Fermilab

U.S. DEPARTMENT OF ENERGY | Office of Science

Notes on work in February 28 - March 9 , 2022

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Meeting on Undulator Light Interferometry Setup

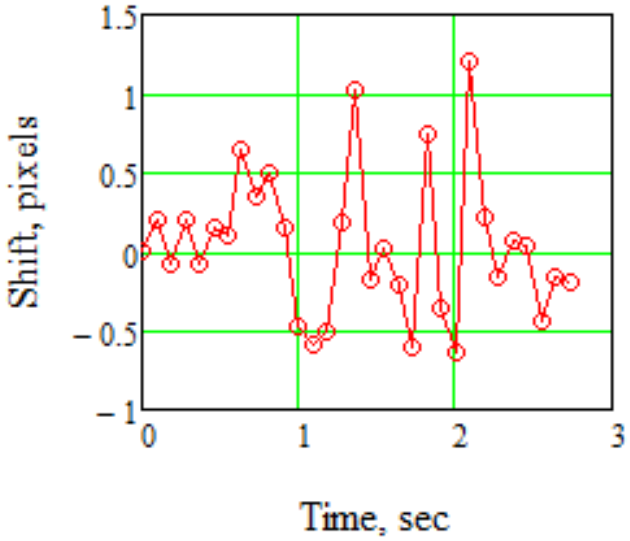
11 March 2022

Content

- Log of the work at ESB
- Next steps

Fringe jitter (28-Feb-22)

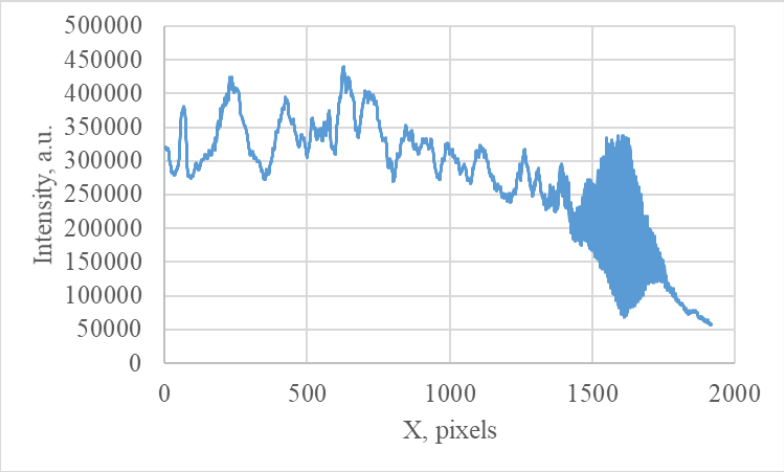
- From frame to frame, the fringes shift by 0.07 λ rms
  - The time scale is not clear. Time stamps report 90 ms between frames but the total time of recording was 60 sec.

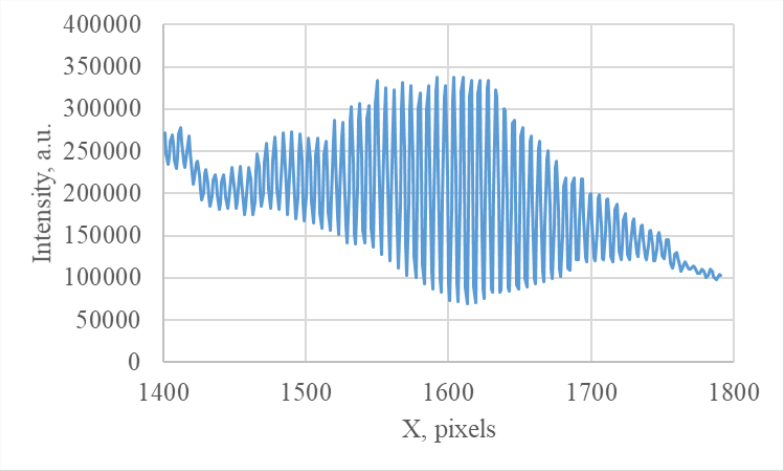


Shift of the images with respect to the first frame (in pixels). Fringe period is 5.8 pixels. Rms = 0.44, Max-Min= 1.8. The time difference is reported according to the recorded time stamps. The recording time was 60 sec. 31 frames. 2-Mar-22.

Recorded fringes from a short coherence length source

- 2-Mar-22: installed a laser diode and, with some luck, observed fringes
  - Behaved as expected
    - Fringes move left and right with delay in the arm (by a glass tilt)
    - Period changes with rotation of the second beam splitter

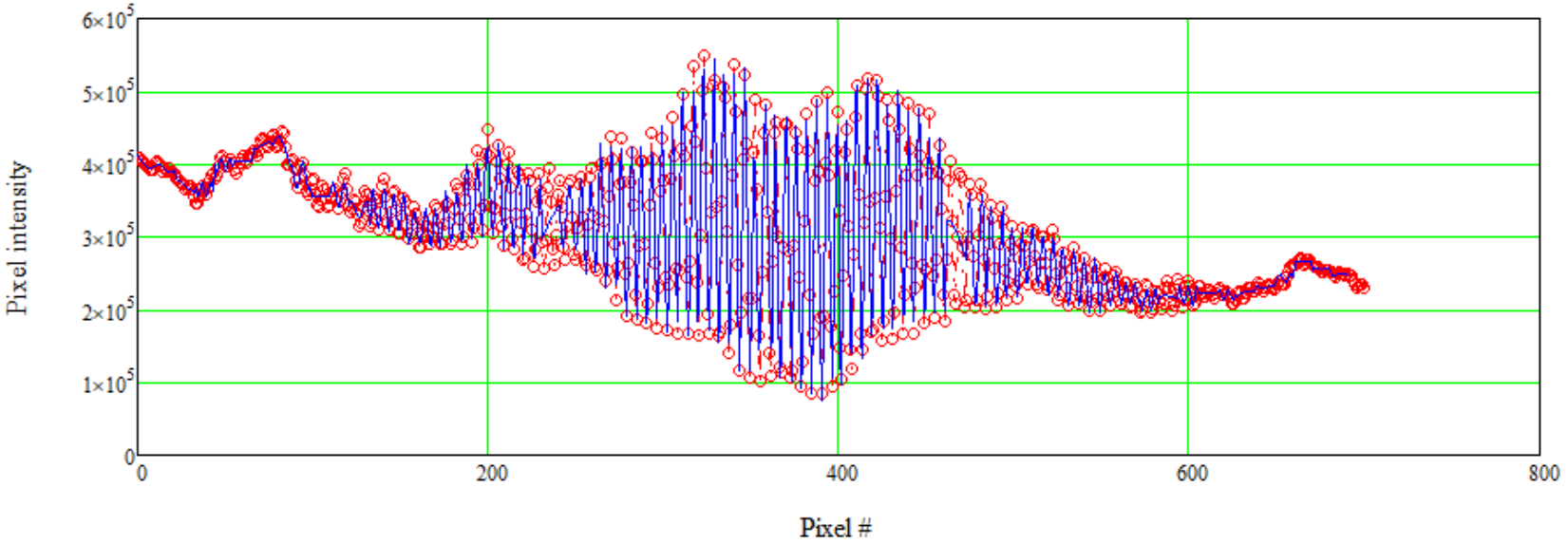




Horizontal projection of the image from a laser diode. The same data in two scales.
Data file LaserDiode1mmGlass.txt. 2-Mar-22.

Fringe fitting

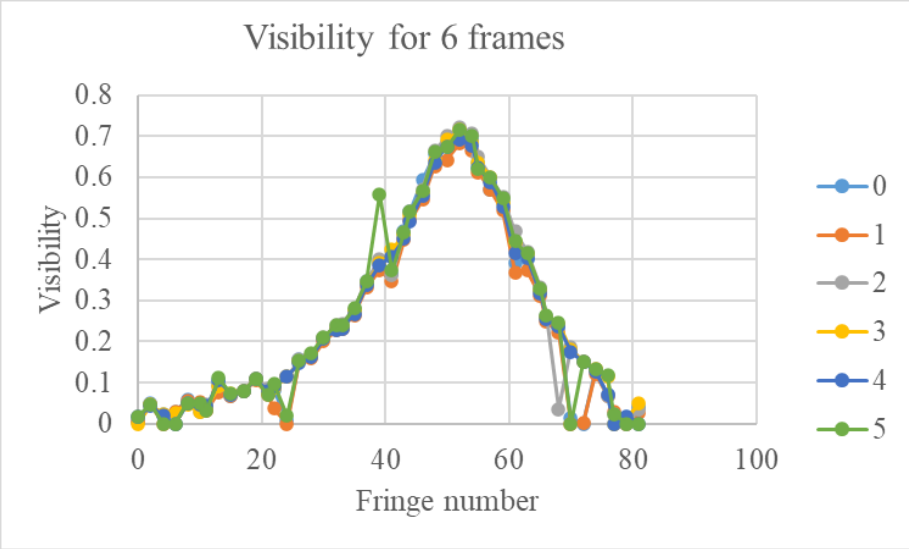
- Signal in the area filled with fringes is fitted to sine + const
  - Fitted over the length of ~periods
  - Free parameters is phase and average offset
    - Frequency is taken from Fourier spectrum
  - Reasonable fit quality except in two transition areas

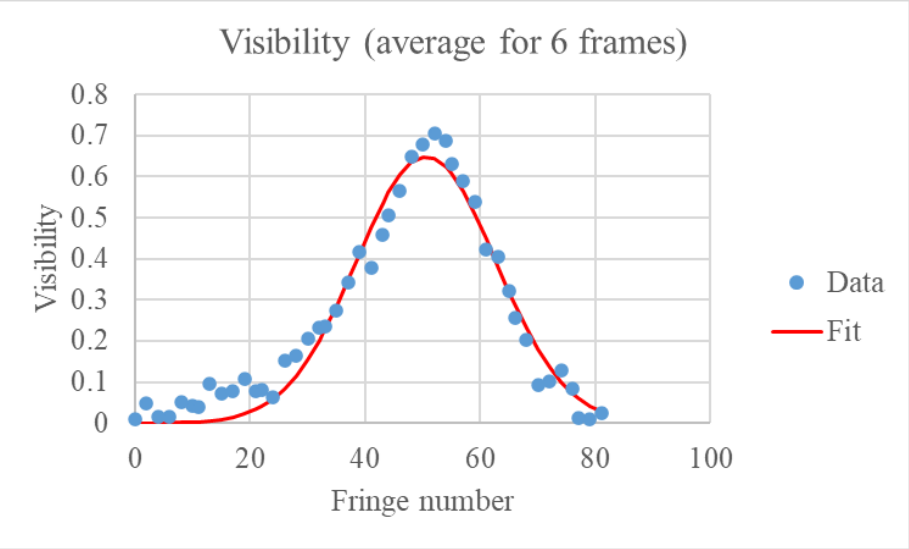


Fit (blue) and data (red) for the file LaserDiodeCentered.txt. 2-Mar-22.

Fringe visibility

- Fringe visibility: $F_{vis} = \frac{Max-Min}{Max+Min}$
  - Max 65-70%
  - Were not able to get the visibility closer to 100% as for HeNe





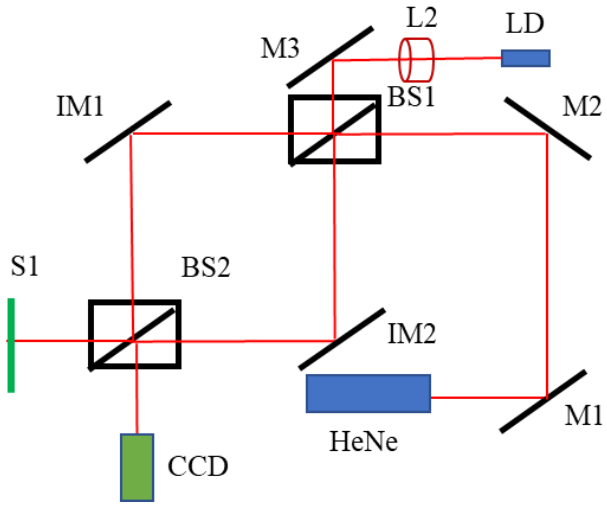
Fringe visibility for the file LaserDiodeCentered.txt. 2-Mar-22. Gaussian fit (red curve on the right plot) is with amplitude of 0.65 and sigma of 12.1 fringes.

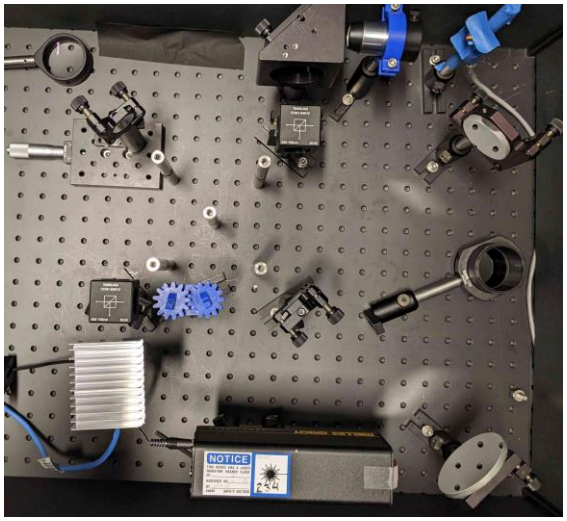
Attempts on 4-Mar-22

- Attempts to touch the length of one of the arms
  - The interference picture gone and attempts to bring it back failed
  - Can’t use the alignment fixture because the LD beam is large and lower intensity
- Conclusion
  - Need a better alignment procedure

9-Mar-22: alignment procedure

- Idea: to inject the HeNe and Laser Diode beams into different ports of the first beam splitter
- Assembled the setup with two sources + linear stage for IM1
  - Started with HeNe. Aligned MZI using the fixture. Combined images on CCD. Adjusted fringe period with BS2.
  - Switched to LD. Adjusted the arm length with IM1 linear stage
    - Got barely visible fringes

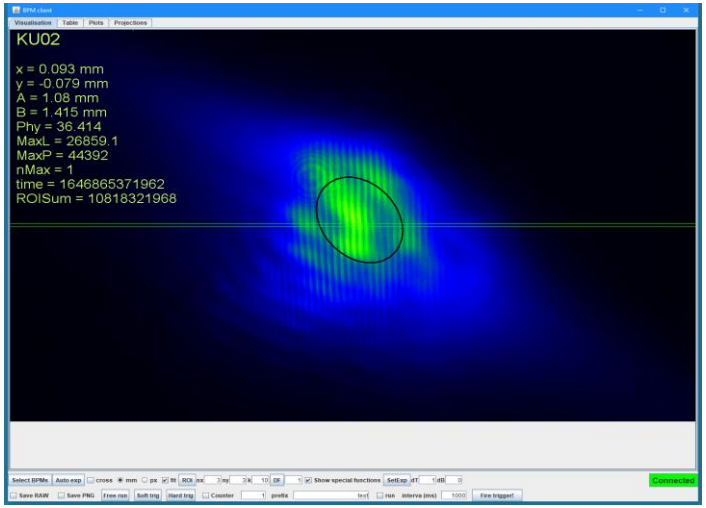




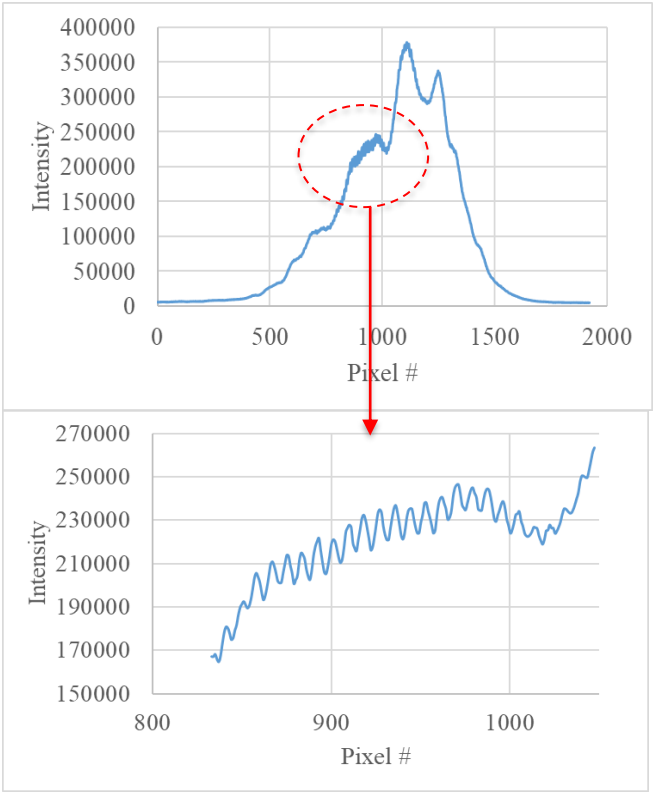
Setup with two sources and its photo in the final configuration. HeNe is HeNe laser. M1, M2 and M3 are mirrors outside of MZI. IM1(on a manual linear stage) and IM2 are mirrors inside of MZI. BS1 and BS2 are cubic beam splitters of the MZI. L2 is de-focusing lens. S1 is a screen. LD is a laser diode. CCD is a CCD camera.

Fringes

- Look and behave like fringes
  - Sensitive to the arm length (< 25 μm) and BS2 angle
- The fringe visibility is so low (<10%) likely because of low spatial coherence
  - May need to put a pinhole
    - Increase the distance LD-MZI?



CCD image with an increased fringe period. 9-Mar-22.



Horizontal intensity distribution across the image center with the laser diode at one of settings. The same data in different scales. 9-Mar-22.

Steps forward

- Get good fringes with a short-coherence source
  - Preferably comparable with N_λ~10
- Finalize the list of the planned measurements
- Estimate parameters of the undulator light at MZI
- Come up with the measurement scheme
- Order parts, assemble, test

Measurements

- Coherence length of light produced by a multi-particle beam
  - With CCD
- Coherence length of light produced by a single electron
  - With SPADs (or PMT?)
  - It is also demonstration of classicality of the undulator light
- Possible variations to look for interference of photons emitted by different electrons
  - two (or several) electrons; delay in one arm > coherence length

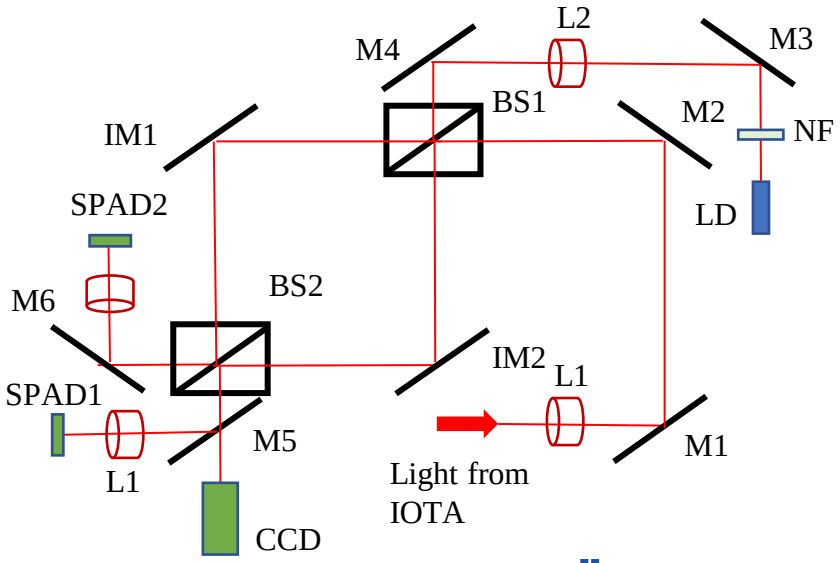
Expected parameters of the undulator light

- Photon flux
- Spatial coherence
- Divergence
  - To define the optical elements
- Estimate number of photons in a coherence volume
    - Degeneracy parameter?
  - If >1, should affect the interference picture
    - Interference between photons emitted by different electrons

- Had a discussion with Jonathan about him simulating with SRW

Possible scheme

- Features
  - Remote switching between multiple- and single-photon modes
    - Removable mirror M5
  - Short-coherence source (LED?) injecting light into second port of BS1 to check alignment of MZI
    - May be to tune the light to SPADs as well
  - MZI is assembled on a separate plate to decrease effect of vibrations
  - The arm 1 length is adjusted by moving mirror IM1 mechanically
    - Or with glass rotation; depends on light spot size



Elements

- M1, M2 – mirrors with remote angular adjustment in 2 planes
- BS1, M3, M4, IM2, probably M6 –manual angular adjusters in 2 planes
- M5 – remotely removeable mirror with manual angular adjusters in 2 planes
  - Having angles of M5, M6 remotely adjustable would be great
- IM1 –linear shift with <0.1 μm resolution+ remote fine angular adjustment in at least 1 plane
- BS2- beam splitter with remote fine angular adjustment in 2 planes