PFS: Instrument integration and maintenance at Subaru

The commissioning of the various PFS hardware subsystems started in 2018, with the metrology camera installed on the Cassegrain focus.

Since then, the 4 science fiber cables have been installed on the telescope, PFI has been installed in POpt2 wide field corrector, and the 4 spectrograph modules have been assembled in the dome.

In this poster, we present the status of PFS hardware integration at Subaru, the early maintenance and corrective actions done on the instrument, and the remaining commissioning work needed before the start of operation.

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Spectrograph Modules (SM) integration

PFS ~2400 science fibers are connected to 4 identical spectrograph modules (SM), each receiving ~600 fibers. Every spectrograph module host 3 cameras, covering the blue (380-650 nm), red (630-970 nm) and near-infrared (940-1260 nm) wavelengths [1].

The NIR cameras of the first 2 spectrograph modules already at the summit (SM1 and SM3), were delivered and installed in March and July 2023, respectively. The 3 arms (blue, red, NIR) of these 2 SMs are now complete, allowing the calibration and test of the first NIR cameras at the summit during the following engineering observation runs.

The last 2 PFS spectrograph modules (SM2 and SM4) were delivered and installed at the summit in November 2023 with the support form LAM (Laboratoire d'Astrophysique de Marseille) (see Fig. 1). SM2 was integrated with all 3 cameras (bleu, red, NIR) (see Fig. 2), while SM4 was integrated with only the 2 visible cameras (bleu, red).

During SM2 and SM4 integration, a second "Dummy Cable B" was also setup in the spectrograph clean room, capable to send light from calibration lamps to either SM, for test and calibration.

The only remaining hardware piece to be integrated to the spectrograph modules is the last NIR camera for SM4. As of writing, this camera still has issues with the QE of its detector, delaying its delivery to Subaru (more details in Tamura-san presentation).
We still hope to receive and integrated this last camera sometime before April 2024.

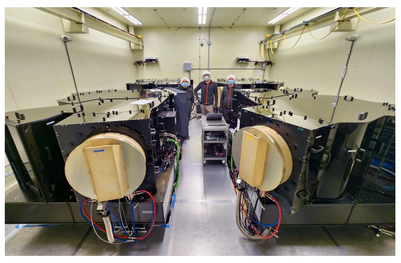


Fig. 1; Picture of the inside of the Spectrograph Clean Room after integration of the final spectrograph modules, with the visitors from LAM leading the integration (Left; Patrick Blanchard, Middle; Fabrice Madec, Right; Michael Carle).

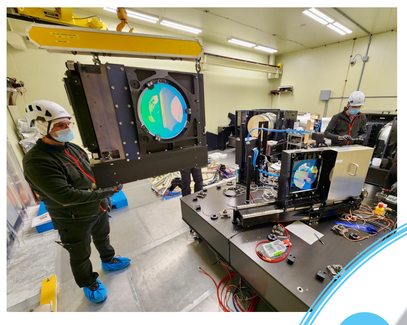
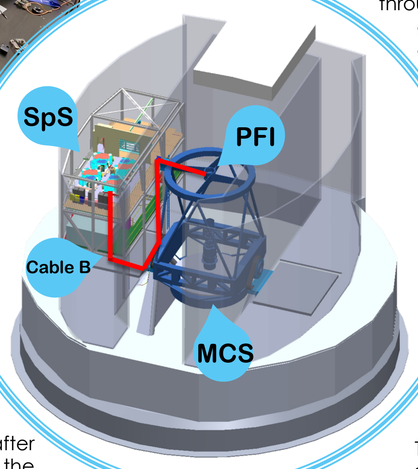


Fig. 2; Picture of the inside of the Spectrograph Clean Room during integration of SM2 with LAM.



Spectrograph Modules (SM) corrective actions & maintenance

The engineering observations using the first 2 spectrograph modules revealed a throughput significantly lower than expected. After an extensive investigation and checking other possible explanations, like fiber alignment, calibration or data processing, it was confirmed that all VPH gratings were wrongly oriented by 180deg around their optical axis.

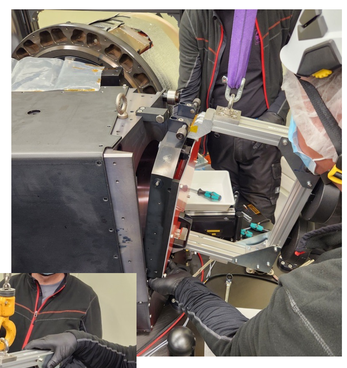
After careful preparation, our colleagues from LAM successfully corrected the orientation of all 12 low-resolution VPH gratings by Nov. 2023. They used a custom-made tool and a hoist to carefully remove, rotate and reinstall all low-resolution gratings on each spectrograph modules (see Fig. 3-4).
Preliminary results from the calibration data after correction indicates a recovery of the throughput with the low-resolution gratings by a factor 1.5-2 on all cameras.

All 4 medium-resolution gratings were also found to be rotated, but their size and weight required more complex preparation and tooling. These tools are now being fabricated and the correction of all medium-resolution gratings is being planned for Feb. 2024 with LAM.

We hope to confirm the recovery of the throughput from the medium-resolution gratings during the next engineering observations scheduled for March 2024.

The first spectrograph module was installed at Subaru in Dec. 2019, while the second one was delayed and only installed in Nov. 2022. In the meantime, the design of the camera's electronics and vacuum system were slightly improved. During 2023, SM1 cameras were upgraded at the summit with support from our colleagues from JHU (Johns Hopkins University) to match the ones delivered more recently.

Fig. 3; Picture of LAM removing the NIR low-resolution VPH grating from SM1, using a custom-made tool and a hoist.



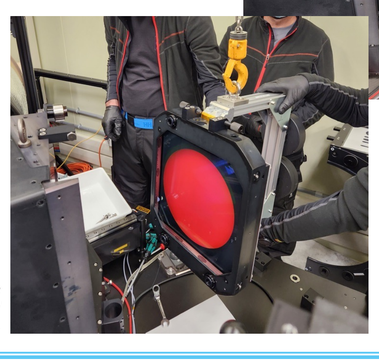


Fig. 4; Picture of LAM reinstalling the NIR low-resolution VPH grating on SM1 after correcting its orientation.

Science fiber Cables (Cable B) integration

The ~2400 science fibers are spread amongst 4 pairs of metal conduits, ~55m long. Each pair connects PFI on the telescope prime focus (see Fig. 5) to one of the spectrograph modules on the top floor of the dome (see Fig. 1). Each pair of cable includes 2 strain relief boxes (see Fig. 7) and a monitoring system to confirm the fiber connection on PFI [2].

The last 2 science fiber cables (CableB3 and Cable B4) were installed on the telescope in Feb. and May 2023 respectively (see Fig. 5-6).

The performance of the fibers, including uniformity, throughput and FRD (focal ratio degradation), were measured before and after installation. The routing of the fiber cables in the dome was adjusted until their performance matches the measurements from LNA (Laboratório Nacional de Astrofísica) in Brazil, and the one just before installation.

Long term monitoring was also performed on the last 2 fiber cables to measure the performance degradation with temperature variations and the telescope elevation, and no significant impact was measured.

So far, the only maintenance required for the science fiber cables is a regular cleaning of the MTP connectors at both extremities of the cables.

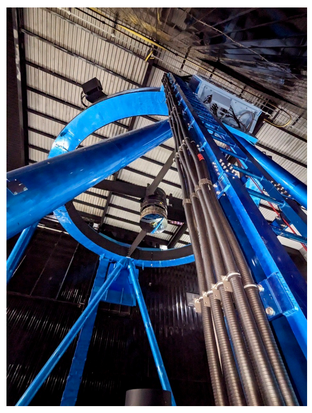


Fig. 5; Picture of the 4 pairs of metal conduits along the telescope structure holding all ~2400 science fibers.

Fig. 6; Picture of the telescope spider arm holding the 4 connectors interfacing with PFI on the prime focus.
In this picture, Cable B1 is connected to the Subaru Night-Sky Spectrograph (SuNSS) [3], while CableB4 is connected to a loopback system for testing

Fig. 7; Inside view of one of CableB4 strain relief boxes, holding ~600 science fibers.

Prime Focus Instrument (PFI) corrective actions & maintenance

The Prime Focus Instrument hosts PFS focal plane with all ~2400 science fibers on their individual cobra positioners, and 6 auto-guiding cameras [4]. During observation, PFI is installed inside POpt2 (the prime focus unit), behind the wide field corrector, at Subaru prime focus, similarly to HSC.
While not in use, PFI is stored on the unit selector with the other prime focus instruments and secondary mirrors.

PFI was delivered and commissioned at Subaru in 2021. Since then, various maintenance and corrective actions have been performed on PFI, starting with the modification of the rotator limit switches.
More recently in 2023, additional optics were installed in front on the auto-guiding camera's field elements, to correct the ~0.6mm focus offset between the auto-guiding cameras and the science fibers (see Fig. 8).
A faulty leak sensors inside PFI was also replaced by our colleagues from ASIAA to protect PFI and the telescope in case of a coolant leak.
PFI Ebox, hosting PFI auxiliary electronics, also benefited from multiple upgrades to improve its stability since its delivery. These changes included more reliable power supplies and onboard computer, and a better cooling system. As a result, PFI stability was significantly improved, but is still not at the level expected and will require additional work in the future.

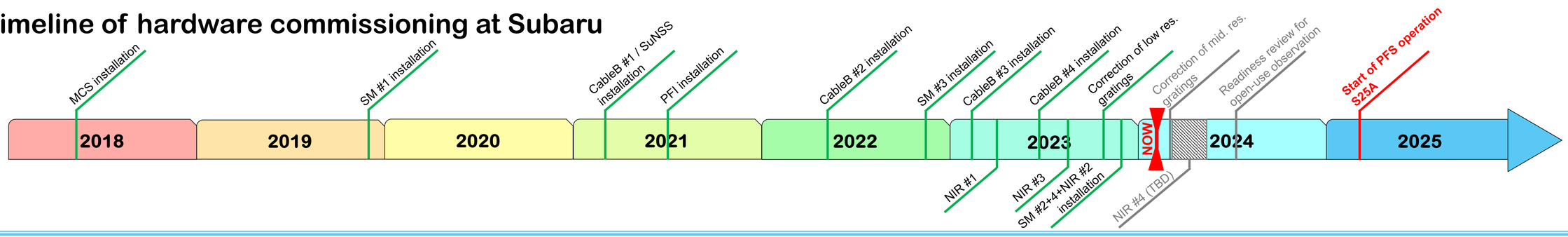
Fig. 8; Picture of the installation of additional optics in front of the auto-guiding cameras to correct a ~0.6mm focus offset.

Metrology Camera System (MCS) maintenance

In early December, an incident occurred during the Metrology Camera System (MCS) [5] removal from the standby flange. As a result, MCS fell by several millimeter on the transportation cart. No obvious damage was found by visual inspection. Still, images taken with MCS in late December confirmed that its optics needed to be realigned.
Our colleagues from ASIAA successfully performed this alignment work at the summit in January 2024.

Fig. 9; Picture of MCS alignment work with ASIAA.

Timeline of hardware commissioning at Subaru



[1] Prime Focus Spectrograph (PFS) for the Subaru Telescope: its start of the last development phase, Naoyuki Tamura et al., SPIE 2022
[2] Prime Focus Spectrograph (PFS): fiber optical cable and connector system (FOCCoS) – integration, Antonio Cesar de Oliveira et al., SPIE 2022
[3] Subaru Night-Sky Spectrograph (SuNSS): fiber cable construction, Antonio Cesar de Oliveira et al., SPIE 2022
[4] Prime focus spectrograph (PFS) for the Subaru Telescope: the prime focus instrument, Shiang-Yu Wang et al., SPIE 2022
[5] Prime Focus Spectrograph (PFS): the metrology camera system, Shiang-Yu Wang et al., SPIE 2020