Microjet Feature Analysis for Sample Delivery Methods

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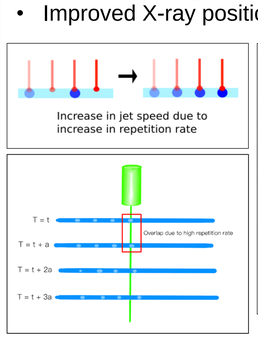
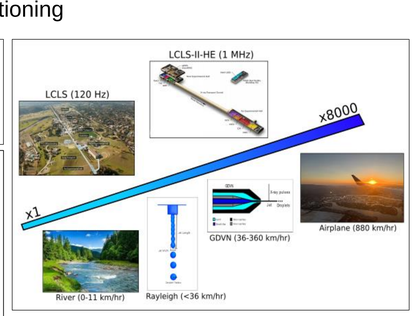
Sample Delivery: Transitioning from LCLS to LCLS-II-HE

[1]

LCLS-II-HE is an extension to the LCLS-II project that will increase the repetition rate by up to 1 MHz [1]
For sample delivery to utilize the technological advancement of LCLS-II-HE, there is a need for:

- Improved timing
- Improved X-ray positioning

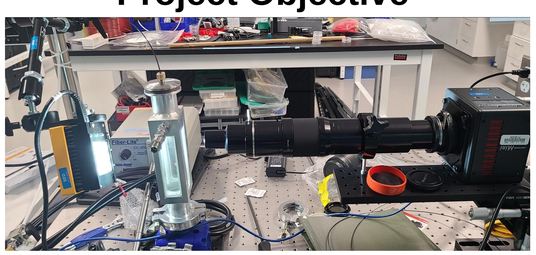




Time resolved experiments require a rapid triggering event to trigger the reaction events [2]

- Lasers and chemical triggers can be used to trigger the reaction before the jet by a delay of the jet

Project Objective

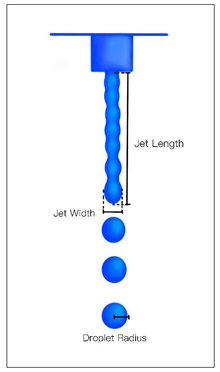


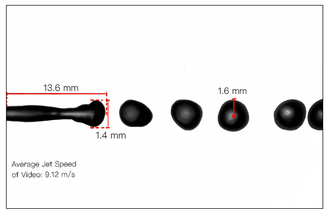
The purpose of the project is to develop a program that:

- Track features of the droplets, center and radius, to determine the speed of the jet
- Extract the jet thickness and length
- Work with both low-speed and high-speed jets

With a better microjet analysis tool, it can help with positioning the jet for a higher hit rate in sample delivery, and also finding the correct timing for time resolved experiments.

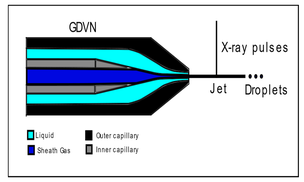
Rayleigh Jet (Slow Jet)

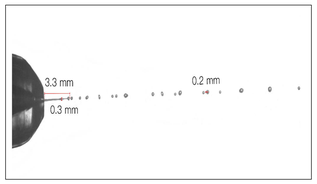




- Jet Speed (<10m/s)
- Large jet diameter (>20 microns)
- Single fluid nozzles
- High flow rates [3

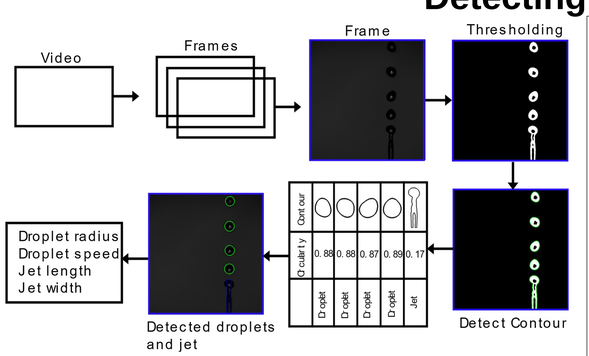
GDVN (Fast Jet)





- Jet Speed (10-100m/s)
- Small jet diameter (1-10 microns)
  - Sheath gas focuses the jet
- Two concentric capillaries with sheath gas on the outside and crystal slurry inside
- Suited for fast sample replenishment and serial crystallography experiments [3]

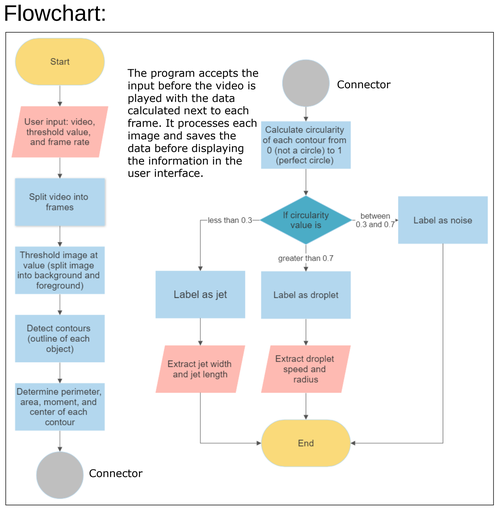
Detecting Features



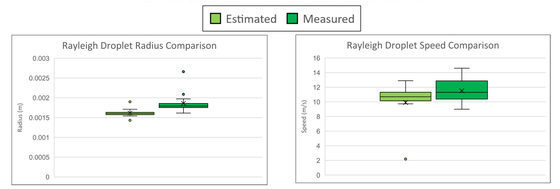

```
#Code Snippet
def detect_droplets_and_jet(self):
    circles_num, radius_sum, radius_avg,jet_width, jet_length = 0, 0, 0, 0
    droplet_list = []
    contours, _ = cv.findContours(
        self.processed_image, cv.RETR_EXTERNAL,
cv.CHAIN_APPROX_SIMPLE)
    for cnt in contours:
        moment = cv.moments(cnt, True)
        if moment["m00"] != 0:
            roundness, area, center_x, center_y =
self.detect_roundness(moment, cnt)
            if roundness >= 0.5:
                circles_num, radius_sum, radius = self.droplet_rad(
                    area, center_x, center_y, circles_num, radius_sum)
                droplet_list.append([center_y, radius])
            if roundness <= 0.3:
                jet_width, jet_length = self.jet_width_length(cnt)
    if circles_num > 0:
        radius_avg = radius_sum / circles_num
    return self.cimg, droplet_list, radius_avg, jet_width, jet_length
```

Github: https://github.com/gracexichen/microjetdetection
Libraries: OpenCV, Numpy, Matplotlib, Qt

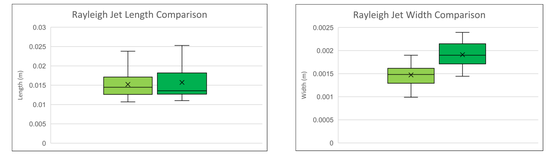
Flowchart:



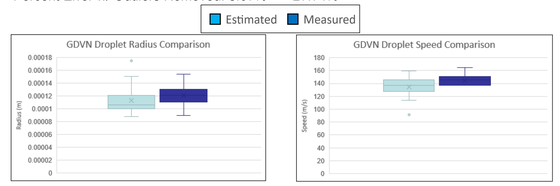
Data Distribution



Percent Error w/ Outliers Removed: 8.78% 12.32%



Percent Error w/ Outliers Removed: 3.07% 27.74%



Percent Error w/ Outliers Removed: 7.21% 7.57%

Conclusion

The error between the data extracted from the program for both low-speed jets (Rayleigh jets) and high-speed jets (GDVN) are minimal. The only feature with a high percent error is the jet width of 27.74%, which is likely due to the inconsistency with the method used to measure the data.

Future improvements for the program:

- A consistent measuring practice for jet width (diameter from thinner or thickest part of perturbation)
- Accuracy of other elements can be further improved possibly through deep learning algorithms
- The user interface controls can be improved to be more fluid

References

[1] https://lcls.slac.stanford.edu/lcls-ii-he
[2] https://pubs.aip.org/aca/sdy/article/4/3/032202/365626
[3] https://lcls.slac.stanford.edu/sed/methods
[4] https://accelconf.wb.cern.ch/ipac2022/papers/thpotk053.pdf

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