Fermilab

U.S. DEPARTMENT OF ENERGY | Office of Science

Notes on work on March 11-24 , 2022

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Meeting on Undulator Light Interferometry Setup

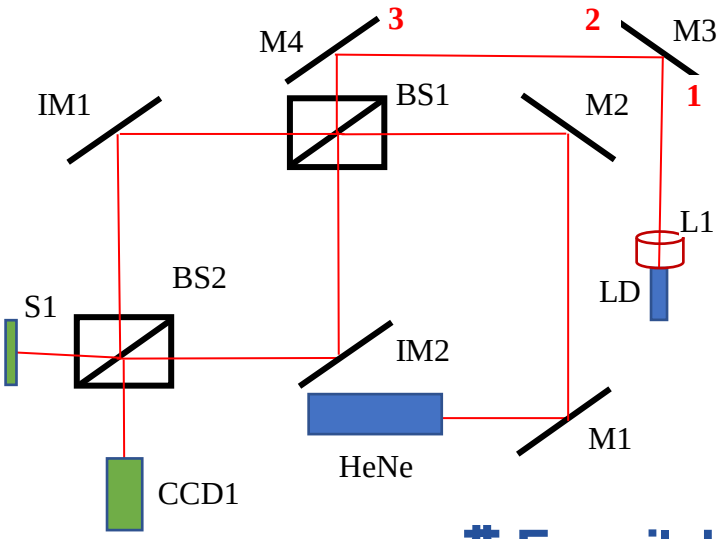
25 March 2022

Content

- Log of the work at ESB
- Next steps

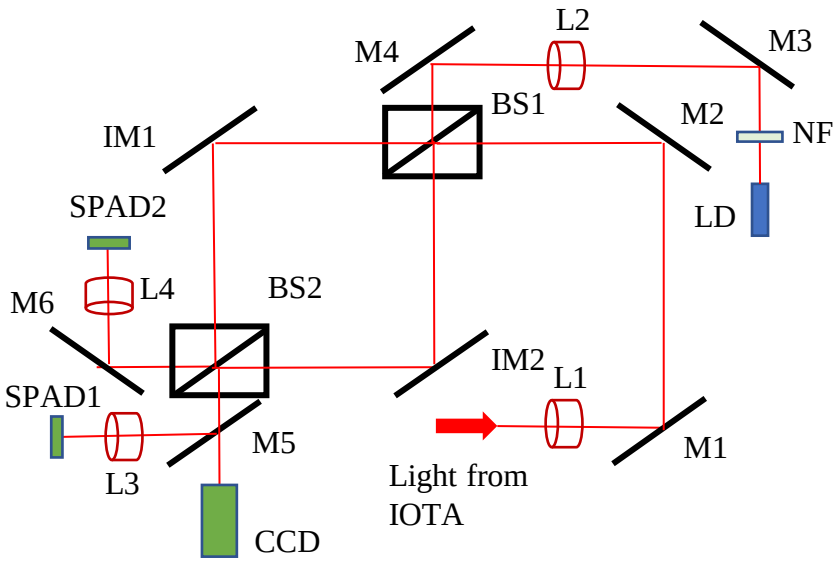
Work at ESB

- In the previous weeks
  - Observed fringes from a Laser Diode and measured the coherence length at CCD
    - First attempt: ~70% fringe visibility
    - After improvements to the alignment procedure: <10%
- March 11-24: several shifts in attempts to increase the fringe visibility and to understand the limiting factors
  - Varied the focusing scheme
  - Did not reproduce the first result
    - At best, ~20% visibility
  - Present understanding
    - Affected by spatial coherence of LD
      - Hope to improve
      - Might be already OK for tuning



The scheme discussed on 11-Mar-22

- Alignment of MZI offline with LD
- Coherence length from e- beam with CCD
  - Large BS2 angle; count number of fringes
- Coherence length from single e- with SPADs
  - As low as possible BS2 angle; scan delay with IM1 position
- Coincidence with two photons vs delay

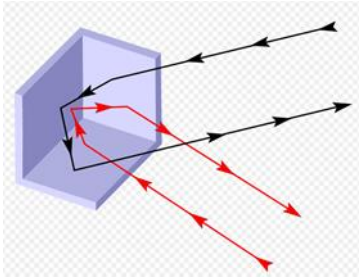


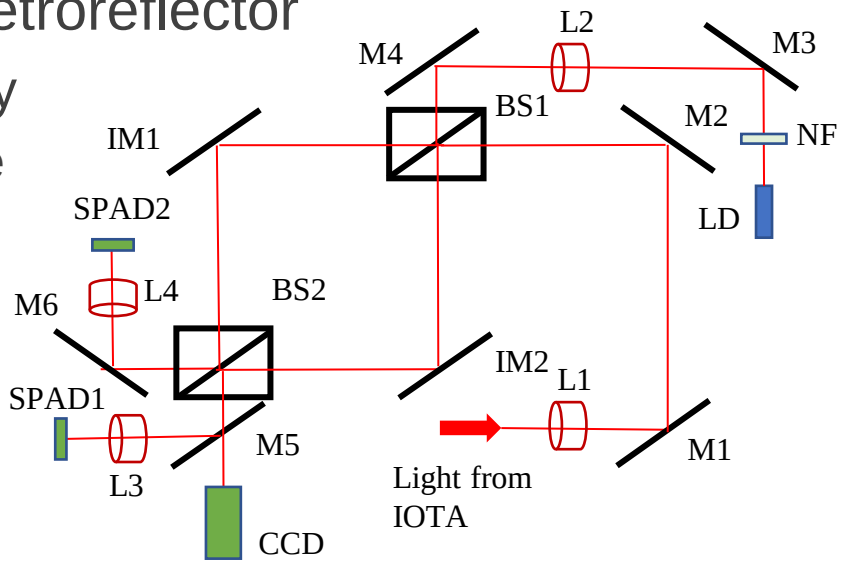
Estimation for alignment accuracy for single photons

- Measurements with SPADs
  - BS2 angle is small enough to make fringe period >> beam size
  - Arms are aligned well enough to drop the intensity to 1%
- Model
  - flat fronts at SPAD lens, Gaussian intensity distribution, spatial incoherence is ignored, all light goes to SPAD
    - Delay is formed by (difference in arm length) + (angle between fronts α_{BS2})*(beam size at the lens σ)
  - Fringe visibility: $V_{fr} \approx 1 - 2\pi^2 \left(\frac{\alpha_{BS2}\sigma}{\lambda}\right)^2$
  - To decrease intensity down to 1%, alignment needs to be
    - Difference between arms < 15 nm
    - BS2 misalignment < 5 μrad

Possible problem with the discussed scheme

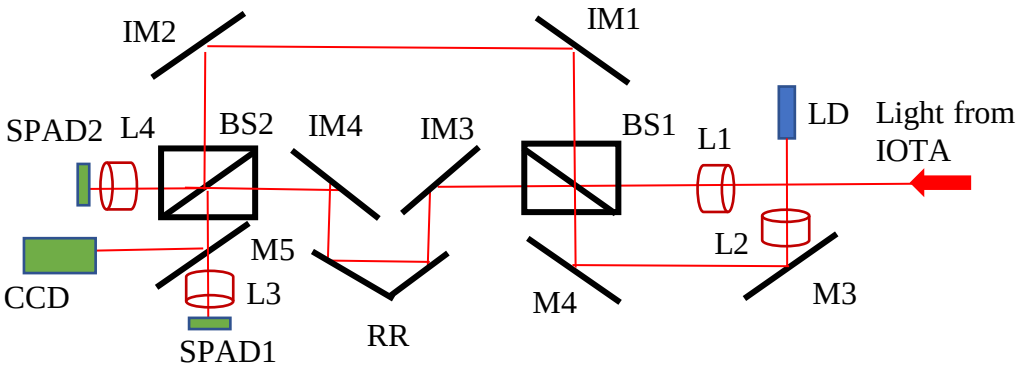
- Mechanical motion of the delay stage (where IM1 is mounted) is likely to create scatter in transverse angles >>5 μrad
  - ~150 μrad for the linear stage we consider
  - No problem for measurements with CCD but it creates difficulty for single-photon measurements
- Proposal
  - Consider a linear stage with a retroreflector
    - What Sergei proposed originally
      - With more precise linear stage





Scheme with retroreflector

- Mount a retroreflector at a precise linear stage
- New motorize elements
  - RR: X, 25 nm/16 mm
  - IM1, BS2: θx, θy
  - M5: flipping
- Existing motorized elements
  - 2 mirrors directing light from IOTA (M1, M2)
  - SPADs: X, Y, shutter
- Everything else is manual



M1, M2 – existing motorized mirrors directing light from IOTA (not shown)
IM1, IM3, IM3 – MZI manual mirrors
LD – laser diode
M3, M4 – manual mirrors to direct LD light
BS1 – manual beam splitter
BS2- motorized beam splitter
RR – retroreflector on a linear stage
https://www.newport.com/p/CONEX-SAG-LS16P
L1- L4 – lenses
SPAD1, SPAD2 – existing SPADs on 2D stages
CCD – existing CCD

Note on rough alignment

- A TZM alignment fixture was an effective tool for preliminary alignment of arms (< 1 mm)
  - Product of Sasha R
  - Will not work for the modified MZI
- Would be great to have a new one
  - More complicated shape