次世代観測装置用の新しい回折格子 IV

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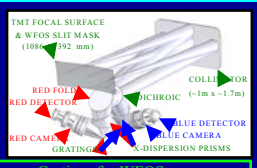


WFOS: Wide Field Optical Spectrograph.
The first generation instrument for TMT. R= 500~5,000 (150~7.500 goal) @0.75" slit

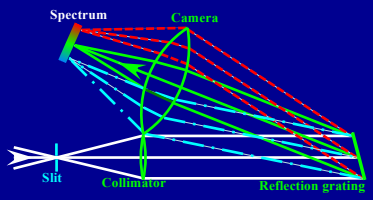
Gratings for WFOS
Incident and diffraction angle: q_0 = 36~53°
Period : Λ= 2~5 μm
Siz : 400 x 550~750 [mm]

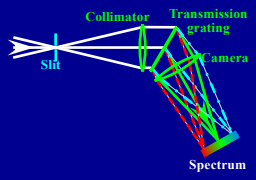
Reflection and transmission grating

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

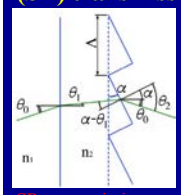
→Transmission grating can reduce size of the camera lens (→total optical system).

→Transmission grating is able to realize perfect Littrow mounting.





Limitation of surface relief (SR) transmission grating



$\theta_2 < 90°$
n = 1.5, $\theta_0 \leq 30°$
n = 1.8, $\theta_0 \leq 36°$
n = 2.3, $\theta_0 \leq 45°$
n = 3.0, $\theta_0 \leq 54°$

Diamond:
n = 2.46@400nm

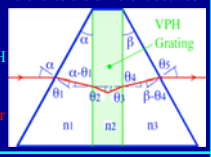
SR transmission grating with saw tooth grooves is not feasible for the high-dispersion grating.

VPH grating

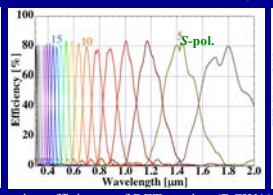
・VPH (Volume Phase Holographic) grating, in which refractive index is modulated sinusoidally achieves diffraction efficiency up to 100% for S or P polarization.

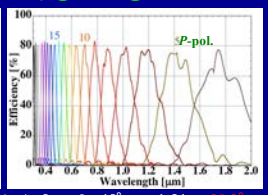
・VPH grating can not achieves high diffraction efficiency for natural and circular polarizations at high dispersion because characteristics of diffraction efficiencies are different between S and P polarizations.
→Birefringence VPH grating.

・Diffraction efficiencies of VPH grating decrease in higher orders.
→VPH grating is not feasible for an echelle grating.

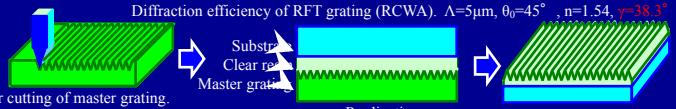


Reflector facet transmission (RFT) grating





Diffraction efficiency of RFT grating (RCWA). Λ=5μm, θ_0=45°, n=1.54, γ=38.3°.



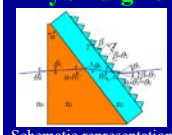
Shaper cutting of master grating.
Work : Ni-P alloy of non-electrolytic plating

Replication

Finish

Fabrication method for RFT grating and for SR grating of MOIRCS hybrid grism

Hybrid grism for MOIRCS (as a prototype of RFT grating)

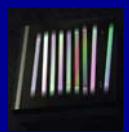


Schematic representation of hybrid grism

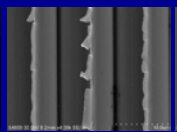
Prism material	: ZnSe (n_1= 2.4529@1.65 μm)
Transmission grating:	Resin (n_2~1.52@1.65 μm)
Prism vertex angle	: α = 23.8°
Grating period	: Λ= 10.79μm (92.68 grooves/mm)
Incident angle	: θ_0= 5°

Slit width: 0.3"
6th, R= 2,790@1.02 μm
5th, R= 2,750@1.25 μm
4th, R= 2,800@1.65 μm
3rd, R= 2,770@2.20 μm

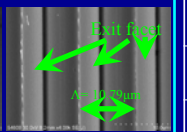
Shaper cutting



Test cuttings for condition setting

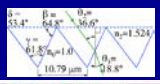


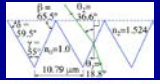
Skew angle: 0°



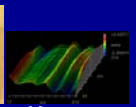
Skew angle: 3°

SEM photograph of RFT grating

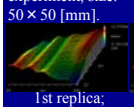




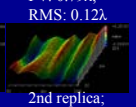
Mold for replication experiment, size: 50 × 50 [mm].



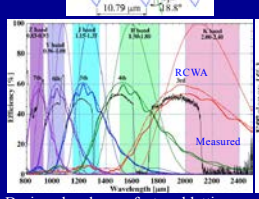
Master; PV: 0.79λ, RMS: 0.12λ



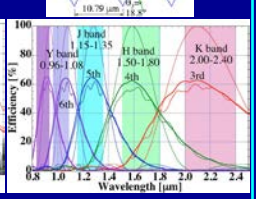
1st replica; PV: 0.76λ, RMS: 0.12λ



2nd replica; PV: 0.48λ, RMS: 0.07λ

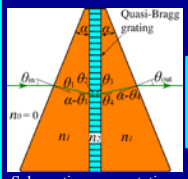


Designed and manufactured lattice shape: β=64.8°, γ=61.8°, θ_2=36.6°
Peak efficiencies sift toward shorter wavelength.



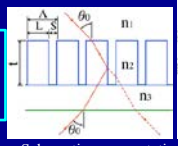
Optimal lattice shape: β = 64.8° → 65.5°, γ= 61.8° →55.0°, θ_2=36.6°

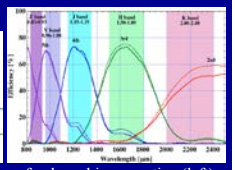
Echelle grism (Volume binary grating) for MOIRCS



Schematic representation of echelle grism

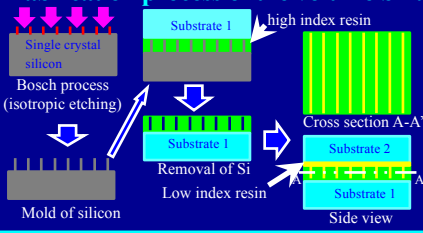
Slit width: 0.3"
5th, R= 4,630@1.02 μm
4th, R= 4,420@1.25 μm
3rd, R= 4,270@1.65 μm

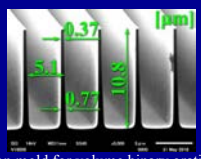




Schematic representation of volume binary grating (left) and diffraction efficiency (RCWA, right). L&S=4.6:0.5 [μm], θ_0=28.4°, n_1=1.33, n_2=1.6, n_3=1.6, t = 16 μm

Fabrication process of the volume binary grating

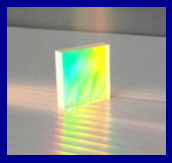


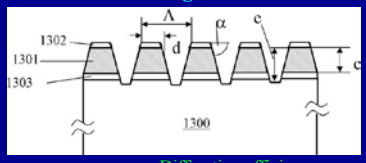


Silicon mold for volume binary grating. Fabricated by Nanotechnology platform of Toyota Institute of Technology.

LightSmyth Transmission Grating

for MOIRCS H band grism insteed of VPH grism

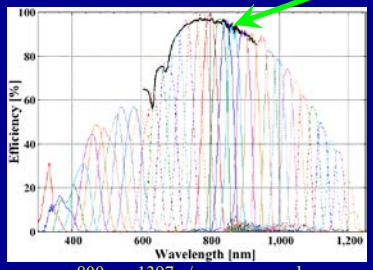




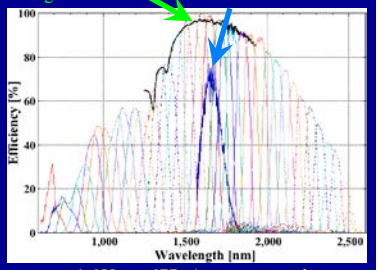
Current status
Size : φ130 (Max)
λ range : 800~2,500nm
Bragg A.: 30~68°

Diffraction efficiency at blazed angle

MOIRCS H band grism (corrected)



800nm, 1397 g/mm, measured



1,650nm, 677 g/mm, converted

Measurement for diffraction efficiency at blazed angle.

Measurement for peak efficiency of super blaze.

Summary

	Optimal Order	Eff. [%] (λ~λ [μm])	Status of development
RFT grating	2th~	~ 80 (0.3~2.4)	Evaluations of diffraction efficiency by numerical calculations of RCWA. Performing diamond cutting of a master grating.
Hybrid grism	2rd~	~ 70 (0.3~2.4)	Performed diamond cutting of a master grating and replication. Optimum master grating for MOIRCS medium dispersion grism is going to fabricate in this september.
Volume binary grating	1st~	~ 80 (0.2~1000)	Performing test fabrications for echelle grism of MOIRCS by using MEMS technique.
VPH grating → LS Transmission grating	1st	~80 →~97 (0.8~2.4)	Developing LS transmission grating for MOIRCS high dispersion grism of H band insteed of VPH grism.
Si or Ge grism	1st	~ 80 (2~4)	Near to mid-infrared grism. Performing direct diamond cutting.

Acknowledgement

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