Droplet on Demand Sample Delivery: Modeling Signal Levels of Droplets Compared To Jets

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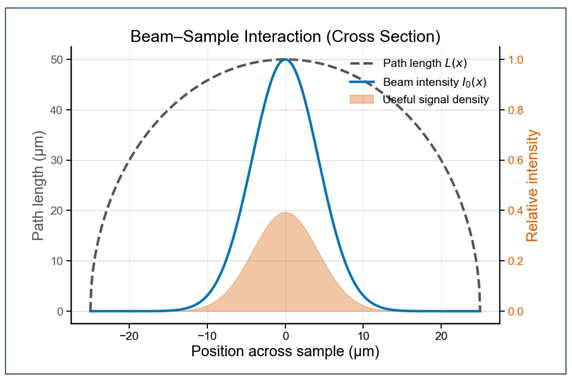
INTRODUCTION

- The goal of this work was to create a python notebook that can be used by scientists to design experiments
- Provide preliminary theoretical results that can serve as a starting point for experimental planning.

USEFUL SIGNAL

$$\text{useful signal} \propto \iint I_0(x,y)\left(1 - e^{-\mu L(x,y)}\right) dx\, dy$$

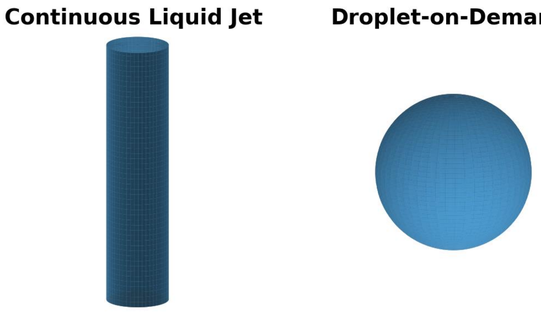


- Signal intensity as defined by Beer-Lambert
- Path length L(X, Y) is defined by sample geometry
- Assumptions such as Constant linear attenuation effects make these results rough approximations for experimental design

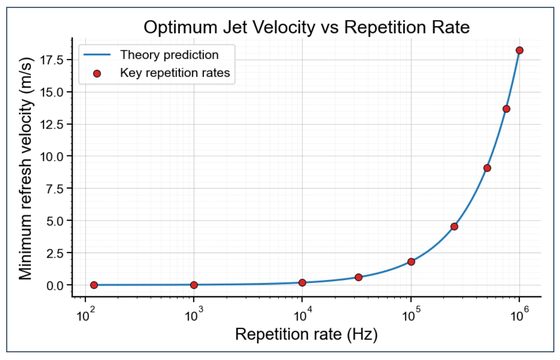
DOD COMPARED TO JET METHODS

- The DoD works by extruding a series of droplets at a specified frequency
- The jet is a stream of fluid
- The droplets are approximated as spheres, while the Jet is an infinite cylinder in this model

Continuous Liquid Jet **Droplet-on-Demand**



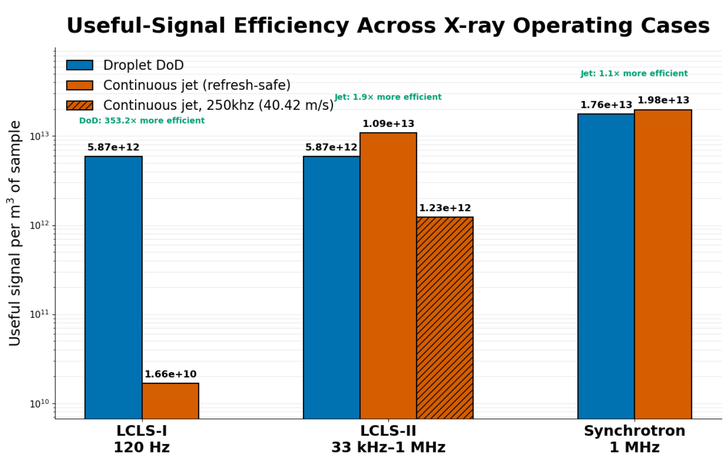
JET VELOCITY AND REFRESH RATE



- Refresh-rate calculations are needed to account for potential "double-hitting" issues with the jet.
- Required speed increases at higher frequencies.

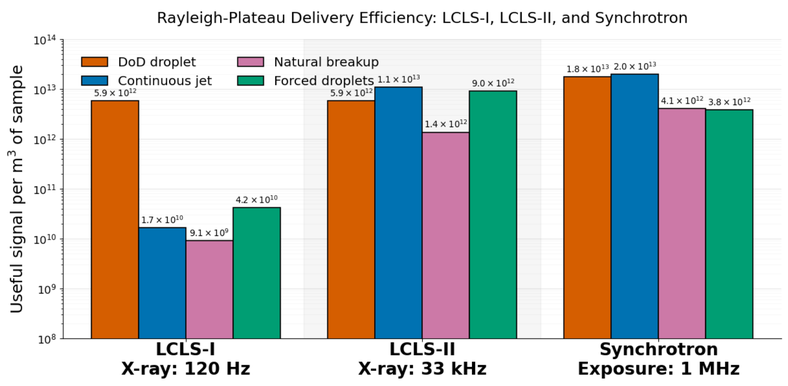
SAMPLE EFFICIENCY

$$\text{Sample Efficincy} = \frac{\text{Useful signal}}{\text{Volume (m}^3\text{)}}$$



- Sample efficiency is higher for DoD in the LCLS-I case.
- Sample efficiency is higher for the jet in the LCLS-II case.
- Synchrotron considers "double hitting"

RAYLEIGH'S BREAK UP

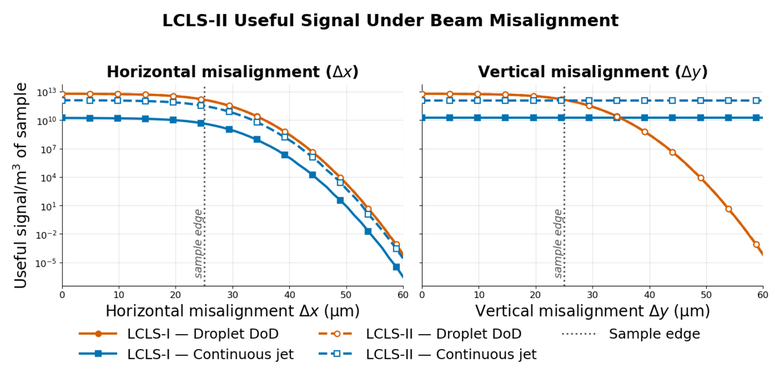


- Kooij et al., *Phys. Rev. Lett.* 135, 214001 (2025).

- Breakup analysis shows that the jet becomes less efficient when the beam is pointed toward the non-continuous region of the jet.
- Forced breakup increases signal efficiency compared to natural break up

Beam Type	Breakup Method	Freq(kHz)
LCLS-I	Natural breakup	6.28
LCLS-I	Forced droplets	0.12
LCLS-II	Natural breakup	2.64
LCLS-II	Forced droplets	33.00
Synchrotron	Natural breakup	43.94
Synchrotron	Forced droplets	40.00

MISALIGNMENT



- Sample efficiency is not affected with misalignment in the y direction in the jet case
- X misalignment is the same for the jet and cylinder

CONCLUSION

- This python notebook will help scientist to do rough calculations
- The model allows comparison of DoD and jet sample-delivery methods.
- Results can be used to estimate sample efficiency, signal levels, and refresh-rate requirements.

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REFERENCES

S. Kooij, D. T. A. Jordan, C. J. M. van Rijn, N. M. Ribe, and D. Bonn, "What Determines the Breakup Length of a Jet?," *Physical Review Letters* **135**, 214001 (2025). doi:10.1103/jf6w-l5sy.