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

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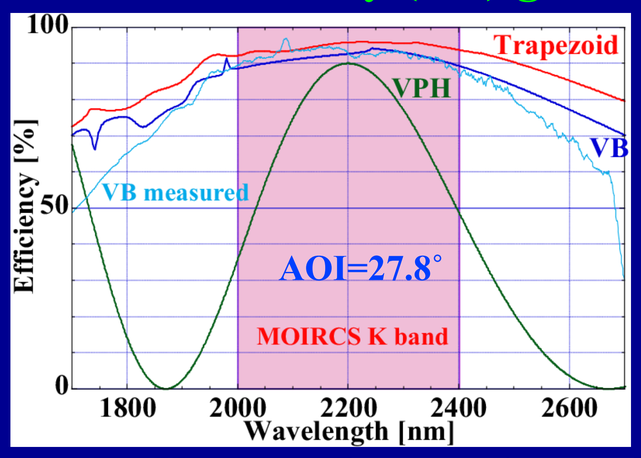
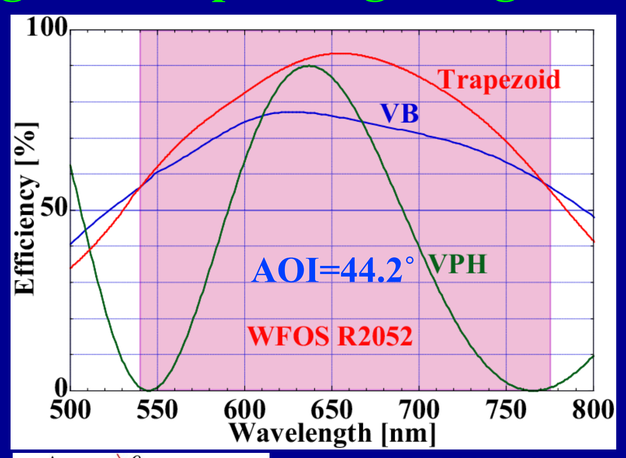
Volume binary (VB) grating and Trapezoid grating



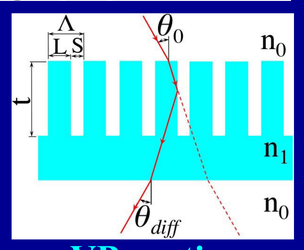


MOIRCS K band

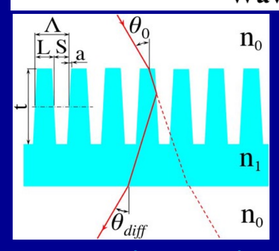
Λ=2.36μm (423.7 g/mm)

VB	Trapezoid
L&S=1:1	L&S=7:5
t=4.25μm	t=4.5μm
	a=0.28μm

There is not much difference between Trapezoid and VB grating at AOI~30°.



VB grating



Trapezoid grating

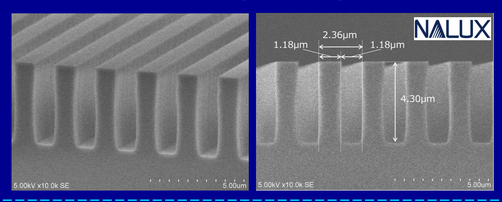
TMT WFOS

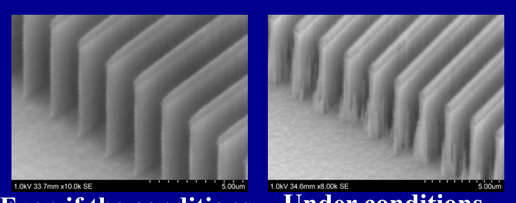
Λ=0.489μm (2,045g/mm)

VB	Trapezoid
L&S=55:45	L&S=2:1
t=1.06μm	t=1.36μm
	a=0.07μm

Trapezoid grating has high efficiency at AOI~45°.

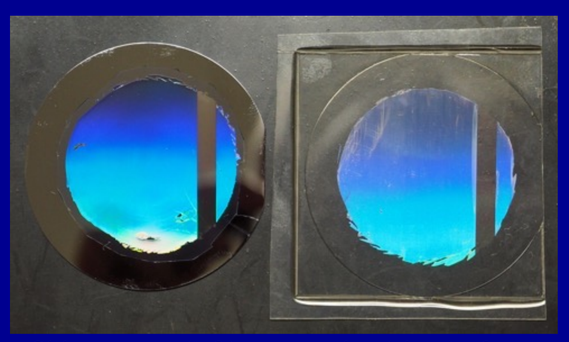
SEM photo of silica VB grating for MOIRCS K-band fabricated by anisotropic ion etching.



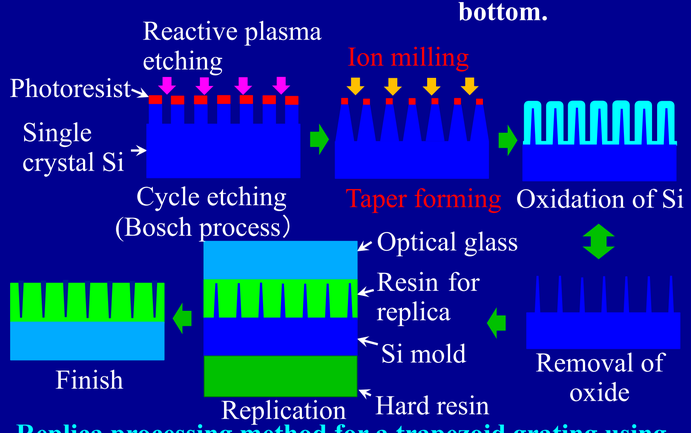


Even if the conditions of the Bosch process are changed, the grooves often end up being vertical.

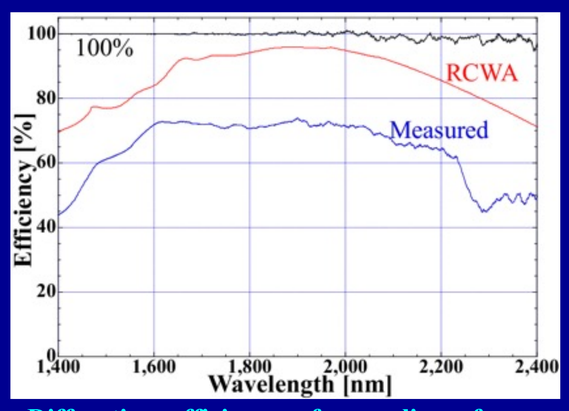
Under conditions where a taper is formed, acicular black silicon is generated at the bottom.



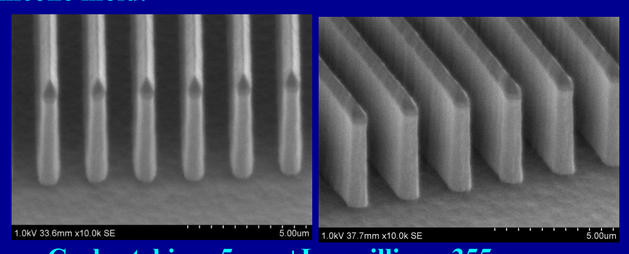
Silicon mold (left) and replica (right) of trapezoid grating.



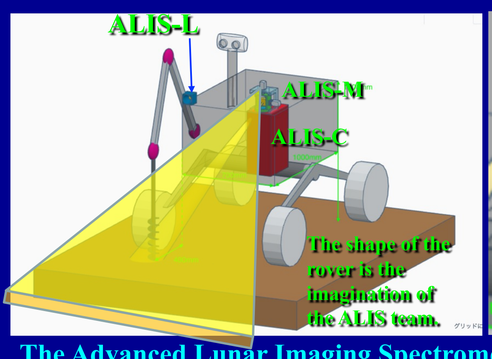
Replica processing method for a trapezoid grating using silicone mold.



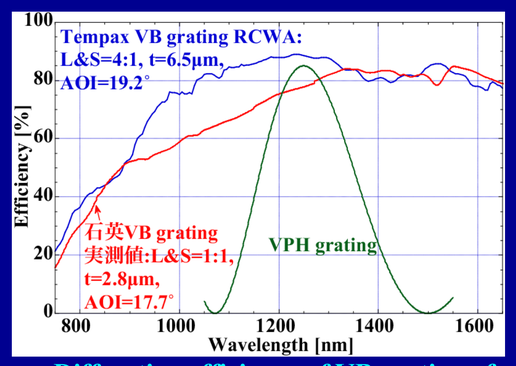
Diffraction efficiency of a replica of a tapered silicon mold (groove width half that of the design).



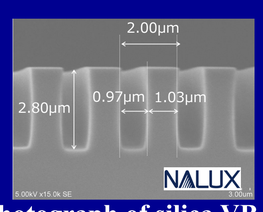
Cycle etching: 5 μm +Ion milling.: 355nm.
Toyota technological institute.



The Advanced Lunar Imaging Spectrometer (ALIS) for the Lunar Polar Exploration Mission (LUPEX). 1 field of view: 2000 × 10 mm @ 5 m, full field of view: vertical scanning,Wavelength band: 750– 1650 nm.
Slides of Prof. Saeki @ Ritsumeikan University

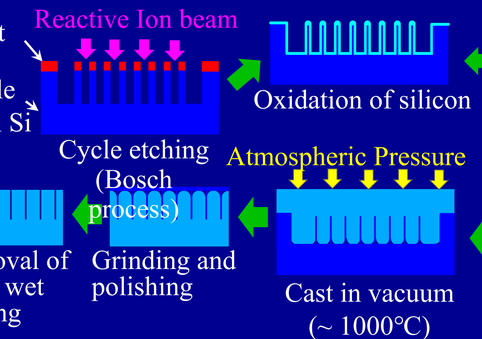


Diffraction efficiency of VB grating of 500g/mm for ALIS.

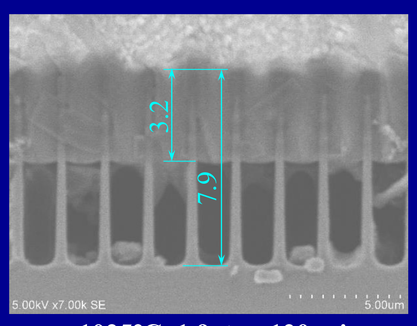


SEM photograph of silica VB grating fabricated by anisotropic plasma etching.

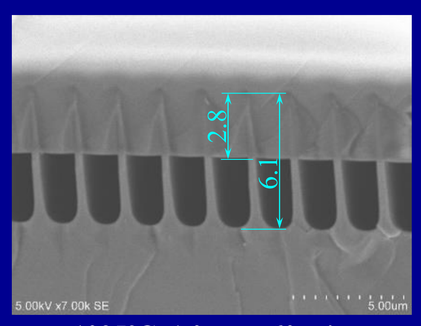
Glass coloring



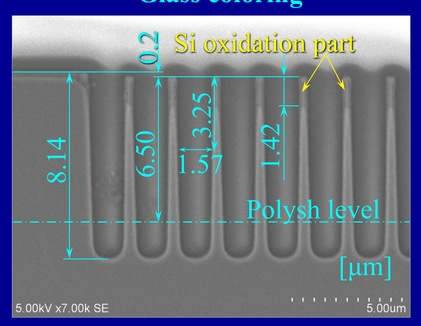
Fabrication methods of Tempax glass VB/trapezoid grating using silicone mold



1025℃, 1.9atm, 120 min
Hot press machine @Metal Technology Co. Ltd. : 金属技研 (株)

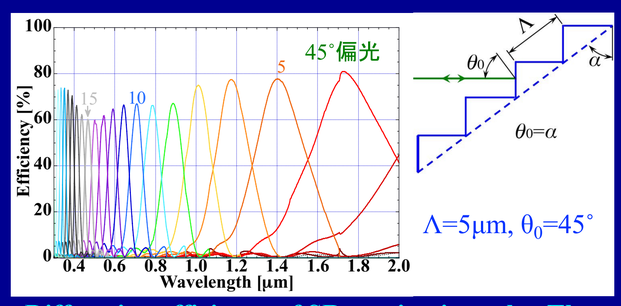


1025℃, 1.0 atm, 60 min
Horizontal electric furnace @Tohoku Univ.

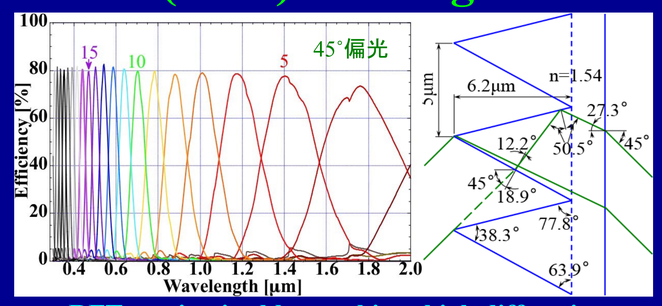


1100℃, 1.0atm, 60 min
Horizontal electric furnace @Tohoku Univ.

Reflector Facet Transmission (RFT) Grating

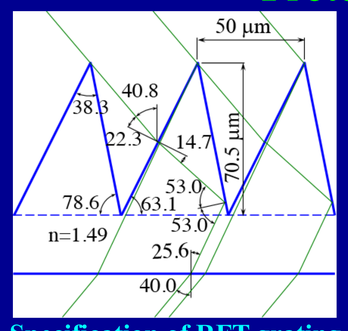


Diffraction efficiency of SR grating is peaky. The efficiency of certain orders decreases due to the influence of surface plasmons.



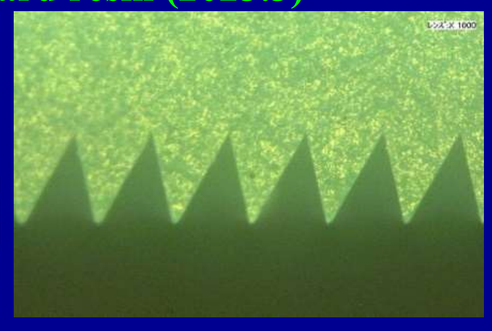
RFT grating is able to achieve high diffraction efficiency by means of internal reflection of a facet of the groove.

Prototype of RFT grating of hard resin (2023.3)

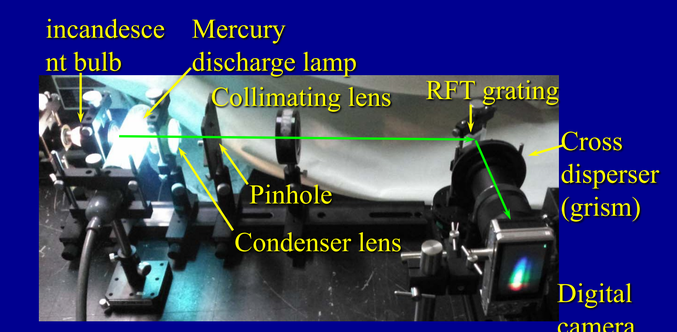


Specification of RFT grating (γ=38.3°, Λ=50μm, AOI=40°).

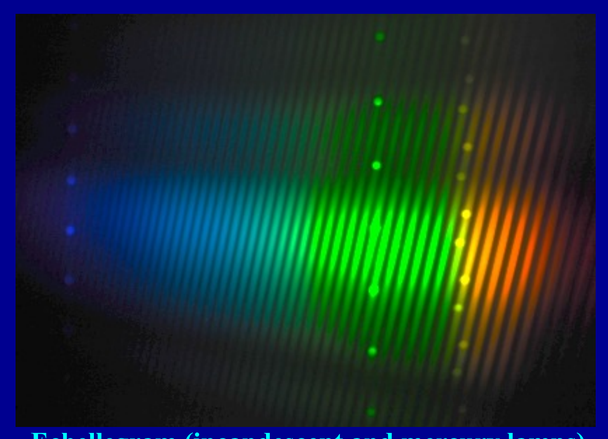
Fly cut processing of hard resin.



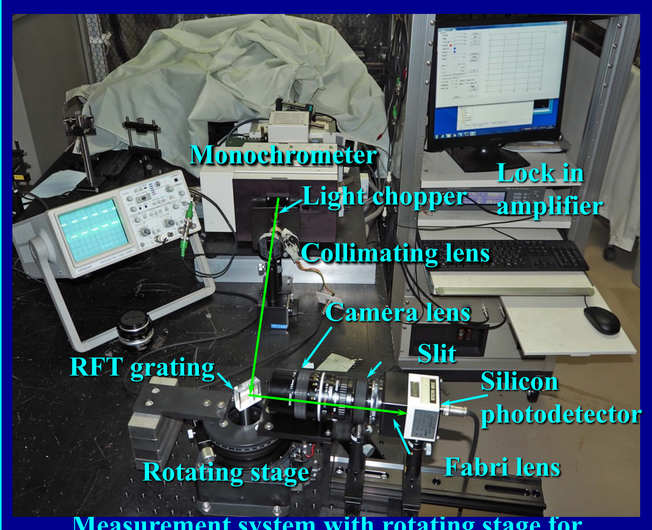
Micrographs of grooves (cross section).



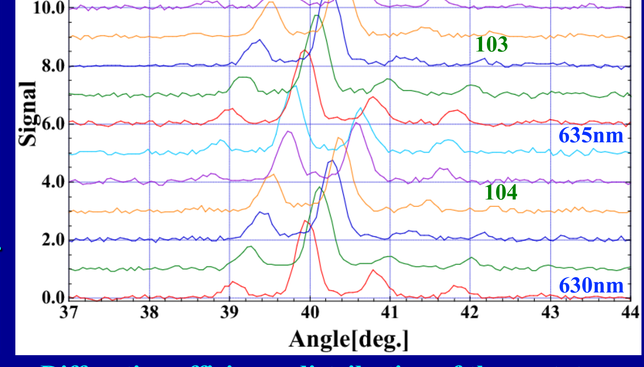
Echellegram acquisition optical system.



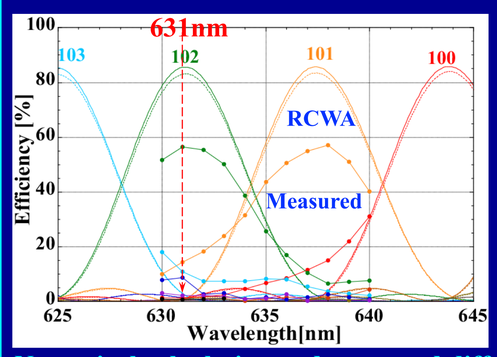
Echellegram (incandescent and mercury lamps).



Measurement system with rotating stage for diffraction efficiency .



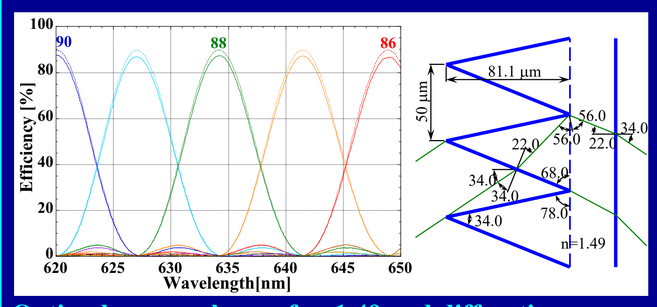
Diffraction efficiency distribution of the prototype RFT grating.



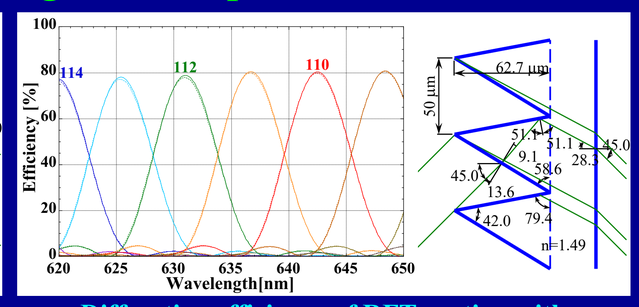
Λ=50μm, θ0=40°, RCWA				Λ=50μm, θ0=40°, Measured			
Orders	Efficiency [%]@631nm			Order	Efficiency [%]@631nm		
99	1.1			99	—		
100	1.2			100	1.3		
101	0.9	88.0%	90.6%	101	14.5	81.9% (±2)	92.1% (±3)
102	84.4			102	56.5		
103	2.7			103	10.9		
104	1.4			104	8.9		
105	0.6			105	2.3		

Numerical calculation and measured diffraction efficiency. Vertex angle 38.3°, grating period 50μm, angle of incidence 40°.
The sample size was small, and the efficiency was distributed between front and rear orders due to diffraction broadening. However loss such as scattering is small.

Consideration of groove shape



Optimal groove shape of n=1.49 and diffraction efficiency: The incident beam that grazes apex of the groove and is reflected near the bottom of the groove then travels parallel to incident plane of the groove.



Diffraction efficiency of RFT grating with apex=42.0°, AOI=45°.

Type	Eff. [%] (λ-λ [μm])	開発状況
Volume phase holographic (VPH) grating	~100 (0.32~2.4)	・Developed VPH grisms with resin of volume hologram for instruments of 8.2m Subaru Telescope, Okayama Astrophysical Observatory and so on. ・Bandwidth of VPH grating is narrow, and in multi-slit mode, efficiency decreases at slit positions far from the center of the field of view.
Volume binary (VB) grating	~ 95 (0.2~1000)	・VB gratings of fused silica have developed for ALIS and for successor to MOIRCS K band VPH grisms. ・VB/Trapezoid grating with Tempax glass is developing by means of hot isostatic pressure processing using a silicone mold.
Trapezoid grating	~ 98 (0.2~1000)	・We are developing a trapezoid grating with a resin by replica processing using a silicon a mold.
RFT grating (Transmission echelle grating)	~ 85 (0.32~2.4)	・NiP mold of 200lp/mm had prototyped → The top of groove becomes cracked. → We are considering improvement of cutting methods. ・RFT grating of 20 lp/mm with hard resin is Prototyped by diamond cutting. → We confirmed that the RFT grating can be achieved high efficiency.