Novel Transmission Gratings with High-dispersion, High-efficiency and Wide Bandwidth III

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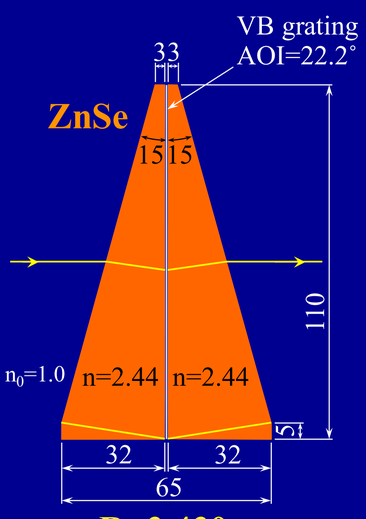
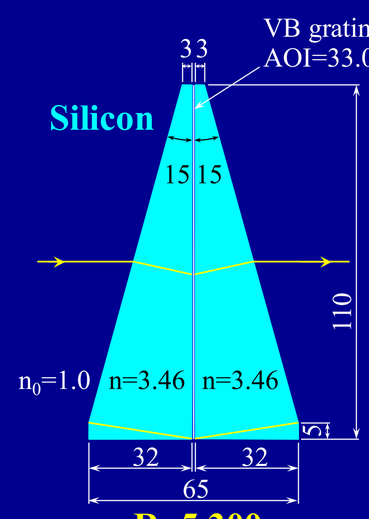
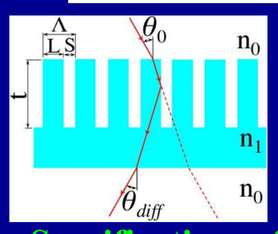
Silicon VB Grating for H-K Band Grism of SWIMS



R=3,430

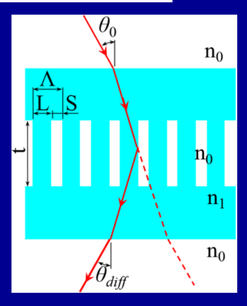


R=5,300

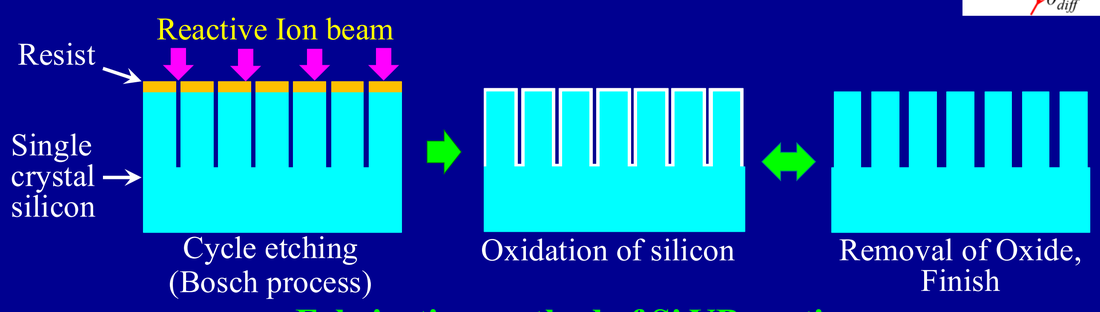


Open type Si VB grating
n_1=3.455@1.9 μm
Λ=10.75μm (93.0 lp/mm)
L&S=19:1, t=60 μm
Aspect ratio=1:111.6

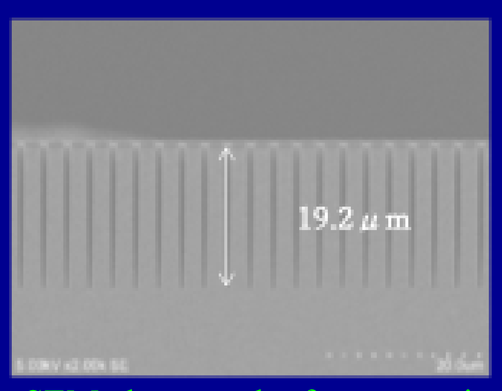
Closed type Si VB grating
n_1=3.455@1.9 μm
Λ=10.75μm (93.0 lp/mm)
L&S=19:1, t=58 μm
Aspect ratio=1:107.9

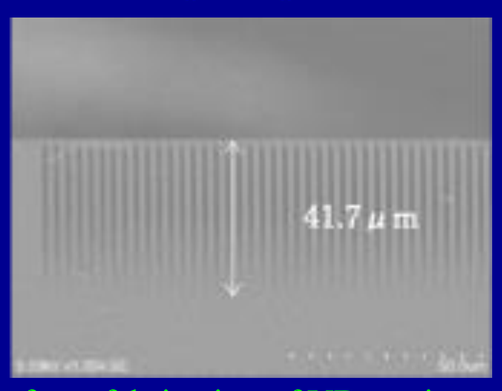


Specifications of Si VB grating for H-K band grism of SWIMS.



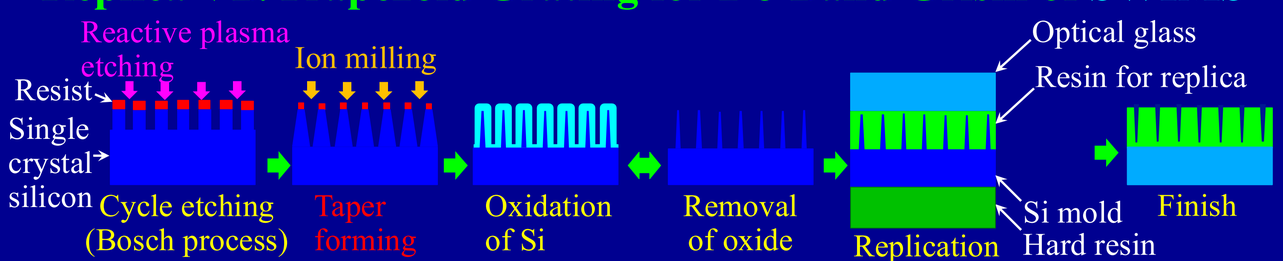
Fabrication method of Si VB grating.



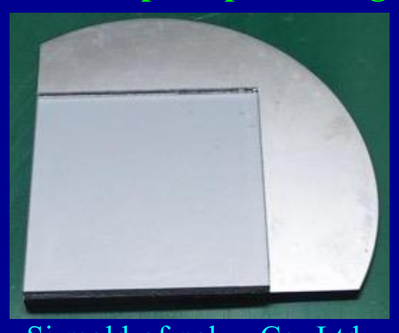


SEM photograph of cross section of test fabrication of VB grating processed by silicon deep RIE.

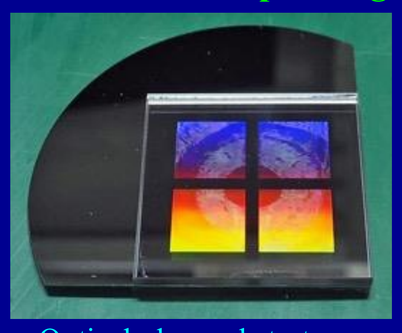
Replica VB/Trapezoid Grating for z-J Band Grism of SWIMS



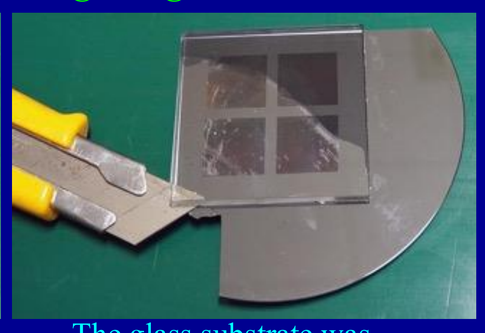
Replica processing method for a trapezoid grating using silicone mold.



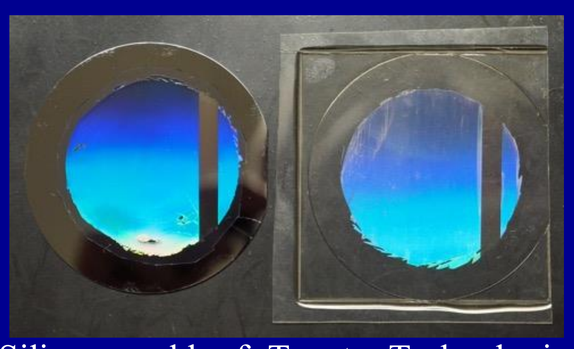
Si mold of nalux Co. Ltd. was protected by hard resin substrate.



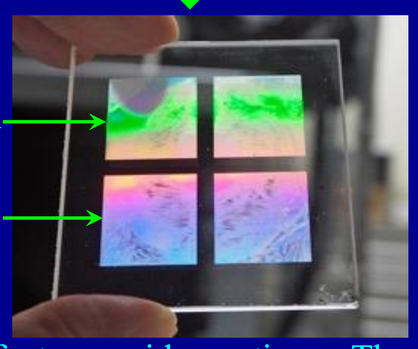
Optical glass substrate was set on the mold.



The glass substrate was removed from the mold.

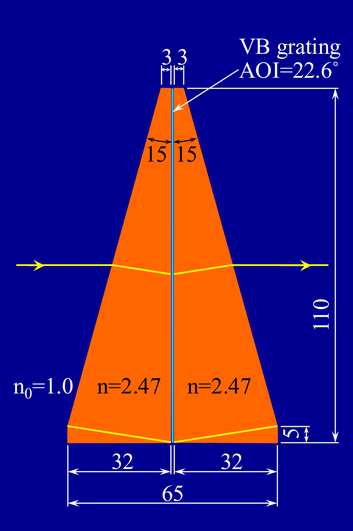


Silicon mold of Toyota Technological Institute (left) and replica (right) of trapezoid grating. The peak efficiency is about 73% (RCWA value is 95%).

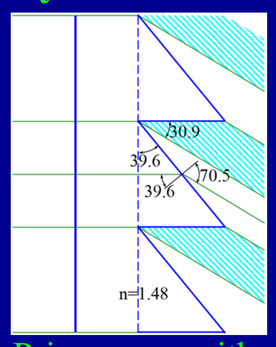


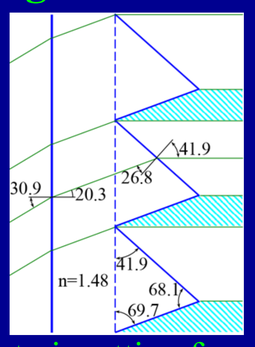
Replica of trapezoid grating. The grating became cloudy, and the peak efficiency dropped to nearly 30%.

Prism Array for Reducing Thickness of Grism

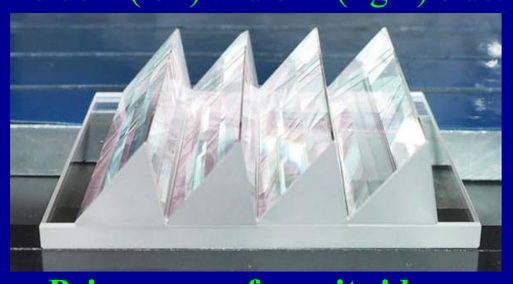


VB grism with ZnSe Prisms. AOI of VB the grating are 22.6°. Which is about 75% of the target resolving power of z-J band grism of SWIMS.

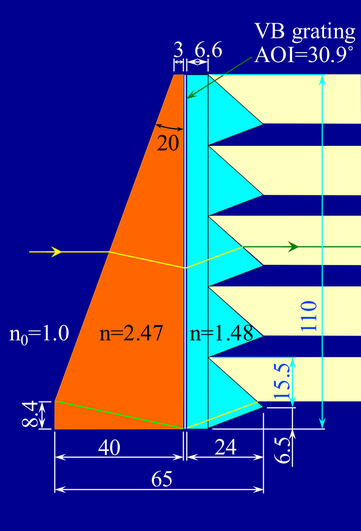




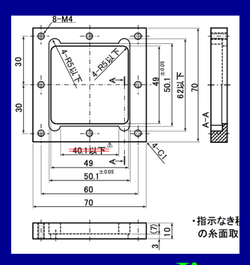
Prism array without vignetting for incident (left) and exit (right) side.

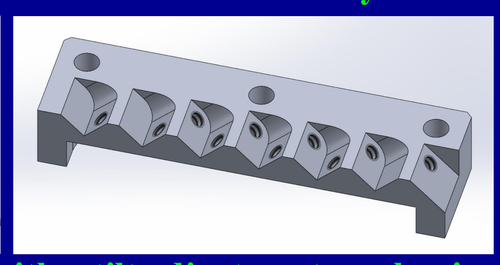


Prism array for exit side.

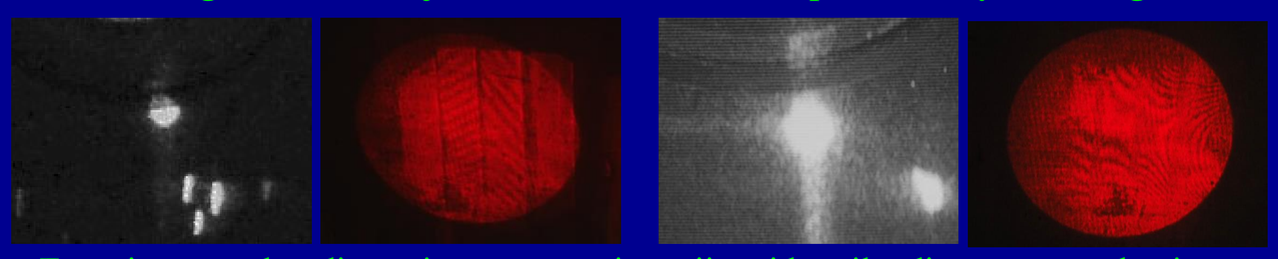


VB grism with ZnSe prism and prism array for exit side. AOI of the VB grating is 30.9°. This value is sufficient for z-J band grism of SWIMS.



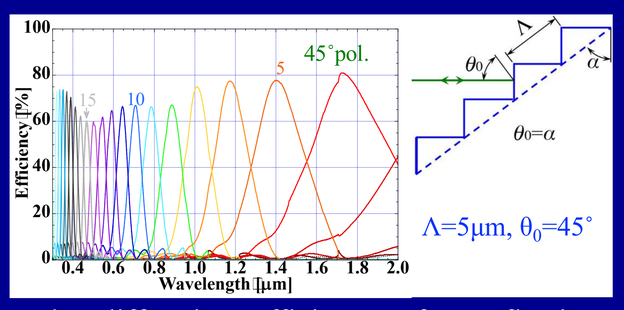


Jig with a tilt adjustment mechanism for prism arrays bonding.

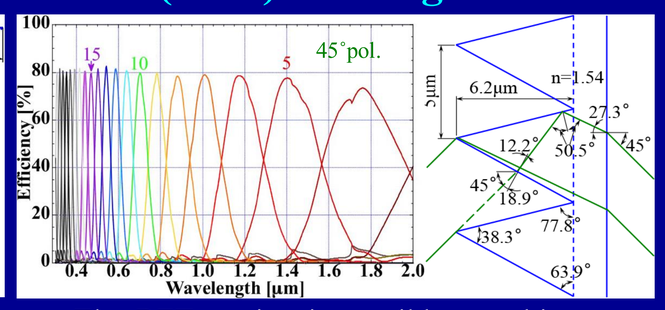


Experiment on bonding prism arrays using a jig with a tilt adjustment mechanism.
Left: Simply attaching the prism rods to the glass substrate with matching oil allows for adjustment of the wavefront parallel to the prism rods, but not in the perpendicular direction.
Right: By attaching a piece of plastic wrap (approximately 2mm wide, t~11μm) to the edge of the glass substrate with UV-curing resin, adjustment in the perpendicular direction became possible, and the wavefronts of the four prism rods could be made almost parallel.

Reflector Facet Transmission (RFT) Grating

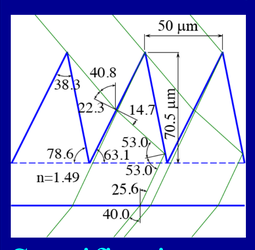


The diffraction efficiency of a reflection echelle grating is peaky. The efficiency of certain orders decreases due to the influence of surface plasmons.



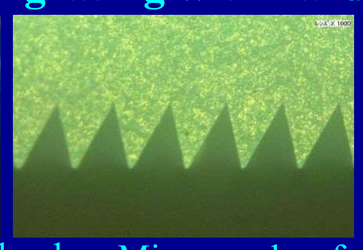
The RFT grating is possible to achieve a high diffraction efficiency by means of internal reflection of a facet of the grooves.

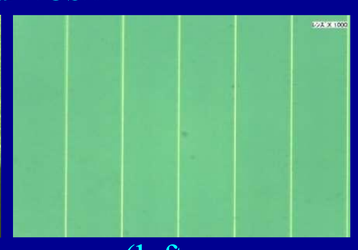
Prototype of RFT grating with hard resin



Specification of RFT grating.

Fly cut processing of hard resin (NTKJ Co. Ltd.).





Micrographs of grooves (left: cross section, right top view).

In FY 2023, we prototyped an RFT grating with a 38.3° apex angle and 20 lines/mm using fly cutting (see figure above). In FY 2024, we prototyped an RFT grating with the same specifications by shaper cutting (a planing-like process). Compared to the fly-cut, the shaper-cut showed more scattering on the RFT grating surface, with efficiency distributed to the preceding and succeeding orders. At a wavelength of 633 nm, the diffraction efficiency at the central order was 59% for fly-cutting and 36% for shaper-cutting, which are lower values compared to the RCWA calculated value of 84.4%. The total efficiency for the central and ±1st orders was 74%, 57%, and 88.0%, respectively, and the total efficiency up to ±2nd orders was 81%, 65%, and 90.6%, respectively.

Summary

- Volume binary (VB) / trapezoid grating: A silicon VB grating for SWIMS H-K band is going to develop. A resin trapezoid grating was prototyped by replica processing using a silicon mold had performed. As a result of the experiment, the peak efficiency was nearly 30% because the grooves became cloudy upon release from the silicon mold. We plan to improve the method for releasing from the mold.
- Prism array for grism: To reduce the thickness of grism of SWIMS z-J band, a prism array for the grism was prototyped. We are developing a prism array using optical glass.
- RFT grating: A 20 lp/mm RFT grating onto a hard resin substrate has been prototyped using diamond fly-cutting and shaper-cutting processing. It was found that the diffraction efficiency of central order is lost by surface scattering. We plan to prototype a RFT grating on a resin onto glass substrate and plan to improve the fly-cutting procedure to reduce scattering.