KPIC Phase II+ calibration sources and procedures

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Daniel Echeverri	05/29/2024	Initial release
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(NOTE: When viewed in SharePoint online, figures may be in odd places. Recommend opening locally)

Contents

Overview

This document explains the various light sources and light location options for KPIC as installed in the April 2024 service mission. Figure 1 below shows the various light sources KPIC has access to and how they are routed to the instrument. Given there are many possible sources, MEMs-based switches are used to select a given light source and direct it to the desired location.

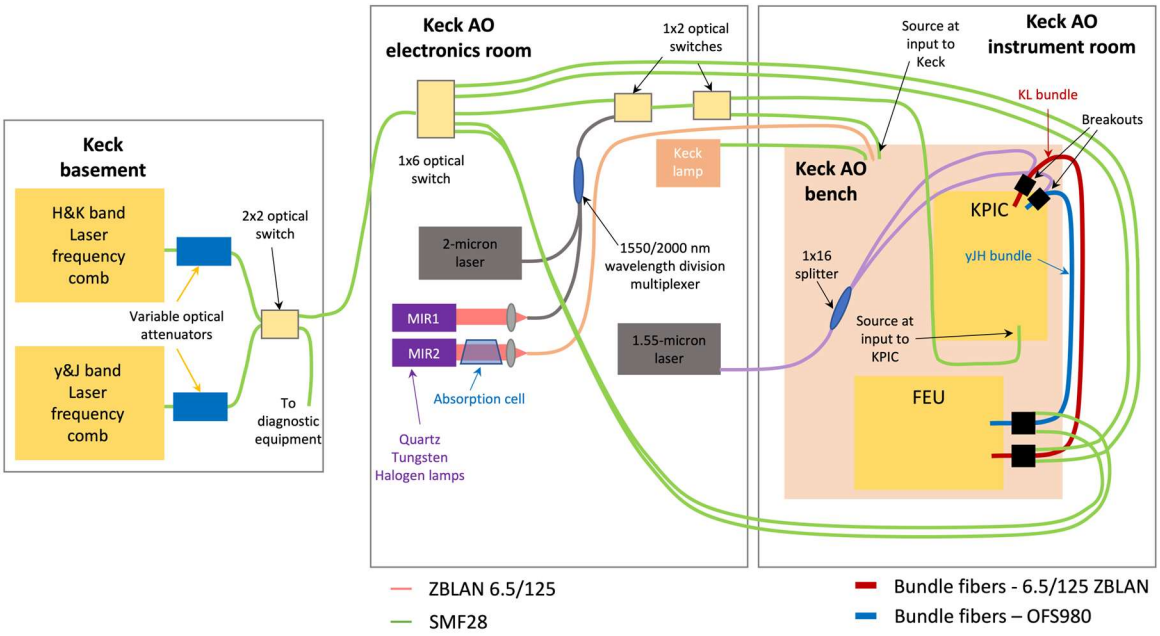


Figure 1: Schematic of the calibration source routing scheme.

KPIC has access to 7 calibration sources:

- **A 2-micron laser** – This is a bright light source to provide strong signal for daytime calibrations on the KPIC photodetector (PD). In the daycals procedure, it is used specifically for fiber finding and non-common path aberration (NCPA) correction through the KL fiber bundle. It is usually used in conjunction with the MIR1 lamp.
- **A MIR(1) lamp – (AKA KPIC-Silica)** This is the main KPIC light source. It is a forward-propagating Quartz Tungsten Halogen lamp (Thorlabs, SLS202L) used during daytime calibrations to provide a broadband beam that can be seen on the SHWFS, tracking camera, and NIRSPEC (first few K-band echelle orders).
- **A MIR(2) lamp + absorption cell – (AKA KPIC-ZBLAN)**This lamp is an identical model to the MIR1 source but we use a ZBLAN fiber for the connection, ensuring minimum losses for the light in K and L band. As such, it is used to calibrate the for L band observations. Its light can only be sent to the Keck AO SFP.
- **Keck lamp** – this is the main Keck AO source, a broadband light with multiple ND settings used by other Keck AO instruments.

- **A 1.55-micron laser** – This can only be retro-fed into the KL and yH bundles. It broadcasts beacons on the tracking camera allowing us to determine the location of the bundles with respect to the tracking camera. This is typically only used to find the science fibers after service missions when the bundles may have shifted.
- **A yJ astrocomb** – This is a Menlo systems astrocomb used by the KPF project. We pick off the long wavelength light and route it to the KPIC optical switch box which can then send it to the SFP, the KPIC input, or the back of the fiber bundles. This gives us comb light in y or J bands. It can be used for spectral characterization of NIRSPEC, on-sky and off-sky, in those bands.
- **A HK astrocomb** – This is a homebrew astrocomb that generates light in J, H and K bands. It's connections in KPIC are identical to the yJ comb connections. This can be used for spectral characterization of NIRSPEC in those bands.

The Laser frequency Combs (LFCs) are in the basement of Keck. They are passed through remotely-controllable variable optical attenuators. A 2x2 MEMs-based optical switch is used to select which LFC is sent up to the Nasmyth platform, into the adaptive optics room, and then over to the electronics vault. In the electronics vault, the LFC light is injected into the input port of a 1x6 switch which is mounted in an optical switch box with two other switches (see Figure 2). The LFC light is intended to be sent to the breakout fibers at the output of both the KL and yH bundles – these are fibers built into the outputs of each bundle that can be injected to without having to feed them into the front of the bundles (see Figure 3). The fibers are typically on the edge of the output pseudo slit. In this way, LFC light can be projected into NIRSPEC during a science exposure. It can also be sent into the other two switches to either the input of the Keck AO bench (known as the Source Fiber Positioner – SFP) or to the input of KPIC. This means it could be used as a light source for daytime calibrations if needed (not baselined) or to spectrally calibrate the entire beam path.

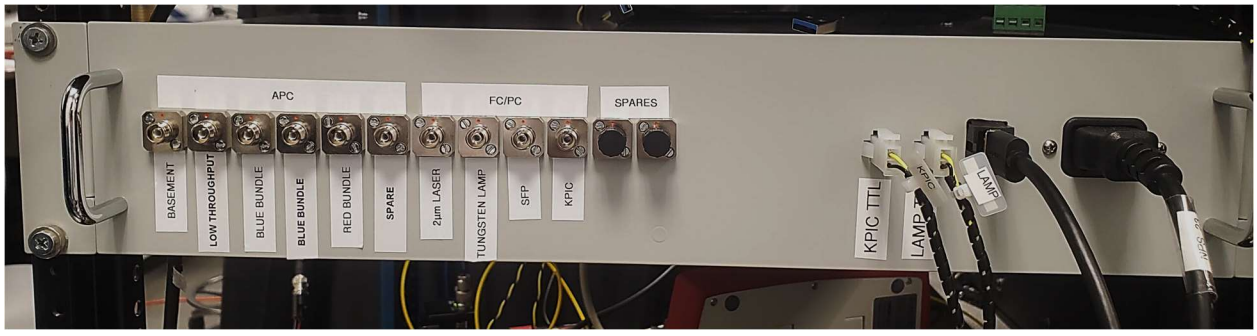


Figure 2: Photo of the front of the optical switch box installed in KPIC phase II+. *Note: the left 6 labels shown above are outdated compared to the as-installed at the summit. See picture below.*

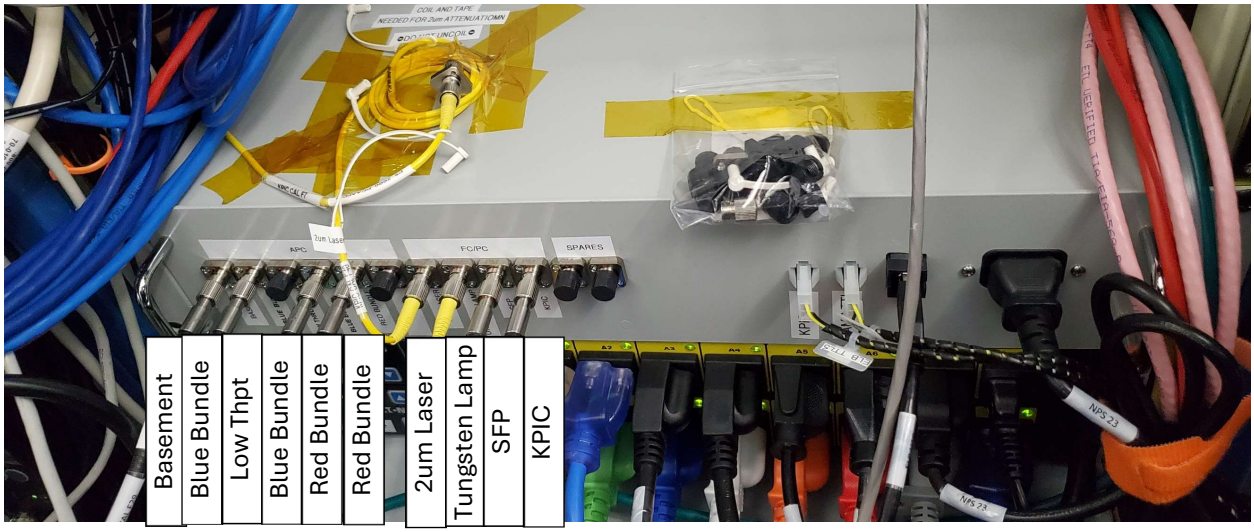


Figure 3: Photo of the optical switch box as-installed in the K2 E-Vault. The overlaid textboxes reflect the labels on the box for easier viewing.

The 2-micron laser is combined with the MIR1 lamp via a fiber-based wavelength division multiplexor. The light is routed to a 1x2 MEMs switch which selects between the LFC or the 2-micron laser+MIR1 lamp. A second daisy-chained 1x2 switch determines if light is sent to the input of the AO bench (SFP) or the input of KPIC. The MIR lamp light is visible on the tracking camera so is used for finding the beam and testing tracking, while the 2-micron laser is bright enough to be seen on the photodiode in the FEU after fiber injection (not shown in the diagram). The 2-micron laser is used for both fiber finding (scanning the input beam across the fiber tip while measuring it on the photodiode to determine the optimal alignment) and NCPA compensation (scanning Zernike mode amplitudes with the BMC DM while maximizing flux coupled through the fiber). The MIR1 lamp is too faint to be seen on the photodiode. N.B: Keck has their own lamp which is routed to the input of the AO bench to the SFP location. It is brighter than our lamp and can be detected by the photodiode but with significantly lower counts than the laser (~1000x fainter). This source has been used in the past for day cals and is currently still used for the yJ bundle calibrations in PI mode operation.

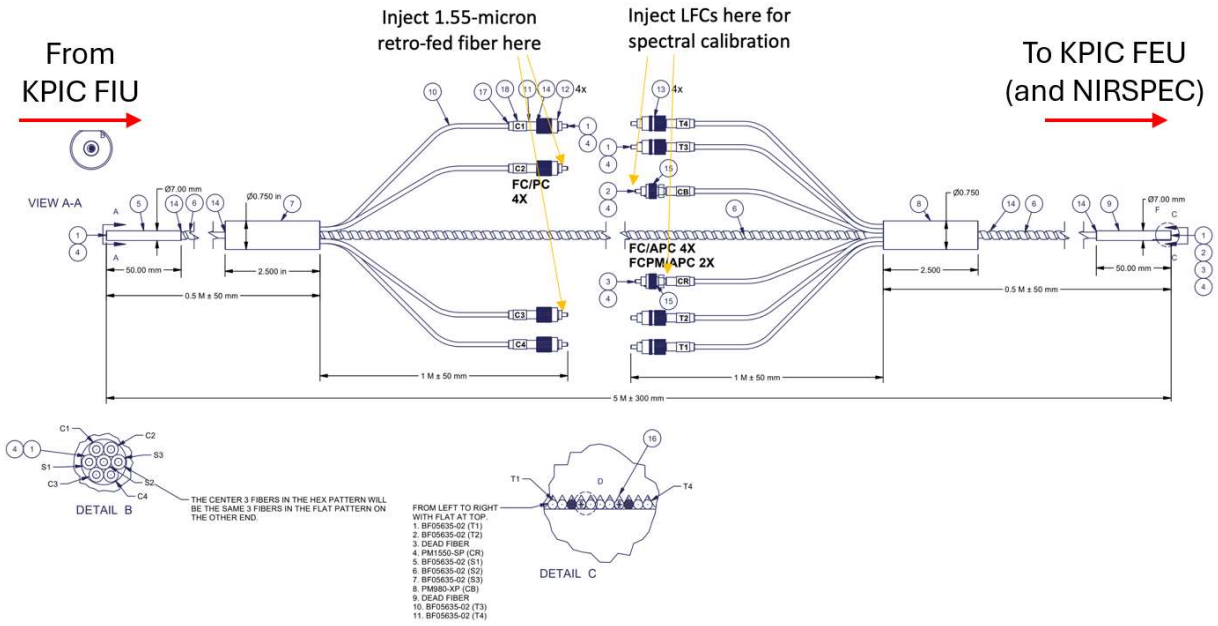


Figure 3: Schematic of the yH bundle. The four broken out fibers at the input (left side) that are used for retro-feeding 1.55-micron light are shown. At the output, CR and CB are used to feed the LFCs to NIRSPEC.

For L band day cals., we use the MIR2 lamp which exploits a ZBLAN fiber to maintain high flux in K and L bands to the input of the AO bench. This source fiber is parfocal with the 2-micron laser/MIR1 lamp focus. Therefore, you can use the 2-micron laser to compute NCPAs and then move to the MIR2 lamp fiber for NIRSPEC setup and calibrations in L band.

The 1.55-micron laser will launch retro-fed beacons from both bundles. These will form images on the tracking camera indicating the location of either bundle. This can be used to triangulate the location of the science fibers. Early in KPIC we determined there was little-to-no relative motion of the bundle with respect to the tracking camera, so we don't use this laser/feature very often and certainly not actively. But it is there if needed to diagnose issues.

Table 1 summarizes where each light source can be sent and what it is used for.

Table 1: Light sources, their most-common uses, and where they can be routed to.

Light source	Used for	Where it can be routed
2-micron laser	Fiber finding, NCPA compensation	Input of AO bench, Input of KPIC.
MIR1 lamp (KPIC-Silica)	Locating forwards beam during daycals, and NIRSPEC setup	Input of AO bench, Input of KPIC.
MIR2 lamp (KPIC-ZBLAN)	L band day cals.	Input of the AO bench.
Keck lamp	Back up for day cals.	Input of the AO bench.
1.55-micron laser	Locating fiber bundles	Retro-fed fibers on KL and yH bundles.
yJ LFC	Spectral calibration of NIRSPEC in yJ band, could be used for day cals.	Input of AO bench, Input of KPIC, edge fibers at the output of the yH bundle.
HK LFC	Spectral calibration of NIRSPEC in HK band, could be used for day cals.	Input of AO bench, Input of KPIC, edge fibers at the output of the yH or KL bundles.

These configurations are visualized in Figure 4.

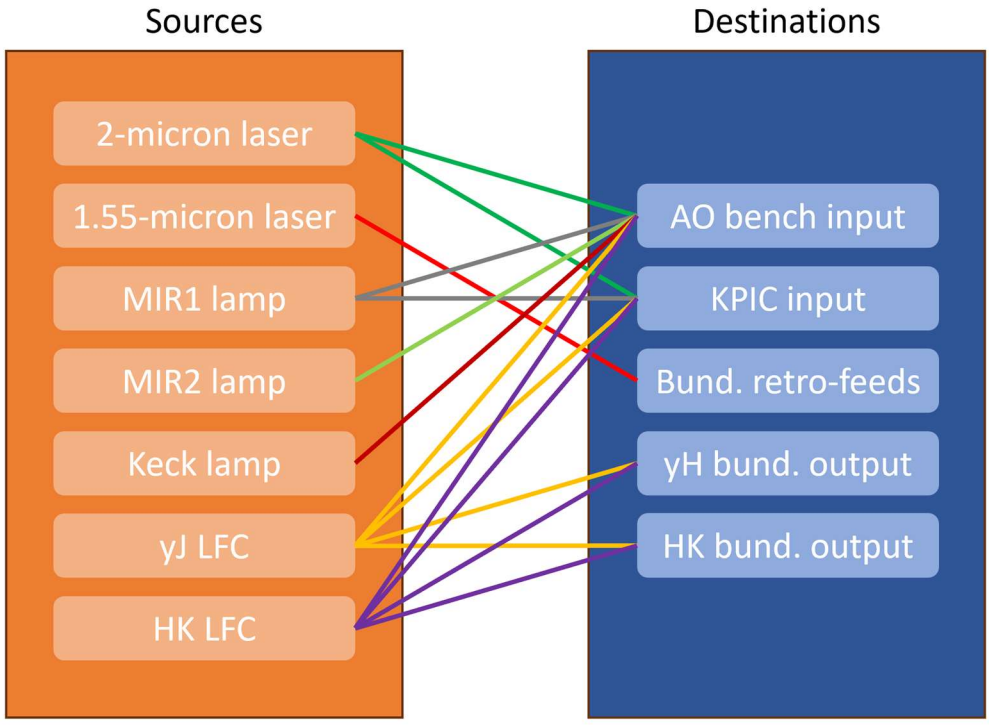


Figure 4: Visualization of where each light source can be sent with the optical switch box.

Procedures:

This section provides instructions on how to control and check the state of the various light sources.

Keywords

First, here are the **keywords** associated with the various lights. Note that only the MIR lamps are controlled solely by turning on/off their OUTLET_H%% port. The optical switches should be controlled by toggling their switch state from the keywords, they should **not** be powered off at the NPS under normal operations, only if debugging is needed. The lasers should be controlled (including enabling/disabling emission) by the associated python scripts and should be turned off at the NPS via keywords. Here are the Keywords associated with the various devices:

- 2um Laser – k2aopower : OUTLET_HE6
  - This outlet should be kept "off" at the pdu whenever the 2um laser isn't in use.
  - Laser emission should be turned off via python before the outlet is turned off though. See the Control or Appendix 1 sections below for instructions.
- MIR1 Lamp – k2aopower : OUTLET_HE4
- MIR2 Lamp – k2aopower : OUTLET_HB3
- 1.55um Laser – k2aopower : OUTLET_HB7
  - Note: This NPS port also has other devices on it. This laser should be controlled via python commands, not by toggling the power outlet unless absolutely necessary.
- Keck Lamp – (refer to K2AO documentation for SFP, lamp, and ND setting control)
- KPIC Optical Switches:
  - Power for both switches – k2aopower : OUTLET_HE7
  - Source 1x2 selecting between combs and lamps – kpic : LSRCSWT
  - Output 1x2 selecting between bench and KPIC input – kpic : BENCHSWT
- 1x6 switch – k2aopower : OUTLET_HE7
  - Note: this keyword controls power to the entire KPIC switch box; it does not control the state of the switch. The switch is controlled via python software instead.

Control

There are several ways to **control** the various light sources. Here are the preferred ways to do so when *not* using the daycals code (spec_scans_combined). When using spec_scans_combined, there are helper functions for some of these actions, and those are described later in this document.

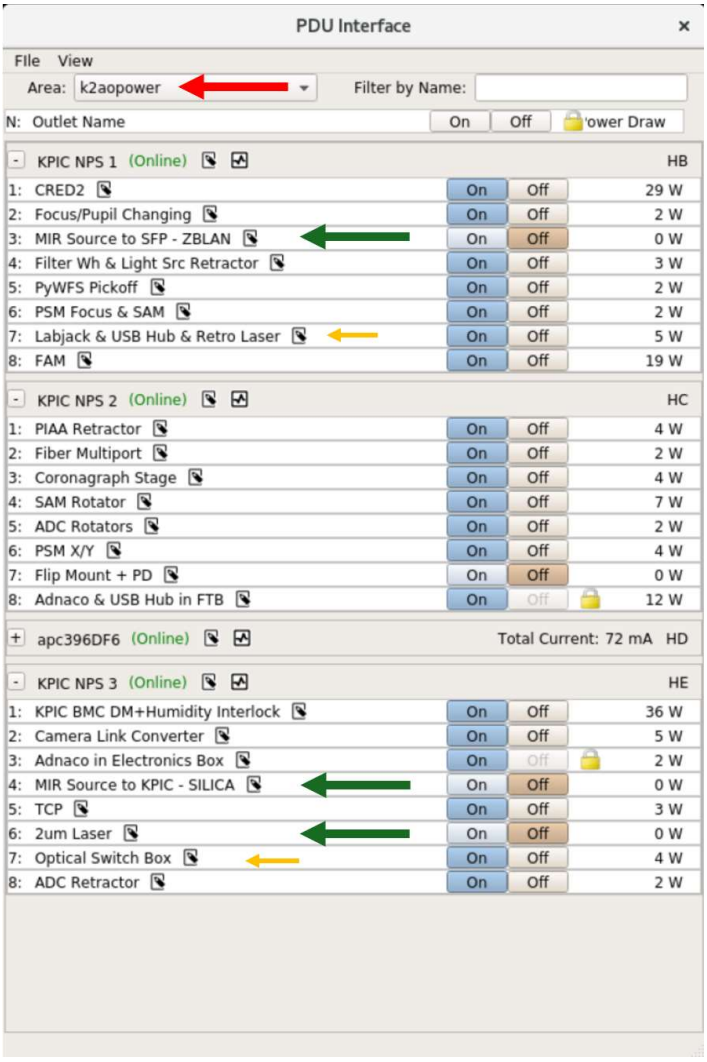
- 2um Laser (from any kpython3 terminal):
  - Note: The NPS outlet for this laser is kept off whenever the laser is not in use. As such, make sure to turn on that outlet before use:
    - `modify -s k2aopower OUTLET_HE6=On`
  - `import VFN_Toolkit_summit as tools` # library with 2um control

    - `tools.laser_connect()` # connect to the laser
    - `tools.laser_setcurrent(250)` # set the laser power (250mA is the standard)
    - `tools.laser_enable()` # enable laser emission at current power level
    - `tools.laser_disable()` # disable laser emission
    - `tools.laser_disconnect()` # close software connection to laser
    - Make sure to turn off the outlet when done with the laser:
        - `modify -s k2aopower OUTLET_HE6=Off`
- MIR1 Lamp: Can be controlled directly at its NPS port using normal KTL control
    - Query: `gshow -s k2aopower OUTLET_HE4`
    - Turn on: `modify -s k2aopower OUTLET_HE4=On`
    - Turn off: `modify -s k2aopower OUTLET_HE4=Off`
- MIR2 Lamp: Can be controlled directly at its NPS port using normal KTL control
    - Query: `gshow -s k2aopower OUTLET_HB3`
    - Turn on: `modify -s k2aopower OUTLET_HB3=On`
    - Turn off: `modify -s k2aopower OUTLET_HB3=Off`
    - To use this lamp, you must set the Keck SFP to "`KPIC-ZBLAN`". See Keck documentation for how to move the SFP. One good way to do it is from the k2aoserver-new's "SC GUI".
- 1.55um Laser (from any kpython3 terminal):
    - `from TLS import TLS_Device` # library with 1.55um control
    - `tls = TLS_Device()`
    - `tls.open()` # connect to the laser
    - `tls.isEnableOut()` # check if laser is enabled (emitting)
    - `tls.reqPowerAct()` # query current laser power setting (in mW)
    - `tls.setPower(1.5)` # set laser power (1.5mA is visible on CRED2 in 2.5ms)
    - `tls.enableOut()` # enable laser emission at current power level
    - `tls.disableOut()` # disable laser emission
    - `tls.close()` # close software connection to laser
- Keck Lamp: *Refer to K2AO documentation for control of the Keck source lamp*
- KPIC 1x2 Optical Switches:
    - Query first switch (source selector): `gshow -s kpic LSRCSWT`
        - `Lamp` = MIR1 + 2um light is passed to the second switch
        - `LFC` = comb light is passed to the second switch
    - Set first switch (source selector): `modify -s kpic LSRCSWT=Lamp`
    - Query second switch (output point selector): `gshow -s kpic BENCHSWT`
        - `KPICIN` = light (if emitting) is forwarded to the KPIC input focal plane (not seen by K2AO, NIRC2, or NIRSPEC)
        - `K2AOIN` = light (if emitting) is forwarded to the K2AO bench at the SFP (ie. seen by K2AO and any downstream instruments if set for that).
    - Set second switch (output point selector): `modify -s kpic BENCHSWT=KPICIN`

- LFCs:
    - *Refer to KPF and astrocomb documentation for control of the sources themselves; KPIC only has control of our internal switches for forwarding the light once it gets to us, but we cannot toggle the LFC settings.*
- KPIC 1x6 Optical Switch (from any kpython3 terminal):
    - *Note: this switch is only relevant when using the LFC with KPIC, which is a PI-mode only feature. As such, the provided commands below* ***simply let you ensure that the LFC light is trapped in the KPIC optical switch box and hence is NOT visible to anything in K2AO****.*
        - *For additional 1x6 switch control information, reach out the KPIC team.*
    - `from Switch_cmds import Switch1x6_cmds`
    - `with Switch1x6_cmds(debug=True) as swit: swit.set_port(1)`
        - This "with" command will send the light to a low-throughput, disconnected port on the 1x6 (see Fig. 3 earlier in this doc), such that the light is trapped in the KPIC switch box and is not forwarded to the K2AO bench.

PDU GUI

Note that the MIR Lamps are also easily controlled from the pdu_gui. This GUI can be opened by calling `pdu_gui` from any nfiuserver terminal. Once the GUI opens, select "k2aopower" from the "Area" drop down at the top left (shown by red arrow in figure). This will open 4 NPS's; you can hide the "apc396DF6" NPS which is the pyramid NPS and is not controlled by KPIC. Once here, you have control of all 3 KPIC NPSs. The screenshot below shows the pdu_gui with the 2 relevant MIR lamp outlets, and the 2um Laser outlet marked by the green arrows. Note that the MIR1 Lamp is called "MIR Source to KPIC – SILICA" in this GUI (since it uses a silica SMF28 fiber). The MIR2 Lamp is called "MIR Source to SFP – ZBLAN" (since it uses a ZBLAN fiber). The screenshot also marks in orange other outlets related to light-source elements, but these should ideally not be toggled unless necessary (those devices have other preferred control methods like keywords or python commands).



Keck AO Stage Positions for KPIC

This section addresses the position requirements for stages in the Keck AO bench to get light from the Keck SFP to KPIC. This does not address *all* stages, but rather the key relevant stages.

- **SFP** should be at one of the following positions:
  - "`pws`" – when using the Keck Lamp as the source. "`nirc2`" also works but will have an ~4mm defocus.
  - "`kpic-silica`" – when using the MIR1 + 2um Laser sources at the Keck SFP input. (remember to also set BENCHSWT="KPICIN").
  - "`kpic-zblan`" – when using the MIR2 source, which is only available at the Keck SFP position.
- **ISM** should be "`out`". KPIC picks off the light that would go to NIRC2 using the DFB (see next line), *not* the light that would go to NIRSPEC.
- **DFB** should be "`mirror`". This moves a mirror into the NIRC2 beam path to send the light to KPIC instead. Note that "`dichroic`" also works **but** there is this does not send K-band light to KPIC so it is *not* the right position for Facility-mode KPIC operations.
- **PWS FSM2** should be at the on-axis position for the pyramid (KPIC has been purposely aligned to be co-axial to the pws). As of July 2023, this position was approximately (6.2937, 6.8417). If this FSM2 is pointed grossly wrong, the PSF could be shifted on the CRED2 (possibly completely off the detector) or the pupil could be clipped in KPIC.
- **KPIC Light Source Retractor** Stage should be set to "`out`" so that it doesn't block the KPIC input focal plane.

Daycals Functions (spec_scans_combined helper functions)

The following section shows how to perform certain common actions with the light sources using helper functions in the KPIC daycals code (`spec_scans_combined`). This assumes that a kpython3 instance with spec_scans_combined has been started per the normal KPIC daycals procedure (KPIC_Facility_Daytime_Calibrations_Procedure.docx). In the text below, I've bolded places where these helper functions do things with the K2AO bench. Note that since these are helper/utility functions, they perform many actions; I've listed key points about what is done where relevant.

- Set various "normal" light source settings for daycals:
  - Turn on MIR1+2um sources and send them to the Keck SFP input point, while turning off the Keck Lamp: `kpic_sfp_source(source='on')`
    - Note that this also: turns off KPIC tracking, resets kpic astrometry, **moves the DFB to "mirror"**, turns on the KPIC switch box outlet if it was off, sets the LSRCSWT to "Lamps", **sets the Keck lamp to "open"**, sets the BENCHSWT to "K2AOIN", **moves the SFP to "kpic-**

silica”, sets the KPIC light source retractor to “out”, and sets the KPIC FAM to “center”.

- Turn off MIR1+2um sources and instead turn on the Keck Lamp: `kpic_sfp_source(source='off')`
  - Note: this does the same stuff as the previous command (above) except – it sets BENCHSWT to “*KPICIN*”, turns *off* the MIR1 and 2um sources, ensures that the MIR2 is off, turns *on* the Keck Lamp, and **moves the SFP to “pws”**.

- Toggle the KPIC 2um laser on/off. This will set the NPS outlet state, will set a default power setting (250 mA), and will enable emission. **This is therefore the preferred way to control the 2um laser**:
  - Turn on the laser (and set 250mA power setting): `set_kpic_laser('on')`
  - Turn off the laser: `set_kpic_laser('off')`

Appendix 0: Keck email Alerts for Lights

In late July, early August 2024, we added the KPIC lights to the Keck email alerts sent to the aousers@ list serve. This was a request for Facilitization, to ensure that users are notified if KPIC lights are kept on at the start of a night. We modified the existing checkLightSource script to also check the KPIC light sources.

For the two MIR lamps, this was very simple since we could just attach the alarms to the NPS outlets. For the 2um Laser, we modified our procedures to keep the 2um Laser NPS outlet off whenever the laser is not in use. This way, we could attach the alarm to the outlet, rather than having to ssh to the KPIC server and try to query the laser from python. By attaching the alarms to the NPS outlets, we are also relying on the k2aopower service, which is part of the Keck-managed UNO system. This provides an extra layer of confidence that the service will always be available and that we are querying the KPIC light source state from the lowest level possible (at their power source).

<u>The main implications are:</u>

- As before, you must notify the aousers channel if you plan to turn on lights in KPIC.
- You should be conscious of the fact that if the lights are on past ~5PM HST, an email alert will be sent to the aousers list serve. **If mean to keep the lights on, make sure to ping the aousers list serve** to let them know that the lights are intentionally on.
- **For Keck staff**: if you get an email alert about a KPIC light being on, you can turn it off by (see earlier sections in this document for more details):
  - `modify -s k2aopower OUTLET_HB3=Off` (turning off MIR 2)
  - `modify -s k2aopower OUTLET_HE4=Off` (turning off MIR 1)
  - `modify -s k2aopower OUTLET_HE6=Off` (turning off 2um Laser)
    - For the 2um laser, it would be great if you could run `set_kpic_laser('off')` from a `kpython3 -i -m spec_scans_combined` session on the nfiuserver, but given that these alarms are a critical system, it is okay to just kill the laser at the outlet directly.
- For KPIC team: the biggest change for us is that the **NPS outlet for the 2um laser must be kept off** unless the laser is in use. As such, it is best to manage the laser on/off state using the `set_kpic_laser()` function, which handles the NPS outlet state for you.

Appendix 1

This section provides a more detailed explanation of how to send light to KPIC from various sources. The options here are already explained in earlier sections, but in this section, they're explained assuming the reader is not familiar with the Keck AO bench. Thus, this section is more suited for KPIC team users (rather than Keck SA's).

MIR1 Lamp (frontend daycals default when used with 2um Laser)

In a daycals (`spec_scans_combined`) kpython3 session:

- (see Daycals Functions section for more details)
- `kpic_sfp_source(source='on')` turns both of these on
- `kpic_sfp_source(source='off')` turns both of these off, and turns on the Keck lamp

Note: you can turn on/off just the MIR1 lamp using the pdu_gui or using keywords from the terminal (any nfiuserver terminal, not a kpython3 session) with:

```
modify -s k2aopower OUTLET_HE4=off
```

2-micron laser (frontend daycals default when used with MIR1 Lamp)

In a daycals kpython3 session (`spec_scans_combined`): `set_kpic_laser('on')` or `'off'`

Additionally, you can set the laser power with: `tools.laser_setcurrent(<power_val>)`, where `<power_val>` is a value between 200 (minimum power) and 450 (maximum power, ~22mW at the laser output, less after fiber to AO bench). Note that you can provide values smaller than 200mA, but the this is basically the laser threshold below which no light is emitted. The KPIC team usually uses 250mA, which in DS mode with a decent PSF and well-aligned SAM provides ~3V of signal on the PD.

Make sure to always turn off the 2um Laser outlet on the NPS when done! This is new as of August 2024. If you fail to turn off the laser outlet, you will set off alarms in K2AO about the laser status.

MIR2 lamp (backend daycals for L band)

To set the ZBLAN fiber on and into KPIC:

- In a VNC session to the K2AO server-new, open an "SC GUI" from the "K2AO Tools" option off the background.
- Select "More" on the row next to "SFP".
- In the popup GUI, enter "`KPIC-ZBLAN`", in the green box next to "`obsfname`"
- Then hit the "`s`" button next to that to (send) the SFP to that position
- Then in our `pdu_gui` from the nfiuserver, turn off any other KPIC lights (ie. MIR Silica lamp at the bottom) and instead turn on the MIR lamp at the top that says "SFP ZBLAN"
- Remember to also check that all Keck sources are off. (Can do so with the "Light Source Control" GUI in the K2AO server-new VNC session).

To turn off the ZBLAN light and reset to the Keck Source (or KPIC silica source):

- Make sure KPIC tracking and K2AO loops are open
- Turn off the MIR2 lamp towards the top that says SFP - ZBLAN
- (if desired) Turn on the MIR1 lamp towards the bottom thatpa says “KPIC – SILICA”
- In the K2AO server-new VNC session, open an "SC GUI" from the "K2AO Tools" option off the background.
- Select "More" on the row next to "DFB".
- If using KPIC – Silica:
    - In the popup GUI, enter "`kpic-silica`", in the green box next to "`obsfname`"
- If instead using Keck Lamp:
    - In the popup GUI, enter “`pws`”, in the green box nex to “`obsfname`”
- Then hit the "`s`" button next to that to (send) the SFP to that position

Keck lamp (backend daycals default)

With the daycals code running, you can set the source using: `Light_Src_cmds.set(‘nd#’)`, where `#` is the ND filter setting value (1 through 6 supported). You can also set it to ‘`open`’ (no filter, maximum light), or ‘`block`’ (light still on but blocked).

You can turn off/on the Keck Lamp (i.e. beyond “blocking” it, you can actually turn it off or on) using:

- OFF: `ktl.write('ao2', 'obswon', '0')`
- ON: `ktl.write('ao2', 'obswon', '1')`

Note that you shouldn’t have to deal with this yourself since the daycals functions should handle these state changes automatically to give you the right light setting. For example, `setup_for_spec()` automatically sets ND1 on the Keck Lamp to give you the right amount of signal to see traces without saturating on NIRSPEC.