# Accelerating quantum research excellence

IQC Executive Committee Meeting Dec. 11, 2017



### **Tracey Forrest**

Program Director, TQT







## Program



### \$140M Collaborative Research Initiative

- \$76M CFREF grant, 7 years
- Recruitment of the "best and the brightest"
- Grand Challenge research & seed fund
  - GC larger group projects
  - GC smaller projects
  - QQSF (seed) projects
- Connect to early adopters, industry & others
- Shared research infrastructure
- Technology development and commercialization
- Train HQP and industry leaders





#### WATERLOO'S QUANTUM VALLEY





#### **Quantum Valley Investments**

Quantum Technology investment fund established in 2013 by Mike Lazaridis and Doug Fregin with a with a commitment of \$100 million in investment capital. QVI has developed as a quantum technology commercialization incubator with the necessary components to enable and accelerate the commercialization of new transformative quantum technologies in the Quantum Valley.



#### **RAC Complex**

Field Lab once completed.

Houses a community of academic, not-for-profit, commercial and startup researchers with access to laboratories and tools for developing and testing quantum devices. A collaborative experiment to speed the development and adoption of quantum technologies. RAC2 is home to QVI Commercialization Labs including the Quiet Labs and will be the home of the Magnetic



Quantum Valley Ideas Lab

the gap between foundational research done in academic research labs and commercialization. The Ideas Lab will connect with industries to identify strategic opportunities for new quantum technologies with practical applications based on existing foundational physics principles.





A dedicated Application Focused Research Lab that will help address





#### Computing at the University of Waterloo

An internationally recognized scientific research institute at the University of Waterloo pushing the frontier of quantum information theory, practice and applications. Scientific research focuses on harnessing the quantum laws of nature to develop powerful new technologies that will transform information technology and drive the 21st century economy. Home of a collaborative training program for areas of computer science, engineering, mathematics and physical science.





#### Quantum NanoFab

Fabrication facility of shared tools and expertise for quantum device fabrication. For example, it is used for fabricating superconducting gubits and electronics, for deposition of thin film devices including spintronics, for patterning of semiconductor devices including quantum dot qubits. The facility is open to academic and industrial users across Canada

UNIVERSITY OF

WATERLOO





#### Lazaridis Institute for the Management of **Technology Enterprises**

The Lazaridis Institute is developing training and research programs that will help to produce exceptional tech-savvy business managers and leaders that Canadian technology companies need to grow and scale globally



#### The Perimeter Institute for Theoretical Physics

A leading centre for scientific research, training and educational outreach in foundational theoretical physics. Founded in 1999 in Waterloo, Ontario, Canada, its mission is to advance our understanding of the universe at the most fundamental level, stimulating the breakthroughs that could transform our future. Perimeter also trains the next generation of physicists through innovative programs, and shares the excitement and wonder of science with students, teachers and the general public.



# Vision

## **Develop and deliver impactful** quantum devices.

### Computation

A quantum computer with capacity beyond any classical processor.

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Sensing

Impactful quantum sensors with realworld applications.





### Communication

Create and control quantum entanglement over long distances.



# **Faculty Hires**



### **Target 6 New Faculty**

- Proposed hiring
  - 1 − 2 − 2 − 1 (any department)
- First two hires
  - Dr. Crystal Senko
  - Dr. Christine Muschik
- This 17-18 academic year 1 or 2 new hires Connects to Grand Challenges







7 technical staff

## **New Ideas**



#### Qubits and Quantum Effects in Biology

<mark>t is unknown whether biological</mark> processes make direct use of quantum effects, as opposed to

PI: Michel Gingras, Zoya Leonenko #Newideas #Physics & Astronomy #Seed Fund

#### Next Generation Quantum Sensors

We are developing new semiconductor p-n junctions and designing novel nanowi

Jun 01, 2017 PI: Michael Reimer #Electrical & Computer Engineering #Seed

### **Quantum Quest Seed Fund**

- Promotes the exploration of new ideas and applications for quantum devices
- Intended to uncover opportunities from diverse fields outside the scope of researchers working dayto-day with quantum devices
- Seven projects awarded in Round 1
- Round 2 closed on Nov 29, fourteen applications received and currently under review
  - Overall 32 applications from 3 faculties. Science, Engineering and Math Physics, Chemistry, Electrical and Computer Engineering, Combinatorics and Optimization



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# **TQT Support of Postdoctoral Fellows**



### Funding available to support PDFs

- For TQT-funded Grand Challenge projects
- Grand challenge advertisement:
  - Physics Today
  - Other
  - TQT web





# **TQT Support of Infrastructure**



### Targets a wide community

- All equipment is shared
- Equipment access to all via Quantum Nanofab
- Add large infrastructure to provide essential tools for fabrication, testing, deployment of quantum technology (e.g., SEM)
- Add essential tools for rapid research progress (e.g., waterjet)
- Develop new tools (e.g., FPGA)
- Migrate existing tools into shared spaces enabled by TQT support & staffing (e.g., RAC2 AFM)





# **TQT Support of Infrastructure**

### Lab renovations

- QNC 1707 converted into ISO 7 cleanroom: new Characterization Lab (\$141k)
- RAC1 cleanroom renovation: clean assembly + chemical & mechanical processing (\$65k)

### Staff hires on Quantum NanoFab Team

- Dr. Lino Eugene: Nanofabrication Process Specialist/Engineer
- Dr. Greg Holloway: E-Beam Lithography Scientist
- Mr. Peter Sprenger, Senior Technical Lead, Magnetic Resonance
- Dr. Guanru Feng, Quantum Device Research Technician
- Mr. Taso Alkiviades: RAC1 Lab Technologist (starting on January 2)
- TBD: Nanofabrication and Characterization Scientist

### **Equipment & S/W maintenance contracts**

- JEOL JBX-6300FS 100kV E-beam litho system (\$150k/yr over 4 yrs)
- BEAMER EBL S/W package (\$27k)
- JEOL JSM-7200FS Scanning Electron Microscope (\$32k)

### New equipment

- Maskless aligner & exposure system (\$625k) Heidelberg MLA150 installed & released
- Scanning Electron Microscope (\$511k) JEOL JSM 7200F currently being installed
- AuBe evaporator for p-type ohmic contacts (\$133k) Angstrom Eng. ordered Nov 2017
- Critical point dryer (\$125k) Tousimis Autosamdri 815B installed & released
- Atomic Force Microscope (\$447k) Bruker Dimension FastScan installed
- Stylus profilometer (\$54k) Bruker DektakXT installed
- JEOL EBL cassettes & pre-alignment microscope (\$147k) expected Jan 2018







# **RAC Satellite Labs**

- Sample polisher
- Crystal cutter
- Lapper
- Wire saw
- Fume hoods: acids, caustics, organics
- UV ozone & O<sub>2</sub>/Ar plasma cleaners
- Microscopes
- Veeco AFM
- Wirebonder
- ESR, cw X-band
- Cryogenic STM & AFM
- Cryogenic probe station
- 12T magnet
- XRD
- 3D Optical metrology system
- Gold deposition











# A substantial (& growing) toolset backed by a dedicated team of professionals

#### Available Process Equipment & Capabilities

NOTE: Equipment is available at multiple sites on campus.

<u>QNC building (main campus)</u> <u>RAC1 building (north campus)</u> \*scroll down RAC2 building (north campus) \*scroll down

#### Deposition

- 1. ALD / PECVD Cluster Deposition System
- 2. LPCVD Low Temperature Oxidation (LTO) Furnace
- 3. LPCVD Poly Silicon and Silicon Carbide Furnace
- 4. LPCVD Silicon Nitride Furnace
- 5. Rapid Thermal Processor (RTP)
- 6. PVD E-Beam & Resistive Heating Thermal Evaporator
- 7. PVD Nb Superconducting Films Sputter System
- 8. PVD Twin Chamber Sputter System
- 9. PVD Al Superconducting Films Evaporator System
- 10. Thermal Oxidation Furnace

#### Lithography

- 1. E-Beam Lithography System (30kV)
- 2. E-Beam Lithography System (100kV)
- 3. Beamer/Tracer Software Suite
- 4. Front/Back Mask Aligner
- 5. UV Direct Write Lithography System
- 6. Oven: Convection
- 7. Oven: HMDS & Image Reversal
- 8. Spin Coater: Dual General Purpose Hood
- 9. Spin Coater: E-Beam Resists
- 10. Spin Coater: UV Resists

#### Dry Etch

- 1. Ion Mill
- 2. Photoresist Strip
- 3. RIE: Deep Silicon Etch (DRIE)
- 4. RIE: Metal & III-V Materials

#### Wet Benches

- 1. Bulk Silicon Etch
- 2. Critical Point Dryer
- 3. Diffusion Pre-Clean (RCA Chemistries)
- 4. E-Beam Resist Develop
- 5. HF Acids Only
- 6. Non-HF Acids & Bases
- 7. Piranha Organics Clean & Resist Strip
- 8. Solvent Processing Station #1
- 9. Solvent Processing Station #2
- 10. UV Resist Develop

#### Characterization

- 1. Atomic Force Microscope
- 2. Scanning Electron Microscope (JEOL JSM 7200F coming in Nov 2017)
- 3. 4-Point Probe
- 4. Electrical Probe Station # 1 (SUSS PM5)
- 5. Electrical Prober Station # 2 (Everbeing 8" coming in Dec 2017)
- 6. Ellipsometer
- 7. Microscope #1
- 8. Microscope #2
- 9. Reflectometer: Thin Film Mapping
- 10. Reflectometer: Thin Film Spot Measurement
- 11. Surface Profiler
- 12. Wafer Stress Measurement

#### Packaging Lab (QNC 1706)

- 1. Convection Cure Oven
- 2. Dicing Saw
- 3. Die Bonder
- 4. H2 Plasma Cleaner
- 5. Measurement Microscope
- 6. Wirebonder: Manual Wedge/Ball
- 7. Wirebonder: Semi-automatic Wedge
- 8. Wire Pull Tester
- 9. Epoxy dispenser

#### Sample Prep Lab (QNC 1508)

- 1. Contact Angle Goniometer
- 2. Diamond Scriber
- 3. Solvents Chemical Processing Hood
- 4. Acids & Bases Chemical Processing Hood

#### RAC1 Lab (RAC1 1013) [UNDER CONSTRUCTION]

[UNDER CONSTRUCTION]

- 1. Sample Polisher
- 2. Sample Cutter
- 3. Sample Lapper
- 4. Wire Saw
- 5. Microscope #1
- 6. O2/Ar Plasma Cleaner
- 7. Wet Bench: Non-HF Acids & Bases
- 8. Wet Bench: HF Acids
- 9. Wet Bench: Solvent Processing

#### RAC2 Lab

- 1. Microscope # 1
- 2. Microscope # 2
- 3. Atomic Force Microscope
- 4. Wirebonder







# **Early Engagements / Adopters**



# **Academic Collaborations**







# QuSoft



Research Center for Quantum Software

# Enhanced collaboration on quantum software, CS, materials, devices

- Small joint workshop was held in early November 2017
- Future workshops proposed for 2018
  - CS @ Amsterdam
  - Materials @ UW
- Student videoconferencing, joint projects and the development of exchange programs in planning or underway



CANADA FIRST RESEARCH EXCELLENCE FUND

## **Space Development**



- QNC fab build out for metrology (complete)
- RAC2 build outs (ongoing, complete in ~ 3 months)
- RAC1 clean room (complete)
- RAC1 (planning)
  - Low temperature physics hall
  - Quantum optics addition





# **CFREF** as an Enabler of Institutional Change

Leverage the capacity of large centers and programs to advance UW goals.

Regularly scheduled meetings of leaders from large centers and programs w/ VPR and deans. • Equity

- Finance and reporting UW
- Connect HR and program goals
- Sustainable technical staffing
- Build and support research infrastructure
- Research themes that connect across campus, across disciplines, to social sciences
- Effective outreach
- Effective advancement
- Effective participation in Canadian initiatives
- Effective participation in International initiatives

### Support the vision of UW as a source of innovation.





# Equity



### An essential measure of success

- We are working to achieve high performance across equity, diversity and inclusion measures
- Online survey tool
- Support for outreach (Quantum Innovators and USEQIP) and recruitment
- Champion 'equity by design' principles and use of CFREF program as a means to effect change





# Equity by design

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### WHAT WORK

GENDER EQUALITY

BY DESIGN

### Pragmatic, systematic approach

- Focus on evidence-based interventions that could be adopted right now, often at low cost and high speed
- Demonstrate how we are addressing gender bias and improving performance throughout the continuum of hiring, mentoring, development etc
- Check your own unconscious bias: https://implicit.harvard.edu/implicit/





# **Equity and Outreach**



### **USEQIP**

- Summer school for upper year undergrads
- Forms part of TQT program

### **Quantum Innovators**

- Workshop for promising young quantum postdoctoral fellows around the globe
- TQT offers CFREF financial support





### Finance



Tarralee Weber, CPA, CGA Research Project Accountant Office of Research

### Effective "in-situ" model

- Engaged in Office of Research experiment
- Embedded research accountant, sits with TQT
- Helps connect financial knowledge and practice with day-to-day running of quantum research





# **CFREF Summit, Nov. 29, 2017**



### **UW Welcomes CFREF Programs**

- Organized by TQT and CFREF
- 50 attendees, incl. Scientific Directors and Leadership from CFREF-funded programs
- Inaugural meeting to share experiences, best practices and explore collaboration opportunities
- Dr. Danika Goosney, Executive Director of Triagency Institutional Programs Secretariat





# **UW Community Events**

140 researchers connect to TQT 50 joined the information session 6 scientific talks

### **Building connections**

Quantum Quest Seed Fund
Information Session

 $\sim$  50 visitors

during open house

- TQT Information Session
- RAC 2 Open House





# **TQT Visits & Visitors**



### **Get Connected**

Join us at the frontier of quantum technology development and let's bring people and ideas together.



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### www.uwaterloo.ca/tqt



- QuantumIQC
- @quantuml.ca
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