KPIC Technical Description

Note: this document is written assuming the reader is knowledgeable about K2AO, like an SA or other Keck staff. It primarily runs through the KPIC optical beam path and stages. This, and the Facilitization Proposal Instructions (link) are the technical description of the instrument.

The figure below shows a schematic diagram of KPIC after the 2024 service mission. For simplicity, it does not have all the intermediate foci and pupil planes, but it shows the primary beam paths and all the options the user has. The Facility Phase I science mode optics/options are highlighted by the orange boxes. It shows both the Fiber Injection Unit (FIU) and the Fiber Extraction Unit (FEU).

Light from the telescope is injected into KPIC via the field steering mirror (FSMs - not shown in the diagram). This means KPIC receives AO-corrected light after the Keck II (K2) rotator, K2 tip-tilt mirror, Shack-Hartmann wavefront sensor, and Xinetics DM (also not shown in the schematic). At the input focal plane to KPIC, there is a light source with a single mode fiber which can be inserted/retracted from the beam; this is shown at the top left of the schematic and marks the start of KPIC internal beam path. The Boston Micromachines deformable mirror (BMC DM) is in the first pupil plane and is used to compensate for static aberrations in the beam train. See descriptions of the Non-Common Path Aberrations (NCPAs) corrections procedures in the day cals. The light next passes through the Pyramid wavefront sensor (PyWFS) pickoff. Although the PyWFS is no longer used with KPIC, we still use a dichroic beamsplitter in this plane to provide the pupil offset which the instrument was designed for. There are four position options for this mechanism:

- J - notch which reflects 80% of J band, and transmits y, H and K band fully (Facility)
- KL long pass, which reflects 90% of y-H bands and transmits K and L band fully (PI)
- H - notch which reflects 80% of H band, and transmits y, J and K band fully (PI)
- And an empty slot. This is only used by the Zernike wavefront sensor team (PI).

Only the J-notch is supported in Facility mode. In the pupil plane following the PyWFS pickoff, there is the coronagraph mechanism which consists of two translation stages that allow the user to select from:

- A pupil mask - a circular unobstructed aperture that passes the entire Keck pupil (Facility)
- A charge 1 vortex mask (PI)
- A charge 2 vortex mask (PI).

The vortex masks are only used for fiber nulling (PI mode only) and cannot be used in the conventional vortex coronagraph sense.

After the coronagraph is the atmospheric dispersion corrector (ADC). This is only used for phase II (PI mode) observations. It is out of the beam by default but can be inserted or retracted with the ADC Retractor.

The Fiber Alignment Mechanism (FAM) is the tip/tilt mirror which steers the beam onto the fibers. It is used for fiber finding and tracking. In PI mode, it's also used for fast tip/tilt.

The tracking camera pickoff (TCP) mechanism hosts 3 dichroics that are used to select the band of light to be sent to the tracking camera. The options are:

- KL long pass, which reflects 90% of y-H bands and transmits K and L band fully (Facility)
- H - notch which reflects 80% of H band, and transmits y, J and K band fully (PI)
- J - notch which reflects 80% of J band, and transmits y, H and K band fully (PI).

Only the KL long pass is supported in Facility mode.

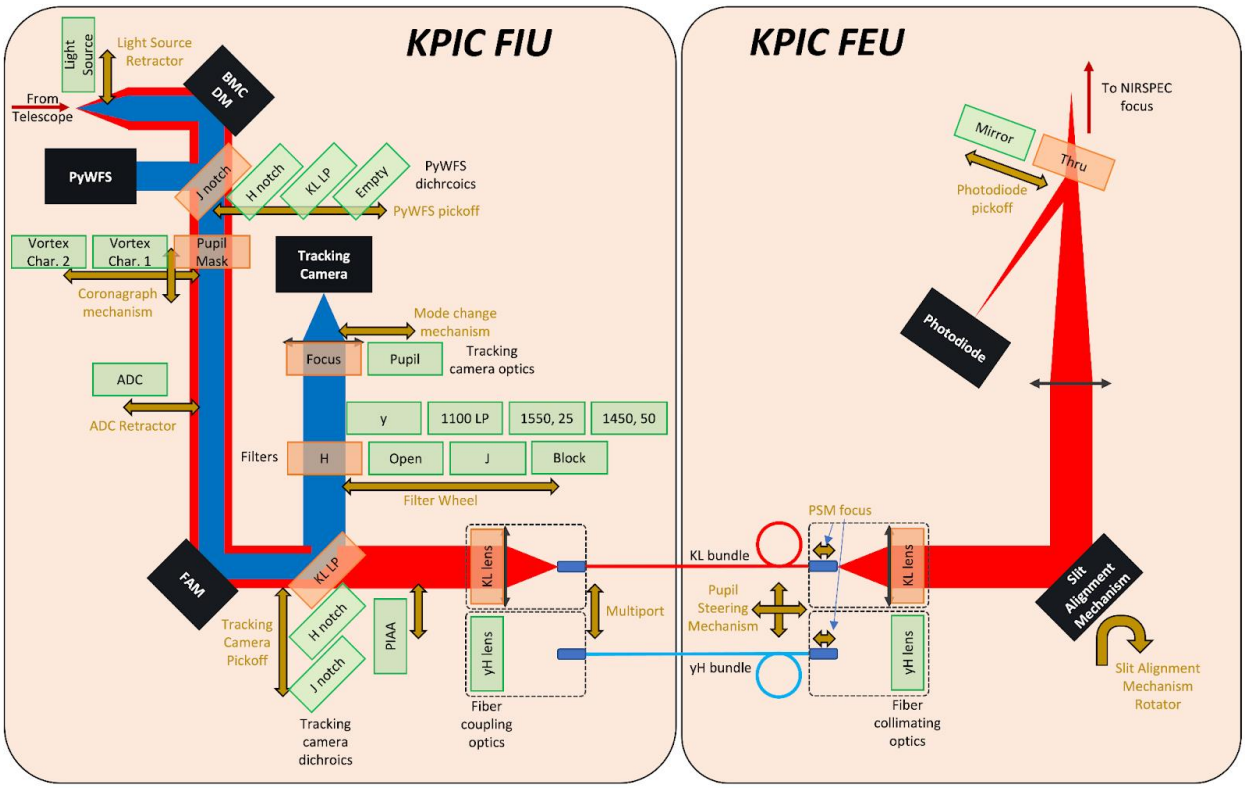
In the reflected beam path, the next mechanism is the filter wheel (referred to as Filter_Wh in the software and GUI). This wheel hosts the following options:

- H band filter (Facility)
- Open (PI)
- Block (PI)
- J band filter (PI)
- 1550 nm filter with a 25 nm bandwidth (PI)
- 1450 nm filter with a 50 nm bandwidth (PI)
- Y band (PI)
- 1100 nm long pass filter - effectively passes J and H band to the tracking camera (PI).

Only the H band filter is supported in Facility mode. Following the filter wheel is the mode change mechanism. This is a linear stage that switches between a set of optics to provide either focal or pupil plane viewing on the tracking camera.

In the transmitted beam path after the tacking camera pickoff is the PIAA mechanism. This allows for a set of PIAA lenses to be deployed into the beam when operating in PI mode. In Facility mode, this stage is removed from the beam path to the ‘out’ position.

The final mechanism in the FIU is called the multiport (referred to as FIU_Fiber in the software). It is a linear translation stage that allows the user to select which fiber coupling lens and bundle to use. The lens and bundle are attached to one another and travel together. KPIC supports two lens-bundle pairs: the first spans K and L bands (Phase I) and the second supports y, J and H bands. Only the KL bundle is supported in Facility mode.



At the output of the bundles, a fiber collimating optic is used to collimate the beam. The bundles are once again co-mounted to these lenses. The Pupil Steering Mechanism (PSM) holds the backend lens-bundle pairs and can be used to move between the two options (kL and yH). It can also be used to translate the pupil across the cold stop inside NIRSPEC to optimally align it for maximum throughput. Each bundle is mounted on a small linear stage so its distance with respect to the collimating lens can be adjusted. This allows for the beams to be defocused on the NIRSPEC slit to get optimal sampling in the spectrograph. This backend focusing system is referred to as the PSM focus in the software. The collimated beam is then projected onto the Slit Alignment Mirror (SAM). The SAM is a pitch/yaw stage that sits in the pupil on the NIRSPAO plate, steering the beam and allowing it to be aligned with the NIRSPEC slit. The SAM mechanism can be retracted from the beam using the SAM rotator. Since the FEU shares most of the NIRSPAO optics, moving the SAM out of the beam with the rotator allows the normal NIRSPAO science beam to pass.

A flip mirror stage is located right before the edge of the bench, and it can flip a mirror into the beam to direct it towards a photodiode. For this reason, this mechanism is referred to as the Photodiode pickoff (PDPO). The photodiode supports fast (>100Hz) sampling and is used for fiber finding and NCPA compensation during day cals. To pass light to NIRSPEC, the mirror is removed from the beam using the flip stage. Note that "Thru" for the PDPO is called "NIRSPEC" in the software and "Mirror" is called "PD".

The phase I capabilities that have been facilitized include:

- Observing in K band only,
- Observing targets ranging from on-axis to ~2 arcsec off axis,
- Tracking in H band only,
- Fiber bouncing between 2 or more fibers for enhanced background subtraction.

The following optic selection is used to establish the phase I/facility mode:

- J notch filter in the PyWFS pickoff - maximizes H and K band transmission needed for tracking and science respectively (jband).
- Coronagraph stage set to have the pupil mask in the beam (pupil_mask).
- KL long pass in the tracking camera pickoff - this sends 90% of the H band light for tracking and transmits all K band for science (ds).
- H filter in the filter wheel in the tracking camera arm (h)
- Focus mode optics in the tracking camera (Mode Change – Focus)
- KL fiber coupling lens and KL bundle selected on the multiport (kl_bundle)
- KL fiber collimator lens and KL bundle selected and aligned in the pupil steering mechanism injecting light into the FEU (kl_bundle)
- PSM focus adjusted to focus the K beam optimally onto the NIRSPEC slit (~2.51).
- Rotator set to place the Slit Alignment Mechanism in the beam (in).
- Slit Alignment Mechanism set to steer the beam onto the slit (on_slit).
- Photodiode pickoff set to the “NIRSPEC” position to allow light through to NIRSPEC.

The remainder of the optics not used in this mode should be set to:

- Light Source Retractor should be out of the beam (out).
- ADC Retractor set to out (out).
- ADC settings don’t matter if retracted (does not matter).

There is a command in the dayclas script that will default to these settings for convenience (calib_setup_sfp()). This command is run at the start of the daycals procedure to set the system up correctly; note that it should not be run after daycals have been completed as this would move stages that are set during the daycals.

The observer GUI also has all the mechanisms grayed out that a phase I observer should not be adjusting. Day cal. procedures help the SAs optimize the position of some of these stages (PSM focus, PSM XY, SAM X/Y).