次世代観測装置用の新しい回折格子 V

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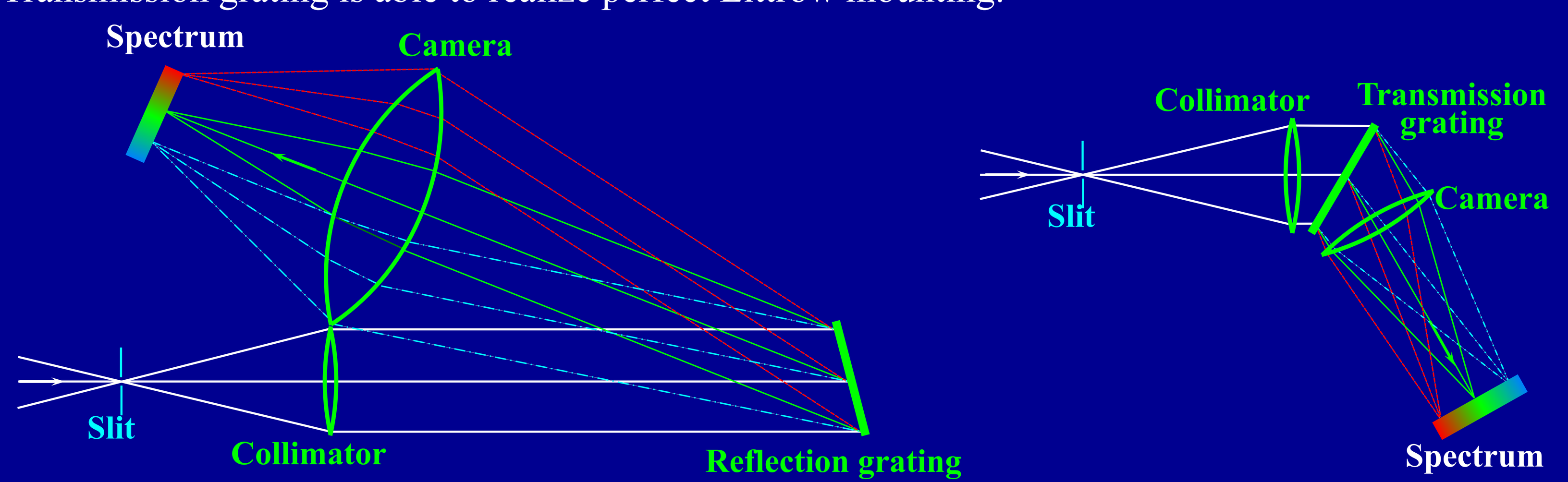
Reflection and transmission grating

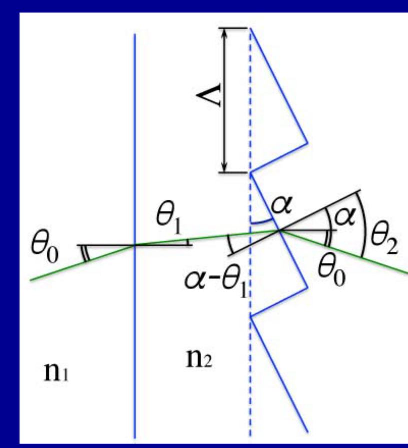
・Diameter of a camera lens exceeds maximum size (φ440) of calcium fluoride if a reflection grating is used as the disperser.

→Transmission grating can reduce size of the camera lens (→total optical system).

→Transmission grating is able to realize perfect Littrow mounting.



Limitation of surface relief (SR) transmission grating



$\theta_2 < 90^\circ$
n = 1.5, $\theta_0 \leq 30^\circ$
n = 1.8, $\theta_0 \leq 36^\circ$
n = 2.3, $\theta_0 \leq 45^\circ$
n = 3.0, $\theta_0 \leq 54^\circ$
Diamond:
n = 2.46@400nm

SR transmission grating with saw tooth grooves is not feasible for the high-dispersion grating.

VPH grating

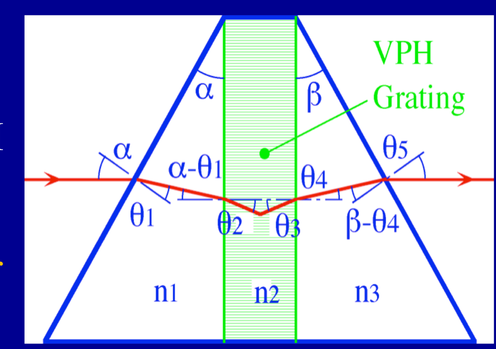
・VPH (Volume Phase Holographic) grating, in which refractive index is modulated sinusoidally achieves diffraction efficiency up to 100% for S or P polarization.

・VPH grating can not achieves high diffraction efficiency for natural and circular polarizations at high dispersion because characteristics of diffraction efficiencies are different between S and P polarizations.

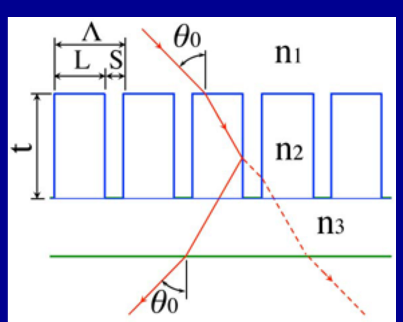
→Birefringence VPH grating.

・Diffraction efficiencies of VPH grating decrease in higher orders.

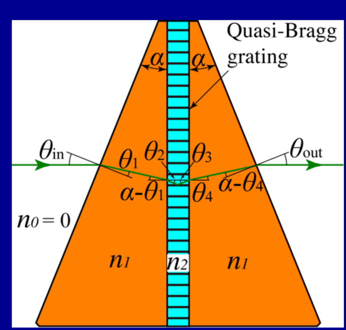
→VPH grating is not feasible for an echelle grating.



Volume binary（VB）grating for MOIRCS echelle grism

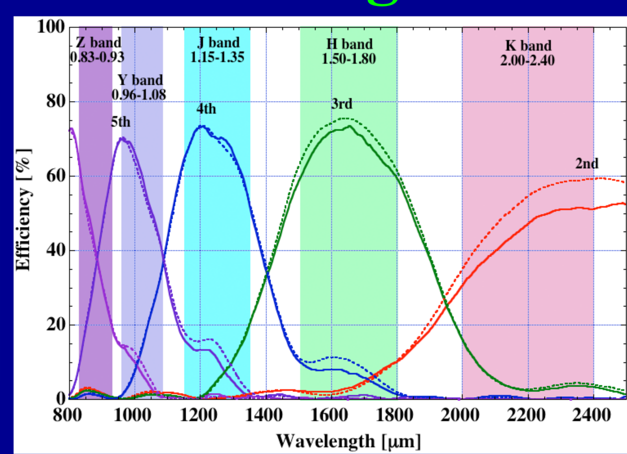


Schematic representation of volume binary grating.



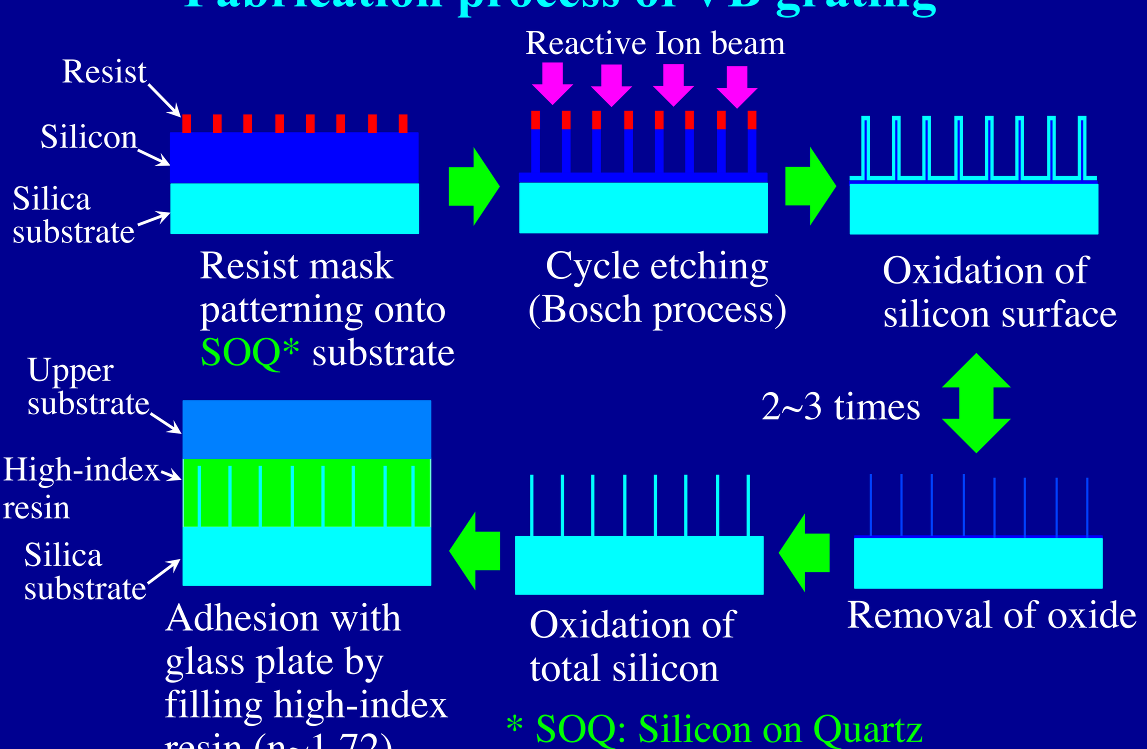
Schematic representation of echelle grism

MOIRCS echelle grism
Slit width: 0.3”
5th, R= 4,630@1.02 μm
4th, R= 4,420@1.25 μm
3rd, R= 4,270@1.65 μm

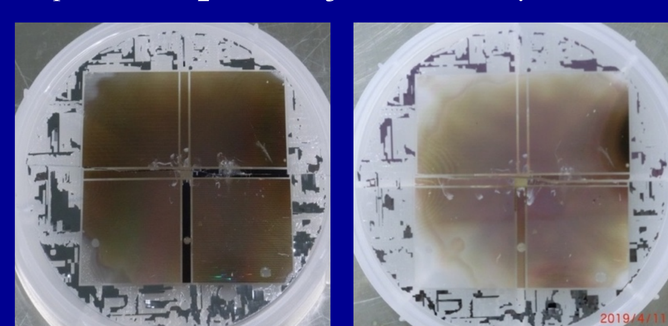


Diffraction efficiency of VB grating (RCWA). L&S= 4.6:0.5 [μm], θ_0=28.4 , n_1=1.33, n_2=1.6, n_3=1.6, t=16 μm.

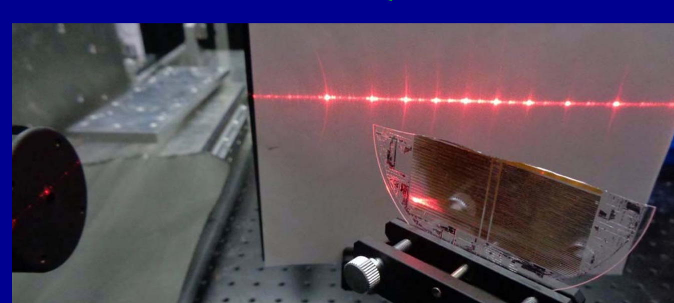
Fabrication process of VB grating



* SOQ: Silicon on Quartz



Before (left) and after (right) Si oxidization of VB grating fabricated in SOQ substrate.



Diffraction beam of VB grating

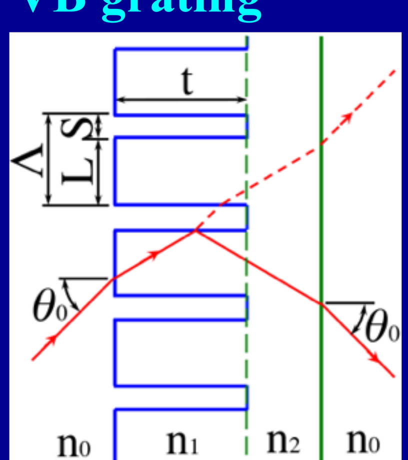
Normalized specifications and performance of VB, SR and RFT gratings

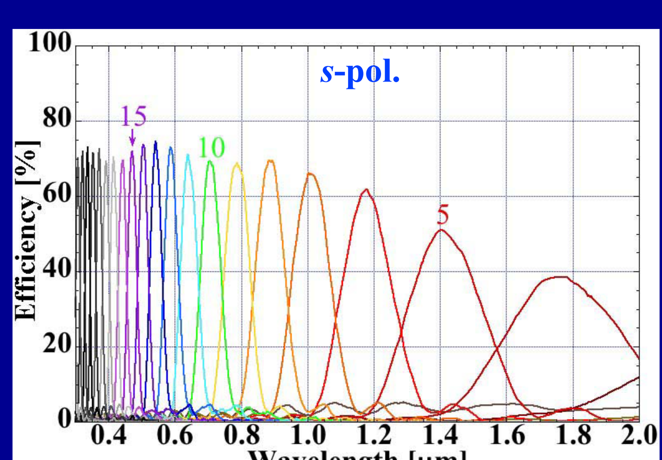
AoI [°]	Order*	n_1/n_0	L:S	Duty	t [Λ]**	Aspect (S:t)	Peak eff. [%]	Bandwidth [λ]***	Remarks
27.8	1	1.54	1:01	0.5	2	1:4	~90%	0.68	MOIRCS, K band
27.8	1	1.54	2:01	0.67	2.5	1:7.5	~93%	0.77	MOIRCS, K band
45	1	1.55	4:01	0.8	4	1:14	~95%	0.33	WFOS, etc.
28.4	3+	1.6/1.33	9:01	0.9	3	1:30	~75%	-	MOIRCS, echelle
45	7+	1.54	19:01	0.95	1.8	1:36	~75%	-	WFOS, VB grating
45	7+	-	-	-	-	-	~80%†	-	WFOS, SR reflection grating
45	7+	1.54	-	-	1.8	-	~83%	-	WFOS, RFT grating

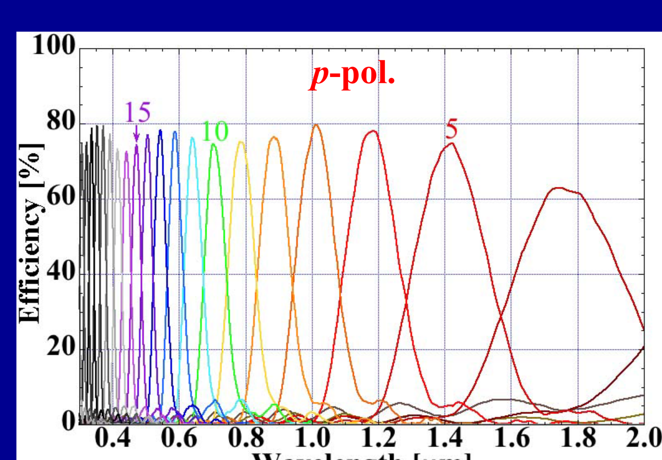
*Where + indicates additional orders. **Normalized by grating period: Λ. ***Normalized by peak wavelength: λ_0 †Efficiency of *p* polarization is significantly shifted toward longer wavelength.

VB, SR and RFT gratings for WFOS

VB grating

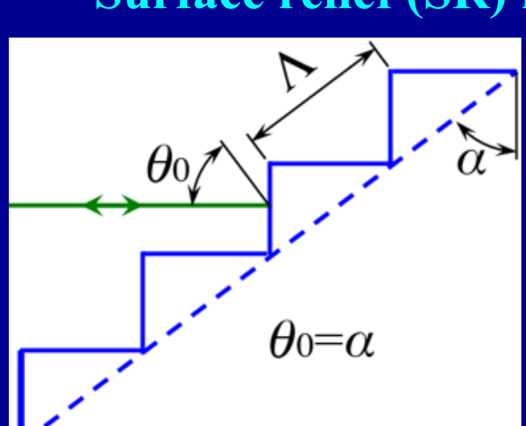


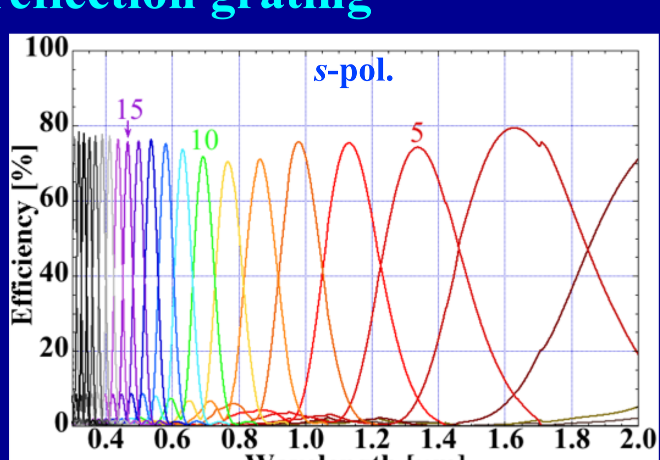


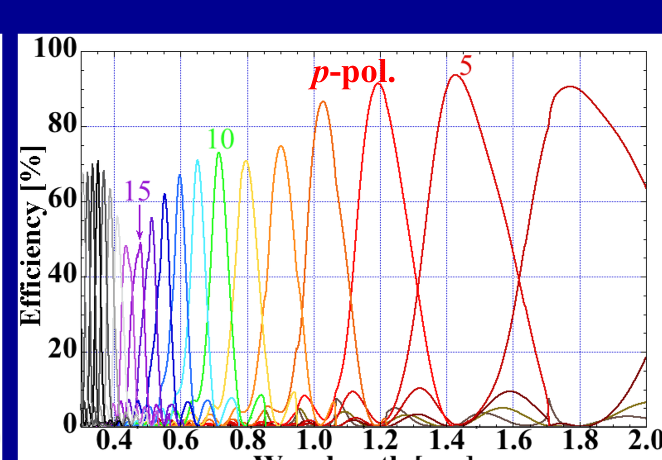


Schematic representation of VB grating (left), diffraction efficiencies of *s* (TE, middle) and *p* (TM, right) polarizations VB grating of θ_0=45° without anti-reflection coating, n_1=1.0, n_2=1.54, Λ=5μm, L&S = 4.75:0.25 [μm], t = 9μm.

Surface relief (SR) reflection grating

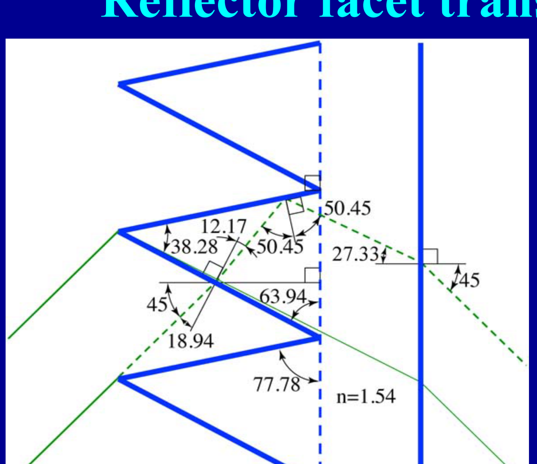


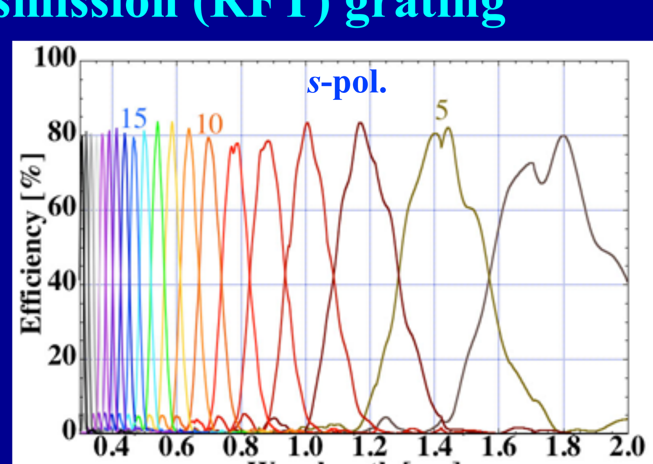


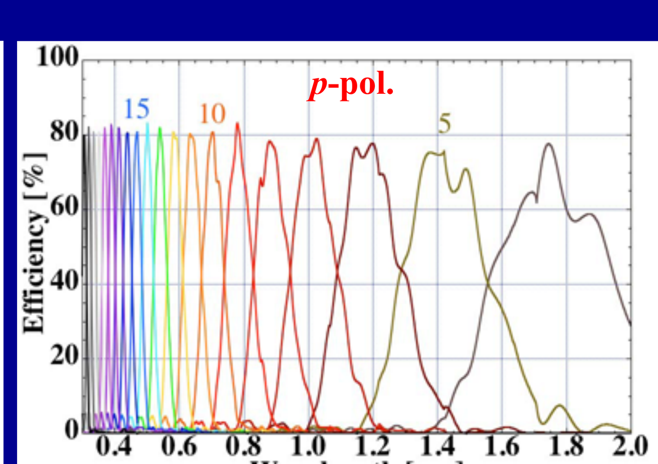


Schematic representation of SR grating with Littrow configuration. (left), diffraction efficiencies of *s* (TE, middle) and *p* (TM, right) polarizations* for SR grating of θ_0=45° with Al mirror (thickness: 100 nm).

Reflector facet transmission (RFT) grating



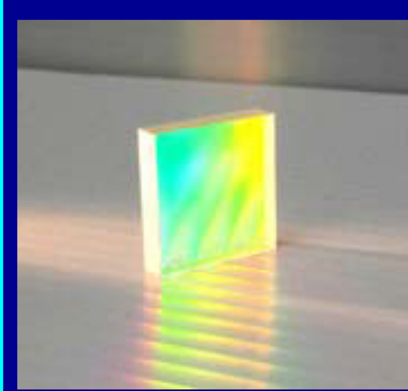


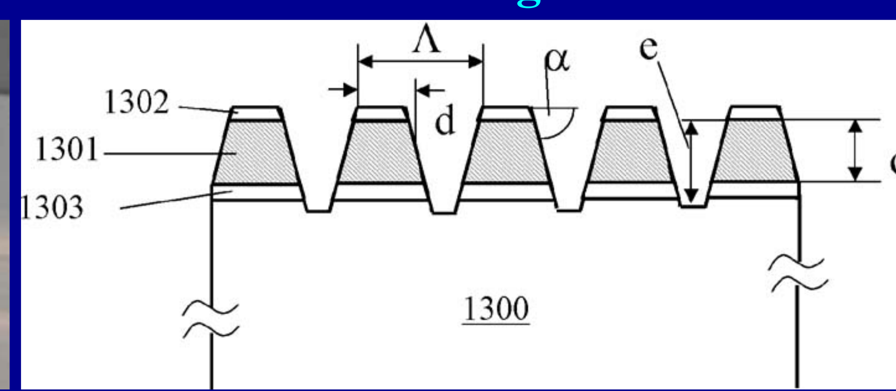


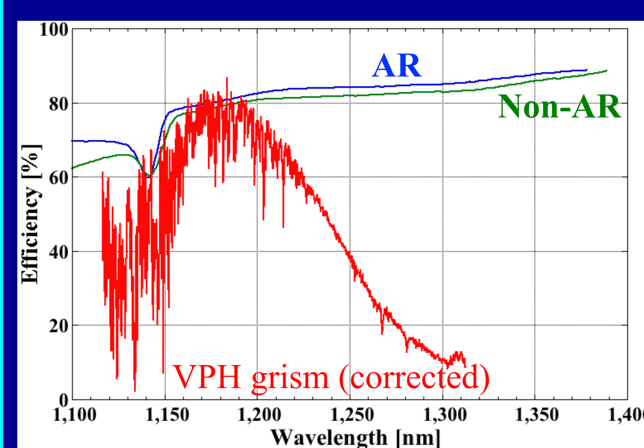
Beam propagation in RFT grating for θ_0=45° (left), diffraction efficiencies of *s* (TE, middle) and *p* (TM, right) polarizations of the RFT grating without anti-reflection coating. Λ=5μm, θ_0=45°, n=1.54, γ=38.3°.

LightSmyth Transmission Grating

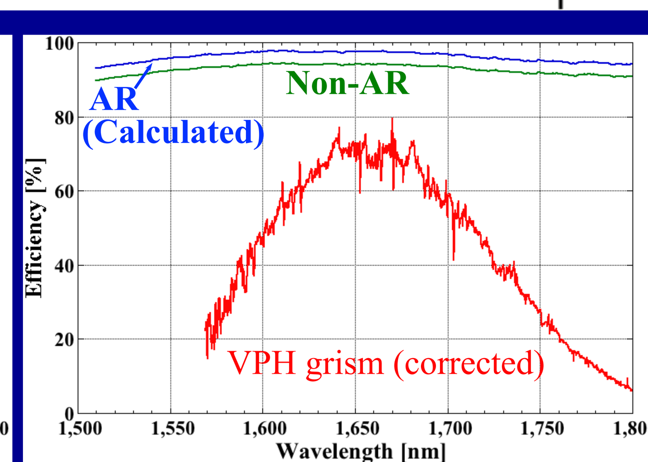
for MOIRCS J and H band grisms instead of VPH grisms



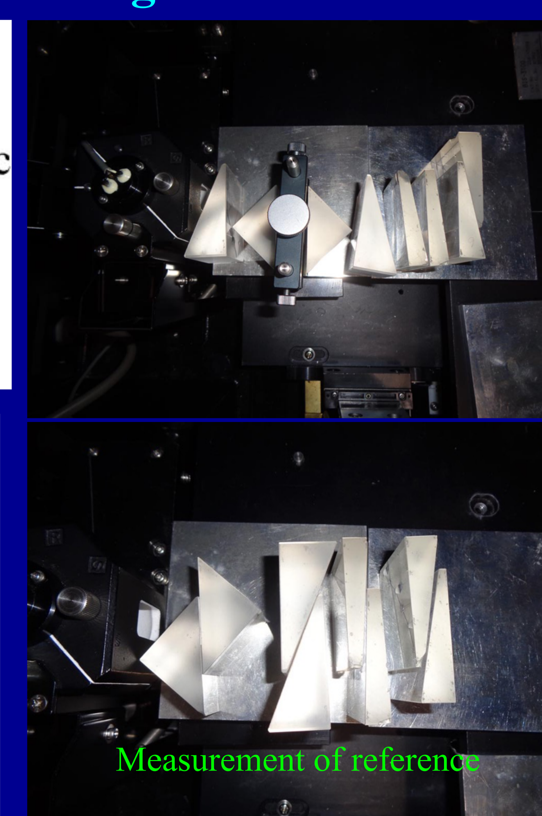




J band grism 940 g/mm (T-940C)



H band grism, 677 g/mm (Test peace)

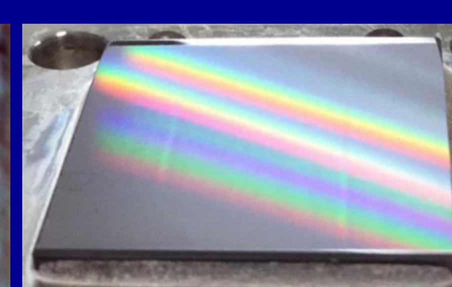


Measurement for diffraction efficiency at blazed angle.

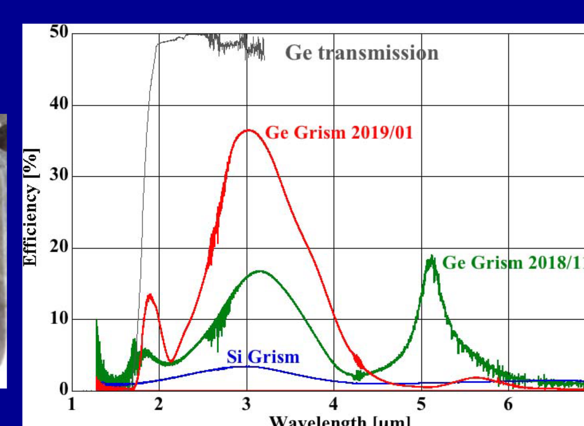
Grism for MIMIZUKU

Fly cutting of Si grism

Microscope photograph of Si grism.

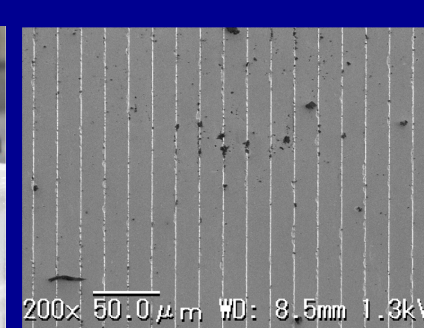


Si grism: α = 4.2°, Λ= 17.09μm.

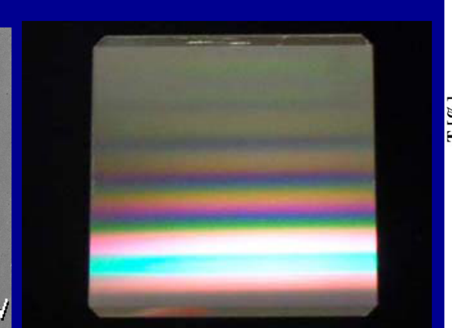


Efficiency of prototype Si grism (including reflection loss).

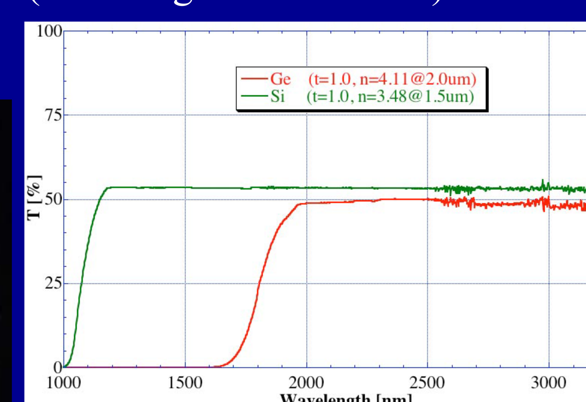
Fly cutting of Ge grism



SEM photograph of Ge grism.



Ge grism α = 3.41, Λ= 17.07μm.



Transmission of Si and Ge (including reflection loss).

Summary

	Optimal Order	Eff. [%] (λ-λ μm)	Status of development
VB grating	1st~	~ 95 (0.2~3.0)	Performed prototype of silica VB gratings by using SOQ substrate.
RFT grating	2th~	~ 80 (0.3~2.4)	Compared diffraction efficiency with VB and SR gratings, Planning the third trial fabrication in near future.
LightSmyth Grating	1st	~ 100 (0.8~3.0)	Buy 3 transmission gratings of catalogue product for MOIRCS J band. Ordered transmission gratings for H band.
Si or Ge grism	1st	~ 80 (1.2~14)	Performed direct diamond cutting of Si grisms. Planning fabrication of a Si and Ge grisms.

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