TRIUMF

TRIUMF 20 year vision: Quantum Technologies Group

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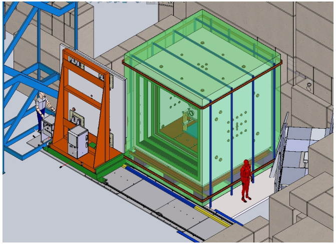
TRIUMF

- Invited to chair the Quantum Technology group for TRIUMF's 20 year vision
- My first question: what is Quantum Technology?
  - At some level, everything.
  - But R&D money for this field is really aimed at technologies that push boundaries to the quantum limit - opening up new possibilities both in industry and research
  - Relevance to us: Many possible uses for novel detectors enabling new fundamental research
  - Spin-off possibilities
  - Funding opportunities
- We also include Detector Development in our remit: not covered in other groups
- Many thanks to the committee members:
  - Thomas Koffas (Carleton), Fabrice Retiere, Makoto Fujuwara, Wolfgang Rau, John Behr, Andrea Teigelhoefer, Albert Stolow (U Ottawa, NRC), Anna McCoy
  - Met about every 2 weeks for wide ranging discussions
- Produced two documents:
  - Summary 5 page report
  - One page highlights of where we are now, what steps we should take, and where that could lead us
  - Available in the 20 Year Vision Team/sharepoint pages

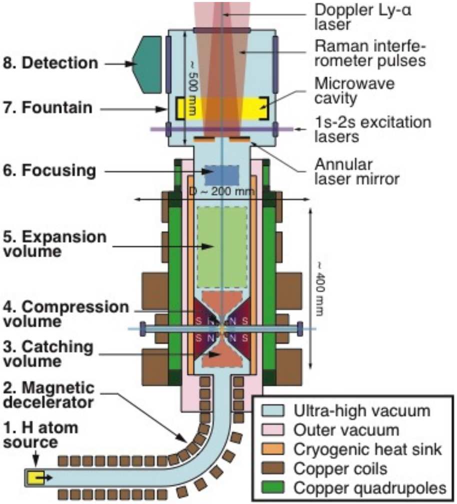
Why QT for TRIUMF

- Precision of typical experiment today $\sim \sqrt{(1/t)}$ or $\sim \sqrt{(1/N_{\text{targets}})}$
- With QT can become $\sim 1/t$ or $\sim 1/N_{\text{targets}}$
- E.g. with Ramsey fringes where t is the undisturbed evolution time, or in super-radiance where N is the number of emitters in the single quantum state
- TRIUMF is already using QT
  - Spin-echo techniques by μSR and βNMR
  - Francium trap
- Near future uses (both to measure EDMs)
  - Francium fountain
  - nEDM Ramsey fringe method to precisely measure precession frequency and hence any difference in energy due to an EDM
- Further future
  - HAICU (anti-)hydrogen fountain
  - AMO Precision Centre: careful development on stable nuclei before using TRIUMF comparative advantage of availability of unstable isotopes
  - Trapped Ion quantum computer



nEDM experiment at TRIUMF

- Proposal to develop hydrogen atom manipulations that also work with anti-hydrogen
- Allowing very high precision spectroscopy, ultimately testing CPT/Lorentz invariance at ALPHA-g successor
- It will use all technologies: magnets, cryo, vacuum, lasers, ...
- Many synergies with the ongoing Francium, nEDM experiments and AMO



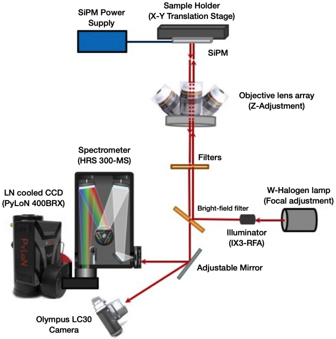
QT Competitive Advantages at TRIUMF

- All needed technologies available under one roof
  - Magnets, electrodes, vacuum, cryogenics, lasers, electronics, controls, DAQ, ...
- Radioactive beams
- Knowledgeable and willing workforce

Group Vision for Evolution of QT at TRIUMF

- As seen, TRIUMF already uses QT, and has near and further-term plans
- Currently we adopt techniques developed elsewhere to achieve our research goals
- We expect this to continue, but as we build up experience we expect to start developing and adapting the techniques, improving and tailoring them to our needs
- Further down the line: we see a possibility that TRIUMF develops QT in its own right: generic R&D both for our own goals and as tools for the wider community, including industry
- Other institutes have a lead on this. We cannot and should not compete. Rather we should partner with lead institutes (e.g. NRC for atomic clocks) to speed up the process

- TRIUMF designs, develops and assembles detector systems for many experiments
- Large local team with expertise in mechanical, electronic, DAQ, and particle detector techniques
- Many university partners
- Most development is for specific experiments, known requirements
- Team members have ideas beyond current state of the art
- Advances in SAP, materials, medicine, need advances in detectors
- Need for Detector Development recognised in several Strategy reports (European Strategy Group, Snowmass, ACOT, ...)
- TRIUMF should maintain a strategic detector development program, in line with our mission, but not necessarily tied to a single experiment
- Important for motivation and skill retention too
- No idea now what will be being developed in 2042
- Depends on experimental needs, internal interests and abilities, funding, etc.
- Near term: two development avenues. Si pixels, and SiPM photon detectors.



- Si Pixel development
  - Leverage MHESA Cleanroom equipment and Si beam telescopes from NA62 and Carleton to develop pixel detectors: LGAD for timing for NA62, new materials for rad hardness, ++
  - Interest from SFU, Carleton and TRIUMF to contribute to long term development program; work with CERN RD-51
  - Seen as entry to pixel-sensor development for long term program not targeted at any specific experiment
- SiPM Photon Detectors
  - PHAAR, LEIM: develop low dark current, low power, high efficiency vuv photo detectors with excellent timing
  - Relevant to nEXO, LAr detectors, PET, ... and spin-off: smoke from forest fires

- Mostly covered by Computing Group
- Uses/will use several QT techniques and several technologies which will be available at TRIUMF
- Clear synergy
- Whether or not we should house a quantum computer at TRIUMF is not in our scope

One-page summary of status, action, outcome

TRIUMF 20 Year Vision Quantum Technologies Group Action Summary

	Now	Action	2042
New measurements	Some quantum technologies used	Continue to develop quantum technologies as part of the AMO toolkit	Cross-discipline precision measurements enabled
Detectors	Detector assembly, commisioning, operational support for running experiments	Identify technological challenges for the next generation of experiments and develop the novel quantum technologies that will enable the next generation of experimental efforts	Have made high impact contributions to new detector technologies at the center of new ground-breaking experiments
People	Engineering and technical staff to support assembly/operation of experimental hardware	Identify scientific and technical skills required to undertake the development of new experimental techniques and detector technologies; institue a development and hiring plan to meet the skills required.	TRIUMF staff at the forefront of technology and experimental innovation in international scientific endeavors; TRIUMF attractive to innovative scientific and technical staff
Quantum Computing	New Machine learning and Quantum Computing group	Develop hardware with Canada-wide collaboration to gain access to quantum computing.	Quantum leap in SAP physics with for example ab initio nuclear structure calculations possible
Exotic atoms	Competitive advantage in ability to produce and capture exotic atoms and radioctive isotopes	Develop techniques to produce, manipulate and probe exotic atoms and molecules	Host a world-leading EDM experiment or other fundamental symmetry experiment
Leadership	Leading roles in antimatter physics at CERN	Take on ambitious projects to develop and apply quantum technologies (e.g. HAICU) by leveraging TRIUMF/Canadian expertise in (anti)AMO, traps, lasers, microwaves, detectors	Dramatic improvements in symmetry tests by TRIUMF/Canadian-led experiments, e.g., CPT and Equivalence Principal tests by hydrogen vs. antihydrogen comparisons

Summary

- Hard to predict what Quantum Technology will be doing for us in 2042, but a solid prediction it will be important
- Detector development will also remain important
- Open for discussion