TQT

Transformative
Quantum
Technologies

QUANTUM

OPPORTUNITIES + SHOWCASE

2023

TQT Updates

Tracey Forrest
Program Director
TQT

Graeme Smith
Associate Professor
Department of Applied Mathematics

Taso Alkiviades
Lab Technologist
QNFCF

Saba Sadeghi
Lead Quantum Materials and Fabrication Scientist
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Troy Borneman
Senior Scientist
High Q Technologies

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Michael Grabowecky
Quantum Technology Lab Coordinator
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George Nichols
Research Associate
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Inert Atmosphere Fabrication Capability Update

TQT Quantum Opportunities & Showcase

12/13/23

Inert Atmosphere Fabrication Lab: Dec 2023

Nathan Nelson-Fitzpatrick

Director, Quantum Nano Fabrication and Characterization Facility

UNIVERSITY OF WATERLOO

QNFCF
Quantum Nano Fabrication and Characterization Facility

TQT Transformative Quantum Technologies

Project overview

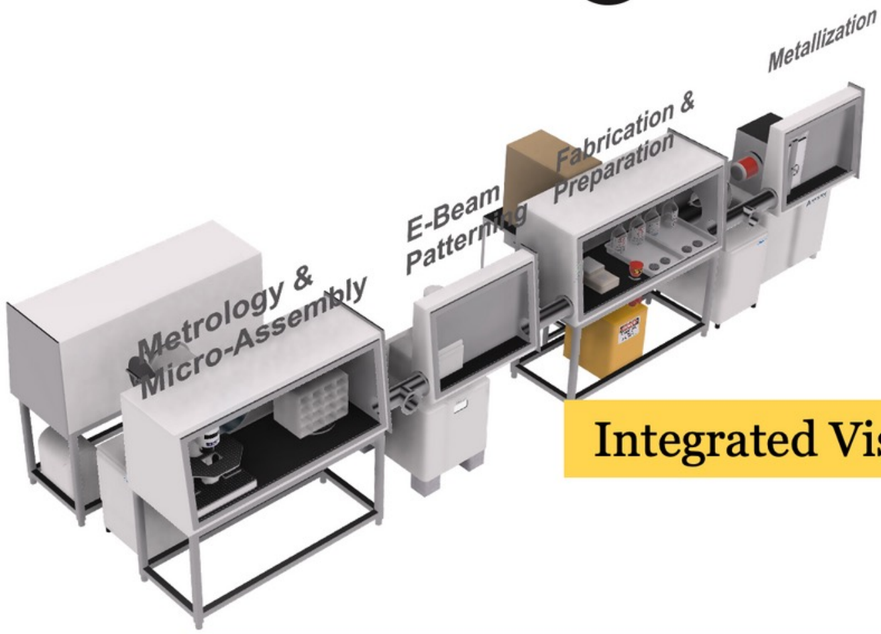
TQT Transformative Quantum Technologies

Vision:

- Enable a fabrication process where sample never leaves inert environment
- Example application: 2D heterostructure quantum devices

What does this involve:

- **Material exfoliation, identify and place monolayers**
- Solvent/resist processing
- **Lithography (EBL)**
- **Film deposition for electrodes**
- Plasma etching and cleaning
- Device inspection (AFM/SEM/optical microscopy)



Integrated Vision

QNFCF staff contributing to project




QNFCF Quantum Nano Fabrication and Characterization Facility

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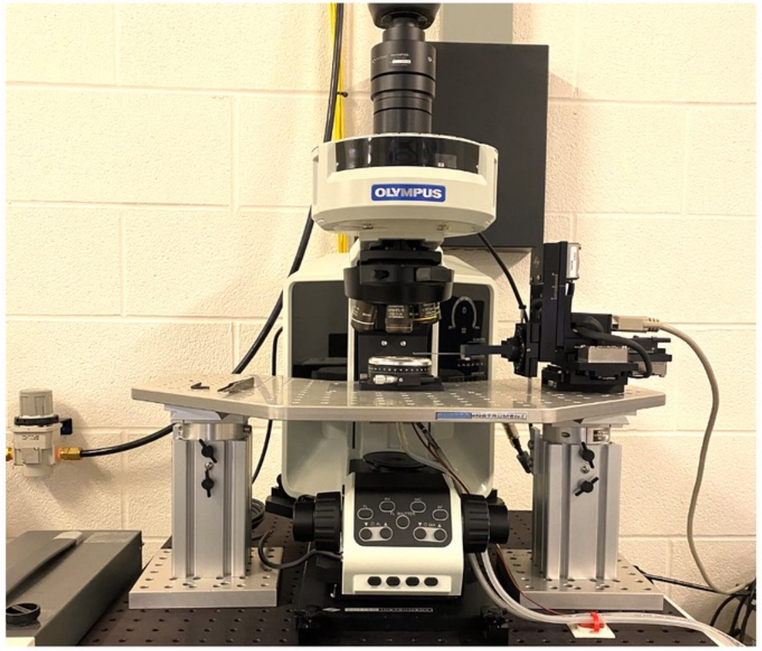
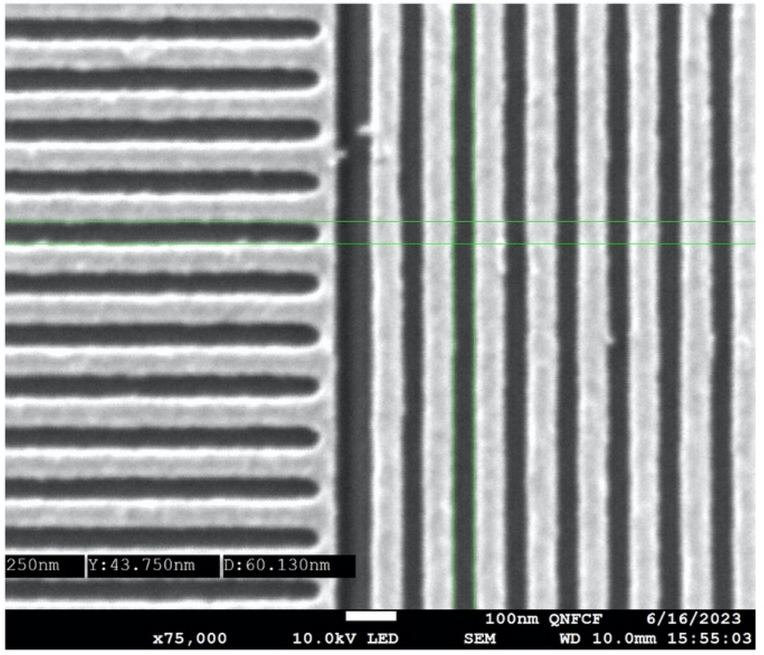
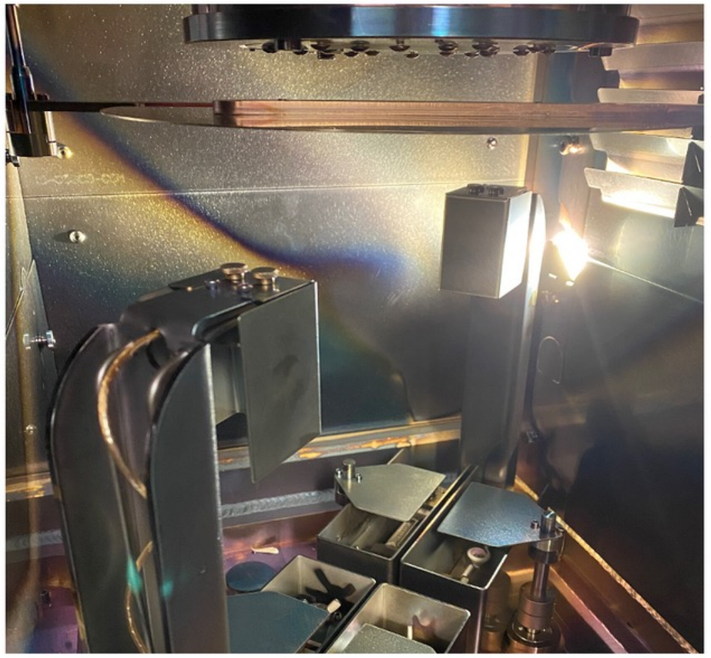
Select Equipment Capabilities

Transformative Quantum Technologies







Exfoliation and manipulation

Microscope with:
- Heated rotation stage with vacuum
- Motorized manipulator for flake placement

Demonstrated controlled pick and place of graphene flake

Lithography

JEOL IT-510LV Tungsten SEM with:
- Nabity Pattern generator
- Beam blanker and Picoammeter
- Low vacuum and BSE capabilities

Demonstrated 40nm lines written

Deposition

Angstrom Nexdep thermal evaporator:
- 4 deposition sources
- Glovebox integration

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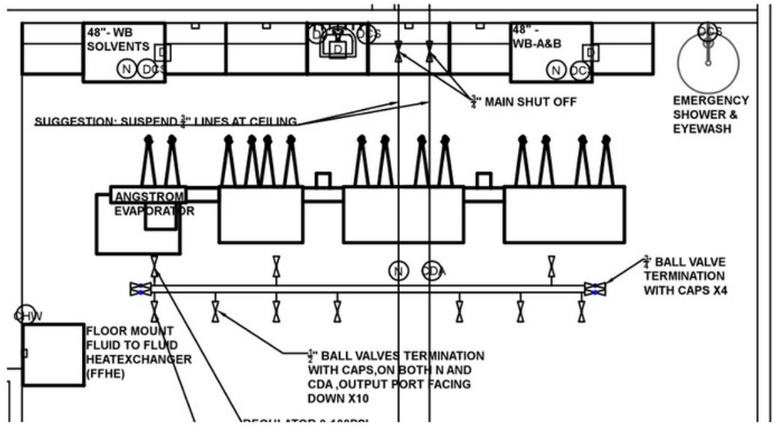
Milestones

Key activities:

- Design and renovate lab - **Done**
- Integrate 2D transfer to optical microscope - **Done**
- Acquire and commission deposition system - **Done**
- Acquire, build and commission SEM w. NPGS - **Done**
- Acquire and commission RIE - **Done**
- Design, acquire, commission gloveboxes for equipment – **In progress**



Progress due to diligent work and generous help from:

A.W. Tsen group, Tarun Patel
Angstrom Engineering and JEOL

Project conclusion

Transformative Quantum Technologies

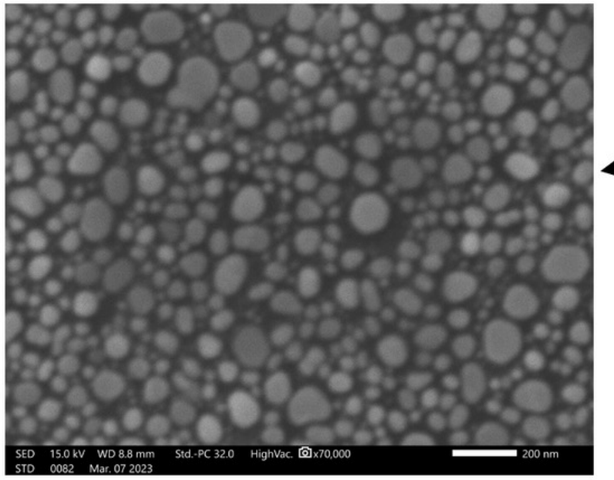
Outstanding items:

- Final glovebox install of smaller tools
- Human Machine Interface work
- Recommission of sensitive tools (AFM / SEM)

Goal: March 2024 project completion and release

Administration by QNFCF:

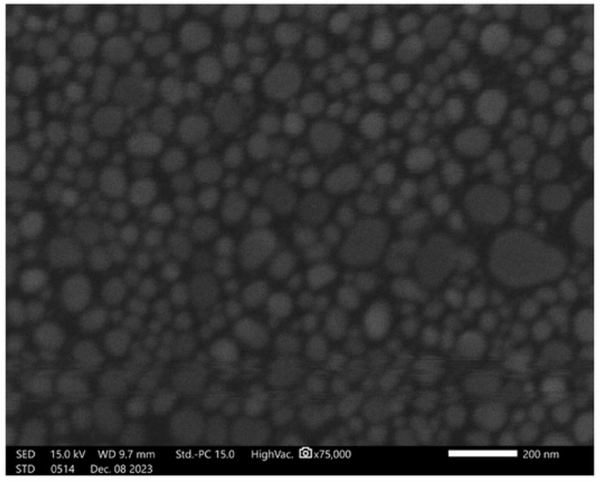
- Stable baseline operation
- Professional and responsive maintenance
- Extensive documentation and training
- Open and equal access to all users



SEM standard image before glovebox

SEM standard image after glovebox

Vibration



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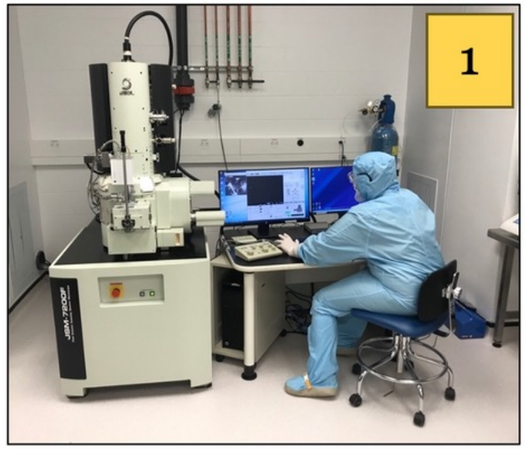
Thank you

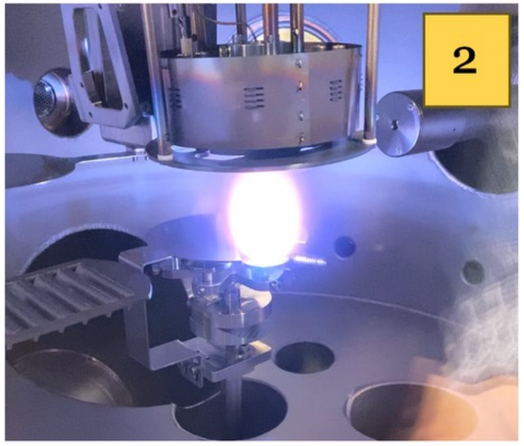
TQT Transformative Quantum Technologies

Check out website for access & equipment information

Other TQT enabled QNFCF capabilities:

1: FE-SEM optimized for wafer inspection
2: Pulsed Laser Deposition
3: AFM and "in cleanroom" characterization suite
4: S/TEM (photo from launch event)





Website

QNFCF Quantum Nano Fabrication and Characterization Facility

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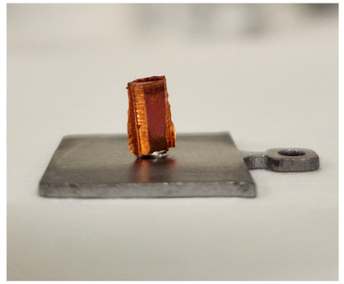
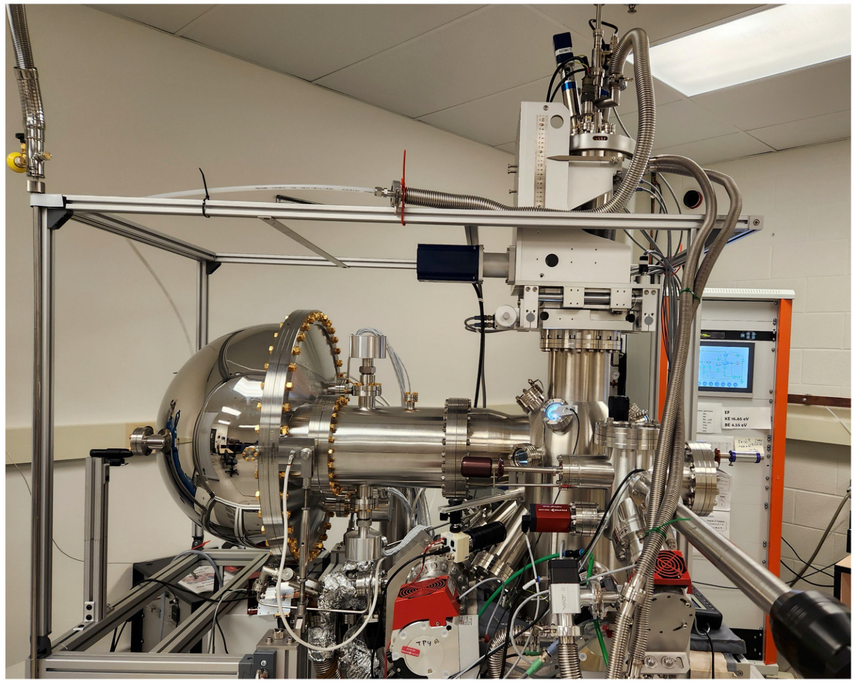
Angle-Resolved Photoemission Spectroscopy (ARPES), location: RAC2

- Open to researchers starting from January 2024

- Some specification:
  - L-He cooled <4.5K
  - Helium discharge lamp
  - Spectrometer DA30-L-8000

- Samples: single crystals; to be able to cleave/exfoliate
  - e.g.: Bi_2Se_3, Bi_2Te_3





- https://tqt.uwaterloo.ca/
- https://quantumcolab.ca/
- **Email: saba.sadeghi@uwaterloo.ca**

Stay tuned for a workshop in 2024!

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EPR for Biophysics

Electron Paramagnetic Resonance (EPR) Spectroscopy

Label two sites on a target protein
- Electron spin labels

Apply a magnetic field across the protein
- Electron spins align with the applied field

Use microwave pulses to change electrons' spin orientation
- Measure the dipolar interaction between the spin labels to determine the distance distribution

Changes in protein conformation are resolved

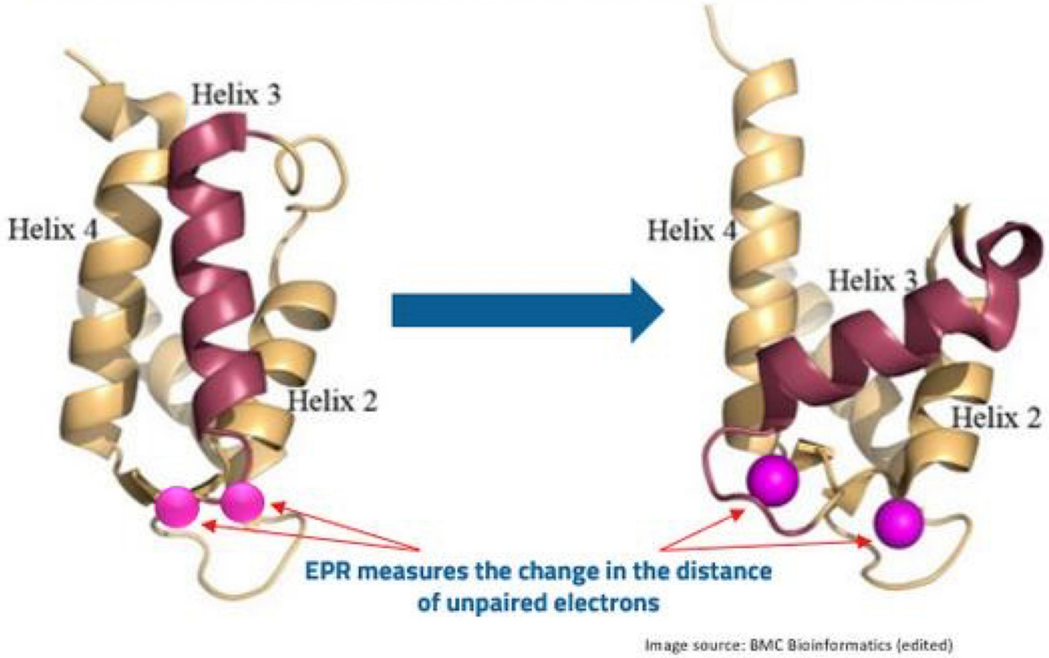


Image source: BMC Bioinformatics (edited)

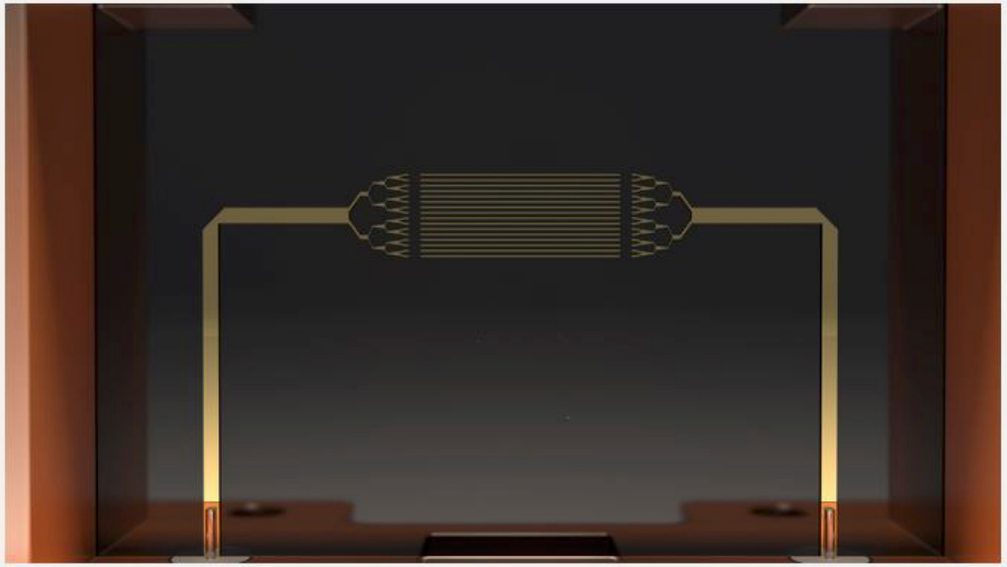
"Although static structures are known for many proteins, the functions of proteins are governed ultimately by their dynamic character..."

– Nature

Superconducting Sensor for Biophysics

Quantum Devices

High Q EPR spectrometers use proprietary planar superconducting microstrip resonators, harnessing quantum mechanics to enhance EPR measurements. The resonator's large filling factor and small mode volume enhance sensitivity.



Quantum device technology unlocks unprecedented capabilities for real-world EPR applications.

- Increased sensitivity reduces distance measurement times of low-concentration samples from days to hours
- Instrument stability removes bias and variance in systematic studies
- Phase-stable AWG capability reduces or eliminates distance measurement artifacts
- Unparalleled performance and flexibility enable exploration and development of novel methodologies for biophysical EPR

FATHOM™ Product

High Sensitivity

Enables routine access to dynamics of difficult, biologically relevant samples

Easy Operation

Intuitive systems
Simplified user interactions
Streamlined workflows

Short Acquisition Time

High sensitivity shortens data acquisition time from **days to hours**

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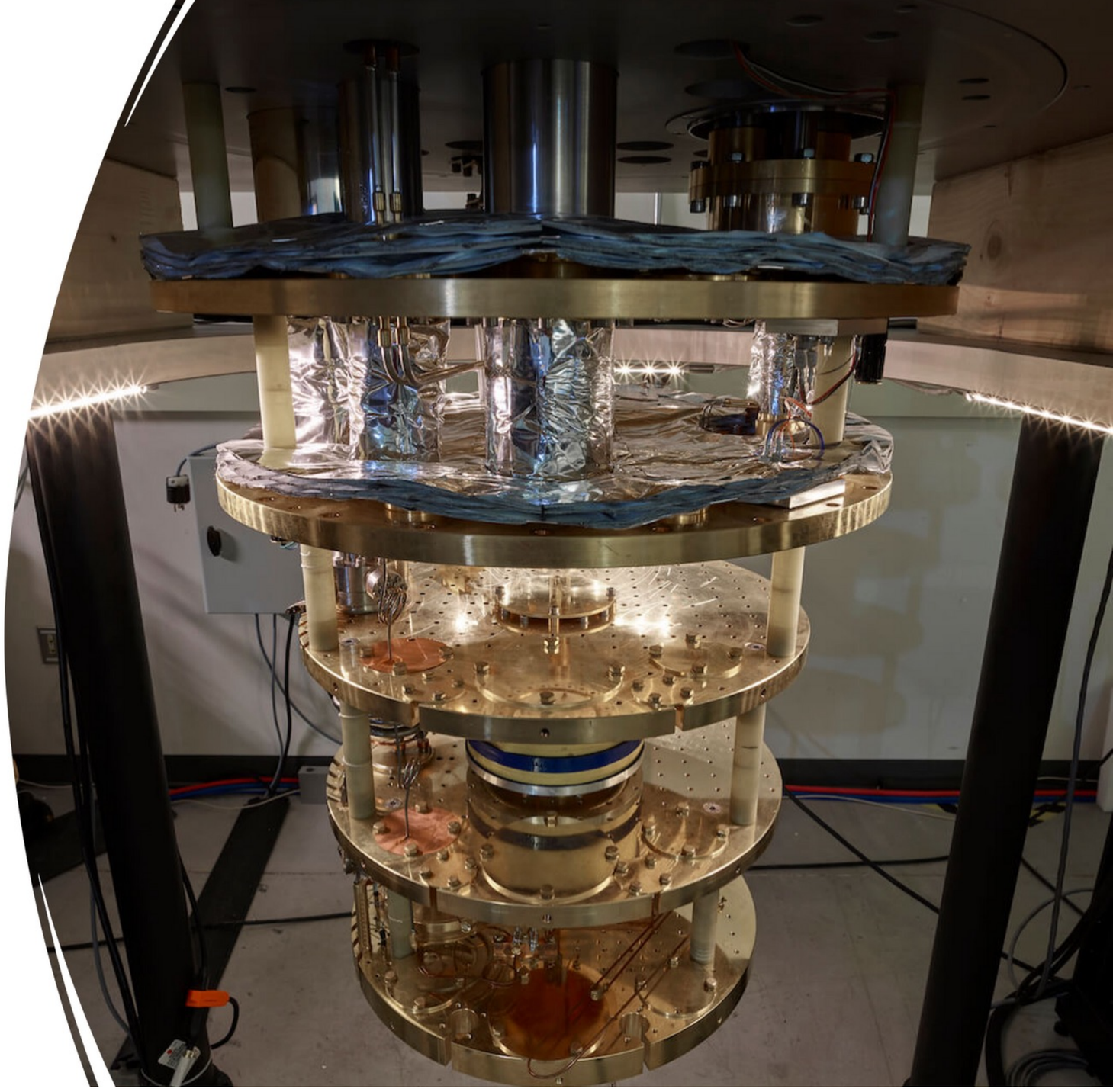
Material and Device Characterization

- 12T 300mK-300K
- 20T 12mK-4K
- Flow cryostats
- Dipping probes
- NMR & ESR tools

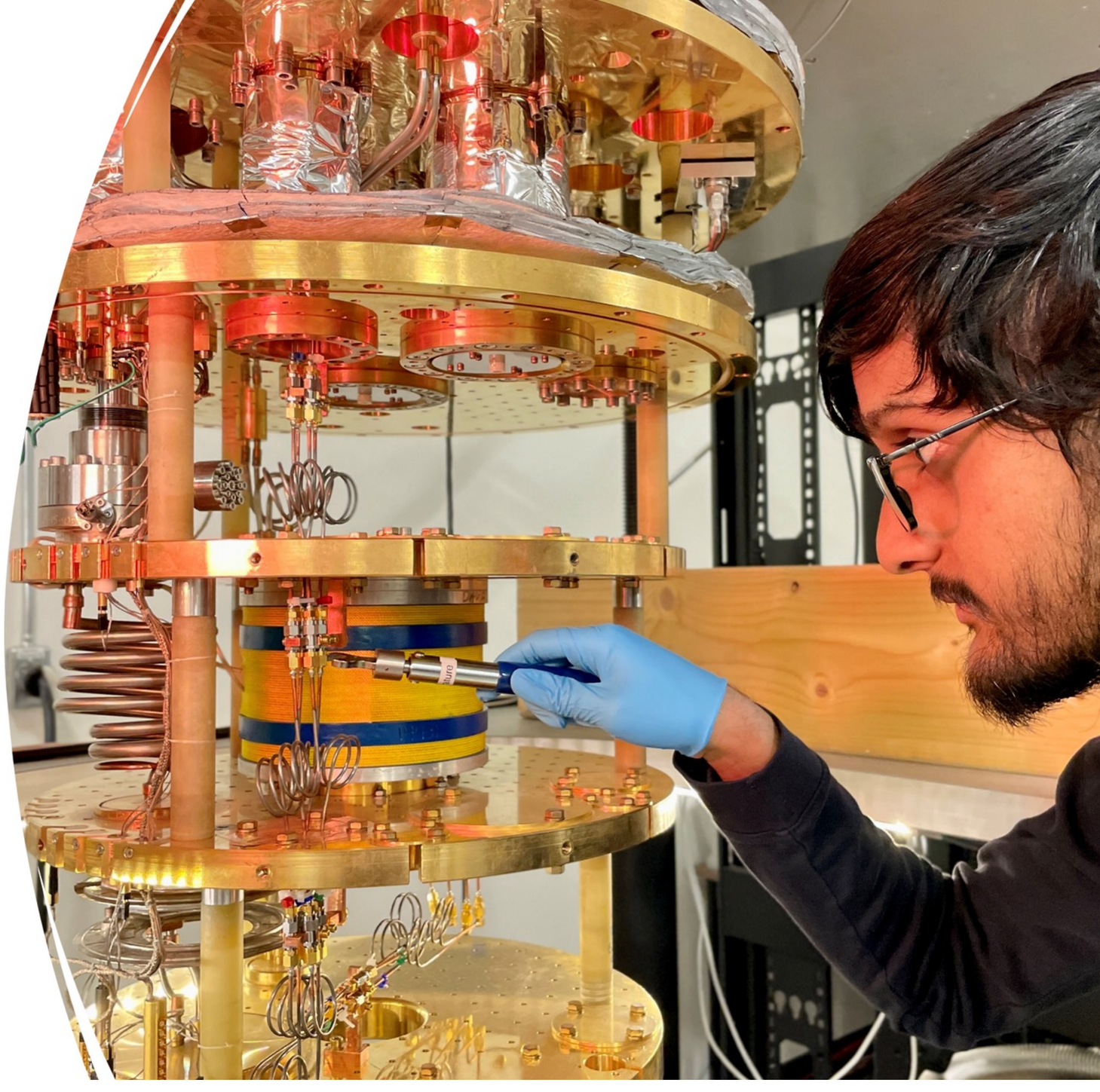
- 5 Qubit processor coming 2024



Low Temperature Techniques Training

- Cryogen handling
- Cryostat and magnet operation
- Material and device characterization
- Noise mitigation
- Lock-in detection

- Contact George.Nichols@uwaterloo.ca



Quantum for Environment Panel

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PANELIST

Alexandre Cooper- Roy
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PANELIST

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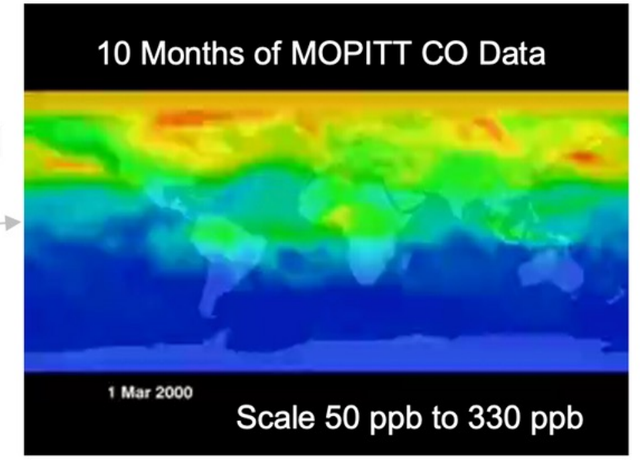
Department of Chemistry

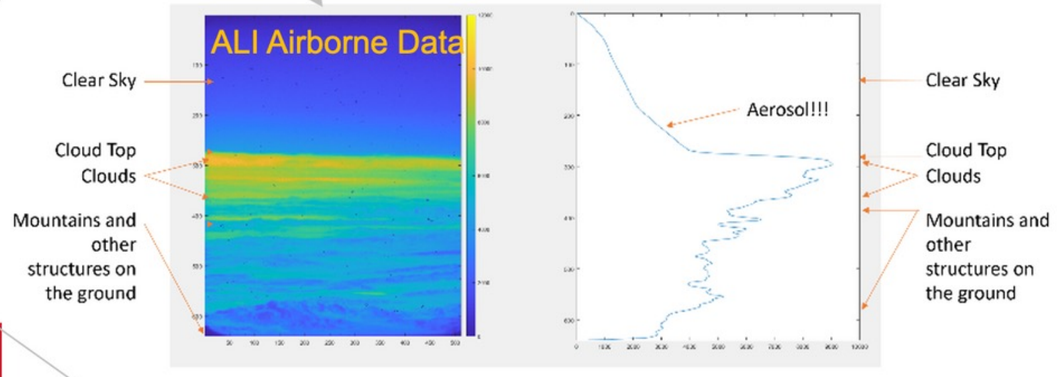
PANELIST

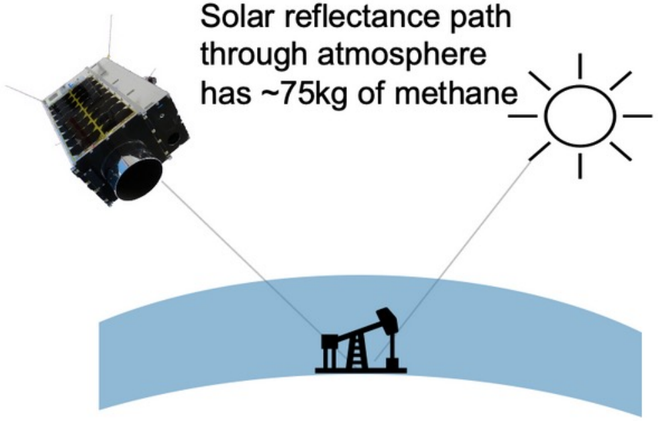
Neil Rowlands
Engineering Fellow
Honeywell

REMOTE SENSING OF THE ENVIRONMENT FROM SPACE

- Most space-borne remote sensing is passive - lots of photons & backgrounds overwhelm signal
  - Measurement of Pollution in the Troposphere (MOPITT) mid-infrared pressure correlation spectroscopy
  - Aerosol Limb Imager – in development – based on acousto-optical tunable filter technology
  - Methane Leak Detection - using imagers & spectrometers – solar reflectance from surface
    - Worldview-3 short wavelength infrared (2.2 μm) example
    - All current instruments detection limit is typically > 100 kg/hr (best case > 30 kg/hr)
- Most active space-borne remote sensing is at radio frequencies
  - CloudSat Cloud Profiling Radar nadir looking radar at 94 GHz
- Active space-borne remote sensing at UV/optical/IR wavelengths is rare
  - starved for photons – return signal is ~distance^4

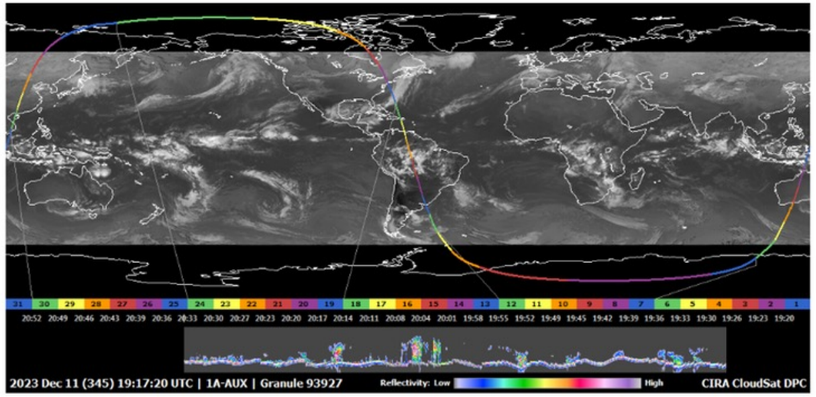






World-View 3 Data: Base image; panchromatic 0.3m
Overlay: Methane ~200 kg/hr leak from SWIR data

NASA's CloudSat Cloud Profiling Radar Dec. 11, 2023



MOPITT, CloudSat CPR & ALI Instruments all developed by Honeywell Aerospace

Quantum for Health Panel

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Tracey Forrest
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