Instrument Design of Warm INfrared Echelle Spectrograph(WINERED)

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ABSTRACT

There are strong needs for high sensitive near-infrared (NIR) high-resolution spectrograph for a variety of science, such as doppler search for low-mass planetary companion, kinematics study of stellar systems, chemical composition study of stars, interstellar medium & intergalactic medium. Such spectrograph will be one of the main instruments for ELT, making use of its large collecting area. However, the required large instrument size in proportion to the telescope aperture will be one of the major issues. This is a challenging problem especially for NIR Echelle spectrograph because of the necessity of 1) cooling of the entire instrument, and 2) fabrication of large infrared optics.

As a practical solution to this problem, we are developing a new type of high-resolution (R_{max}=100,000) NIR spectrograph "WINERED", which is specifically customized for short NIR bands at 0.9-1.4um. It has the following two main features: 1) all WARM optics, 2) high-throughput, 3) portable design with a ZnSe immersion grating. This design brings several essential advantages: easy to build, align and maintain, which results in short development period and low cost. The high-throughput, as a result of the limited wavelength coverage, makes the instrument sensitivity competitive to other facility instruments being built for existing 8m-class telescopes.

Here we present the concept and the optical design of WINERED, the Warm INfrared Echelle-spectrograph with high Resolution and high Efficiency Devices. We are developing this instrument for any 3-10m class existing telescopes as a proto-type for ELT instrument. We plan to complete this instrument at the end of 2007.

Specification

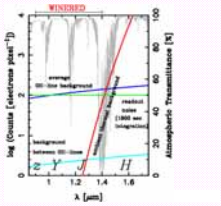
Spectral Resolution
R_{max} = 100,000
@0.9-1.4μm

Telescope
TBD…
3-10m telescope is wanted for WINERED. If interested in, please contact us,
Email: naoto@ioa.s.u-tokyo.ac.jp

Three Major Features

1.Warm (T~270K)

The bottom figure shows various back-grounds as noise sources for IR spectroscopy. In short near-infrared (λ<1.4μm), ambient thermal background can be neglected compared to readout noise or OH airglow background. Cooling of optics is not necessary as long as we stay in this short wavelength range.



2. High Throughput (>30%)

Existing near-infrared Echelle spectrographs usually have throughput of ~10-20%. By limiting the wavelength range to the narrow short near-infrared, the performance of AR coating on lenses can be significantly improved.(e.g. R<1% per surface while R > a few % per surface for 1-2.5μm BBAR)
The resultant throughput can be more than 30% in total.

Optical Element	Efficiency	Comments
collimator mirror	99%	Au coating
echelle	68%*	*target value
cross disperser	80%	Au coating
camera lenses	85%	total by 12 surfaces
dewar window	98%	AR coating on CaF2
thermal cut filter	95%	
detector	80%	VIRGO HgCdTe
TOTAL	34%	

3. Immersion Grating

The spectral resolution (=R) of echelle spectrograph is given by,

$$R = 2n\Phi\tan\theta / sD_{tel}$$

Φ :diameter of collimator beam
s :slit width (rad)
D_{tel}:telescope diameter (m)
θ :blaze angle of the echelle grating
n :refractive index of the grating material

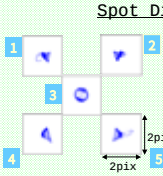
In order to keep the same "R" for ELT, the diameter of collimator beam (=Φ), namely the instrumental size, must become larger as long as a relief echelle grating in the air (n=1) is used. An "immersion grating" with a high refractive index (=n) can keep the instrument size as small as that for existing telescopes.

OPTICAL LAYOUT

Detector

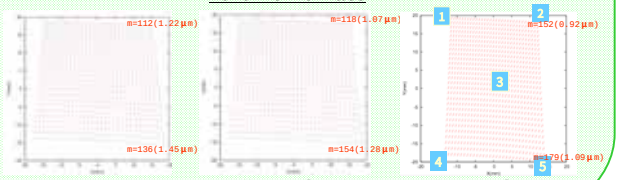
✧Raytheon VIRGO HgCdTe
- 2048×2048 pixels
- 20μm/pixel
- LN_2 cooled (~77K)

Spot Diagram



◆Spots are well within 2×2 pixels for short wavelength mode.
◆Similarly good performance for all three modes.

Echelle Formats



long wavelength (L-mode:1.22-1.45μm) | medium wavelength (M-mode:1.07-1.28μm) | short wavelength (S-mode:0.90-1.09μm)

Camera

✧ *Focal Length* **280mm**
✧ *Clear Aperture* **160mm**

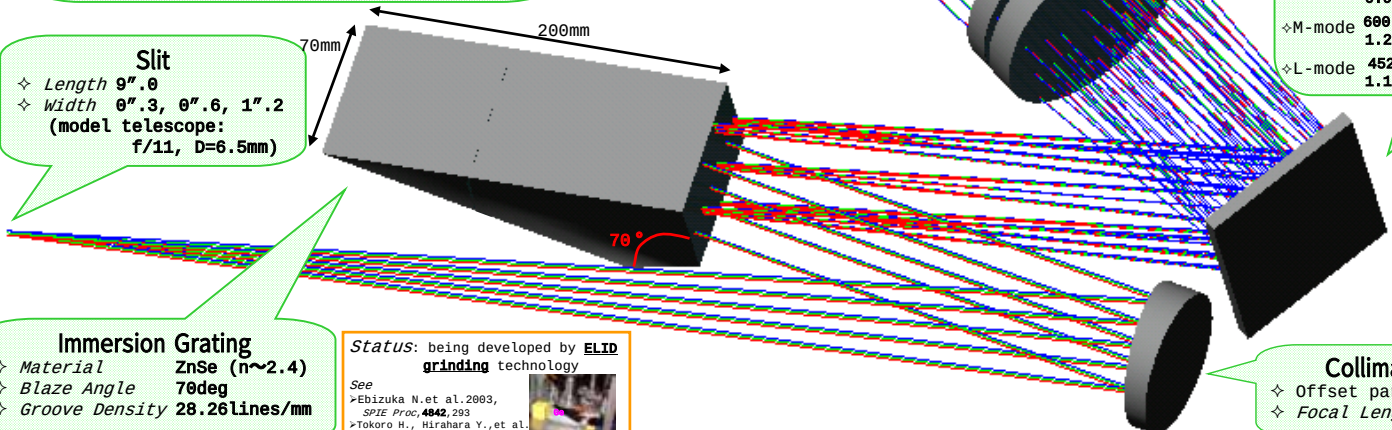
X-disperser

Three X-dispersers are switchable by rotating a turret.

✧S-mode **830 lines/mm 0.90μm blaze**
✧M-mode **600 lines/mm 1.25μm blaze**
✧L-mode **452 lines/mm 1.14μm blaze**

Slit

✧ *Length* **9″.0**
✧ *Width* **0″.3, 0″.6, 1″.2**
(model telescope: f/11, D=6.5mm)



Immersion Grating

✧ *Material* **ZnSe (n~2.4)**
✧ *Blaze Angle* **70deg**
✧ *Groove Density* **28.26lines/mm**

Status: being developed by **ELID grinding** technology

See
➢Ebizuka N.et al.2003, *SPIE Proc*, **4842**, 293
➢Tokoro H., Hirahara Y.,et al. 2001, *SPIE Proc*, **4841**, 1016

Collimator

✧ Offset parabola
✧ *Focal Length* **777mm**