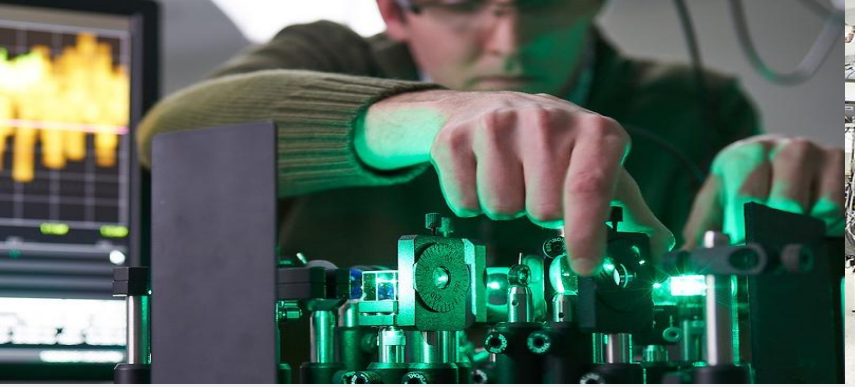
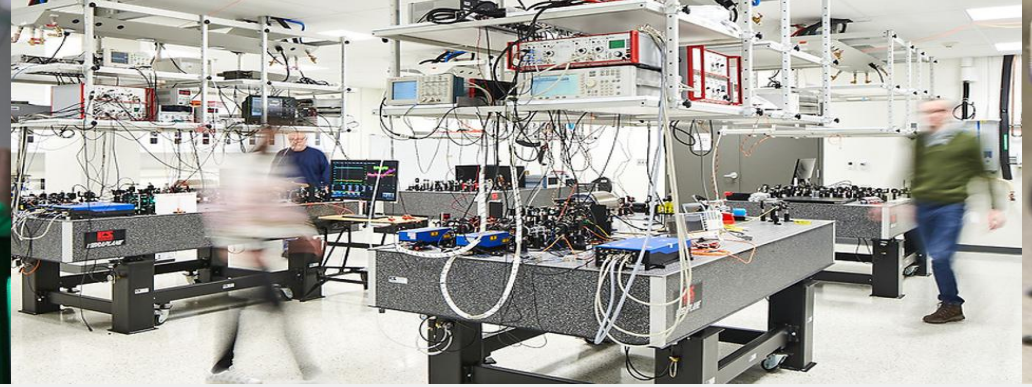
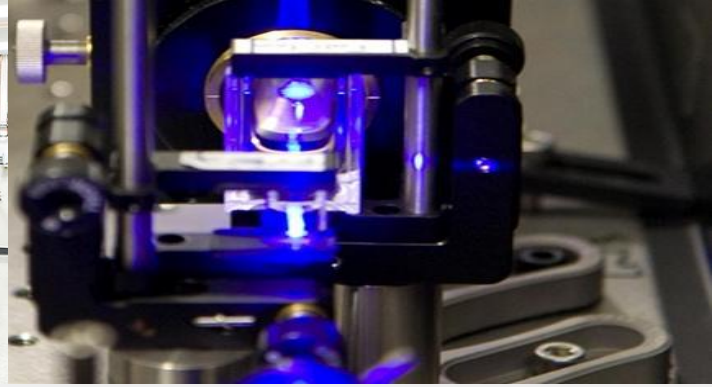

Quantum Valley Ideas Lab

Quantum Sensing In Defence

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Quantum Valley Ideas Lab

- QVIL is a **unique, independent, non-profit industrial research lab** in Waterloo, ON, specializing in dual-use quantum technologies
- **Founded in 2016 by Mike Lazaridis and Doug Fregin**, QVIL is a growing 40+ person team, >50 patents filed globally and a broad ecosystem of defence, government and commercial partners
- **Mission**: accelerate the development and commercialization of quantum technologies
- Invest in **3-5 year long quantum sensing** projects and develop from 'idea' to commercial prototype. Create spin-out companies to commercialize
- **Application-driven research** with proficiency in Quantum Sensing, Fabrication, Atomic Vapour Cells, NV Diamond, Quantum Optics, Photonics, PIC's, RF and PNT use cases.
- Recognized as a **global leade**r in Rydberg Atom radio frequency (RF) sensing for radar, communications and electronic warfare
- Commercialization underway with our first spin out **WaveRyde Instruments**, developing products for Spectrum Intelligence in Telecom and Defence
- Experienced **collaborator** with international defence primes

Government and Defence Partners

Federal Economic Development Agency for Southern Ontario / Agence fédérale de développement économique pour le Sud de l'Ontario	Economic development funding to create an ecosystem of Quantum companies in Canada
Ontario	
NRC · CNRC	3 Quantum sensing programs including collaboration with Germany for satellite based use cases
DARPA	Lead Participant in 3 programs over last 4 years. Supporting commercialization of our first spin out.
DRDC / RDDC	Multiple awards from DND in Canada
INNOVATIVE SOLUTIONS CANADA	Delivered Quantum RF system prototype to DND lab in Ottawa. Radar Receiver target delivery in 4Q26
NATO OTAN	Working group on Quantum RF for military applications. Collaborating with primes and national labs for field testing.

QVIL R&D and Commercialization Projects

QVIL has Multiple R&D projects underway to develop and commercialize quantum sensors for dual use, commercial and defence use cases

RF Spectrum Sensing

- Developed atom based sensors for Telecom and spectrum monitoring/ intelligence use cases
- Created spinout company, WaveRyde Instruments commercializing this technology with early products available for sale.

Quantum Enhanced Radar/ Receiver

- Enhanced atom based sensors to develop multi-static, low SWAP-C, radar system across multiple use cases
- High frequency communication use cases under investigation

Quantum Navigation

- NV Diamond based multi-axis gyroscope and accelerometer for use in GPS denied navigation

Optical Atomic Clock

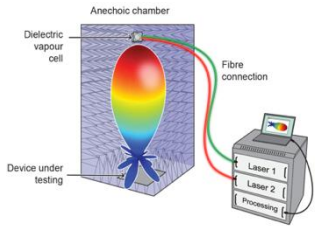
- Developing a 2 photon, cesium, optical clock for high performance timing and GPS denied navigation.
- Core technology to support distributed multi-static radar and sensing use cases.

To support our research we have are also building out a wafer scale pilot lane capability to fabricate the atomic vapour cell sensors used in the RF, Radar and Atomic clock projects,

QVIL Use Cases and Technology

5G Networks

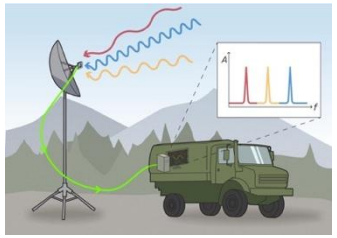
Quantum sensor system for accurate over-the-air (OTA) testing of 5G networks.



Spectrum Intelligence

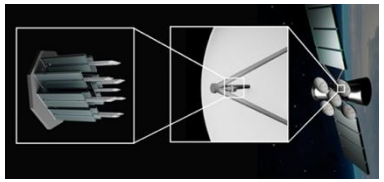
Single sensor for EW spanning frequencies from MHz to THz with frequency agility

WaveRyde



Satellite Deployments

Spectrum monitoring and Radar use cases along with unique value to improve satellite antenna operation



Multi-static Radar

Quantum receiver, reduced SWaP-C, increased sensitivity for C-UAS and IAMD use cases

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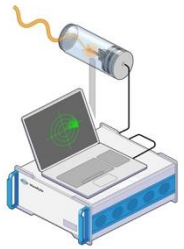
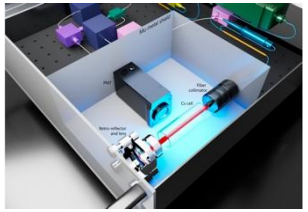


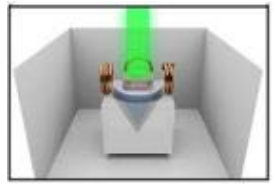
Optical Atomic Clock

High performance cesium optical clock for A-PNT in GNSS Denied environments



Quantum Gyroscope and Accelerometer

Multi-axis gyroscope and accelerometer for enhanced dead reckoning navigation



Sensors

Fibre connected, mm to cm sized, engineered and fabricated for specific use cases

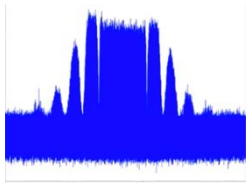
+

Control Systems

3U, integrated, lasers, control, processing enabling a range of scenarios

+

Signal Processing



Novel approach for phase, pulse, modulation

+

System Integration/ Test

Device Fabrication + Optics + FPGA Programming + Engineering

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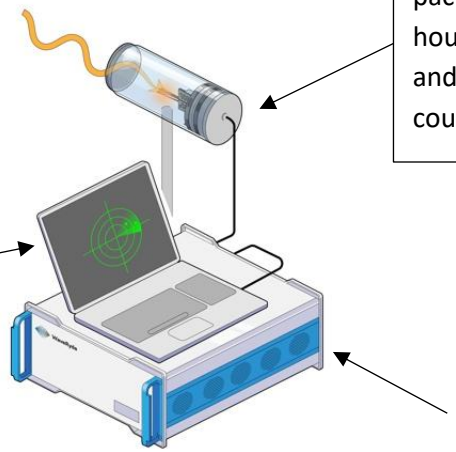
RF Spectrum Sensing - WaveRyde Commercialization

- Scans Broad Bandwidth of 1-100 GHz without any equipment changes: 1-Box & 1-Sensor inherently broadband
- Self-Calibration with 20X better accuracy & repeatability
- Atomic-spectrum Sensing making it immune to large-pulses & jamming
  - Resilient in the presence of large pulses or CW signals.
- Atomic-spectrum Sensing Readout making it Immune to Interference with Optical Read-Out & Direct-Baseband Read-Out
- Non-detectable Passive All-Dielectric-Sensor Does not generate Emissions due to Nonlinearities:
- Non-perturbative due to its dielectric construction (No conductors)

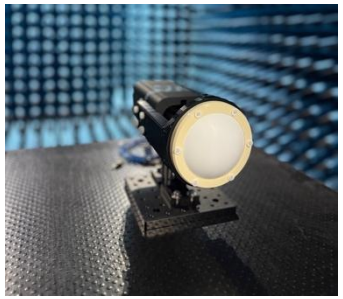
QVIL Multi-static Quantum Enhanced Radar X-Band Prototype



Quantum radar receiver sensor packaged in a protective housing for field deployment and testing. Sensor is fiber coupled to control system

Operator interface displaying system output and target detection

Compact control unit with laser and signal processing and timing/synchronization

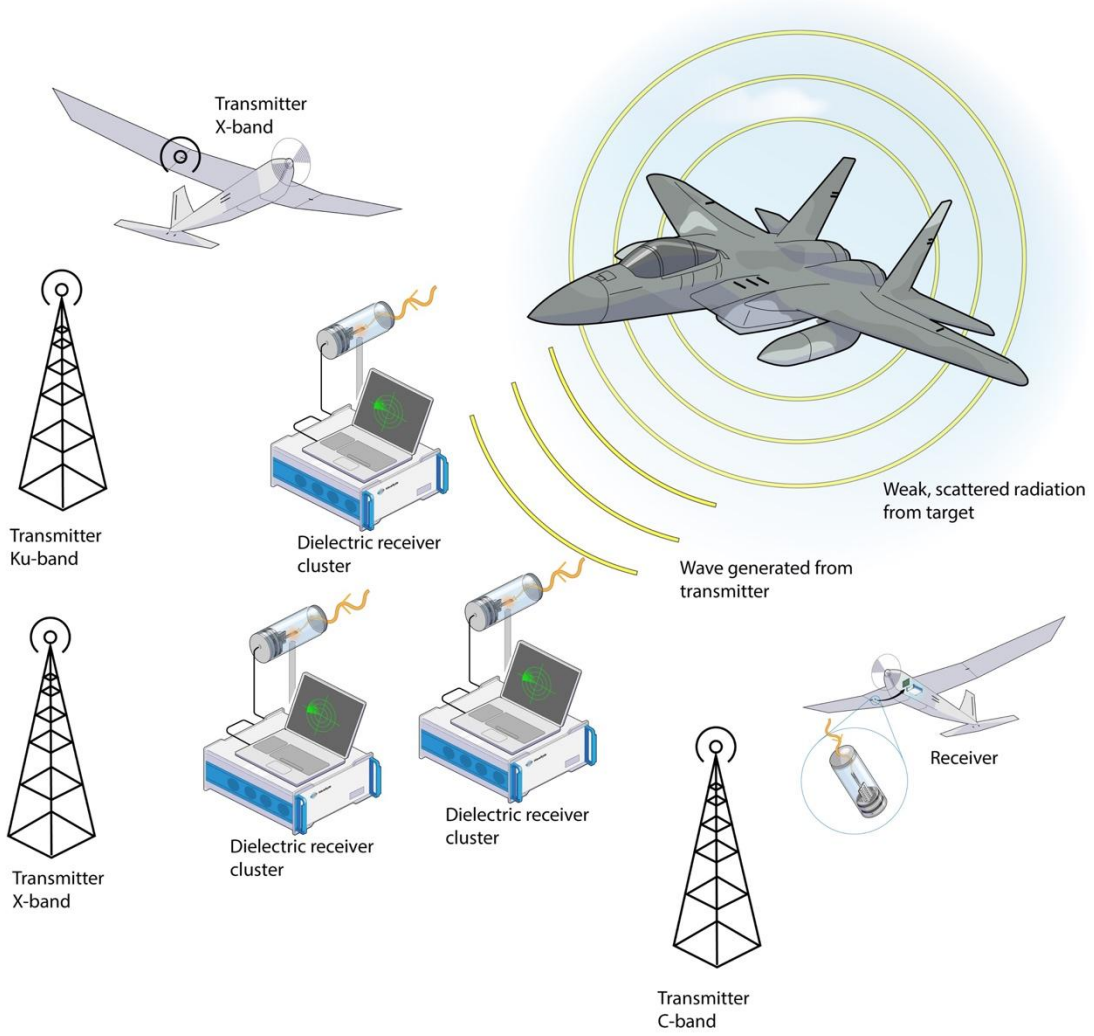


Quantum Radar Receiver photonic crystal vapour cell packaged in protective housing for field testing

- 10.7 GHz Quantum RF receiver has up to 40dB of passive amplification
- Compact design – ~10cm sensor with 25l control system
- Can deploy multiple sensors in synchronized network to create cost effective multi-static configuration.
- Can deploy additional sensors at different radar bands to provide co-located multi-band receiver.

Multi-frequency radar in a single system for enhanced target detection
Sensitivity below thermal noise limit to enhance detection of faint target returns. (= range and/or stealthy targets)
Low SWaP-C and reduced complexity enabling practical deployment on compact platforms like UAS or satellites.
Modular System Architecture –flexible and cost effective deployments across multiple use cases.

Quantum Enhanced Radar: Multistatic/Multi-Band Deployment



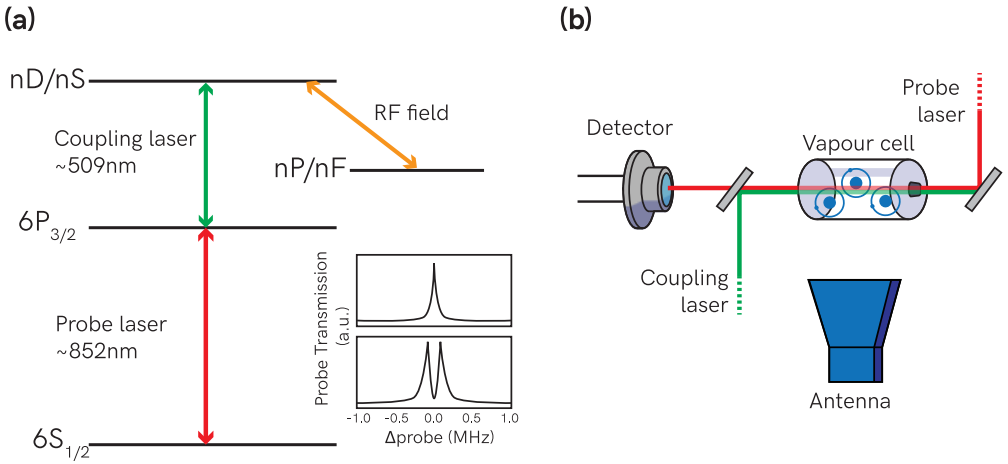
- Transmitters separated from multiple networked receiver locations to reduce detection
- Flexibility to deploy receivers across multiple bands, to enhance target detection across bands.
- Measure and correlate returns from each receiver to reduce ‘clutter’ and jamming impact
- Low SWAP-C enables dynamic receiver deployment on compact platforms like medium sized drones
- Enhanced ability for target resolution with distributed sensors
- Lower cost array with better performance than large complex phased array systems.
- Atomic clock and synchronization enable performance in GPS denied environments

Important Considerations for Implementation

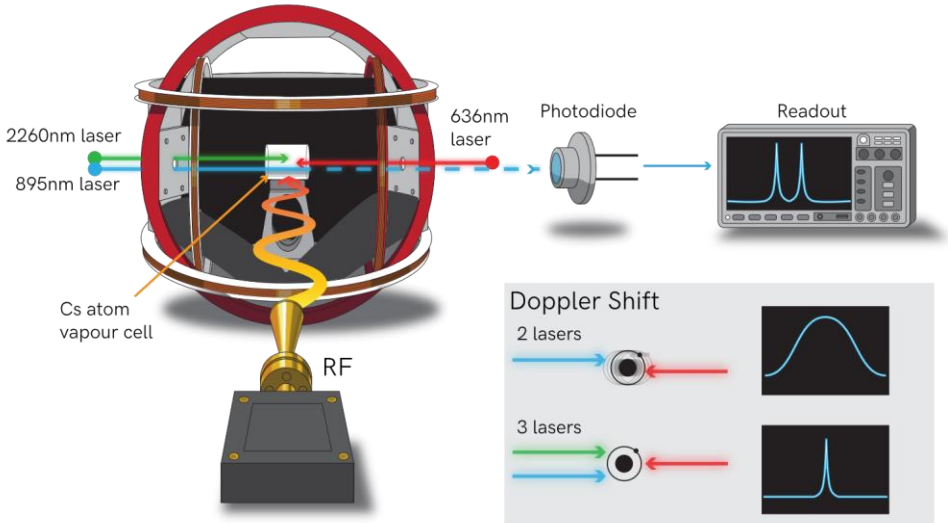
- Size, Weight and Power - Cost (SWaP-C)
- Receiver Timing and Synchronization
- Sensitivity

Photonics and Photonic Integration
RF Sensing – Atomic Control and Sensitivity

Existing 2 Photon System



Future 3 Photon System



Laser Requirements and Supply Chain Needs

- Low SWaP-C narrow spectral bandwidth, high power, broadly tunable laser sources and amplifiers at a number of wavelengths, eventually at large quantities (2.2mm, 636 nm, 895 nm, 852 nm, 1018 nm, 509nm)

The 2260 nm and 895 nm lasers are counter propagated against the 636 nm laser through a Cs vapour cell, and the 895 nm transmission is measured on a photodiode. The improved cancellation of the Doppler shift in this scheme allows for a much narrower linewidth, improving sensitivity.

arXiv:2505.00595 - All-optical radio-frequency phase detection for Rydberg atom sensors using oscillatory dynamics
Phys. Rev. Applied **20**, L061004:- Three-photon Rydberg-atom-based radio-frequency sensing scheme with narrow linewidth

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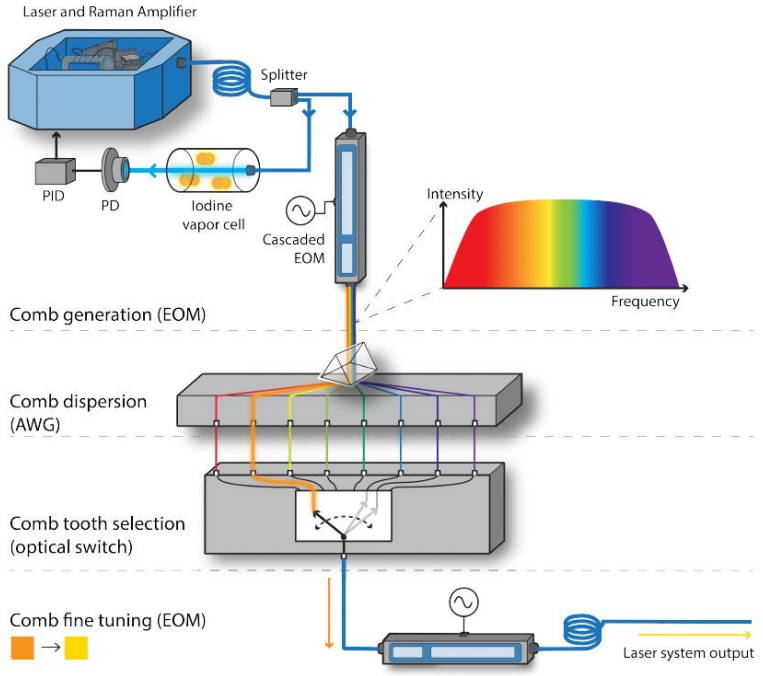
Photonics and Photonic Integration
RF Sensing - Spectrum Agility

The Challenge

- Broad spectrum radio frequency field detection using Rydberg atom-based sensors requires rapid shifting of the optical frequency of the coupling laser. Wavelength shifts of several nanometers are required, while maintaining the absolute frequency stability of the laser.
- The wavelength of the coupling laser must be fixed precisely on the optical frequency of the desired transition
- Conventional sensing systems require the laser to be tuned and locked to the required wavelength each time the detection frequency is changed.
- To ensure sufficient stability the laser must be locked to a stable frequency reference, a process which takes 0.1 to 100's of seconds.

The QVIL Solution

- The QVIL agile laser system enables fast (~200 ns) switching of the coupling laser to change the RF sensing frequency
- Currently Developing compact system using SIN PIC's, TFLN and other components to enable low SWAP-C enhancement to control system.



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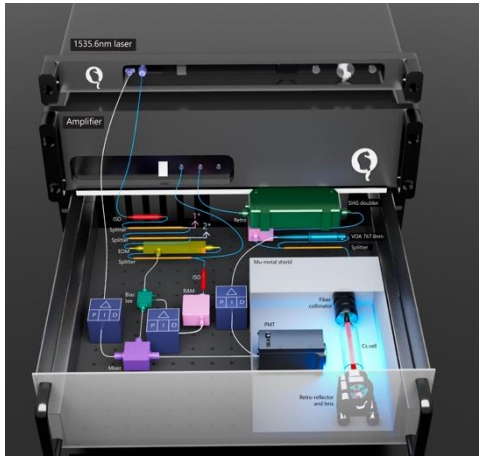
Photonics and Photonic Integration – Optical Atomic Clock



State-of-the-art atomic clocks achieve exceptional stability but are often bulky, requiring significant space and resources.

Masers are expensive and hard to obtain.

Stability Target: Fractional frequency instability of 10^{-14} at 1 second and 10^{-15} at 1 day (10^5 s).

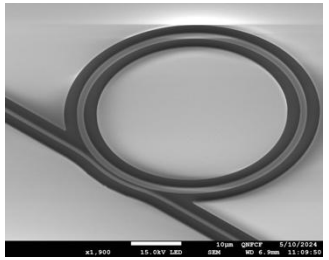
SWaP Target <24 L, <15 kg, and <80 W.

Future direction: Chip-scale atomic clock

Frequency Comb: Optical Stability to RF

Creating frequency combs using **on-chip Ta_2O_5 ring resonators**.

In such resonators, Kerr solitons have been demonstrated to generate broadband frequency combs.



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