Subaru Nasmyth Beam Switcher

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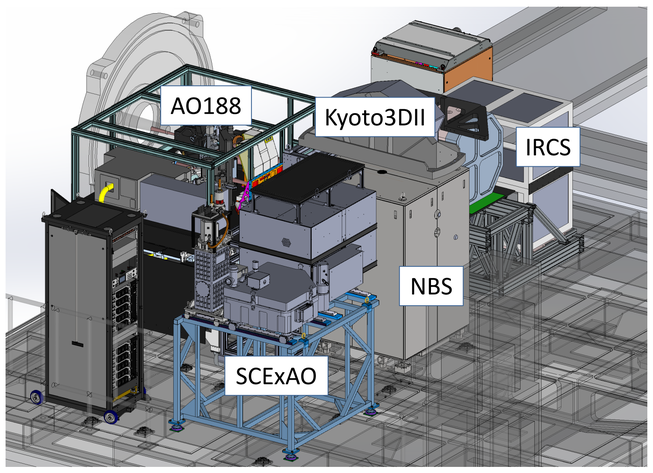
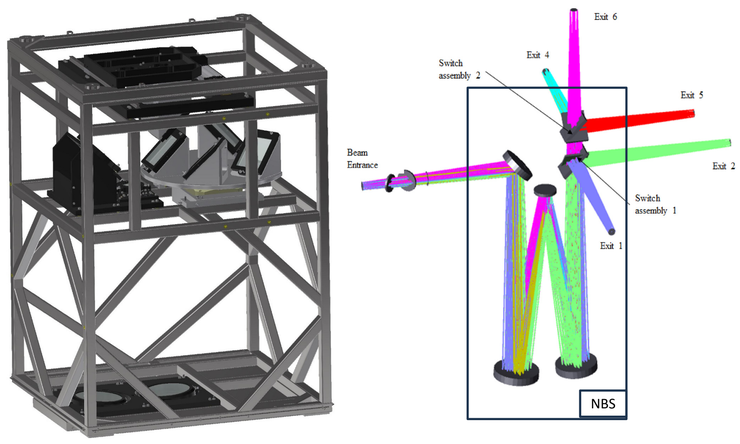
Abstract

Nasmyth Beam Switcher (NBS) is a device for redirecting the beam from the facility AO system (AO188) to the backend science instruments at Subaru's Nasmyth IR (NsIR). The NBS is a key device to realize the flexible instrument switch among the AO188 fed science instruments, which significantly reduces the workload of the daytime instrument exchange and, more importantly, allows a new queue mode operation for improving the observing efficiency of AO observations. The NBS also enables us to accommodate the Laser tomography AO (LTAO) system, ULTIMATE-START.
The design of the NBS was conducted in collaboration with Australian Astronomical Optics - Macquarie University in 2017-2021. The fabrication of the mechanical and optical parts were done in 2022. We recently completed the design of the common-platform, which is necessary to mount the NBS, LTAO-WFS, IRCS, and NINJA/SPIDERS. The fabrication of the common-platform is ongoing and expected to finish in late March.
We present the design, expected performance, and current status of the NBS.

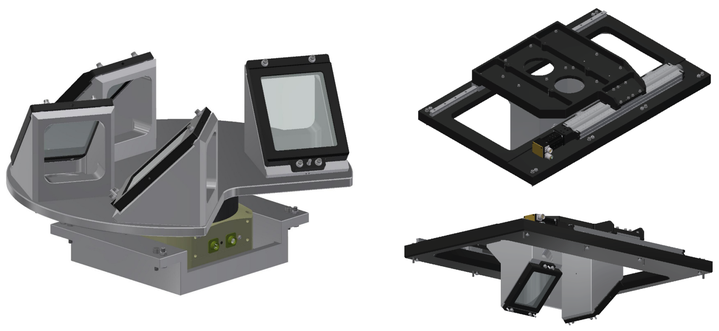
Design



This figure shows 3D CAD model of the Nasmyth IR platform when the NBS is installed. It redirects the light from AO188 to IRCS, SCExAO, or Kyoto3DII.

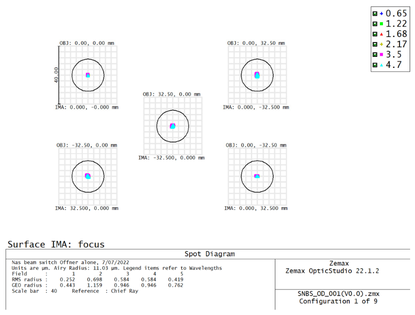


The overview of the mechanical design (left) and optical layout (right). It is composed of an Offner relay and two switching mechanisms.

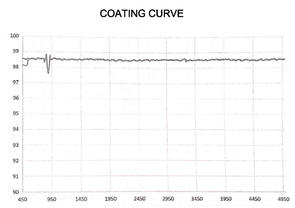


The detailed views of the switching mechanisms.
(Left) The switching mechanism 1 is a rotation stage and can have 4 mirrors, dichroic-mirrors, or through-plate.
(Right) The switching mechanism 2 is a linear stage and has 2 mirrors.
Both mechanisms have an open-slot.

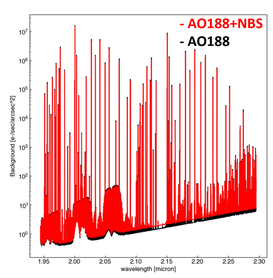
Expected Perfromance



This is a spot diagram when point sources are located at the input of the NBS within the field-of-view. Their Strehl ratios are almost 100% across the full wavelength range and the field-of-view. This means the degradation of the Strehl ratio by the NBS is expected to be small.



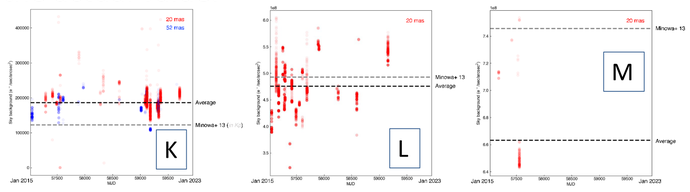
The measured reflectivity of one of the fabricated NBS mirrors. With the reflectivity of >98% at 0.45-5.0um for the five mirrors of NBS, we expect the through-put of NBS to be >90%.



Band	Background comparison by model (AO188+NBS / AO188)
Kp	1.10
K	1.18
Lp	1.17
Mp	1.12

We calculated the expected background emission for IRCS with (red) and without (black) NBS using the model by Minowa et al. (2020). The increase of the background emission is estimated to be 10-20% in K- to M-band.

The figures below show background measurements with IRCS imaging mode in 2015-2023, and comparison with the model predictions. The model underestimates the background level, but predicted increase of the background by AO188 is similar to the actual value.

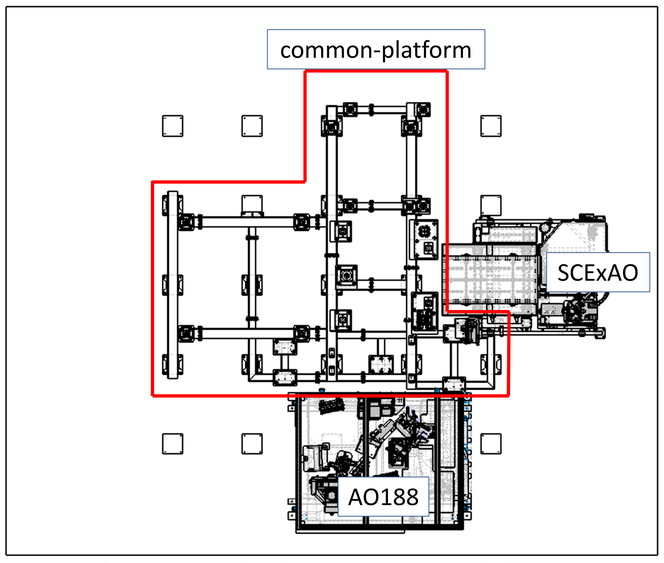


Band	Background (IRCS+AO188, Model) [e-/sec/arcsec²]	Background (IRCS+AO188, Minowa+13) [e-/sec/arcsec²]	Background (IRCS+AO188, 2015-2022) [e-/sec/arcsec²]	Background (IRCS+ImR, Model) [e-/sec/arcsec²]	Background (IRCS+ImR, Minowa+13) [e-/sec/arcsec²]	Background comparison (AO188 / ImR, Model)	Background comparison (AO188 / ImR, Minowa+13)
Kp	6.36 x 10^4	1.22 x 10^5 (192%)	-	5.12 x 10^4	7.86 x 10^5 (154%)	1.24	1.56
K	8.52 x 10^4	-	1.86 x 10^5 (218%)	4.26 x 10^4	-	1.51	-
Lp	2.94 x 10^8	4.93 x 10^8 (168%)	4.76 x 10^8 (162%)	2.06 x 10^8	3.19 x 10^8 (155%)	1.47	1.54
Mp	5.74 x 10^8	7.46 x 10^8 (130%)	6.63 x 10^8 (116%)	4.51 x 10^8	5.90 x 10^8 (131%)	1.27	1.26

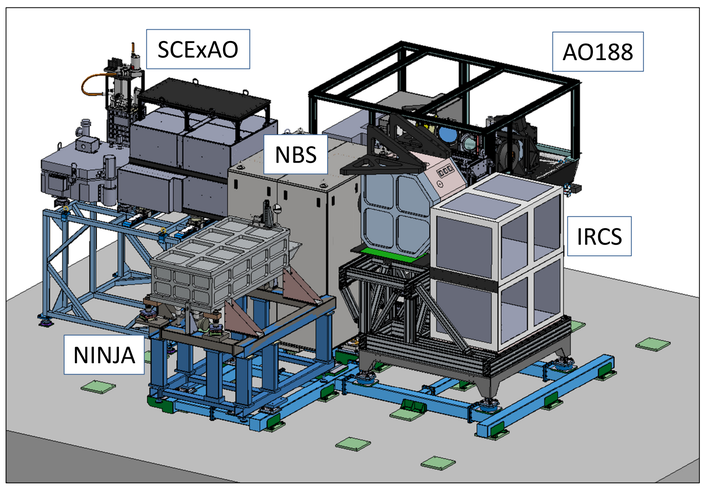
with AO188 | without AO188

Current Status

Recently, we completed the design of the main structure of the common-platform, on which several instruments including NBS will be mounted, and started the fabrication.



Common platform on the NsIR floor



NsIR instruments mounted on the common-platform

Remaining Tasks and Schedule

- Common platform
  - Fabrication in Japan (by late March)
  - Transportation to Hawaii (early next FY)
  - Test assembly in Hilo and at NsIR
- NBS
  - Integration of the mirrors and optical alignment
- Installation in Summer 2025.

		2024			2025								
		10	11	12	1	2	3	4	5	6	7	8	9	10
Common Platform	• Contract • Fabrication in Japan • Transport to Hawaii • Test assembly at Hilo base • Test assembly/install at summit • Adjust instrument interface plate													
NBS	• Mechanical assembly • Mirror install to the cells • Electronics • Optical alignment													
Preparation	• AO188 re-cabling • FARO measurement • NsIR AG/SH removal													
Install	• Installation review • Installation													

References

1. Subaru Nasmyth Beam Switcher final design report (2021)
2. Minowa et al. (2020), Proc. SPIE **11450**, 114500O