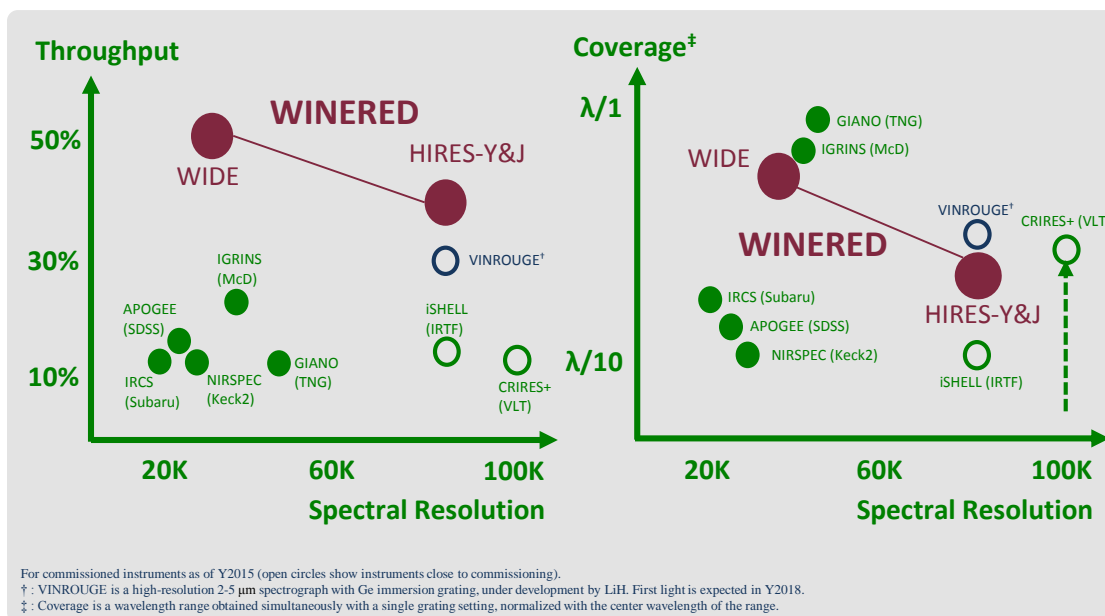


WINERED (Warm INfrared Echelle spectrograph to Realize Extreme Dispersion and sensitivity) is a near-infrared high-resolution spectrograph developed by LiH. WINERED is a PI-type instrument, and is installed in the 3.58-meter New Technology Telescope (NTT) from 2017. WINERED has three distinctive features: warm optics (no cold stop), wide spectral coverage (0.90–1.35 μm), and high sensitivity. WINERED has three observing modes: “WIDE” ($R = \lambda/\Delta\lambda_{FWHM} = 28,000$) and “HIRES-Y&J” ($R = 68,000$); the latter employs a specially designed high-blazed echelle grating. HIRES-Y&J modes are going to be in science operation by the middle of 2017.

“Laboratory of Infrared High-resolution spectroscopy” (LiH) was established at the Koyama Astronomical Observatory, Kyoto Sangyo University, in collaboration with the University of Tokyo and other domestic institutes/industries, for pursuing astrophysics, astrochemistry, astrobiology and planetary sciences as well as instrumentation, based on high-resolution spectroscopic techniques in infrared wavelength region.



Mode	WIDE	HIRES-Y	HIRES-J
Wavelength coverage	0.90 – 1.35 μm (z, Y, J bands)	0.96 – 1.11 μm (Y band)	1.14 – 1.35 μm (J band)
Spectral resolution ($R \equiv \lambda/\Delta\lambda_{FWHM}$)	28,000	68,000 [†]	
Throughput	> 50 %	> 35 %	
Main disperser	Reflective echelle grating	Mosaicked high-blazed echelle grating	
Array	1.7 μm cut-off HAWAII-2RG		
Size	1.75m(L) x 1.07m(W) x 0.50m(H)		

[†]: In the engineering observation on NTT, $\lambda/\Delta\lambda_{FWHM} \sim 55,000$.

Telescope	WIDE			HIRES		
Slit width	0.54, 0.76 and 1.08 arcsec					
Slit length	16.34 arcsec					
Pixel scale	0.27 arcsec / pix					
<i>J</i> -band limiting magnitude [†]	15.6 (0.54 arcsec)	15.9 (0.76 arcsec)	16.2 (1.08 arcsec)	14.2 (0.54 arcsec)	14.6 (0.76 arcsec)	14.8 (1.08 arcsec)

[†]: S/N = 30, integration time = 8 hrs, magnitude per pixel.

Warm optics with no cold stop

1. Optics are at room temperature except for the infrared camera system (camera lenses and an infrared array).
2. Beneficial to reduce time and cost for development, alignment, and maintenance.

Wide spectral coverage

Achieved by a combination of decent optical design with a cross-dispersed echelle and a large format infrared array (2k x 2k).

High sensitivity

High throughput

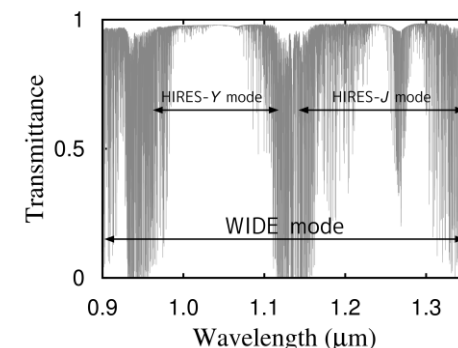
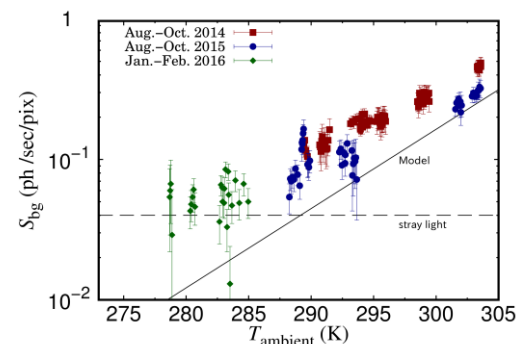
- Gratings with high diffraction efficiency
 - WIDE mode: replica echelle grating by Newport Co. (~83%), VPH cross-disperser (~86%).
 - HIRES-Y&J modes: high-blazed echelle gratings by Canon Inc. (>70%), VPH cross-dispersers (~90%).
- Extremely-low reflection BBAR: $R < 0.5\%$ per lens surface.
- The minimum number of optical elements: no-use of white pupil optics.
- High Q.E. of an array: $1.7\mu\text{m}$ cut-off HAWAII-2RG (~86% @ $1.23\mu\text{m}$).

Low noise

- Low readout noise: $\sigma_r = 5.3 e^-$ (NDR=32). Low-dark noise: $\sigma_d < 2 e^-$ (900sec)
- Suppressed ambient thermal background ($0.05 e^-/\text{sec/pix}$ @ 280 K) with custom thermal-cut filters.

PI-type spectrograph

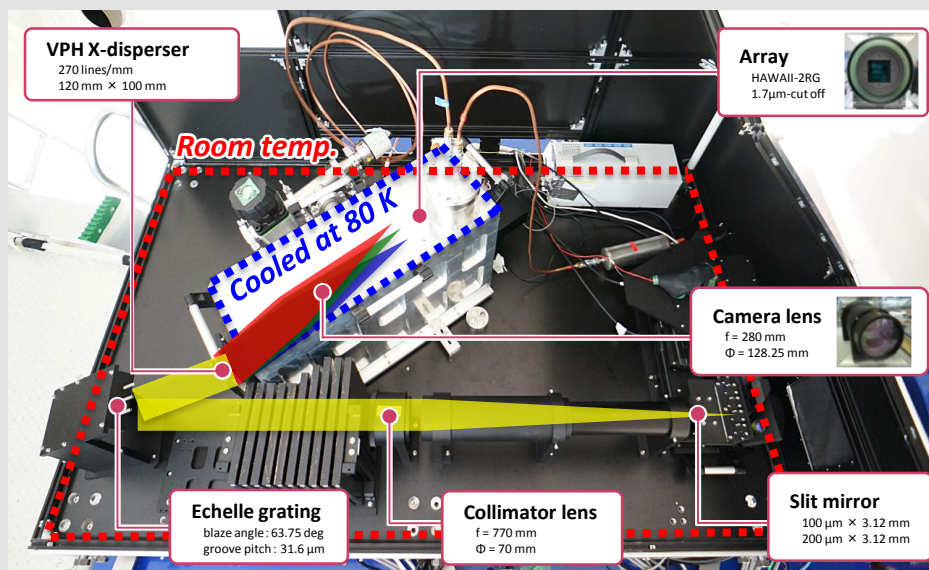
- Compact [1.8m(L) x 1.1m(W) x 1.0m(H)] and light weight [~250kg].
- Attachable to any telescopes with a Nasmyth focus (slower than f/11).



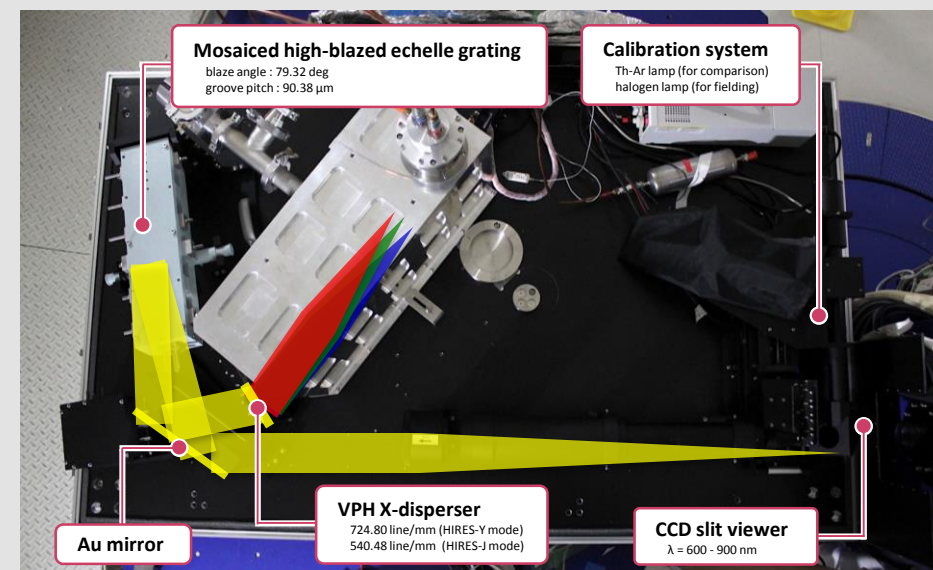
Left: The measured thermal background radiation reaching the array for various the ambient temperatures. The difference of plots shows different season. The solid line is a predicted flux with an assumption that the ambient environment is the block body. The dashed lines is the level of measured stray light in the cryostat.

Right: Wavelength coverages of all the WINERED modes superimposed on an atmospheric transmission curve.

WIDE mode



HIRES-Y&J modes



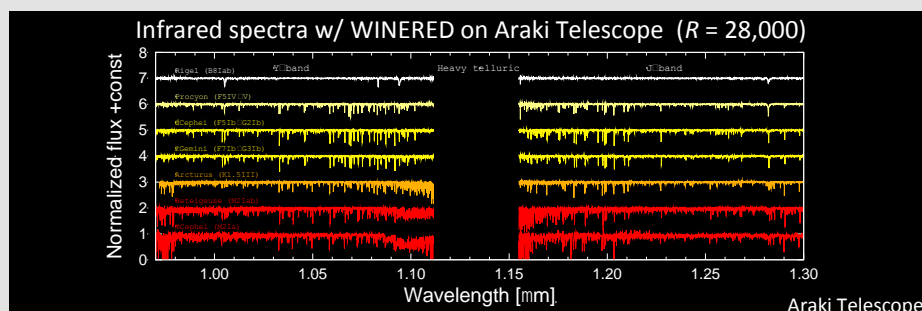
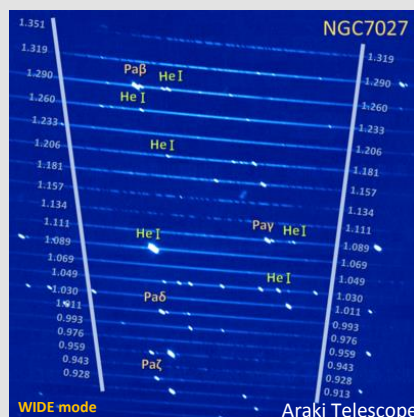
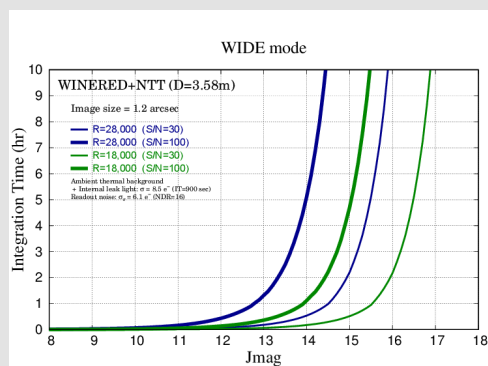
Quality of spectra

- The high-sensitivity of WINERED enables us to obtain NIR high-resolution spectra with high signal-to-noise ratio in much shorter time, or bring us to unexplored faint-end by NIR high-resolution spectroscopy. For example, WINERED mounted on a 10-m telescope equipped with AO can be used for the study of the absorption line systems of $z > 6$ QSOs or GRBs ($J > 18$ mag).

Data reduction pipeline

- We developed the WINERED data-reduction pipeline, which automatically produces 1D spectra from raw data in less than 20 minutes/frame.
- Automatic correction for telluric absorption, which is mandatory for infrared spectroscopy, is under development and is planned to be incorporated into the WINERED data-reduction pipeline.

WIDE mode



Observation

- Observers can select one of the three modes (WIDE, HIRES-Y&J) depending on their priority on spectral resolution¹ and wavelength coverage.
- Three slits of 100 μm-width (2-pix sampling), 140 μm-width (2.8-pix sampling) and 200 μm-width (4-pix sampling) are available.
- A sophisticated user interface customized for WINERED enables efficient observations.

1. Note that the WIDE and HIRES-Y&J modes cannot be switched during the observing night to avoid any hardware trouble.

HIRES-Y&J modes

