K grating, we prepared 1) full-size VB-K gratings 2) ZnSe Prisms 3) Holders. We "recycled" the ZnSe prisms and holders from the retired VPH-J/H grisms to save the production cost. Though it was actually quite challenging, we could manage and overcome it.



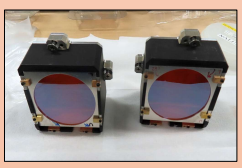


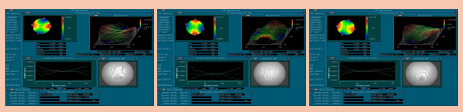


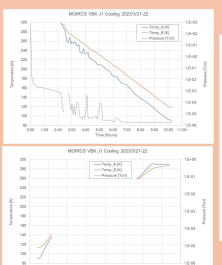


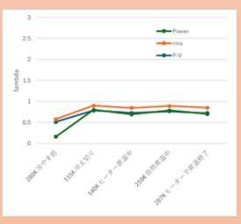
3.4. Assembly and Testing

After final assembly, we did two stability tests by 1) gravity direction and 2) the cooling cycle. Our VB-K grism showed good stability on both tests.









3.5. On-Sky Tests

We installed the VB-K grism into the MOIRCS dewar in Sep 2023. We planned to do characterization and on-sky tests soon. However, it was cancelled due to telescope trouble. Under the current schedule for 2024, we expect the first test in this February. If the result is good, we will open the grisms to public as soon as possible.

4. Current Medium-Dispersion Sensitivity

The graph below is the current medium-dispersion sensitivity of MOIRCS (1hr, 5σ). We also show the same values of the MOSFIRE instrument of Keck 10-m Telescope for comparison.

Despite the smaller aperture area of Subaru (66% of Keck) and lower throughput of lenses of MOIRCS than MOSFIRE, the sensitivity is now fairly close, especially in J and K window.

MOIRCS's slit multiplicity is more flexible compared to MOSFIRE. MOIRCS is one of the most efficient instrument for the crowded region science. Please use MOIRCS!