WINERED : Realizing Hires modes (R=80,000) with mosaicked high efficiency high-blazed echelle gratings

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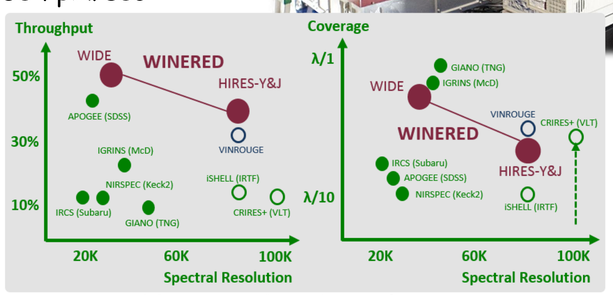
WINERED is a PI-type NIR high-resolution spectrograph which realizes both wide coverage and high sensitivity. The Wide mode of WINERED covers z, Y, J-bands in a single exposure with R=28,000 and has been commissioned since 2013. Recently we built alternative observing channels “Hires-Y mode” and “Hires-J mode” providing R=80,000.
It employs a mosaicked grating consisting of two high-blazed echelle gratings (HBGs). The HBGs are designed to be with a groove pitch of 90.38μm, a blaze angle of 79.32deg, and an apex angle of 88deg, and then they were custom-made by CANON Inc. We also designed the grating holder for the precious alignment of two HBGs, which has the adjusting mechanism with sub-μm resolution using a small ruby ball and adjusting bolts made of invar. The extremely low CTE material (< 2.0 × 10^{-8} at 23℃) “cordierite CO-220 (Kyocera Corporation)” is chosen as the material of the grating holder to reduce the alignment error by the thermal expansions. As a result, we achieved an alignment with the parallelism of < 1.0 arcsec and the stability of <0.1 arcsec under the condition of ⊿T = 5K for 25 hours. Finally, we evaluated the total optical performances of the assembled Hires-modes. The measured throughput and spectral resolution are ~42% and R ~78,000, which a most meet the specification.

1.INTRODUCTION

NIR high-resolution spectrograph, WINERED

- **“No Cold Stop”**
  - Only camera system & IR array are cooled
  - Ambient BG Radiation is reduced to 0.05e-/pix/sec
- **“Wide Spectral Coverage”**
  - Δλ/λ ~ 1/6 realized with a large format array (2K × 2K) and X-disperser echelle spectrograph
- **“High Sensitivity”**
  - Total throughout of optics: >60%
  - High QE array: >80%
  - Low noise electronics systems (σ_r=5.3e-/pix for NDR=32)



The spectral resolution & coverage of various IR high-resolution spectrographs

	Wide mode++	Hires-Y mode	Hires-J mode
Wavelength Coverage	0.90-1.35μm	0.95-1.11μm	1.14-1.35μm
Maximum Spectral Resolution	28,000 (2pix sampling)	80,000 (2pix sampling)	
Slit Width	100μm (0.54”)+, 200μm, 400μm		
Slit Length	3.12mm (17”)+		
Total Throughput	> 50%	~ 32%	~ 42%
Volume	1750mm(L) × 1070mm(W) × 500mm(H)		
Operation Temperature	270-300K (except for camera lens and IR array)		

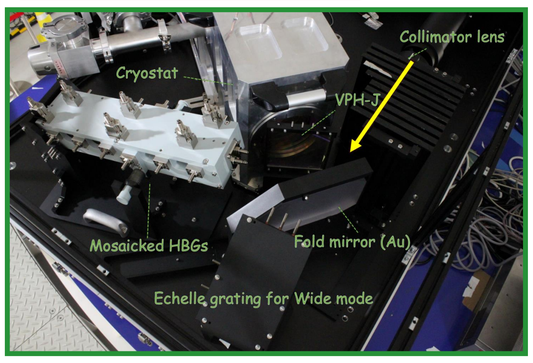
This Presentation

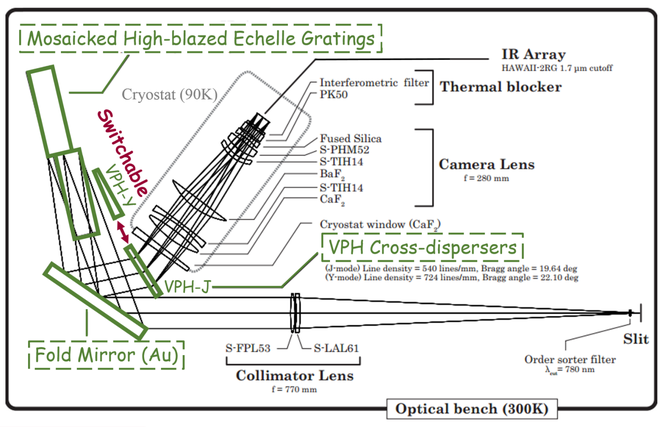
Specification of WINERED

+ mounted on the 3.58m telescope and f/11
++ see a poster presentation: P02

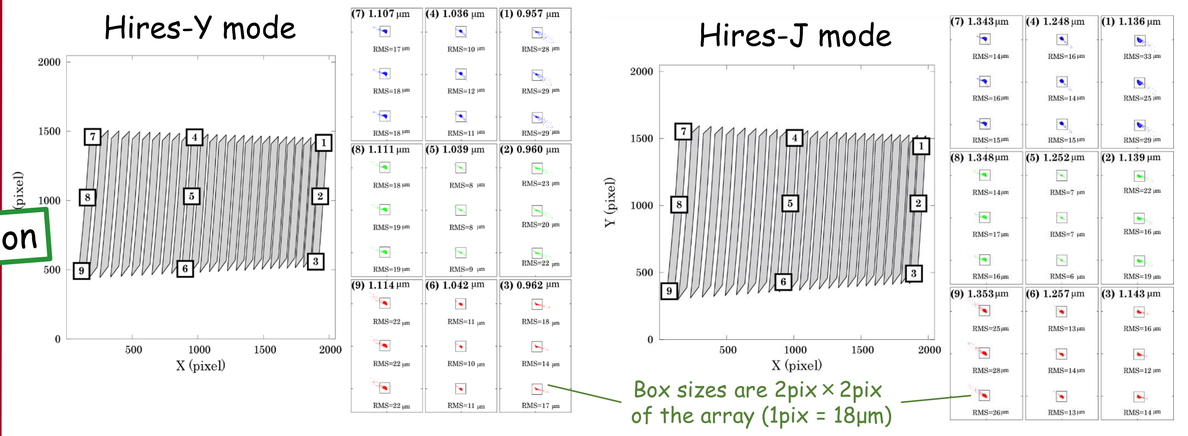
2.OPTICAL DESIGN

2.1 Optical Layout



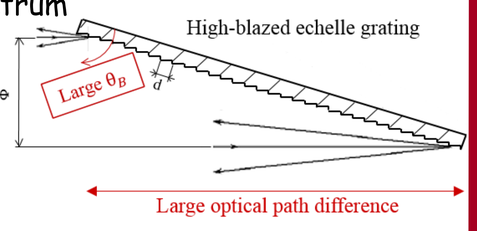


2.2 Echellograms and Spotdiagrams



3.HIGH-BLAZED ECHELLE GRATING

- WINERED employs “high-blazed echelle grating (HBG)” for Hires-modes
- HBG produces an extremely high dispersion spectrum by high-blaze angle (θ_B > 75deg)
- For WINERED, two HBGs are mosaicked (due to the limitation of the physical size for fabrication)

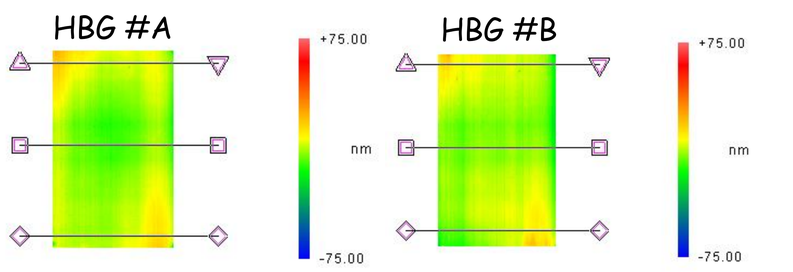


3.1 Design and Fabrication

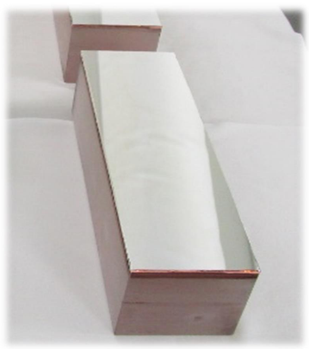
Design and Production results

Item	Designed	HBG #A	HBG #B
Physical Size	200mm × 60mm × 59.4mm		
Orthogonality of grooves*	< 1μm	0.7μm	0.5μm
Blaze Angle	79.32deg (R5.3)		
Apex Angle	88deg	87.95deg	87.95deg
Groove Pitch	90.38μm		
Random Pitch Error	< 8nm (rms)	4.9nm	4.9nm
Surface Irregularity	< 150nm (PV)	54.1nm	45.4nm
	< 30nm (rms)	5.6nm	6.0nm
Rowland Ghost	< 0.1%	< 0.01%	< 0.01%
Diffraction Efficiency**	> 70%	68.6%	68.8%

* measured from the reference surface produced on the side face
** average between TE and TM waves

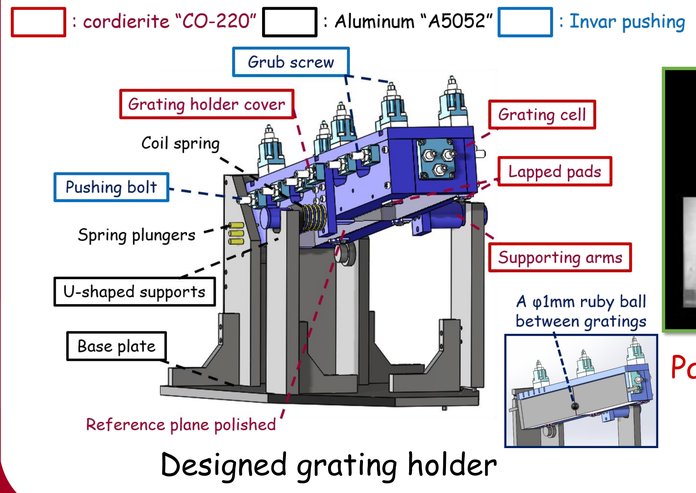


Wavefront maps of diffracted lights of m=201 (@633nm)

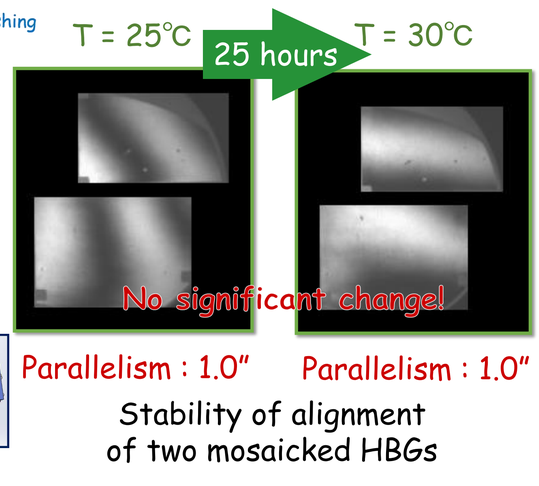


Completed HBG (#A)

3.2 Mosaicking Mechanism



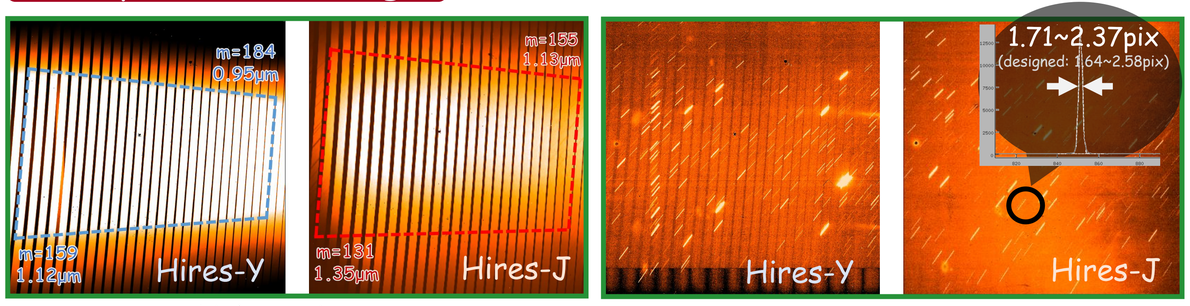
Designed grating holder



Stability of alignment of two mosaicked HBGs

4.VERIFICATION OF HIRES MODES

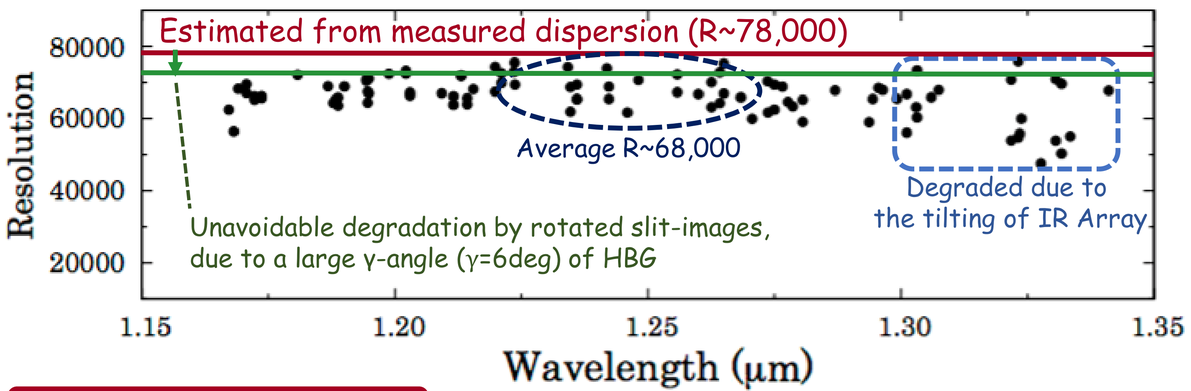
4.1 Spectral Coverage



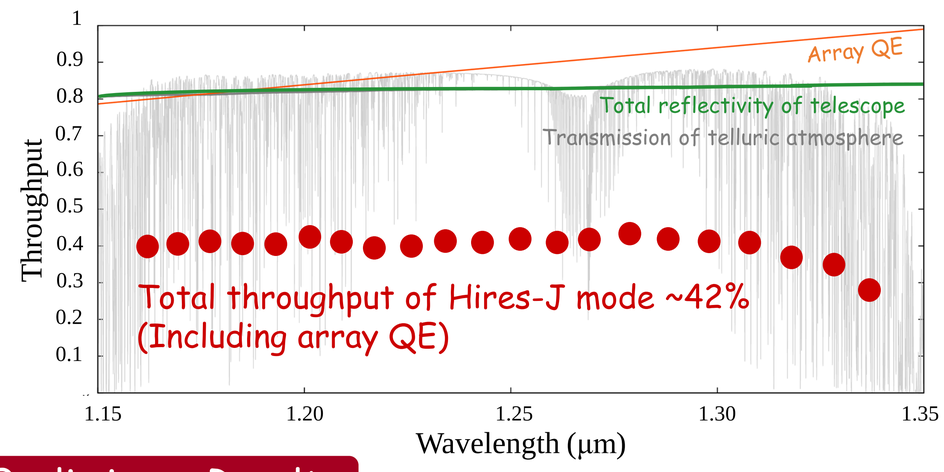
Halogen Lamp

Th-Ar Lamp image

4.2 Spectral Resolution



4.3 Total Throughput



4.4 Preliminary Results