Bringing Back the ’90s: A CD-Spinner Approach to Sample Delivery for High Frequency Lasers

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Background

- Higher-repetition-rate XFEL operation requires faster sample replenishment to avoid repeated shots on damaged regions.
- This project explores a CD-spinner-style platform to move fresh sample through the LCLS x-ray interaction point.

Cross section of spinner

Theoretical Calculations

- The 20-chamber design **only works for low-rate testing.**

LCLS Rep Rate (Hz)	Radius of Disk	Chambers	Required RPM for design	Tangential Velocity at Sample (m/s)	Centripetal Acceleration (g)
30	60mm	20	90	0.57	0.54
120	60mm	20	360	2.26	8.69
2.00E+03	60mm	20	6.00E+03	37.70	2414.58
3.50E+04	60mm	20	1.05E+05	659.73	739465.77
1.00E+05	60mm	20	3.00E+05	1884.96	6036455.3
1.00E+06	60mm	20	3.00E+06	18849.56	603645529.1

- The red values show conditions where the current design would likely fail.

LCLS Rep Rate (Hz)	Radius of Disk	Chambers	Required RPM for design	Tangential Velocity at Sample (m/s)	Centripetal Acceleration (g)
30	60mm	20	90	0.57	0.54
120	60mm	20	360	2.26	8.69
2.00E+03	60mm	60	2000.58	12.57	268.44
3.50E+04	60mm	1.06E+03	1989.44	12.50	265.46
1.00E+05	60mm	3.02E+03	1989.44	12.50	265.46
1.00E+06	60mm	3.02E+04	1989.44	12.50	265.46

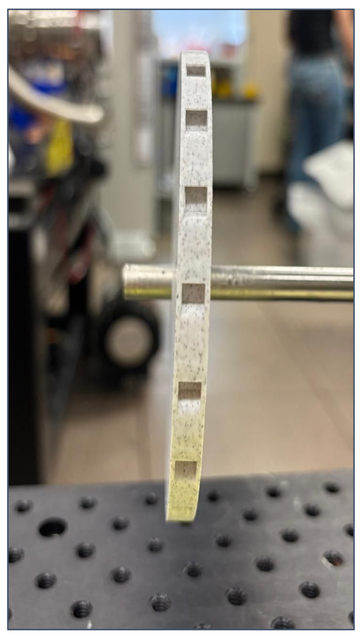
- The green values are more achievable mechanically, but require much smaller chambers and tighter spacing.

Sample Collection

- The disk **passes through a lower sample reservoir** to scoop fresh material during each rotation.
- Collected sample is carried upward into the x-ray interaction region.
- Excess sample is contained by chamber walls and may be cleared using a side purge/cleaning jet.

Design Prototypes

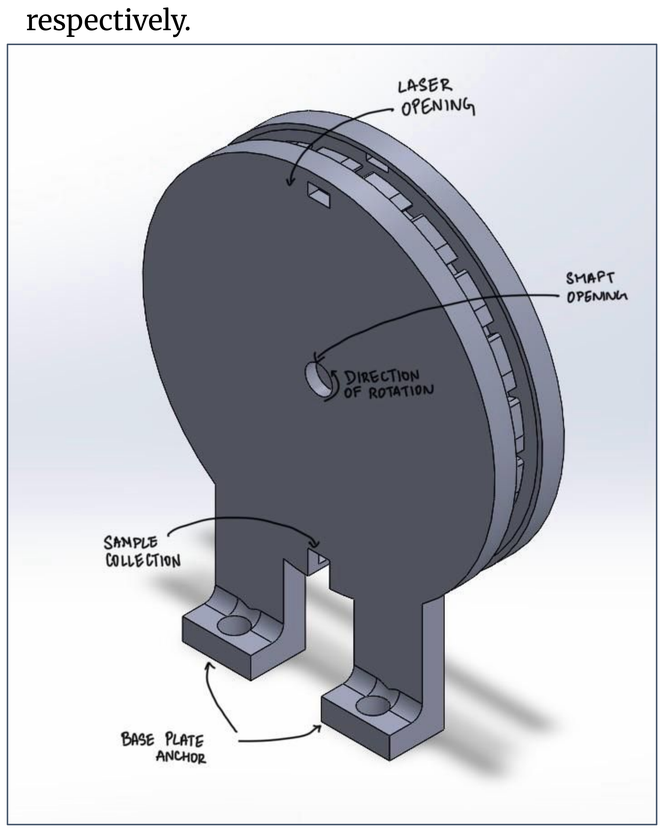
- Main design problem was to address the issue of sample flying off of the chambers while it spins at high speeds. Both the prototypes can hold sample up to 160 mm^3 (0.16 mL).
- **Prototype 1:** Partially covered chamber open from the top to let sample and laser beam through, thickness = 5 mm.



Chambers	Chamber length (mm)	Chamber depth (mm)	Chamber width (mm)	Distance between chambers mm)	Chamber Volume (µL)
20	5	4	8	10.84	160
60	3	4	4	2.28	48
1.06E+03	0.1	0.1	0.27	0.1	0.0027
3.02E+03	0.05	0.05	0.076	0.05	0.00019
3.02E+04	0.005	0.005	0.0076	0.005	0.00000019

- More chambers lower the required RPM but reduce available space per chamber.
- 20–60 chambers are realistic for prototype testing, 1000+ chambers require further design refinement.
- 30,000 chambers are physically impossible.

- **Prototype 2:** Designing a covering and mounting it to the base plate with openings at the bottom and top to collect the sample and shoot the laser respectively.



Previous Work

- Prior work **demonstrated a spinning-disk sample delivery system** that continuously delivered solid sample material.
- The system was tested at LCLS and European XFEL.
- A 25 µm copper foil disk was **successfully operated at 3000 rpm,** with testing up to half-MHz sampling and short periods at 1.13 MHz.

Next Steps

- **Design and test prototypes beyond 120 Hz** for higher-repetition-rate LCLS conditions.
- Use **high-speed/stroboscopic imaging** to observe rotation, sample pickup, and material loss.
- Iterate motor speed, disk design, reservoir depth, and cleaning-jet placement.

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REFERENCES

1. N. Welke et al., “Development of spinning-disk solid sample delivery system for high-repetition rate x-ray free electron laser experiments,” Review of Scientific Instruments, 94, 103005, 2023.
2. SLAC National Accelerator Laboratory, Linac Coherent Light Source documentation and beamline resources.