Development of a fiber mechanical switcher for Keck/HISPEC and TMT/MODHIS

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HISPEC is a new, high-resolution, diffraction-limited, fiber-fed spectrograph in near-infrared. We are planning to install it to the Keck-II telescope, and after the operation mainly for exoplanetary science, re-operate it as MODHIS for the Thirty Meter Telescope. The spectrometer covers multiple sky-fields simultaneously, in addition to capturing the light from several types of calibration sources. Multiple optical fibers feed the light from each sky-field or calibration source to the spectrometer, and we need to flexibly change the fiber connection during the operation. A fiber switcher enables us to automatically change the fiber connections, which optimizes the operation and maximizes the science output. We have newly manufactured fiber switchers and performed the initial test for fiber connections. Furthermore, we have fabricated fiber patch cords and evaluated the coupling efficiency per fiber-joint. As the result, we achieved the efficiency more than 95% for two thirds of our patch codes.

1. Fiber Delivery Subsystem

Light form targeted on-sky sources is injected into single mode fibers after going through the Keck-II telescope and adaptive optics. The other fiber-end is faced to the HISPEC spectrograph optics, which is put at the telescope basement with stable environment and enclosed by a vacuum Dewar. Other types of light needed for calibration or data reduction can also be fed to the same spectrograph through a different fiber route. In the spectrograph, 3 fiber-ends are arranged at the injection focal-plane and their spectra are concurrently captured. Switching the fiber connection enables us to **arbitrarily choose a combination of 3 fiber outputs from 8 candidates in total:**

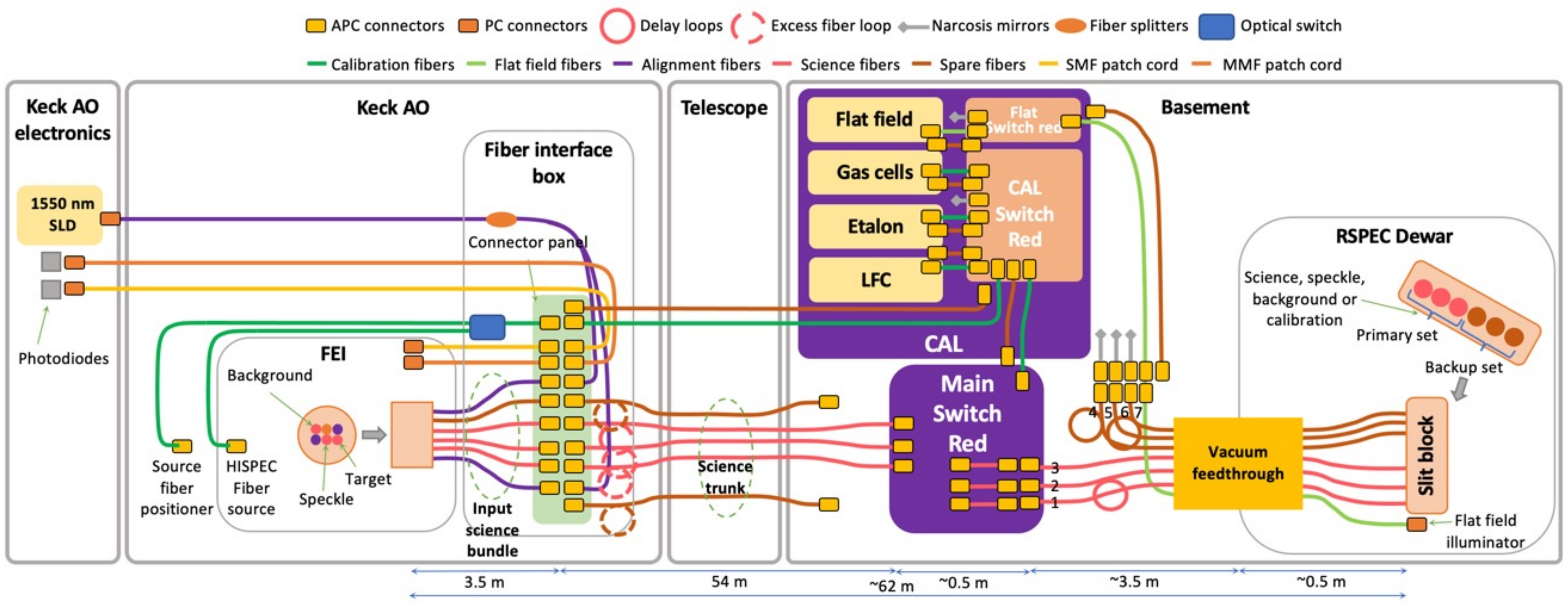

Figure 1: Schematic for fiber routes in the total system of HISPEC Red-channel

- 3 types of on-sky science light - **Target / Sky Background / Speckles**
- 3 types of calibration light (wavelength reference) - **Hollow Cathode or Gas Cells / Etalon / Laser Frequency Comb**
- 2 types of calibration light - **Spectral Flat / Dark**

2. Fiber Mechanical Switcher

For effective operation, we are developing fiber mechanical switchers, which can automatically change the fiber connections by remote control. Fiber switching is configured by two steps: **the choice of one calibration light (in CAL Switcher) and the choice of a set of 3 light sources fed to the spectrograph (in Main Switcher).**

Mechanism in each switcher is the following (see Figure 2):

- Input and output fibers with a FC/APC connector are inserted to FC/APC-SC/APC adaptors fixed on the walls from outside.
- Fiber patch codes with SC/APC connectors link the optical route from the input fibers to output ones, inside the switcher box.
- Fiber ports for the patch codes are mounted on the movable stage and connected or disconnected to adaptors on the walls, by remote control via USB connection from a computer.

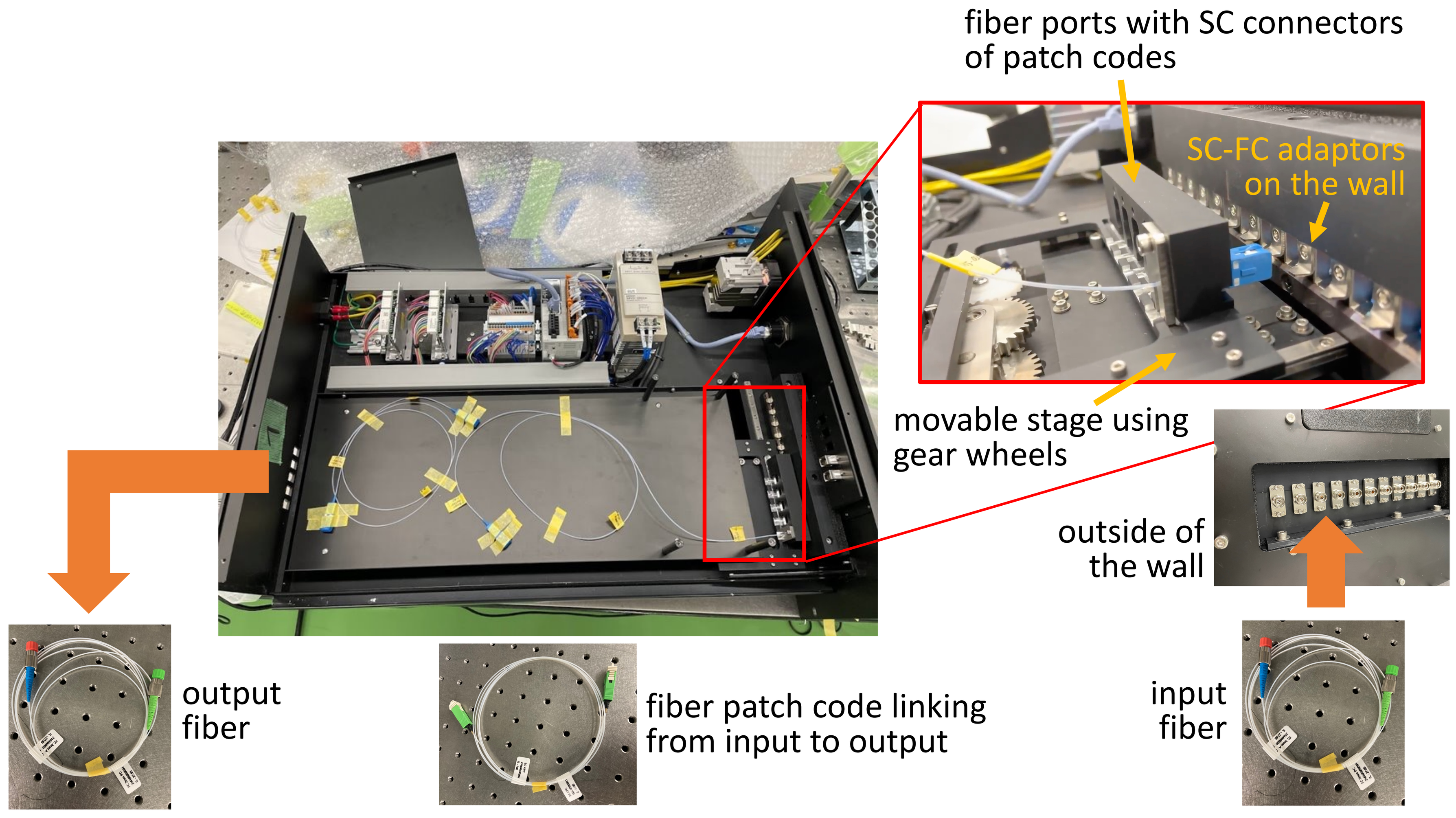

Figure 2: An example of fiber mechanical switchers we fabricated.

3. Coupling Loss Measurements

Coupling loss at each fiber joint is accumulated along the optical route composed of multiple fibers, resulting in the degradation of the total throughput. We allocated the energy-loss budget in total system and **required the coupling efficiency >95% per fiber-joint.** For the verification, we prepared the prototype of fiber patch codes fabricated by several manufacturers (Table 1). Output power has been measured in two configurations shown in Figure 3, and we regarded the ratio of the output power measured in "Main Measurement" to that of "Reference Measurement" as the coupling efficiency at the joint between reference and test fibers in the FC-SC adaptor.

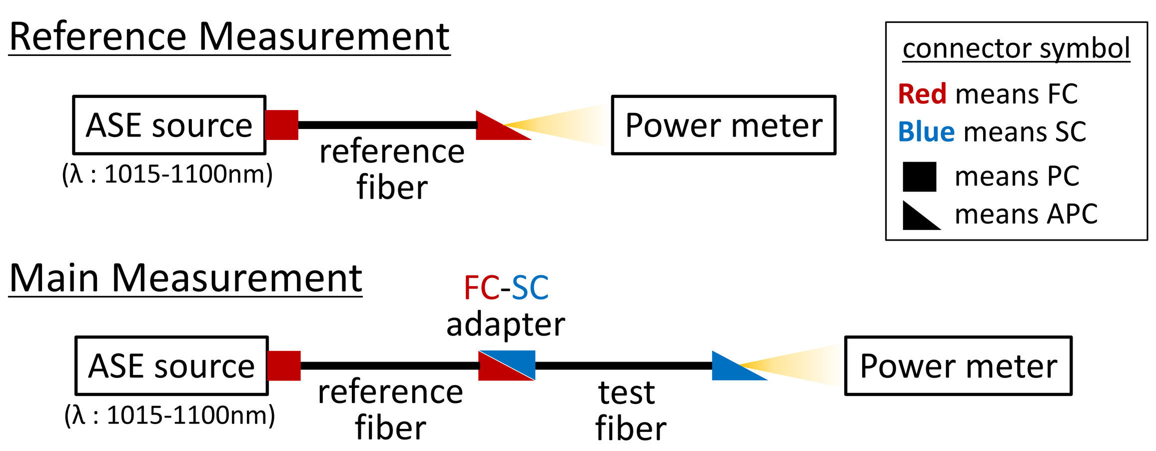

Figure 3: Configuration of coupling loss measurements

Manufacturer	Number of ref. fiber	Number of test fiber	Shape of connector	Coupling efficiency (average)
Adamant Namiki	1	2	familiar to the manufacturer	97.5 %
Adamant Namiki	1	3	compatible with switchers	90.7 %
Diamond	2	7	familiar to the company	96.0 %
OptronScience	1	3	familiar to the company	96.7 %

Table 1: Information of patch codes we used (single mode fiber "OFS BF05635-02" for all) and the resulted coupling efficiency. Patch codes with connectors whose shape is compatible with the FC-SC adaptors in our switchers have been supplied only from Adamant Namiki in this time. Other patch codes have connectors familiar to each manufacturer.

Here is the summary of our current results (see Figure 4):

- **21 of 30 connectors showed the coupling efficiency >95%.**
- 2 of 6 switcher-compatible connectors by Adamant Namiki showed extremely low efficiency (<90%), which may be due to the shift of the core position relative to the fiber ferule.
- Replacing reference fibers and/or FC-SC adaptors (different plot color in each panel) affected the efficiency more than reconnecting the input connector of the test fiber (error bars for each plot).

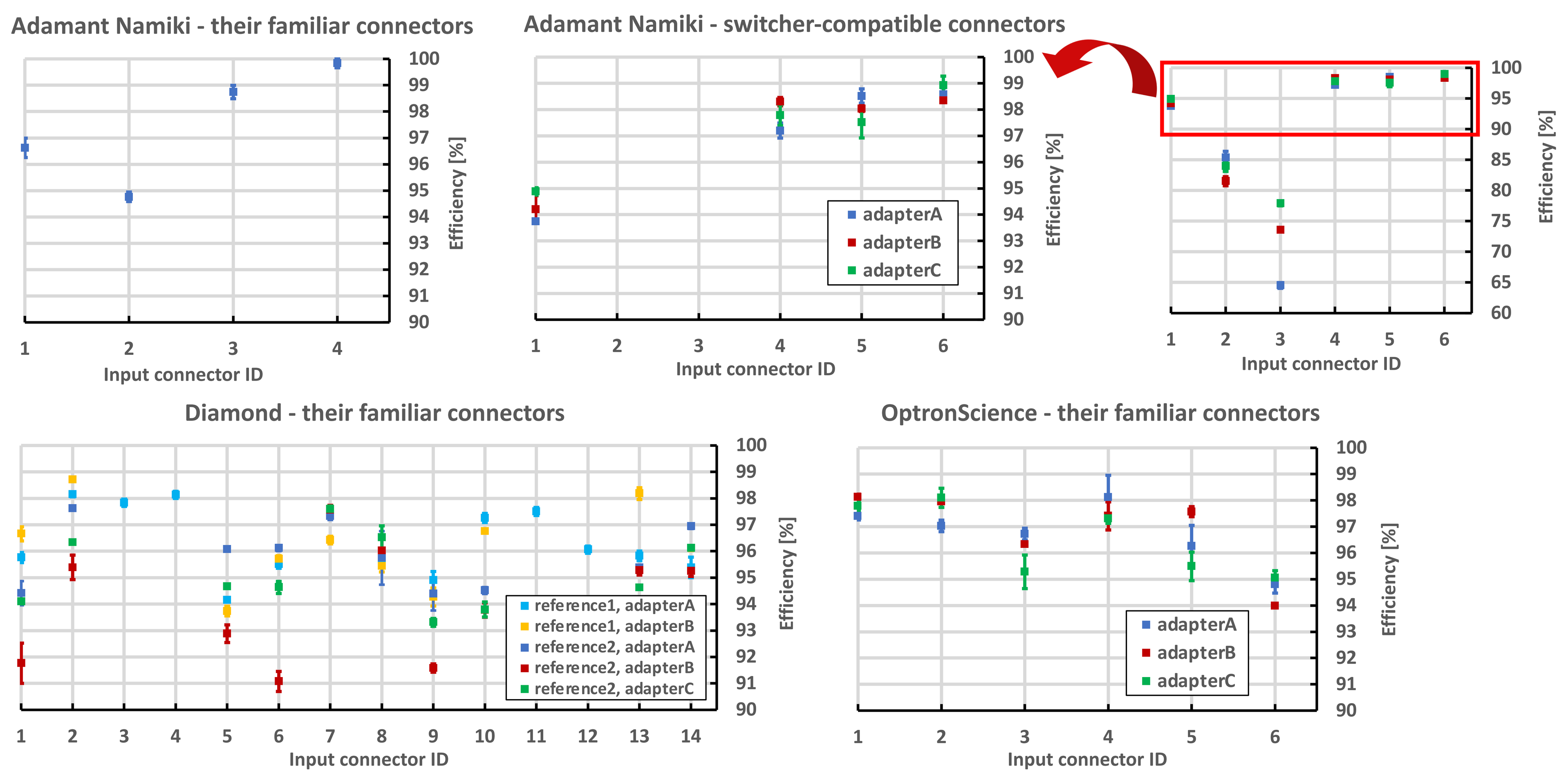

Figure 4: Coupling efficiency measured for each patch codes