Status of CLARA apparatus

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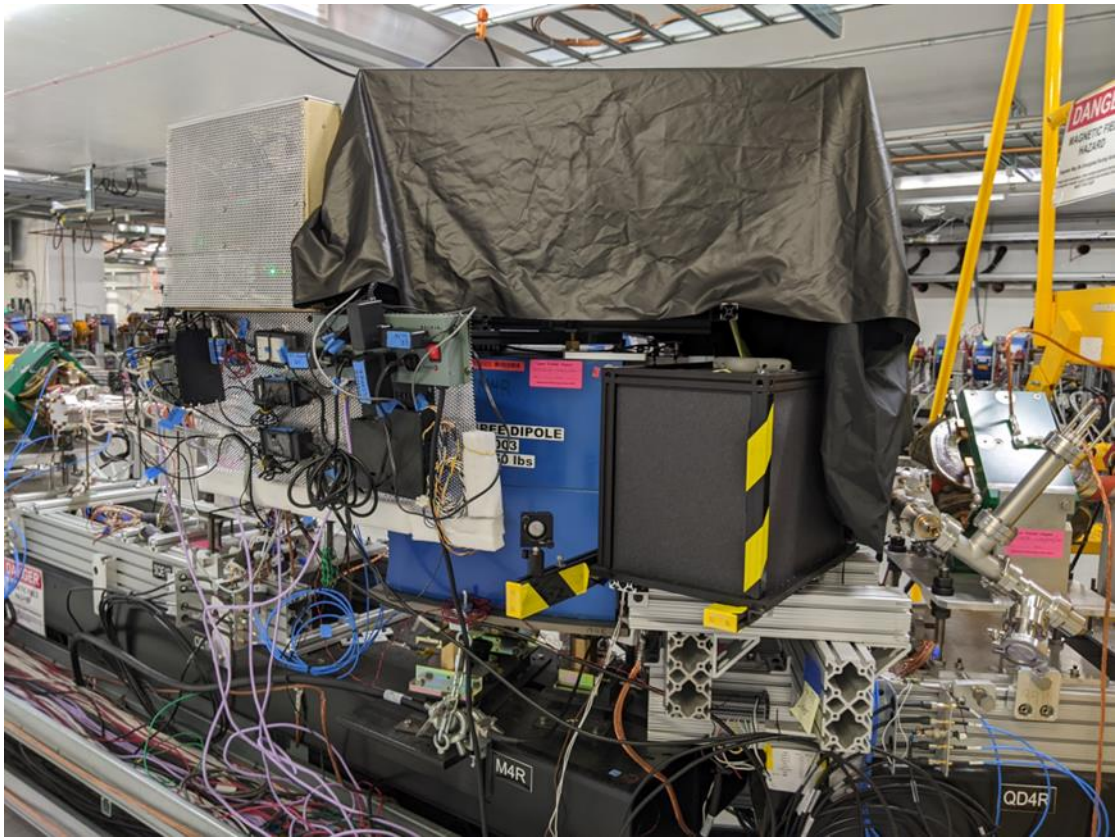
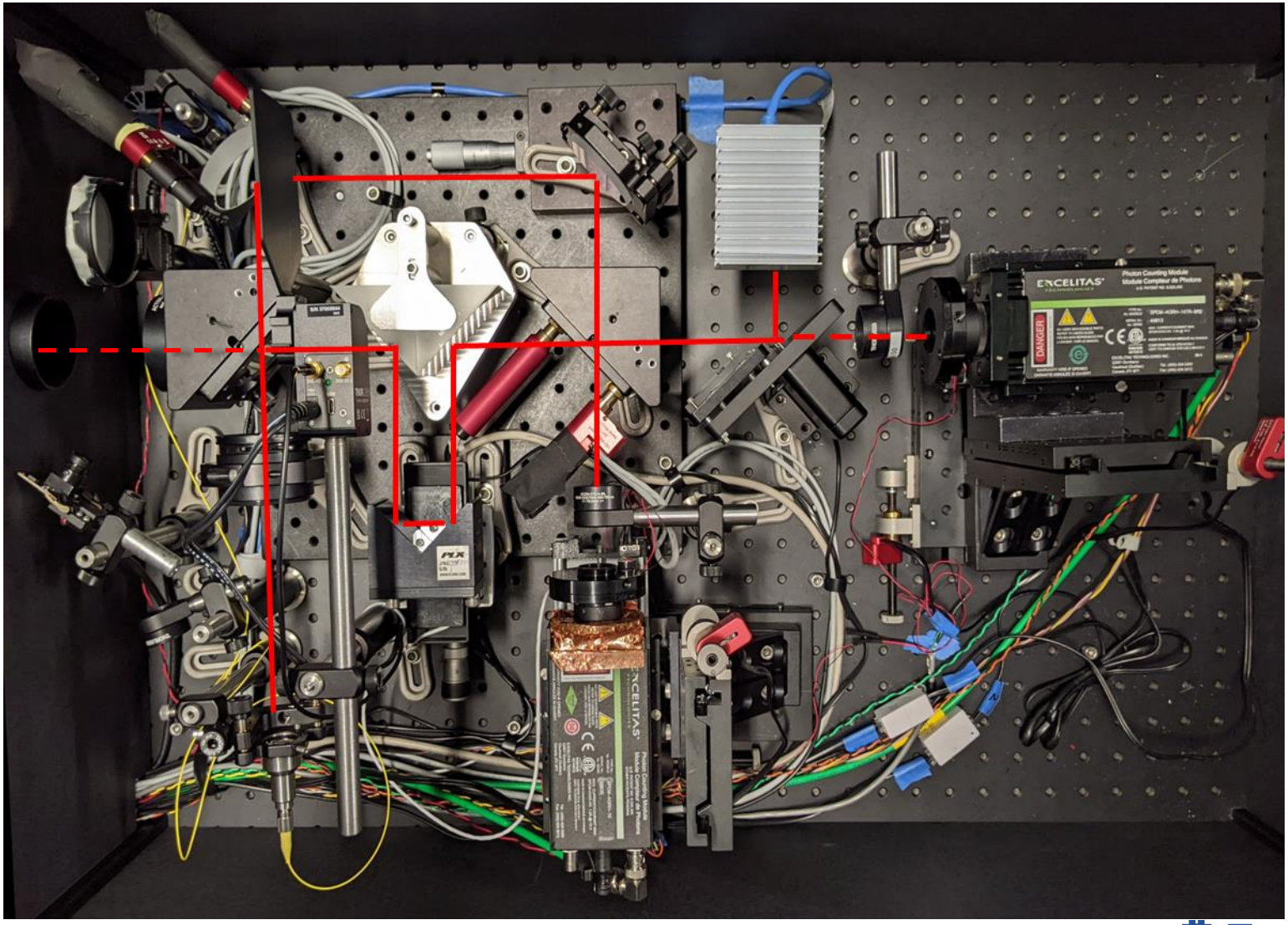
New object in the IOTA tunnel

- The apparatus was moved to IOTA on 23-Jan-23, connected to electronics, and commissioned
  - Before that, it was assembled and tested with a laser diode at ESB in 2022

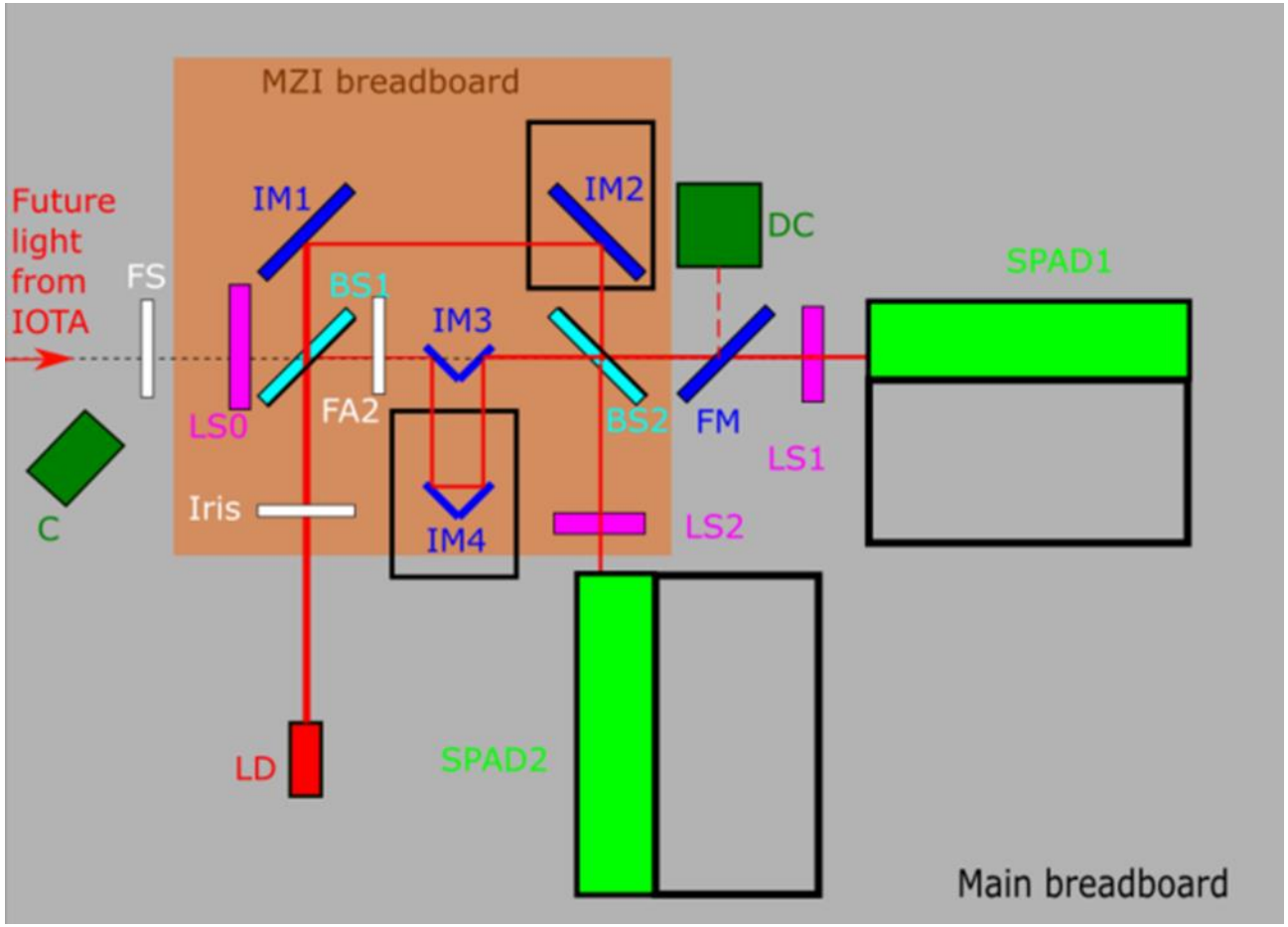


CLARA apparatus mounted on the top of M4R magnet.

What is in the box: Mach-Zender Interferometer (MZI)



Apparatus schematic



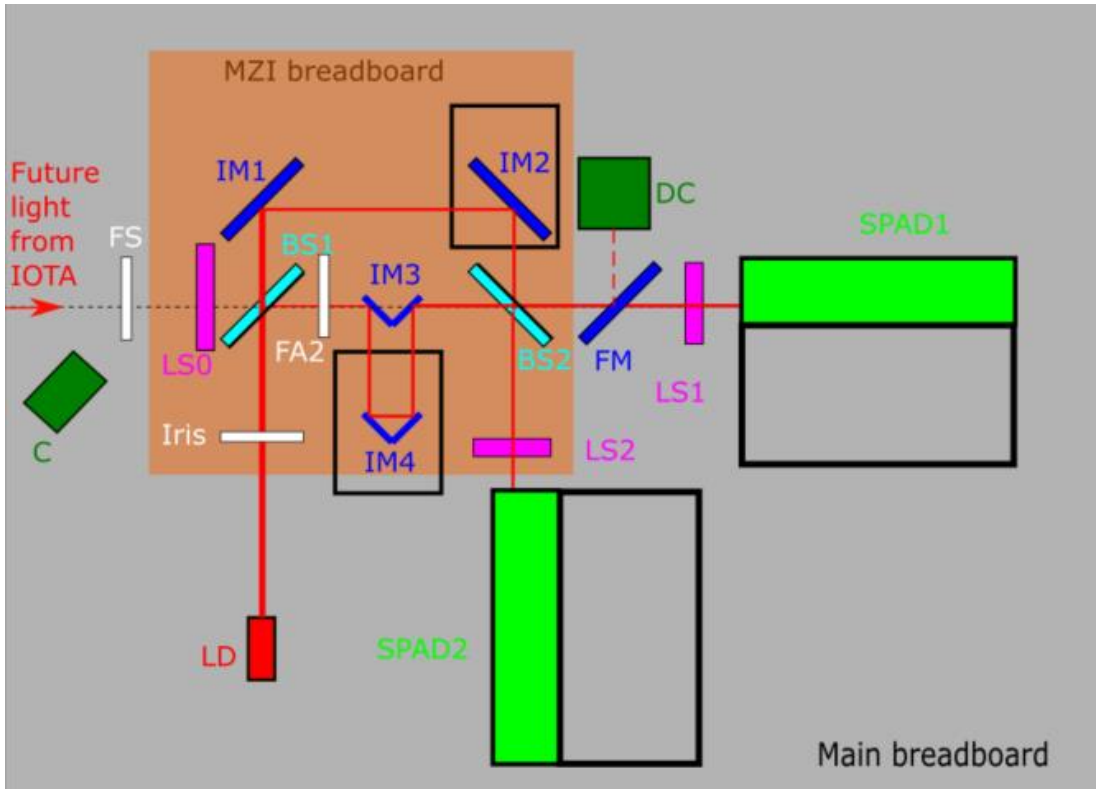
MZI is assembled on a separate breadboard isolated from the main one by rubber supports.

As of 9-Feb-2023

- LD- laser diode
- SPAD1,2 –Single Photon Avalanche Detector
- DC – digital camera
- BS1,2 – beam splitters
- IM1, IM2 – Arm1 MZI mirrors
- IM3 – right-angle mirror in Arm2
- IM4 – hollow roof mirror in Arm2
- LS1, 2 – SPAD lenses
- LS0 – entrance lens
- FM – flipping mirror
- FA2 – flipping screen in Arm2
- FS - flipping screen at entrance
- Iris – LD collimator
- C - webcam

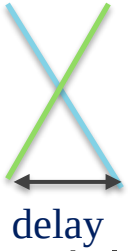
Measurements with the laser diode

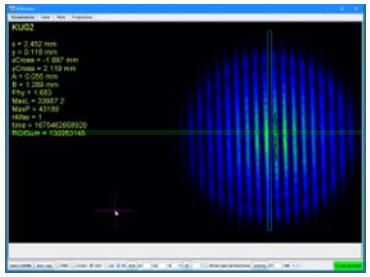
- With camera: flipping mirror is inserted and directs high-intensity light into the digital camera
- With SPADs: flipping mirror is retracted, a low-intensity light hits SPADs

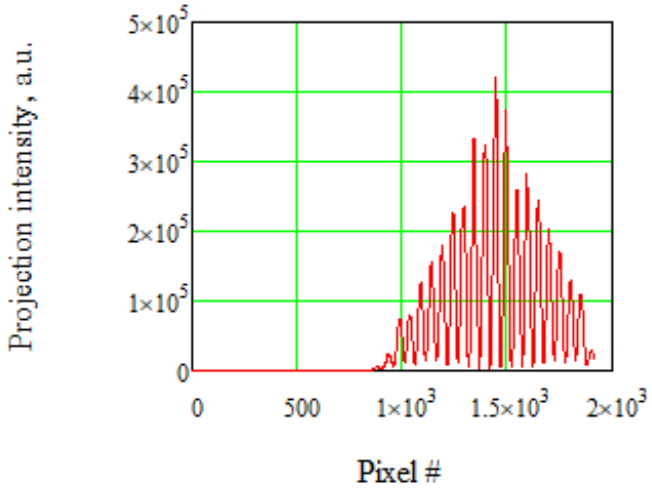


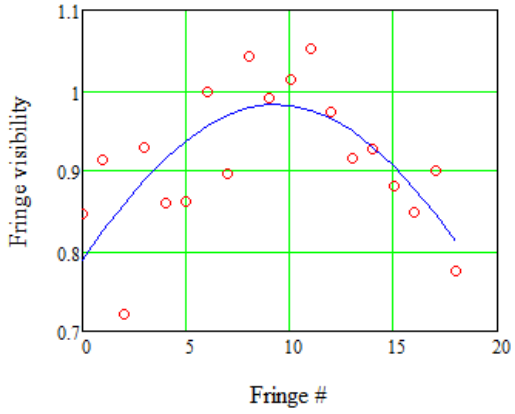
Camera measurements

- MZI delay is optimum; there is an angle between wavefronts coming from two MZI arms (0.1 – 10 mrad)
- Interference information is in intensity distribution (fringes)
  - "Fringe visibility": $\frac{I_{max}-I_{min}}{I_{max}+I_{min}}$
  - Coherence length:
    - How quickly the fringe visibility drops with the delay





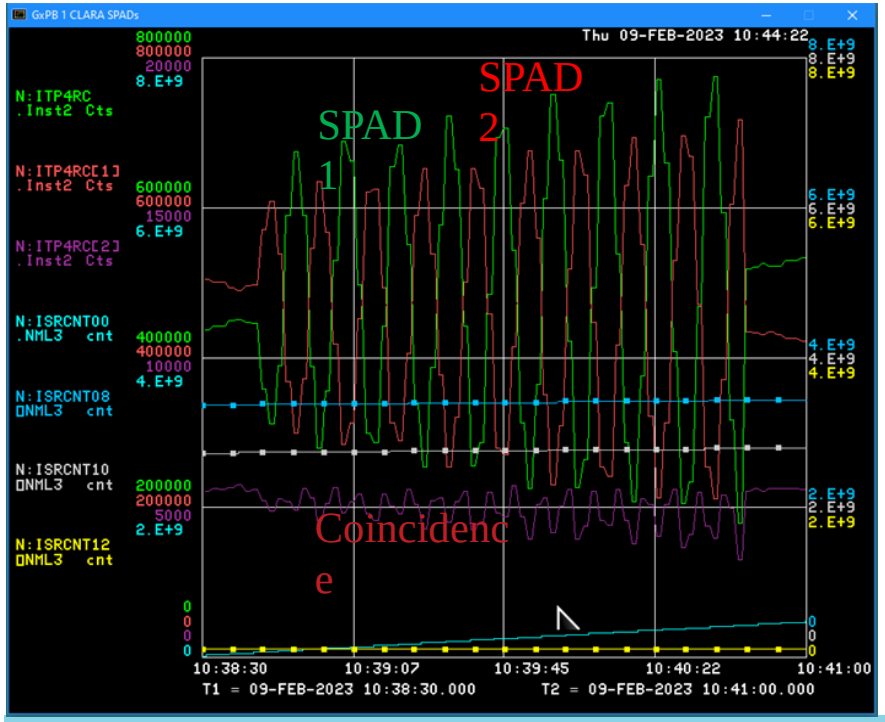


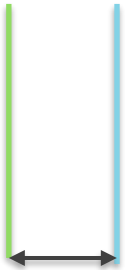


Horizontal projection of the image in 10 –pixel box (left) and fringe visibility in this plot (right).
Measurements with laser diode at 25 mA.
Coherence length is 14λ.
3-Feb-23.

Interference measurements with SPADs

- SPAD rates are recorded while the stage is moving
  - Same information as from camera image
    - Visibility, coherence length
    - For the laser diode, found in SPAD the same visibility and coherence length as with the camera





Fast Time Plot of SPAD signals while the stage position is changed linearly in time (25 nm x 120 moves x 1 s). LD current is ~18 µA. 9-Feb-23.

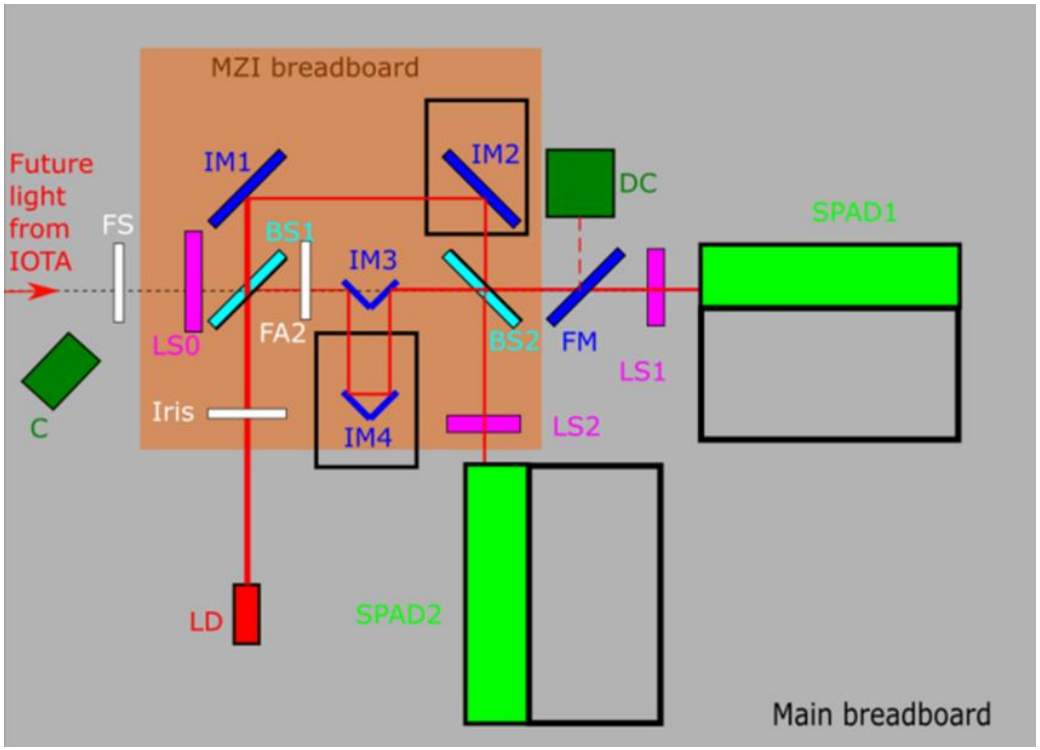
Measurement of coincidence rate between SPADs

- 3 limit cases: identical
  - Photons arrive independently (laser light)
    - Coincidence rate $f_{coinc} = f_1 \cdot f_2 \cdot \tau$
      - τ is coincidence window in electronics, and f_1, f_2 are SPAD rates
  - Photons are indistinguishable (“Fock state” wave packets)
    - As ones emitted by quantum dots
    - Coincidence =0 at perfectly aligned interferometer
  - Photons are emitted by independent atoms (“normal” light)
    - Tend to “bunch”, coincidence rate is increased
- Initial idea for CLARA: can the undulator light be a mixture of these states? Can we put limitations on the content of the latter two?
  - Made an attempt to test procedures with the laser diode
    - Still work in progress

Fermilab

Plans (1)

- The apparatus is fully commissioned at IOTA with laser diode
- With dedicated beam time and the undulator moved in
  - Move in the screen (FS) at the entrance; high-intensity beam.
    - Tune the periscope mirrors to observe the beam on the screen with a webcam.
  - Remove FS; insert flipping mirror (FM); tune the undulator light into the spot on camera (DC) where the LD light was
    - Measure visibility and coherence length



Plans (2)

- Work with one or several electrons
  - Remove FM, tune the beam into SPADs. Measure visibility and coherence length
  - Measure the coincidence rate
  - Analyze statistical properties of the light without interference
    - Block one arm or make a large delay
    - Record arrival times of individual photons