Production of negative helium ions via transmission through nano-foils

Philip Jackle[1], K. L. Kavanagh[1], and M. Dehnel[2] | [1]Simon Fraser University (Burnaby, BC Canada), [2]D-Pace Inc. (Nelson, BC Canada)

Helium Ion Microscope

- Zeis Orion NanoFab helium ion microscope (HIM).
- He^+ ion beam, 10 ~ 30 keV, < 20 pA.

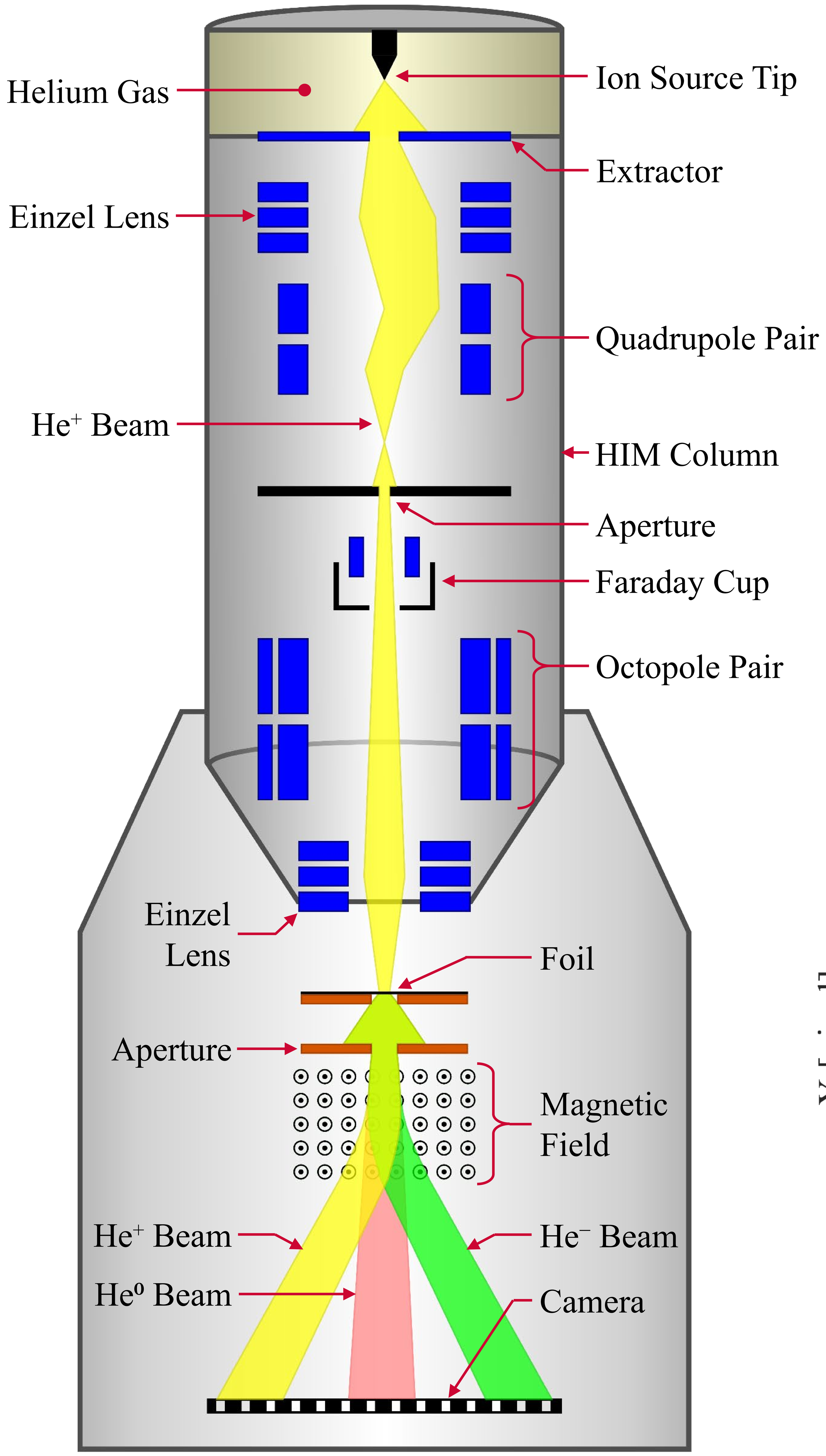


Figure 1: Schematic diagram of the Zeiss Orion NanoFab helium ion microscope (HIM) and experimental setup.

1. Motivation

- He^- commonly made from He^+ and charge exchange with alkali metal vapour (1~2% efficiency).
- The semiconductor industry cannot tolerate alkali, or other metal, contamination in their accelerators [1].
- Efficient charge exchange alternatives are desired.
- Thin foils as the charge exchange material are being investigated for this purpose with the HIM at SFU.

2. Experiment

- Expose He^+ beam (0.1 ~ 0.2 pA, 30 keV) from HIM onto nano-thickness foil, Ø50 µm beam spot size.
- Trim exiting ion/atom beam with limiting aperture.
- Separate exiting ion/atom beam into distinct beamlets (He^+, He^0, He^-) with a dipole magnetic field.
- Measure beamlet intensities with a CMOS radiation camera (Advacam MiniPIX).
- Calculate ratios of transmitted ions/atoms.

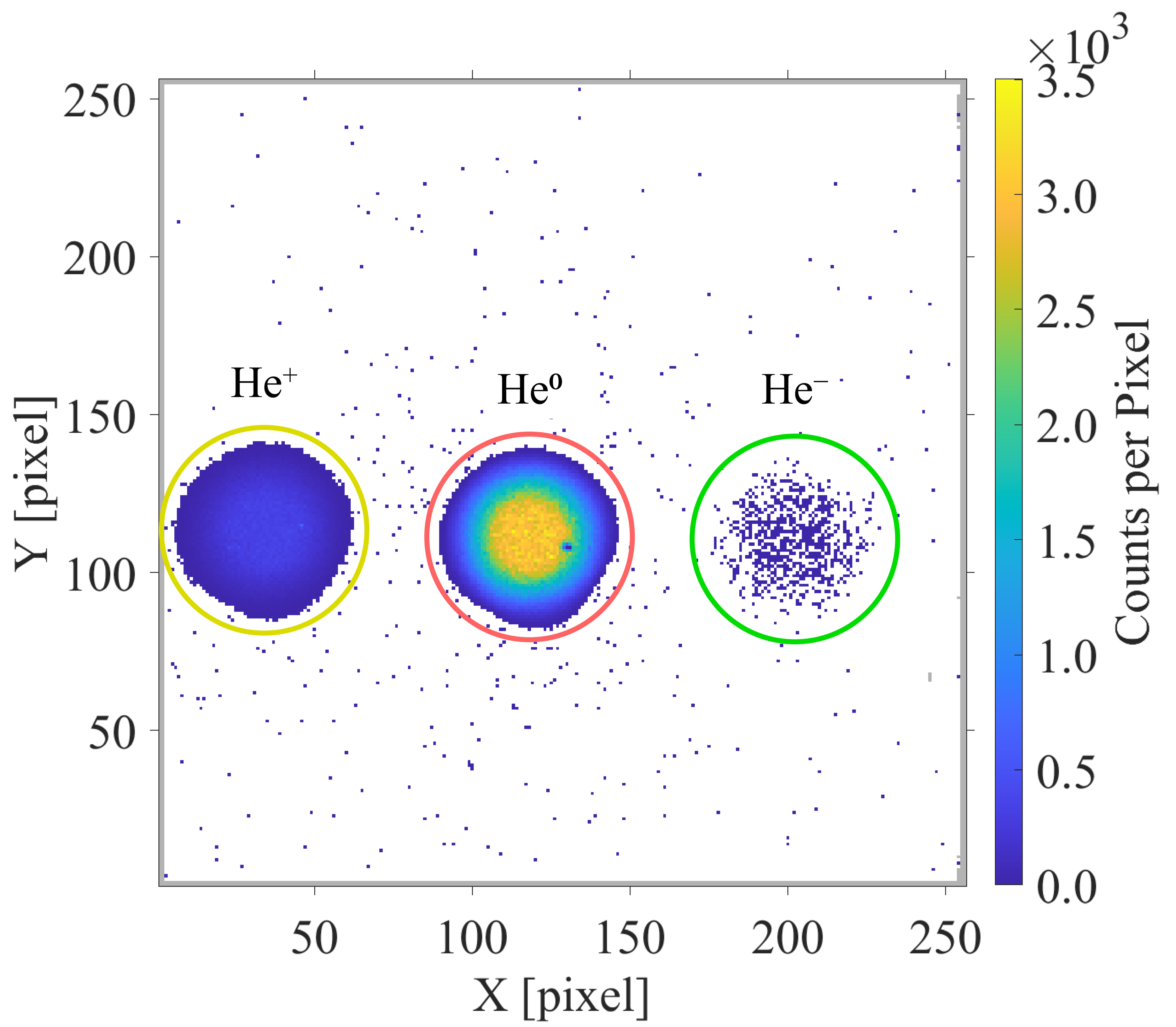


Figure 2: CMOS camera measurement for 0.12 pA, 30 keV He^+ beam onto a 2 nm thick polycrystalline gold foil for 505 sec. He^+, He^0, and He^- beams identified.

3. Results to Date

Percent of Total Transmission [%]

Foil	Thickness	He^- ± 4%	He^+ ± 0.02%	He^0 ± 0.01%	Other ± 10%
Pd	2 nm	**0.024**	8.54	91.4	0.016
Au	2 nm	**0.022**	10.18	89.8	0.011
Pt	2 nm	**0.024**	9.37	90.6	0.016
C	3~4 nm	**0.024**	9.10	90.9	0.010
C	10 nm	**0.023**	8.83	91.1	0.011
SiN_X	10 nm	**0.020**	10.44	89.5	0.012
TiO_X	10~20 nm	**0.023**	9.33	90.6	0.015
SiO_2	20 nm	**0.005**	10.42	89.6	0.019

4. Outlook

- Experiments with carbon foils agree with previous measurements [2].
- Further experiments with 10, 15, 20, and 25 keV.
- Future analysis will compare distributions of the He^+, He^0, and He^- beams.

References

[1] G. Borionetti et al, "Metal and Organic Contamination Effects on the Characteristics of Thin Oxides Thermally Grown on Silicon Based Wafers", NIMB Beam Interactions with Materials and Atoms, Vol 253, Issues 1-2, pp. 278-281 (2006).

[2] R. Holeňák et al, "Simultaneous assessment of energy, charge state and angular distribution for medium energy ions interacting with ultra-thin self-supporting targets: A time-of-flight approach", Vacuum 185 (2021) 109988.

Acknowledgments

We acknowledge the support of the Natural Sciences and Engineering Research Council of Canada (NSERC) and D-Pace, Inc.

Nous remercions le Conseil de recherches en sciences naturelles et en génie du Canada (CRSNG) de son soutien et D-Pace, Inc.

We also acknowledge the help of Dr. Søren Pape Møller at Aarhus University, for his collaboration with Dr. Morgan Dehnel in developing the concepts for this research.

Presented at the 21st International Conference on Ion Sources (2025)

Production of negative helium ions via transmission through nano-foils

Philip Jackle[1], K. L. Kavanagh[1], and M. Dehnel[2] | [1]Simon Fraser University (Burnaby, BC Canada), [2]D-Pace Inc. (Nelson, BC Canada)

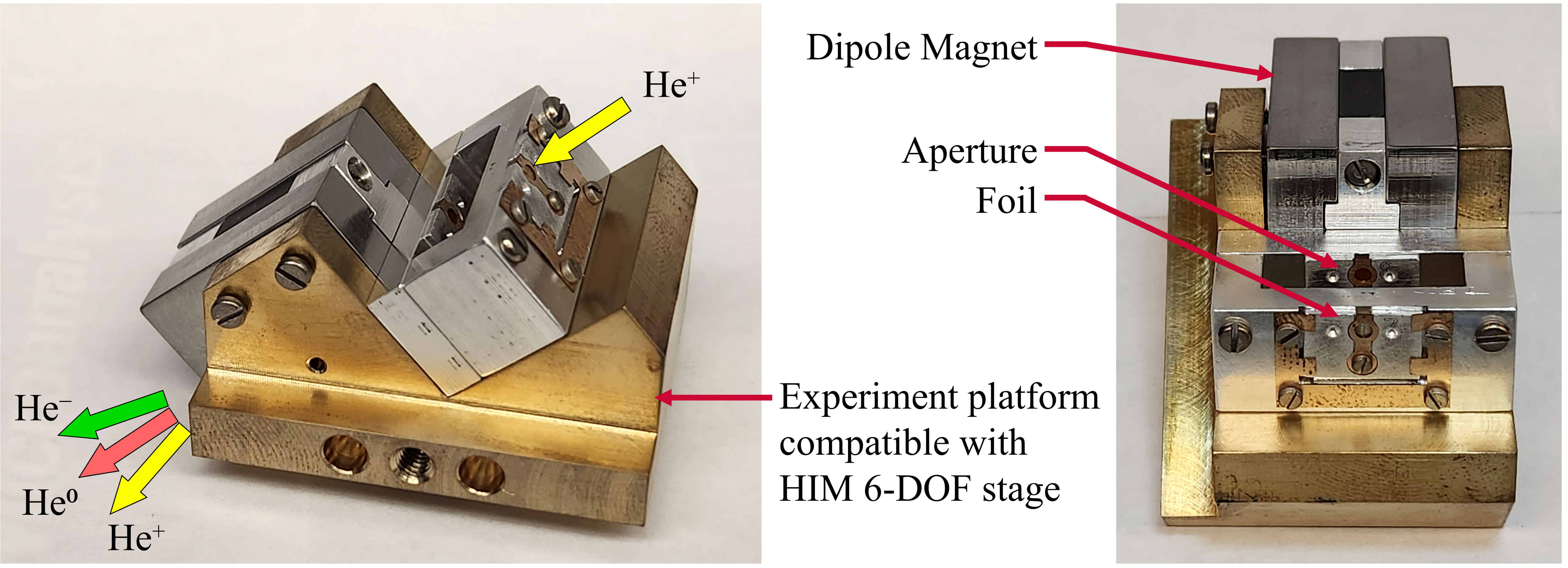


Figure 3: Custom experiment setup for use in the HIM. Mounting for nano-foils on Ø3 mm TEM grids or apertures. Includes collimating aperture, and dipole magnet: 0.020 ~ 0.075 T configurable.

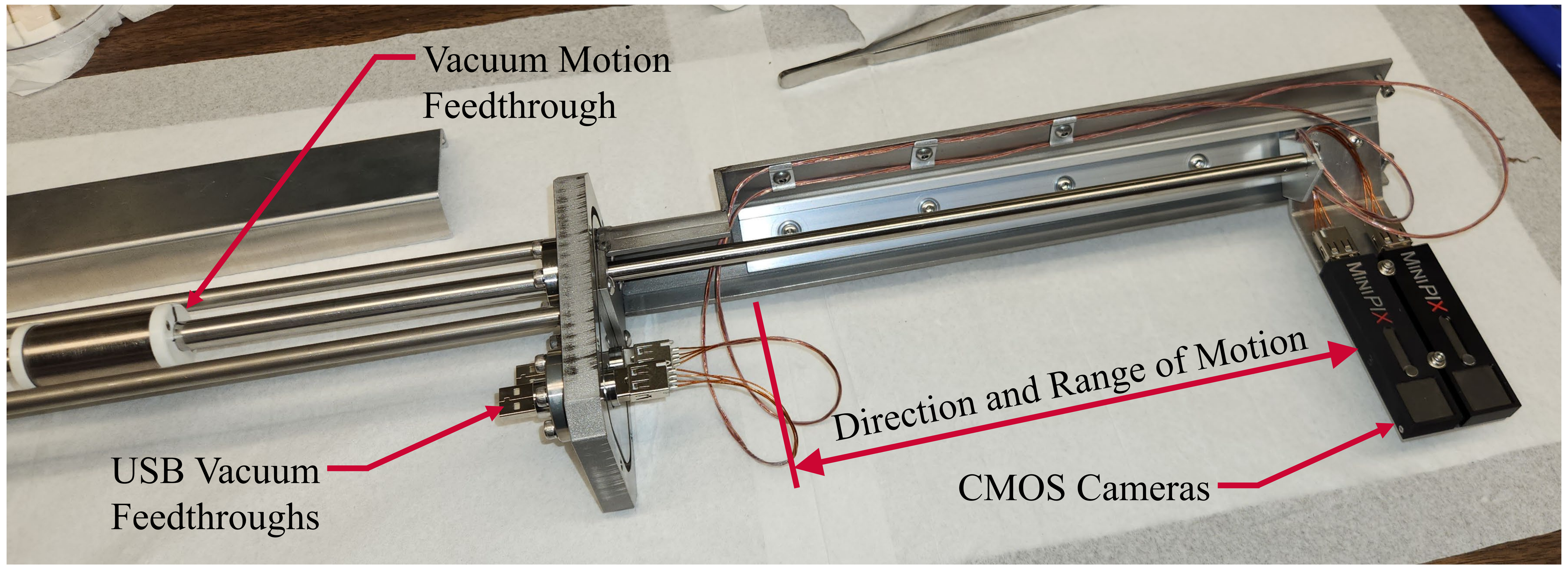


Figure 5: Custom designed camera stage, providing mounting for two Advacam TimePIX radiation cameras, and one degree-of-freedom motion for camera positioning in the transmitted beam path.

Foils for Experimentation

- 3~4 nm thick Carbon: Electron Microscopy Sciences (CFGA100-Cu-UL)
- 5~6 nm thick Carbon: Electron Microscopy Sciences (CFGA100-Cu-25)
- 10 nm thick Carbon: Electron Microscopy Sciences (CFGA100-Cu-TH)
- 2 layer Graphene: Ted Pella (21920-5)
- 6~8 layer Graphene: Ted Pella (21970-5)
- 5~6 nm thick Formvar: Electron Microscopy Sciences (FFGA100-Cu)
- 2 nm thick Gold, Platinum, & Palladium: Ted Pella (21320-25), (21310-25), & (21330-25)
- 10~20 nm thick TiO_X: Ted Pella (21340-25)
- 7.5 nm & 10 nm thick SiN_X: Norcada (M1S18003U) & (NT005Z)
- 20 nm thick SiO_2: Norcada (NTOX025Y-1-50)

Kavanagh Lab @ SFU

- Focus on the properties of interfaces and nanostructures important to semiconductor materials and devices.
- Expertise in scanning transmission electron microscopy (STEM) with electron holography (EH), high resolution x-ray diffraction, Rutherford backscattering spectroscopy (RBS), and He ion microscopy (HIM).

Dehnel - Particle Accelerator Components & Engineering

- Supplies products and services to the international commercial accelerator industry.
- Expertise include **ion sources**, **beam diagnostic** devices, and **beamline** systems for research, industrial, and commercial accelerator systems.

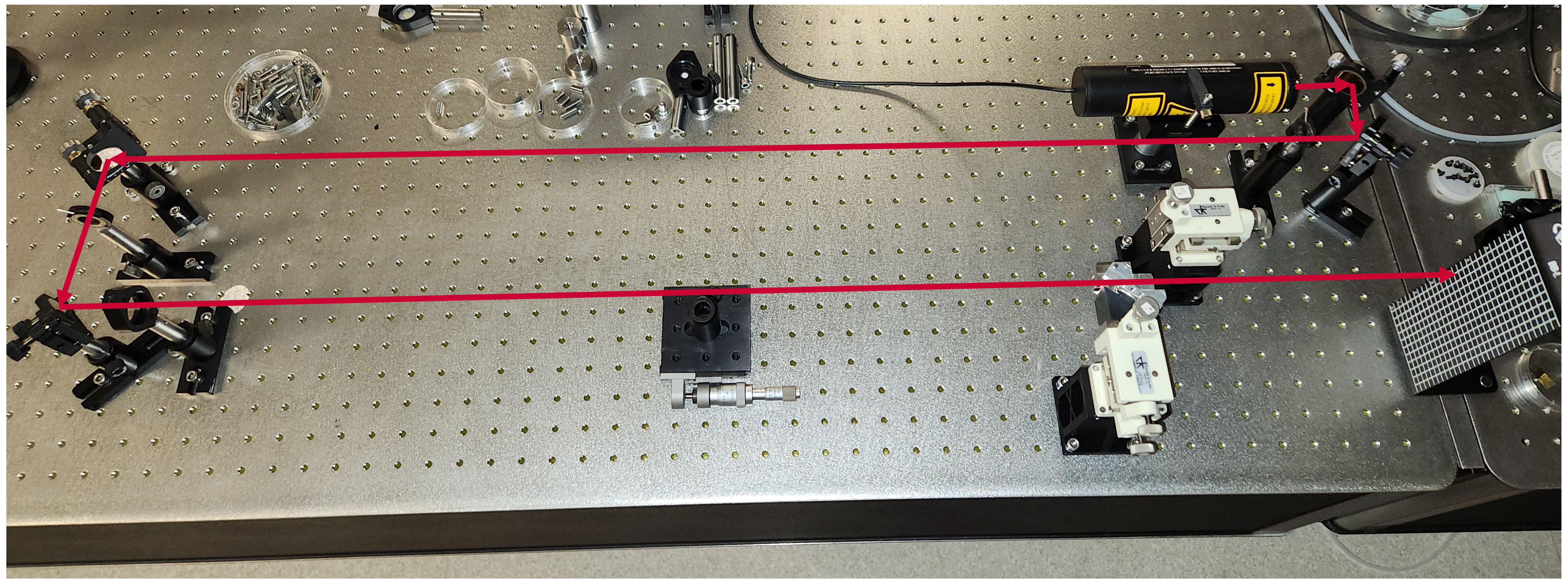
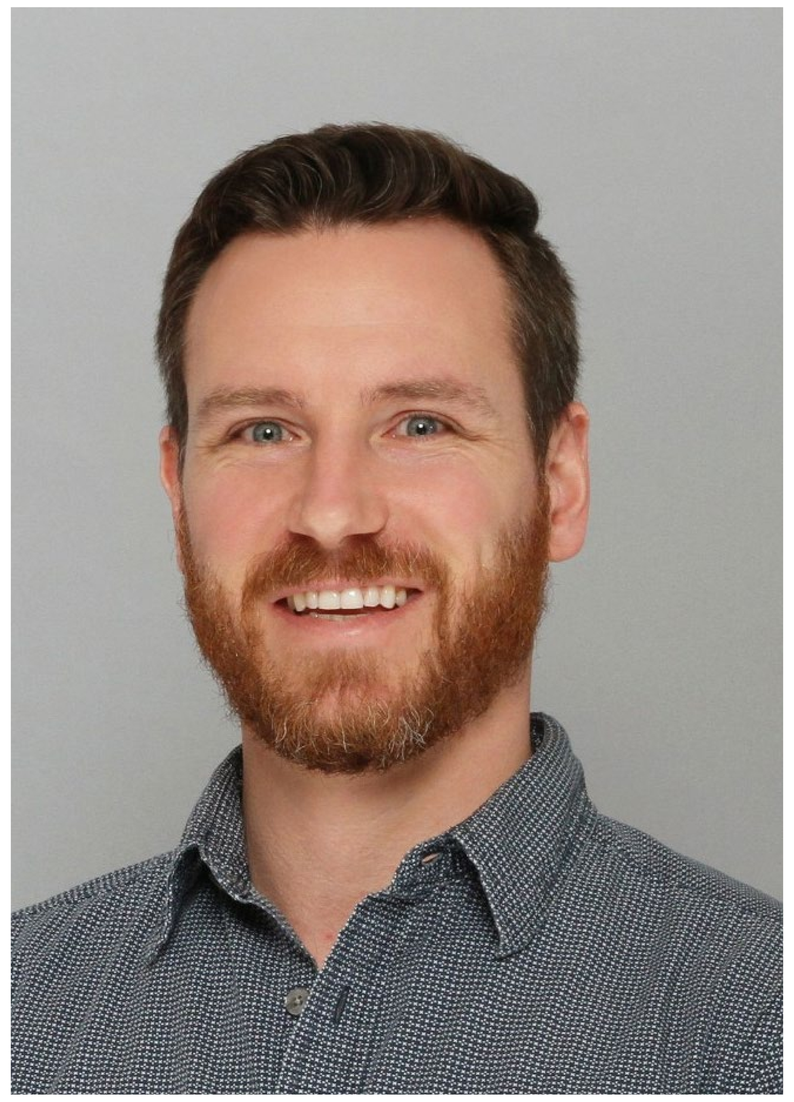


Figure 4: Laser arrangement for alignment of foil-aperture and collimating-aperture. Foil-apertures are Ø100 µm circular holes, or TEM support grids. Collimating-aperture is a Ø100 µm hole.



Philip Jackle

Ph.D Candidate
Dept. of Physics | Kavanagh Lab
Simon Fraser University | TASC2 7040
8888 University Dr., Burnaby, B.C. V5A 1S6
www.sfu.ca/physics/people/graduate-students/pjackle

Beamline Designer
Dehnel - Particle Accelerator Components
and Engineering, Inc
P.O. Box 201, Nelson, BC, Canada, V1L 5P9
Direct: +1 604-353-7335
Office: +1 250-352-5162
www.d-pace.com

SFU

D-Pace