Development of Laser Ablation Ion Sources for Ba-tagging

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Ba-tagging in nEXO

The nEXO collaboration is working on the development of the Ba-tagging technique, a future upgrade which incorporates the detection of the Ba ion daughter by "tagging" candidate $0\nu\beta\beta$ events[1]. A successful Ba-tagging technique will:

- Identify true ββ-decay events.
- Increase sensitivity of the detector[2].

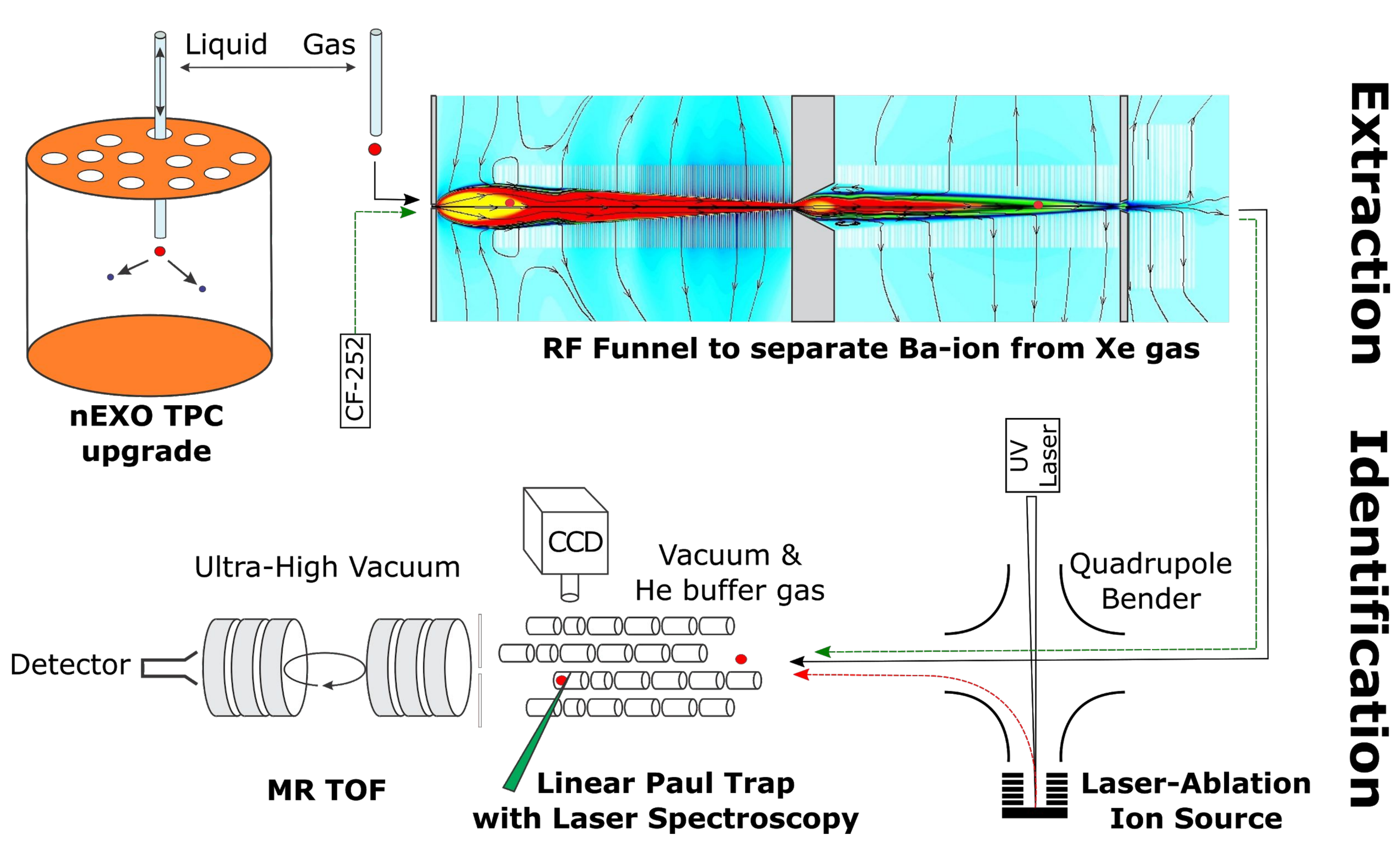


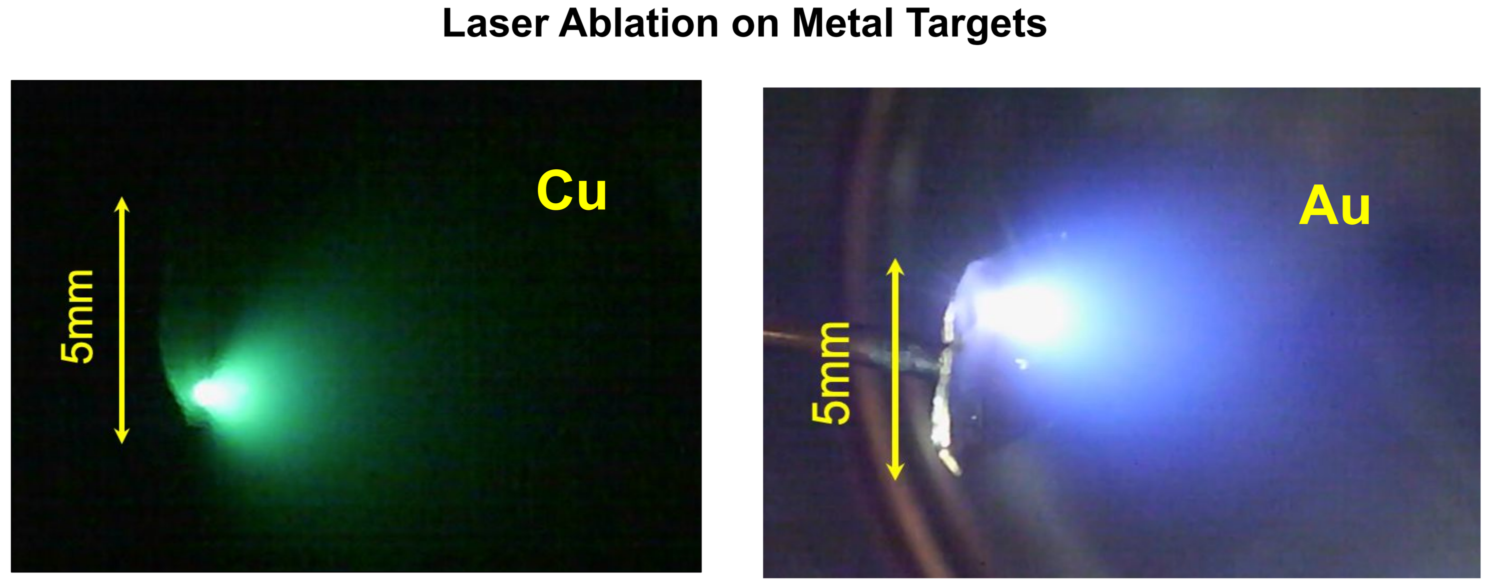
Figure source [3].

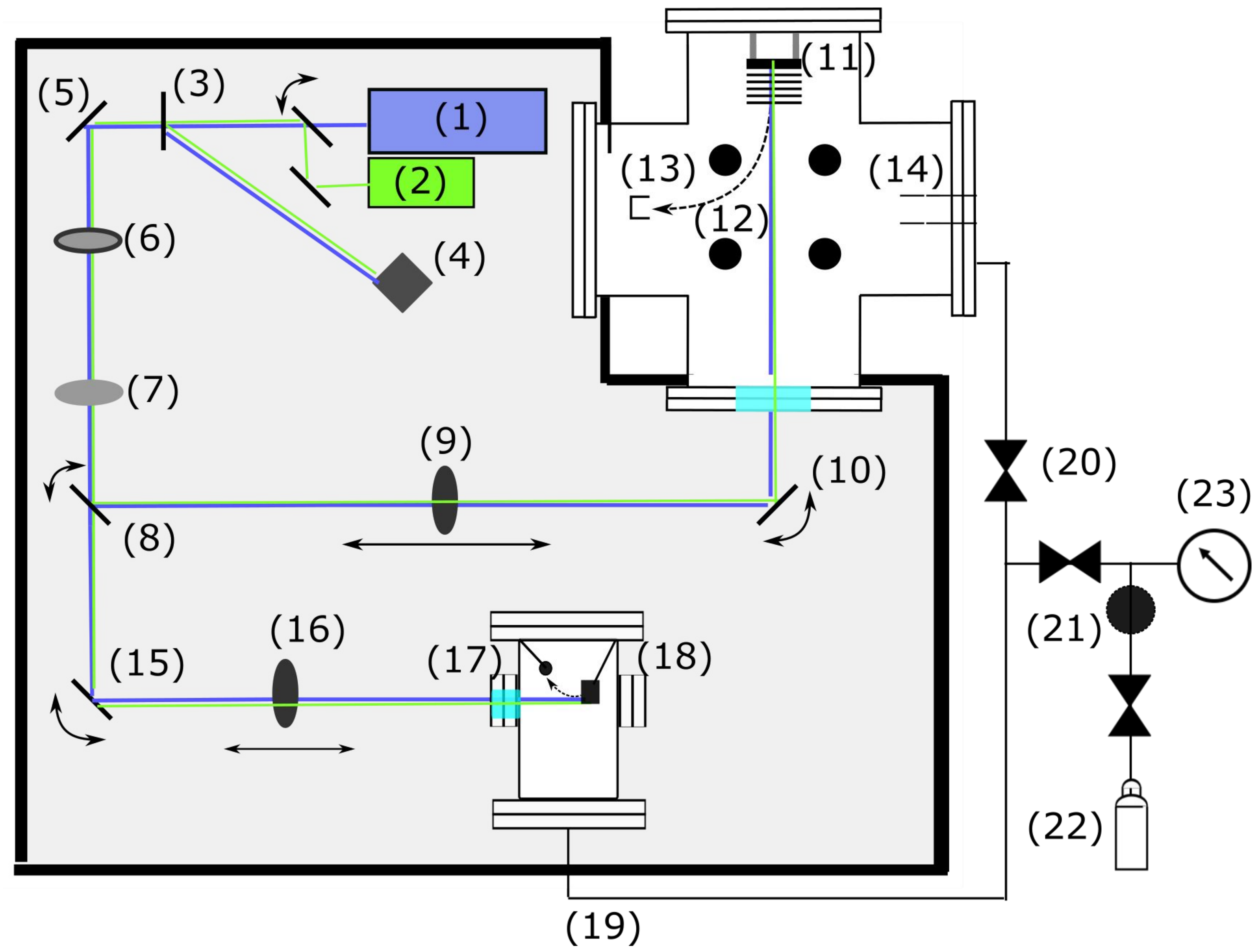
The Laser Ablation Ion Source (LAS) is a system comprised of a 349 nm pulsed UV laser that is guided by optical components to ablate multi-element targets, producing various ion species[4]. This has been demonstrated in vacuum and a system for high-pressure gas is being developed.

It is suitable for Ba-tagging because,

- Ions with different mass-to-charge ratios can be generated to calibrate the mass spectrometer.
- Ba ions can be produced for laser spectroscopy in the Linear Paul Trap.
- Ions can be produced in high-pressure Xe-gas, with relatively low ionization of the Xe compared to radioactive sources.

Laser Ablation on Metal Targets





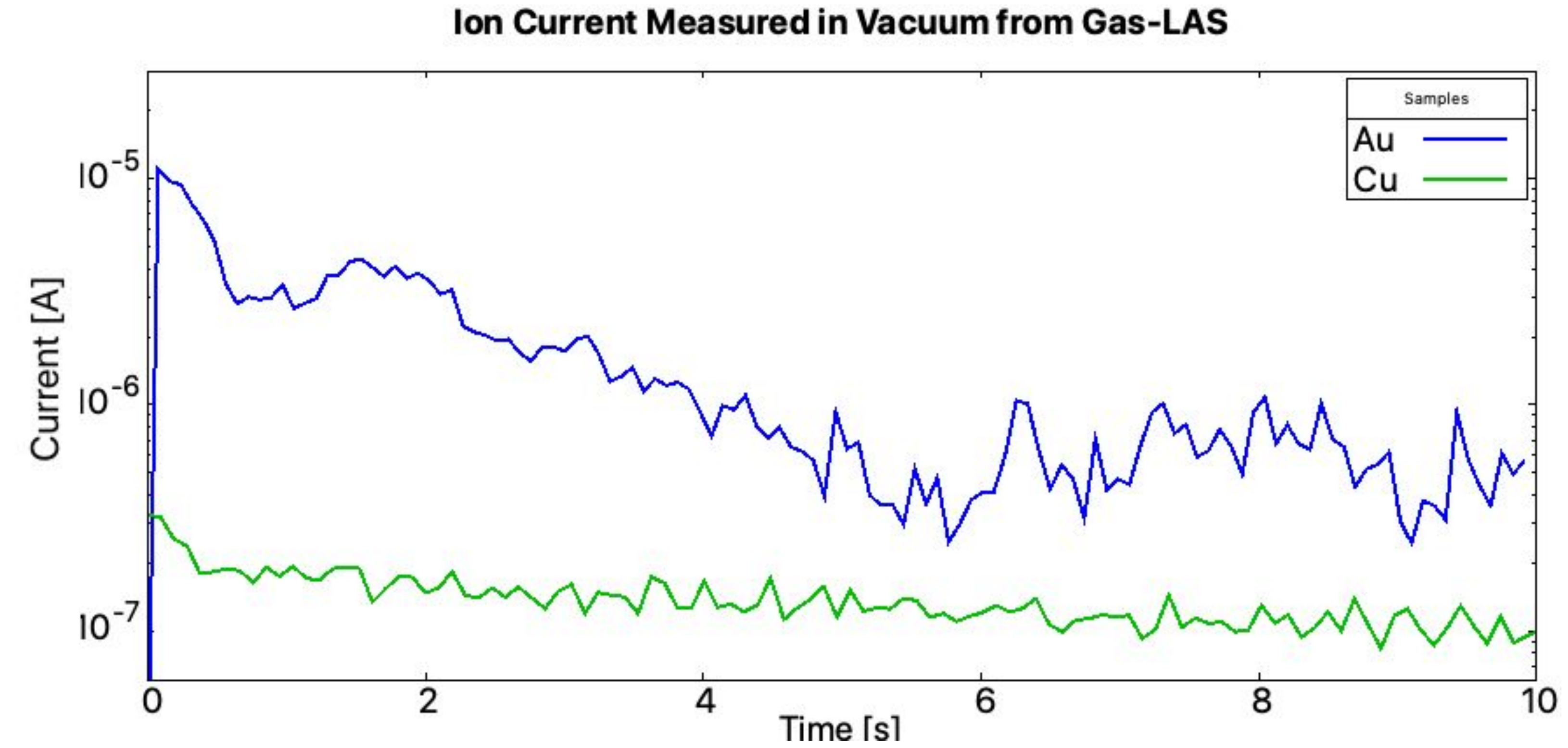
The LAS at McGill starts with a (1) 349nm laser striking a (3) beam splitter to measure the incoming beam's power and energy density by sending one part of the beam to a (4) power meter. The rest of the beam follows the optical trajectory, until it is reflected by (15,10) a motorized mirror that allows a complete scan of the target housed by the in-vacuum and in-gas system, respectively.

LAS in-gas system

The in-gas system extracts ions from a biased target, producing a visible ion plume. It also measures the target material's ion current by capturing the ions through a collector plate.

The goal is to study laser ablation under specific environmental conditions such as GAr and GXe at various pressures. This is done by measuring the target material ion current as function of gas pressure, applied bias, laser power and ion drift length on different targets.

Ion Current Measured in Vacuum from Gas-LAS

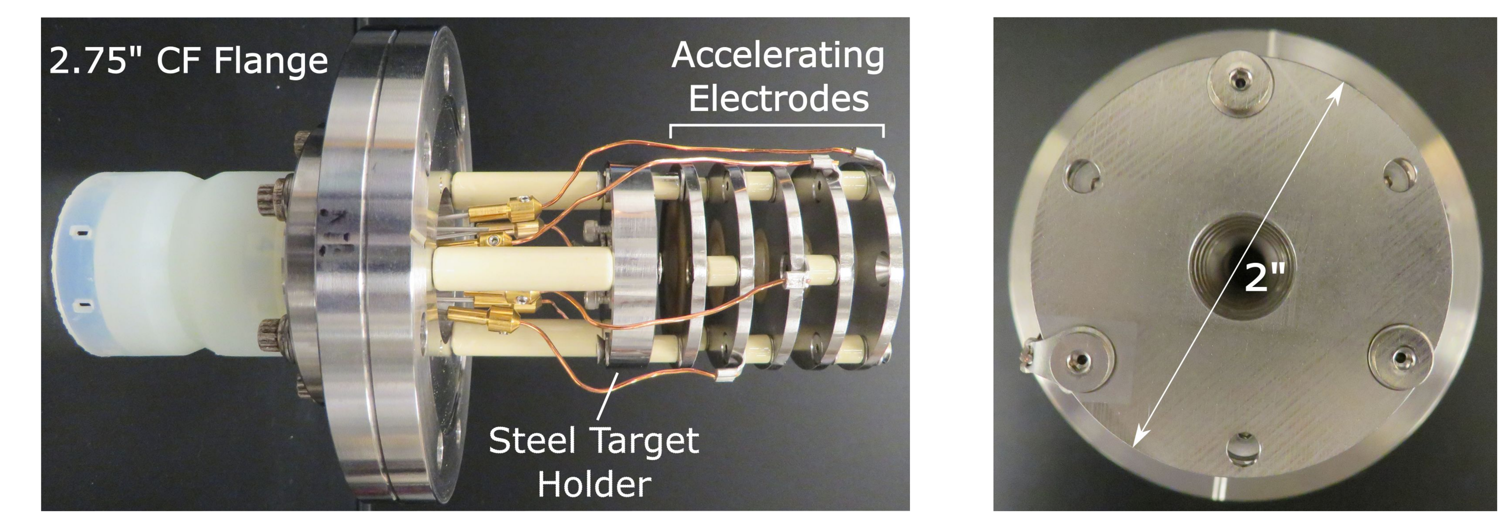


LAS in-vacuum system

This system uses a kinematic motorized mirror mount to selectively ablate a multi-element target with.

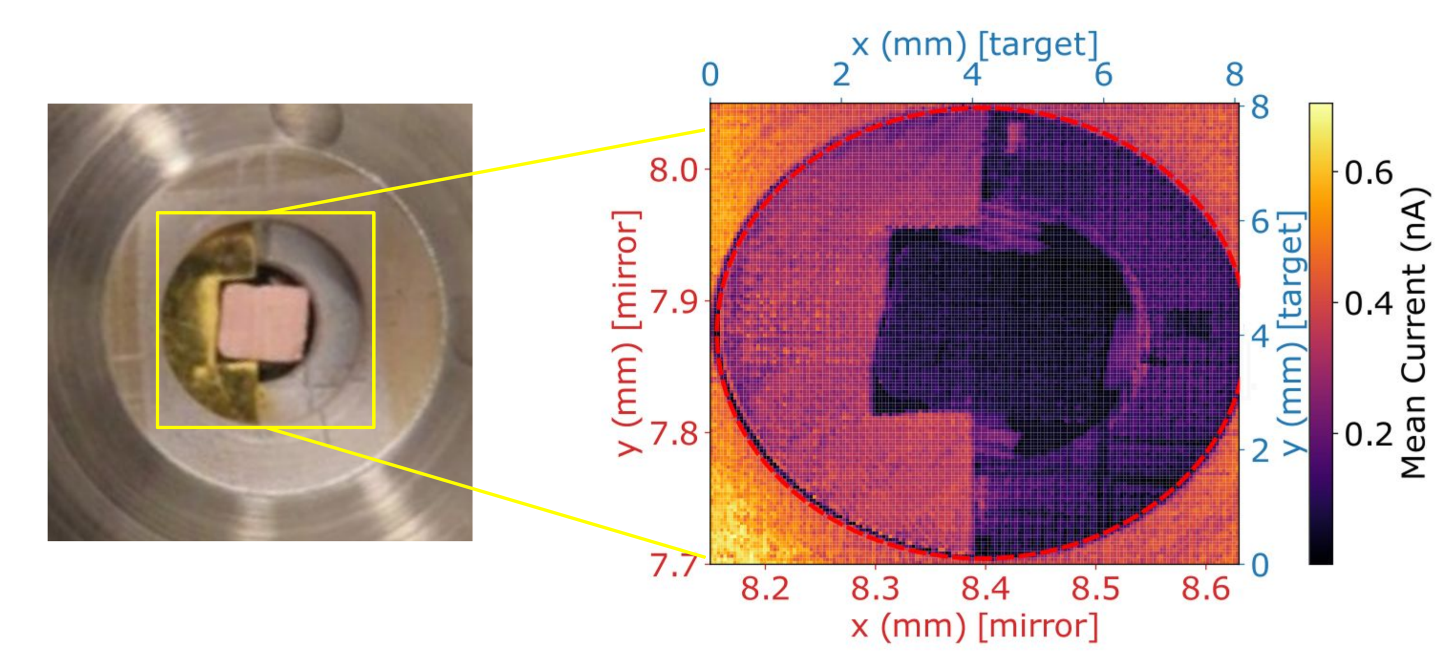
- The UV laser is positioned on the target surface by a final reflection from a motorized mirror.
- A labVIEW program actuates the mirror motors while measuring the ion current to create scans of the target.

In-vacuum ion source



- The spatial resolution for selectively ablating material is approximately 0.1 mm.
- To characterize this, distance actuated by the mirror motors is converted to a distance traveled on the target.
- This calibration is done by fitting an ellipse to the target holder, and comparing this with its actual diameter.

Gold, Niobium and Copper target



Conclusions and Outlook

Both ion sources have been tested in vacuum conditions, where the ion current produced from a target surface has been measured, and can range up to 200 nA.
Next steps:

- Study ions and ablation process within the presence of a background gas.
- Study ions produced from targets with mass spectrometer.

References
[1] Moe, M. K. Detection of neutrinoless double-beta decay. Phys. Rev. C 44 (1991),R931–R934.
[2] Albert, J. et al. (nEXO Collaboration) Sensitivity and discovery potential of nEXO to neutrinoless double beta decay. Phys. Rev. C 97, 065503 (2018).
[3] Murray, K. et al. Design of a multiple-reflection time-of-flight mass spectrometer for barium-tagging. Hyperfine Interactions 240.1 : 97 (2019).
[4] Elsied, A. M. et al. Nanosecond laser-metal ablation at different ambient conditions. Spectrochimica Acta Part B: Atomic Spectroscopy, 143:26–31 (2018).