NINJA: NIR spectrograph carry-in instrument status overview

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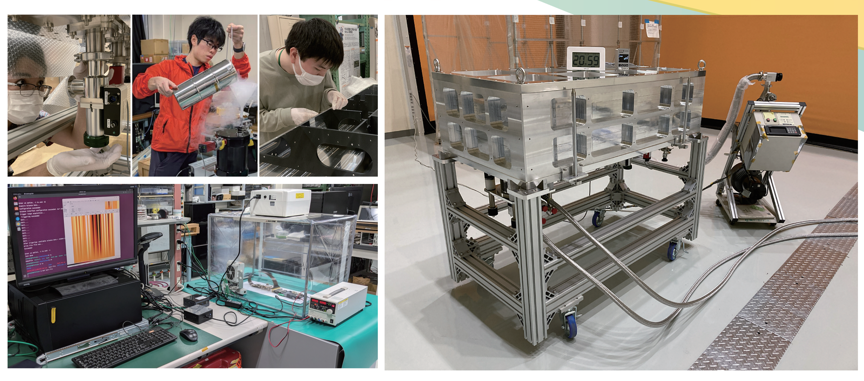
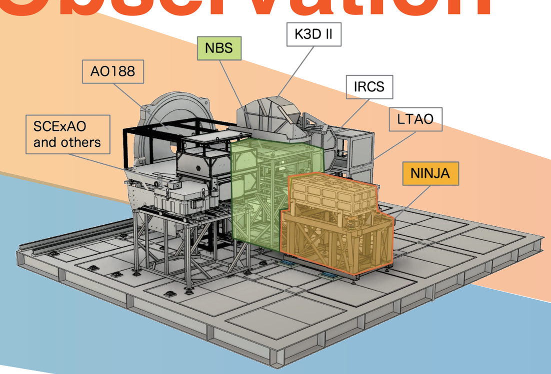
NINJA realizes
1. Excellent sensitivity by optimizing the instrument to the Laser-Tomographic Adaptive Optics,
2. High observational efficiency by taking spectra over the NIR wavelength (0.8-2.5 um) simultaneously, and
3. Quick response to ToO observations with the update of the Nasmyth IR platform of Subaru

NINJA NIR Spectrograph

2025
Test in Mitaka



2026
Fisrst Light Observation



NINJA OPT Spectrograph

Concept Design

2027
Starting Open Use

Introduction

Near-INfrared and optical Joint spectrograph with Adaptive optics (NINJA) is a new PI-type Optical-to-NIR spectrograph developed for the Subaru telescope. We are developing the NIR spectrograph of the instrument in advance to the optical spectrograph. We plan for the first light of the NIR spectrograph in 2025-2026.

Design Overview

The NIR spectrograph is an Echelle spectrograph using a double-path collimator. NINJA can observe the entire NIR wavelength range simultaneously by a single HAWAII-2RG detector (Fig. 1).
The specifications of the NIR spectrograph are shown in Table 1. A slit length of 5" is determined from the requirement for dithering observation. Default slit width of the NIR spectrograph is set as 0.35" (R~3300). Additional options include a 0.21" slit for AO effective case, and 0.5" and 0.7" slits for non-AO cases. Each slit can be changed in slit exchange unit. These narrow slit widths are also the technical challenges in our project.

Tab. 1 NINJA Specifications

Wavelength coverage	0.83 – 2.5 μm
Input F ratio	13.9
Spectral resolving power	R~3300 (0.35″ slit) R~5500 (0.21″ slit) R~2310 (0.5″ slit) R~1650 (0.7″ slit)
Slit length	5″
Detector	HAWAII-2RG x1 (2048 x 2048 pix)
Pixel size	18 μm/pix
Sampling for 0.35″ slit width	3.3 pix

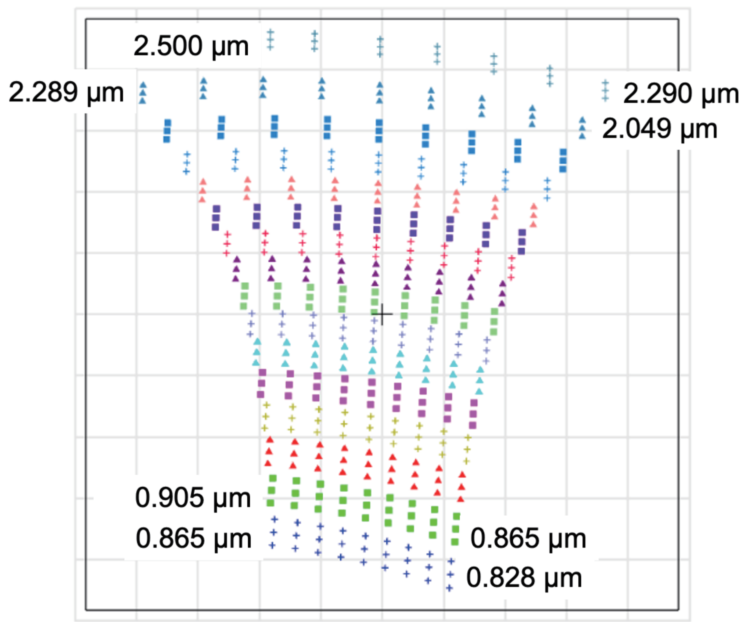


Fig. 1 Echelle format on the H2RG detector.

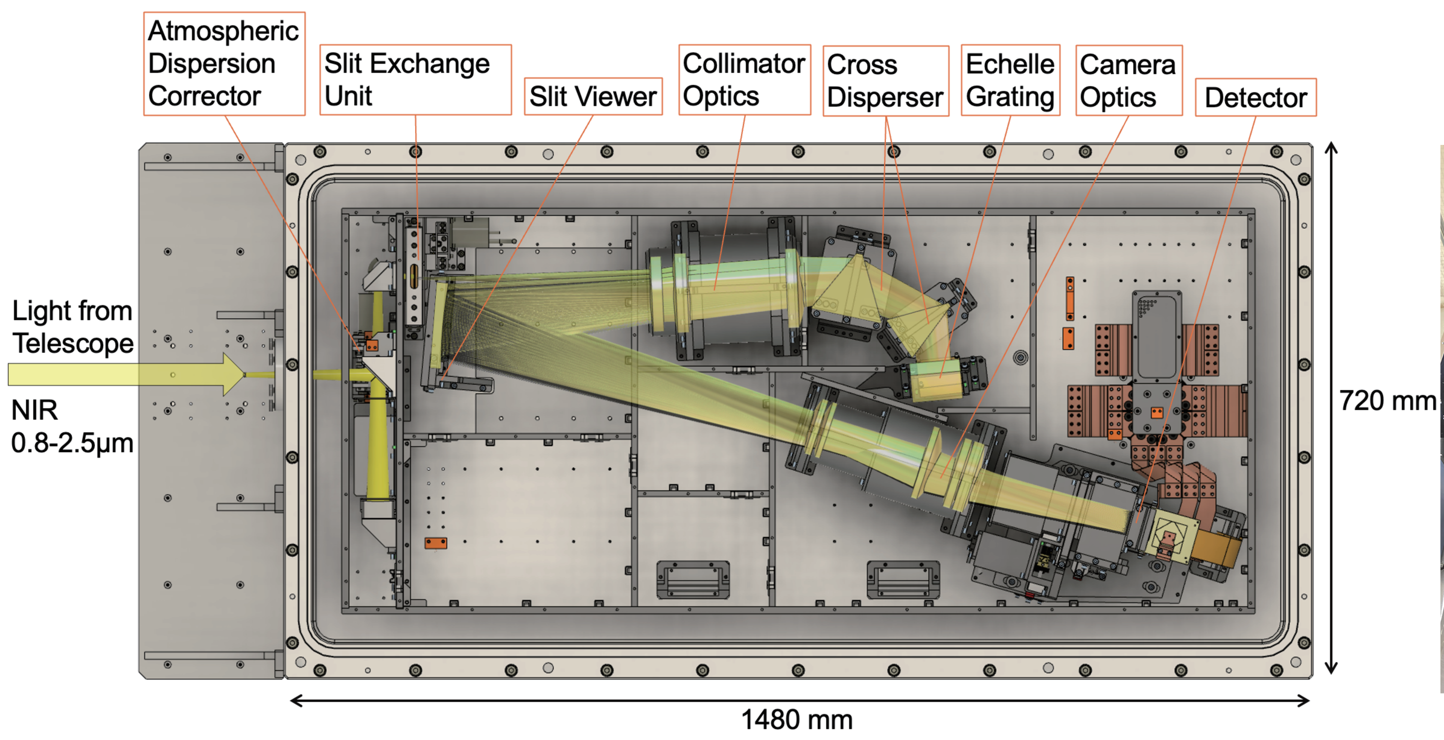


Fig. 2 Optical and mechanical layout of the NINJA NIR spectrograph (Top view of the inside of the cryostat).

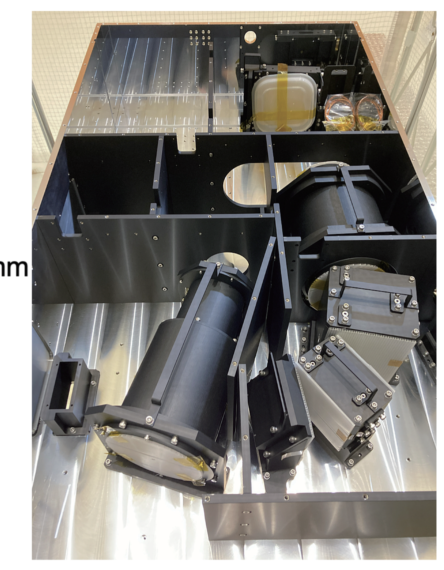


Fig. 3 Optical components fitting test.

Fig. 4 Estimated NINJA efficiency relative to the wavelength (including detector).

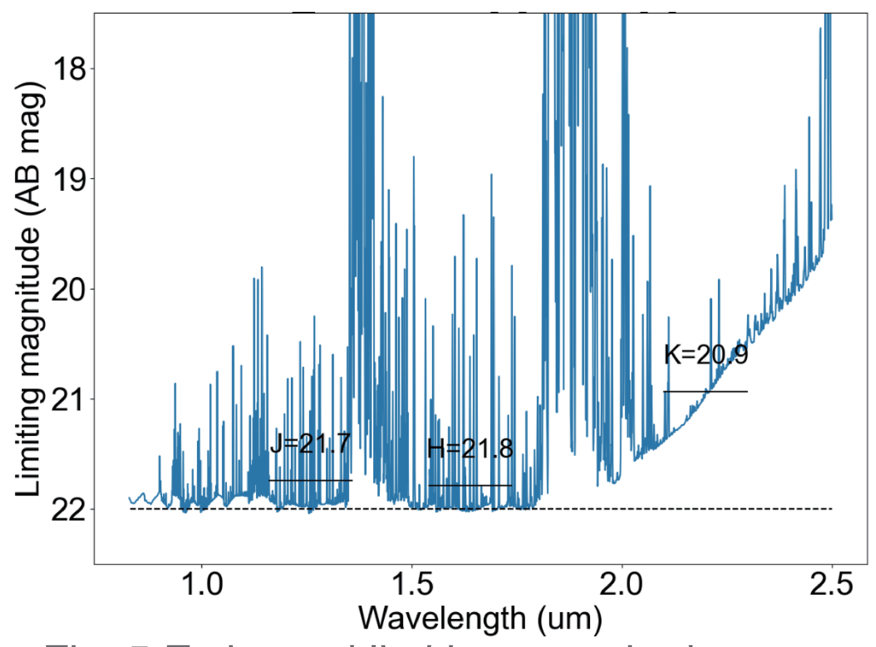


Fig. 5 Estimated limiting magnitudes (2hours exposure, S/N=10, R~3300, nominal condition for LTAO.)

Scientific Objectives

The main goal of NINJA is to study the origins of r-process heavy elements by observing kilonovae. The kilonova AT2017gfo, linked to the neutron star merger GW170817, confirmed that these elements are formed in such mergers. However, AT2017gfo is the only kilonova observed with gravitational waves so far, and more observations are needed to understand nucleosynthesis in neutron star mergers. Kilonovae show key spectral features in optical and NIR wavelengths and are expected to be optically thin a week after the merger. Therefore, spectroscopic observations in these bands during the first week are crucial to estimate r-process element synthesis. During the O5 of the gravitational wave observatories starting in 2027, about 50 neutron star mergers out to 200 Mpc are expected to be discovered by gravitational wave events in a year. To conduct spectroscopic follow-up observations of kilonovae at 200 Mpc for a week after the mergers, we require a spectrograph with a limiting magnitude of 22 mag in the NIR. NINJA is also an ideal instrument for follow-up observations of distant supernovae, as well as high-redshift galaxies and quasars discovered by wide-field surveys using Euclid, Roman, ULTIMATE-Subaru, and so on.

Current Status and Future Plan

The optics, optomechanics, and cryostat have been manufactured. We are currently in the assembly and verification testing phase at the laboratories of the ATC on the NAOJ Mitaka campus. In parallel, we are conducting performance tests on a HAWAII-2RG detector borrowed from the Subaru Telescope.
We submitted our carry-in instrument proposal to the Subaru Telescope in 2024 and are working on coordination with the observatory to finalize the procedures necessary for NINJA observations.
Target of the first light engineering observation is planned no later than S26A.

Acknowledgements

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