NINJA: Current Status of the NIR Spectrograph

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ATC Advanced Technology Center
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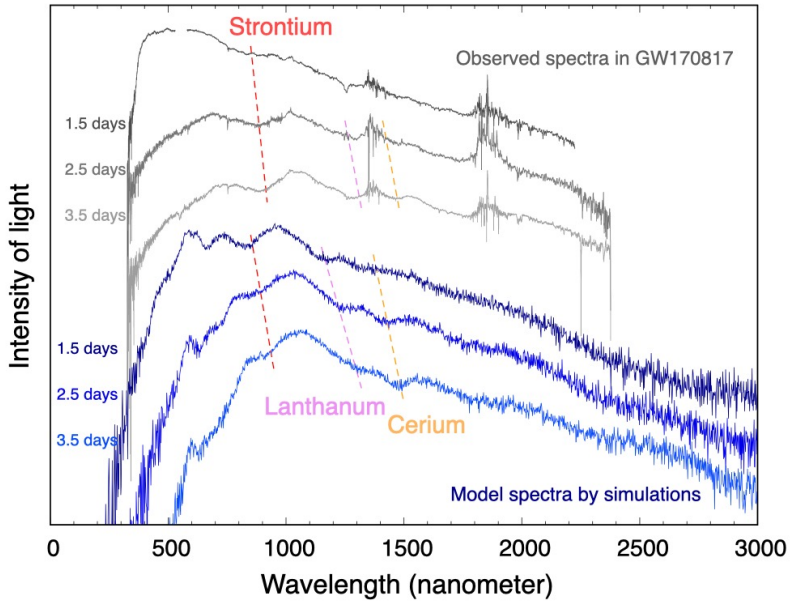
Science Requirements

- Origin of heavy elements
  - Reveal heavy element nucleosynthesis in neutron star mergers.
  - 400-2500nm, R~1000

➡ Follow-up of the counterparts of GW events

- Characterizing quasers at z>6
  - Characterizing quasers in the epoch of cosmic reionization.
  - 800-2500nm, R~1000-2000
- Galaxy formation at z>10
  - Detect emission lines of the bright galaxies that are not identified by the shallow low resolution Roman grism spectra.
  - 800-2200nm, R>3000
- Initial Mass Functions of metal port galaxies
  - Reveal IMFs of extremely metal port galaxies (EMPGs).
  - 360-1300nm, R~5000
- Physical process of quaching galaxies at z>2
  - 1000-2500nm, R~4000



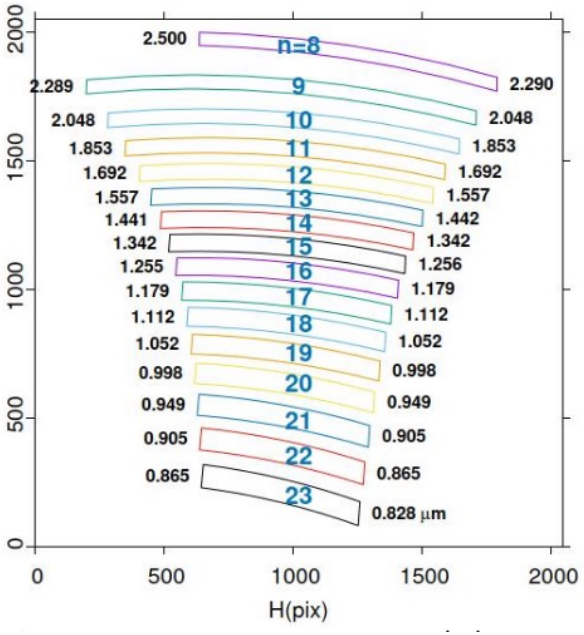
Domoto et al. 2022 and NAOJ

Instrument Requirements

Observing mode	Single Spectroscopy
Wavelength coverage	830 – 2500 nm
Spectral resolution	1000-5000
Slit length	5″
Sensor	HAWAII-2RG (2048 x 2048 pix)
Pixel scale	0.1 arcsec/pix
Sensitivity	22 ABmag (5σ) in 2 hours for follow-up of GW counterparts in O5 (2028-).

Design Constraints

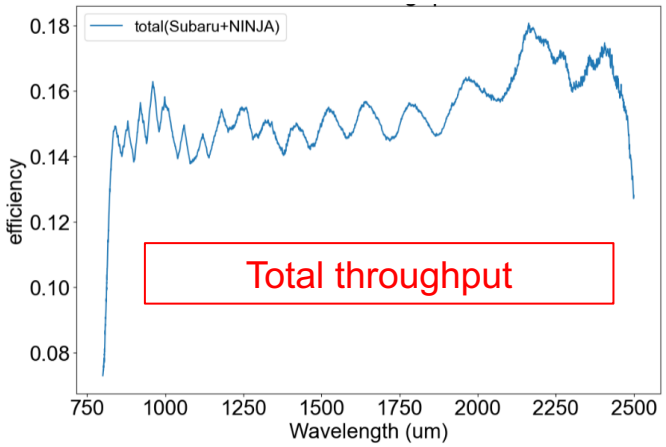
- PI instrument for the Subaru Telescope
  - To be installed in NsIR (optical interface).
  - To be placed on the common platform (mechanical interface).
  - Use the light from port #2 of Ns Beam Switcher (optical and mechanical interfaces)
- High sensitivity
  - Optical design is optimized for Laser-Tomographic Adaptive Optics.
- High observational efficiency
  - Covers 0.83 – 2.5 μm (NIR) in a single exposure.
  - Eschell optics adopted.
- Design capable of supporting ToO observations.



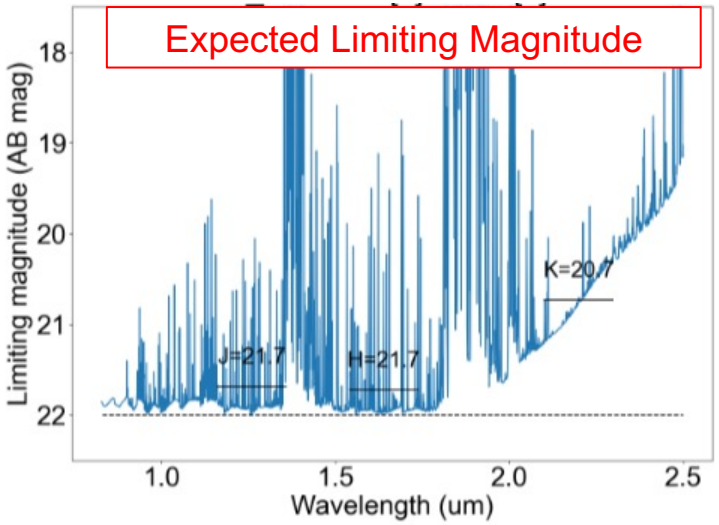
Designed spectra on a H2RG

Design Implementation and Expected Performance

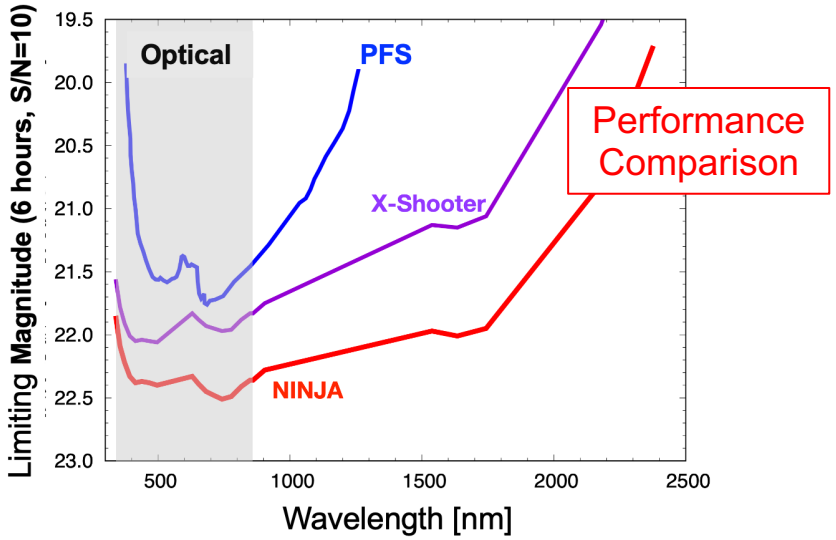
- High throughput and low background (optics, detector readout system, thermal design of the cryostat)
- Slit selectable
  - 0.35″ R~3300 (with LTAO, nominal condition)
  - 0.21″ R~5500 (with LTAO, good condition)
  - 0.5″ R~2310 (without LTAO, seeing)
  - 0.7″ R~1650 (without LTAO, seeing)
- Slit viewer equipped for efficient target acquisition.
- Thanks for LTAO, 0.5 mag deeper sensitivity than X-shooter is expected.



NINJA total throughput including telescope mirrors, AO188, LTAO, and NBS

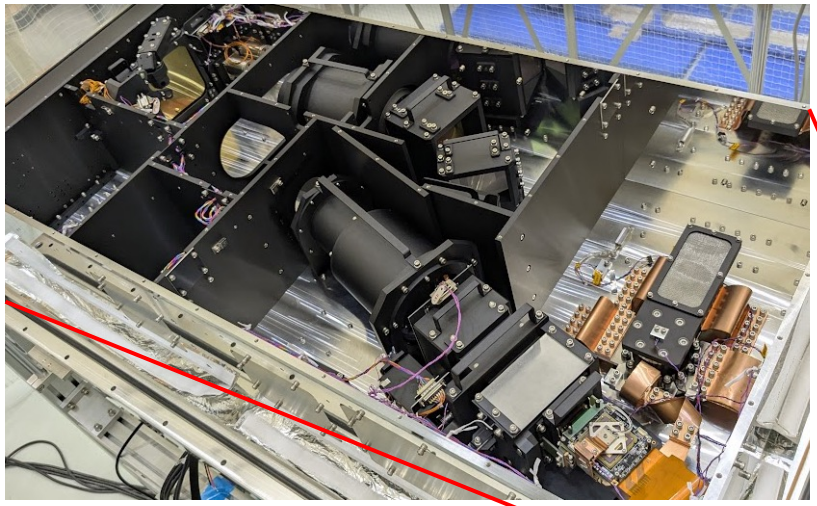


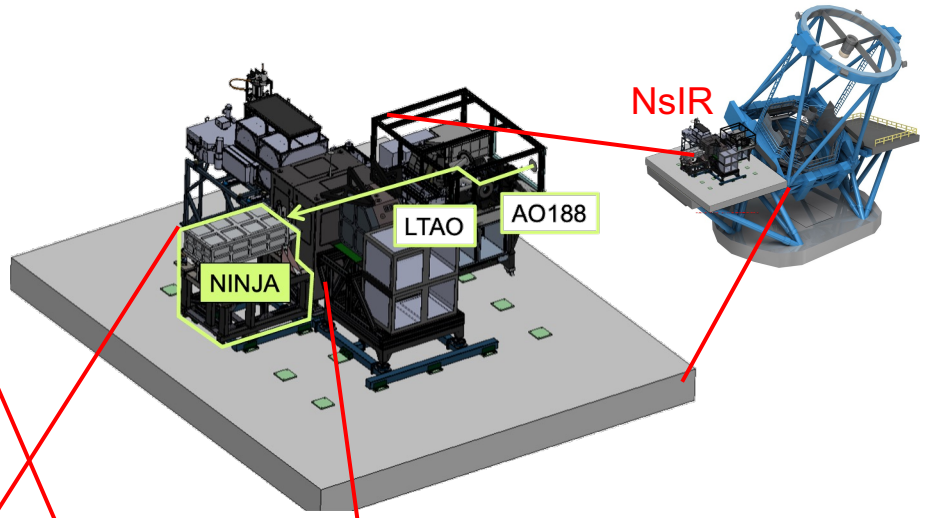
Estimated limiting magnitude (exp=2hours, SN=10, R=3300, EE=0.75, N_read=4e- rms, T_inst=278K)

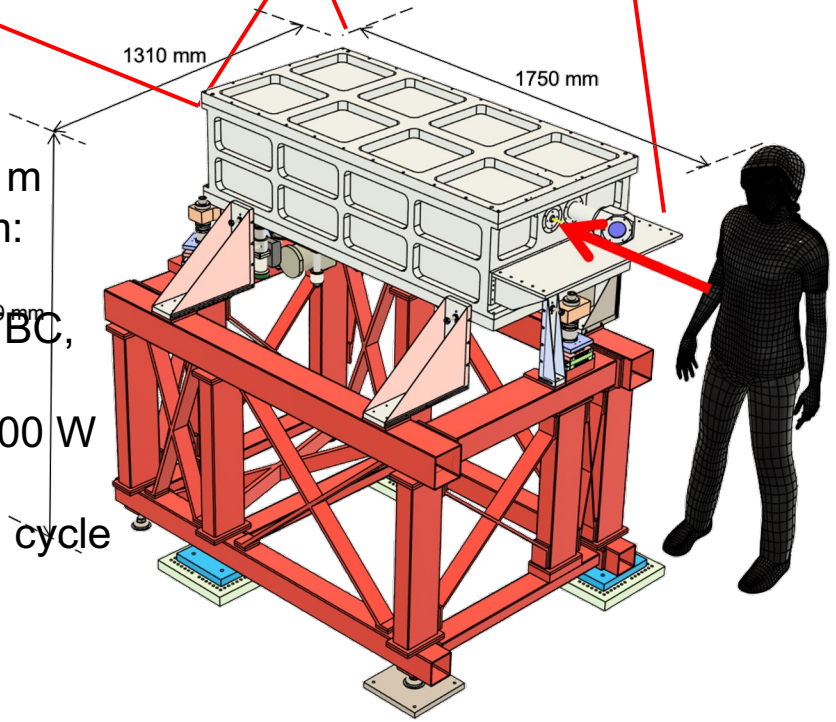


Expected Performance Comparison

Design interface to Subaru





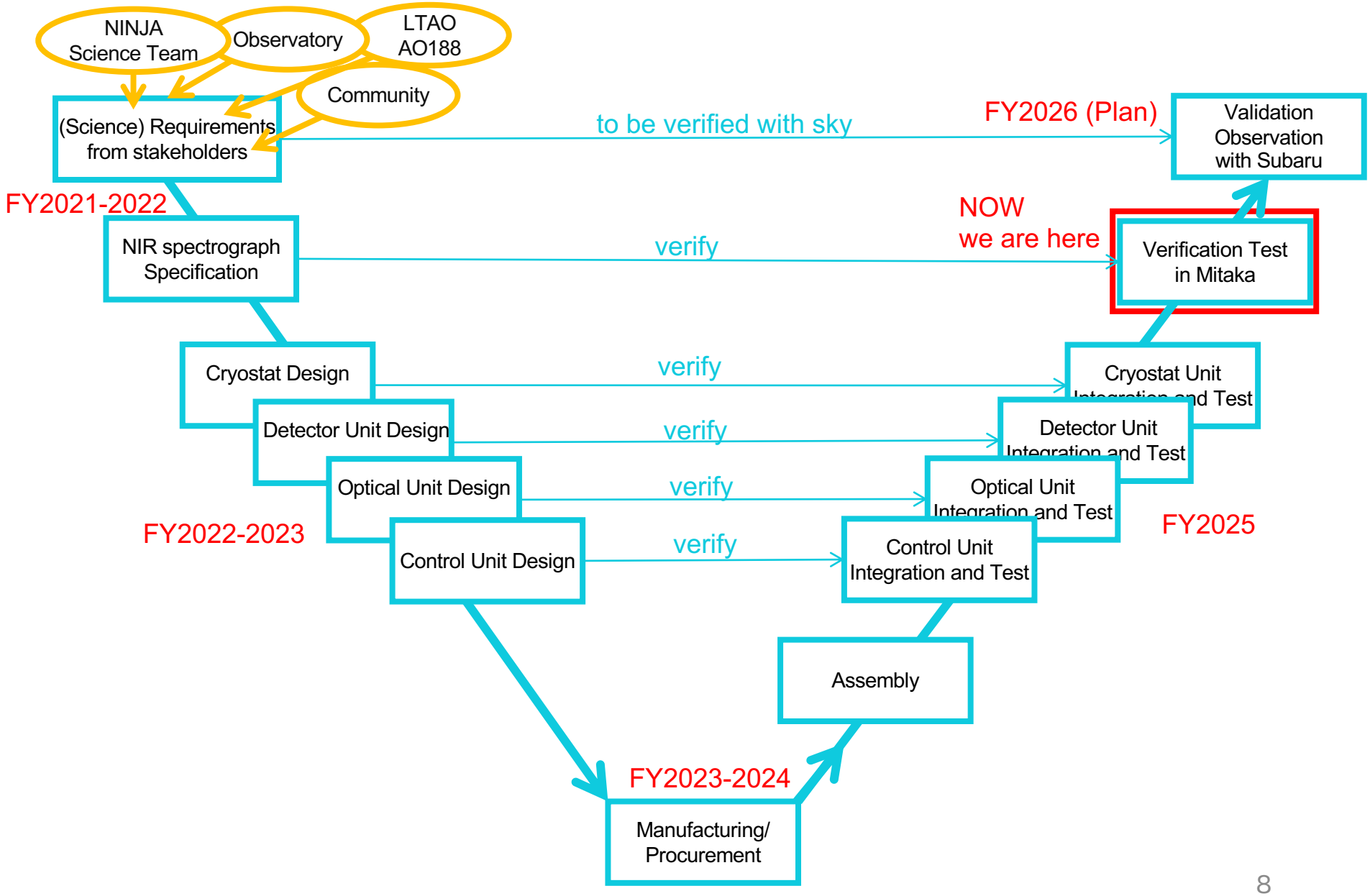


- Size: 1.7(D) x 1.3 (W) x 1.7 (H) m
- Weight on the common platform: ~800 kg (TBC)
- Power consumption: ~2.5kW (TBC, not including a compressor)
- Heat dissipation to NsIR air: ~500 W (TBC)
- One cryocooler is used (Helium cycle and 3P200V power required)

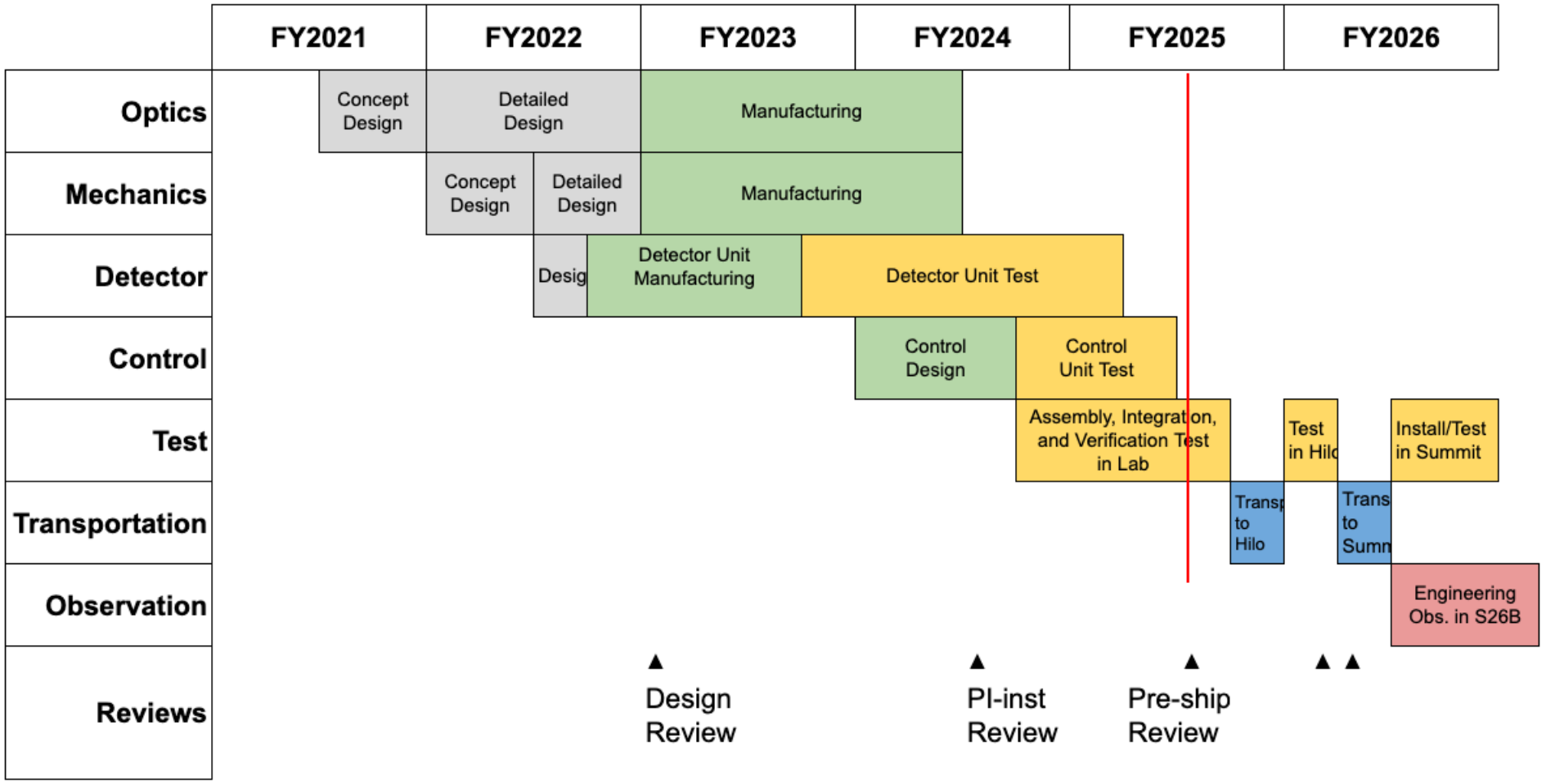
Current Status in the Process of Subaru's PI-type Instrument

Phase I	Phase II	Phase III	Operation
Submit an LoI. Approval of LoI leads the team to Phase II	Develop & submit a PD. Successful review of PD outputs an MOU.	Proceed along MOU for Final Acceptance Review at the end.	Proceed along agreed mode & decommission after 3 years.
September 2023 LoI submitted	September 2024 Proposal submitted	**As of October 2025** **NOW**	

Current Status in the Development Process



Current Status: Schedule

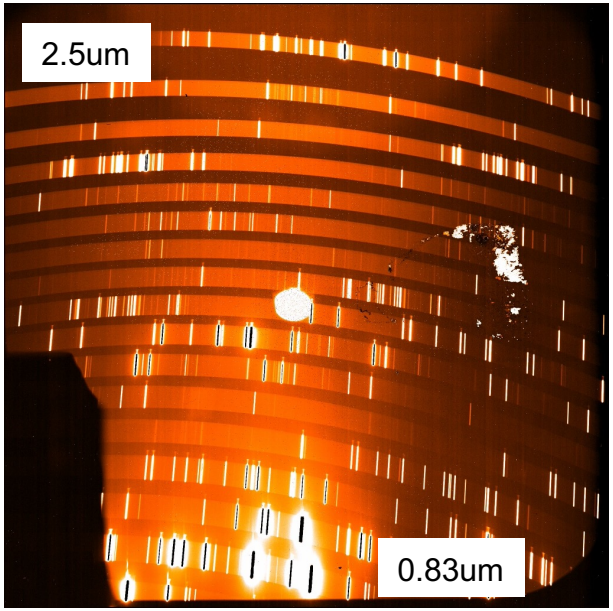


Some Detailed Status

- Optics
  - First spectra obtained in September 2025.
  - Full spectra obtained as designed.
  - Inspection and mitigation of internal reflections, ghost images, stray light, flare, and so on.

- Detector
  - Operation of an H2RG combination with a SIDECAR ASIC and MACIE has been successfully introduced.
  - Performing detector characterization to determine key operating parameters such as bias voltage and preamp setting.
  - A readout noise of 3.08e- was achieved with 64 read multi-sampling, meeting the required level of 4e-.

- Thermal and Mechanical
  - The optical bench is stably operating at 75K under thermal control as designed.
  - Moving mechanisms, including the slit exchange unit, slit viewer, atmospheric distortion correction, and detector dithering unit, are operating properly under vacuum and cryogenic conditions without any significant issues.



First spectra in lab Sep. 2025

Challenges and Approaches

- Operation Program
  - Classic program
  - ToO program
    - Typical observation of the counterpart of a GW event is expected to be a few hours to 5 hours per night.
    - It will continue for up to one week if a target is a kilonova.
    - We need further discussion to realize the NINJA ToO mode with the observatory and the community.
- Technical Challenges
  - Target acquisition to the fine slit
    - Position accuracy requirement ~0.1”.
    - If a target object is faint and a reference star is not near the target, we need “blind offset”. AO188 AU2 will be used as a guide.
    - Under investigation of the position accuracy of AO188 AU2.
- Technical Risk
  - Combination with the LTAO (PI-type instrument, not yet completed, not funded for future operation)
  - [With LTAO but not good PSF]
    - Take the same exposure with a wider slit (Difficult to subtract OH lines).
    - Take a longer exposure with a fine slit (Observable objects are limited).
  - [Without LTAO]
    - NINJA observation available.
    - The limiting magnitude will be degraded.

Summary

- NINJA is undergoing system verification testing in the lab.
  - Each sub-system (optical unit, detector units, opt-mechanical units, cryostat) meets the requirements at the sub-system level.
  - Followed by control software development.
  - Test in Mitaka will be wrapped up at the end of 2026.
- NINJA will be transported to Hilo in Q1, 2026, after transportation review.
- Target of a first light (engineering observation) is planned in 2026.
- Only the development has been funded by Kakenhi until FY2026 (including the planned extended term). We need to secure funding for the science operation.
- We have also initiated efforts to secure funding for the development of the optical arm, to enable simultaneous spectroscopy in the optical and NIR ultimately.
- We encourage the Subaru user community to become familiar with NINJA's capabilities and plan proposals for upcoming observing phases.

NINJA specifications

	NINJA NIR
Mode	Single Spectroscopy
Wavelength coverage	830 – 2500 nm
Slit width	0.35″ R~3300 0.21″ R~5500 0.5″ R~2310 0.7″ R~1650
Slit length	5″
Sensor	HAWAII-2RG (2048 x 2048 pix)
Pixel scale	0.1 arcsec/pix
First light	2026 (TBD)