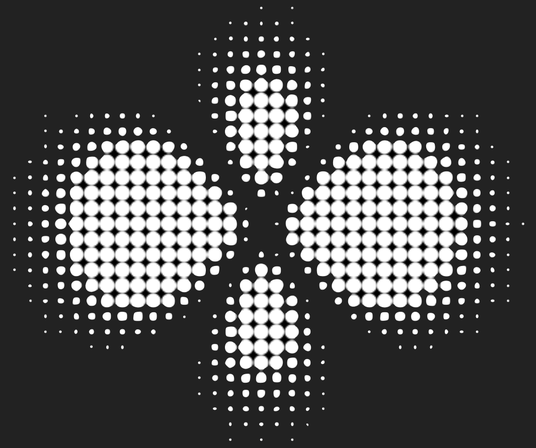

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CEOI Technology Showcase - June '21

Dr P. B. R. Nisbet-Jones, Dr C.P Bridges

LEGO

Lasers for Earth Gravitation Observation

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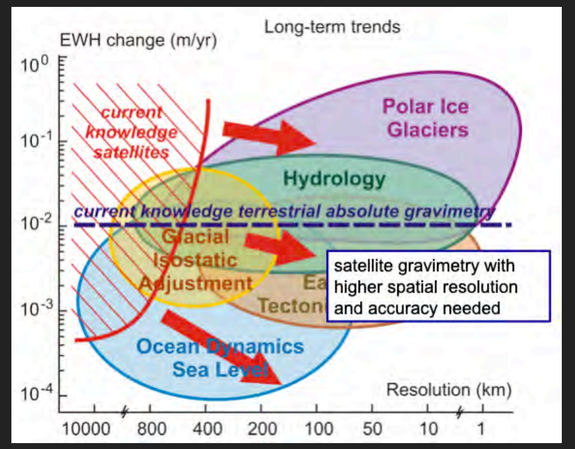
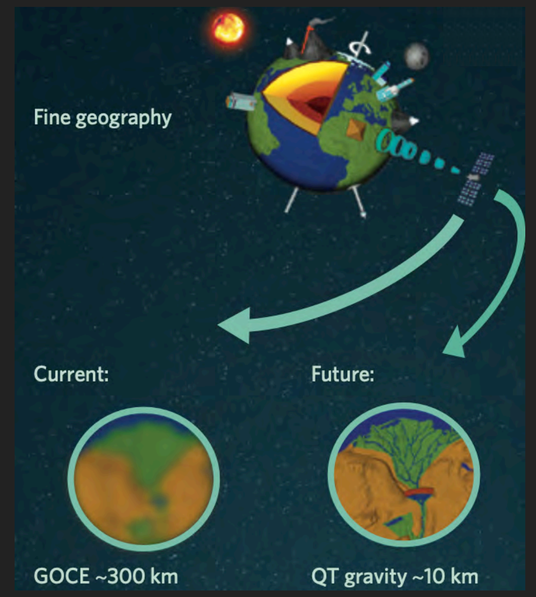
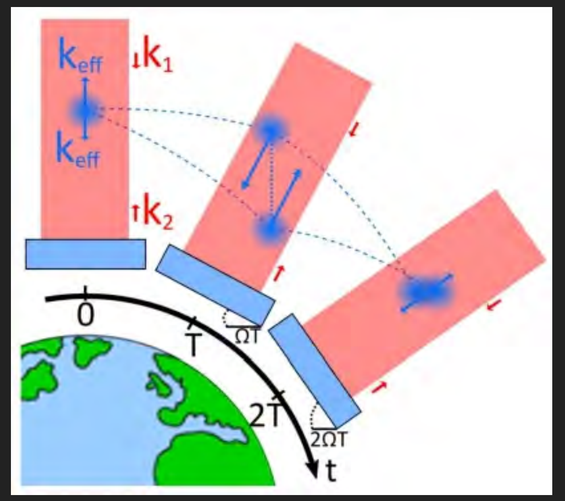
WHY?

- Gravimeters for EO
  - Laser Ranging (e.g. GRACE)
  - Atom interferometer (AI)
  - Relativistic - atomic clocks
- AI & Relativistic not yet in space
- EO gravimeter CubeSats?
- Laser / Electronics TRL is a major issue

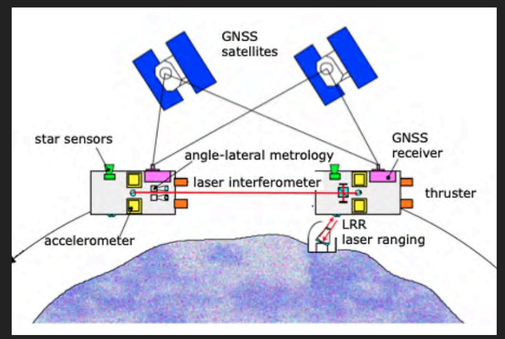




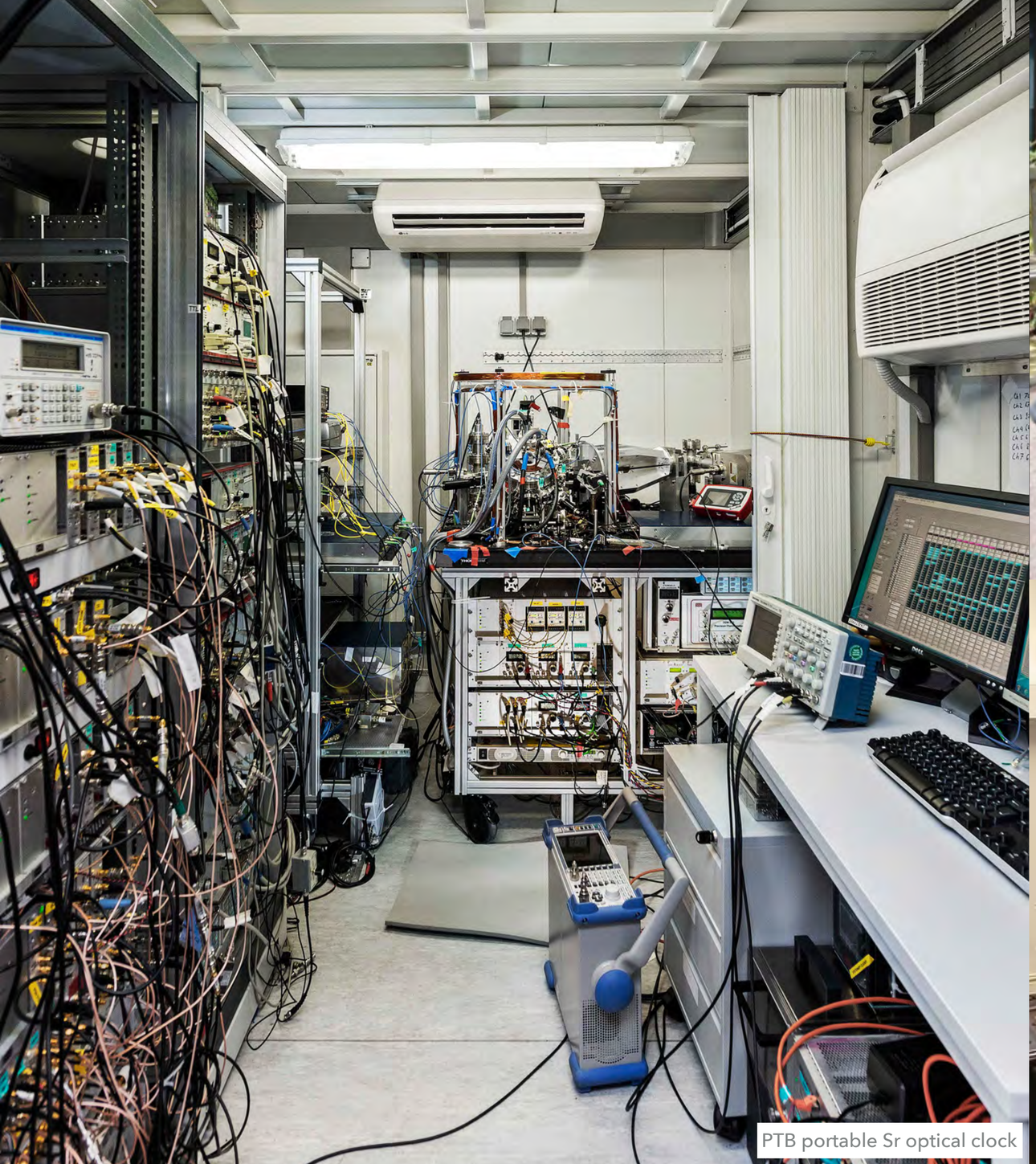
Bongs, Nat.Phys 11 615 (2015)



CAL - ISS

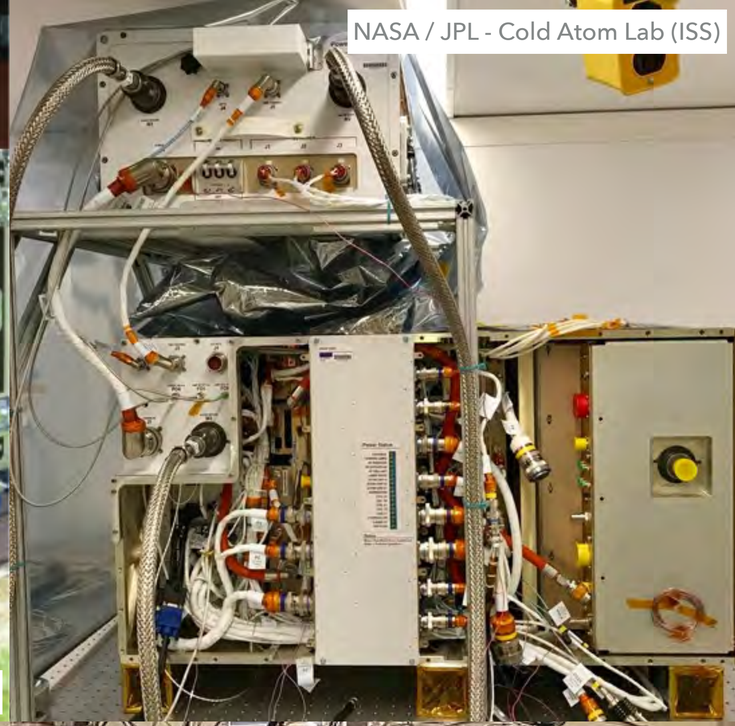


ESA: NGGM

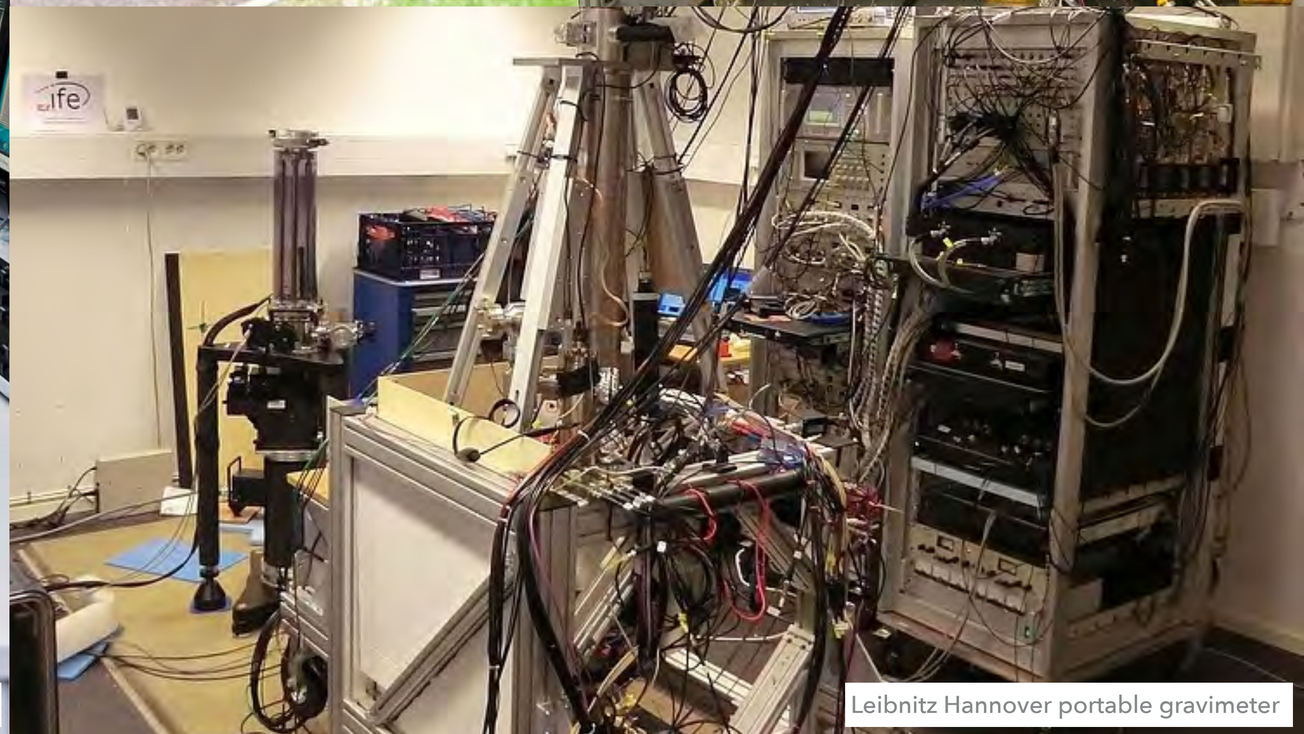


PTB portable Sr optical clock

Birmingham portable gravimeter



NASA / JPL - Cold Atom Lab (ISS)



Leibnitz Hannover portable gravimeter

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Project Objectives

Science

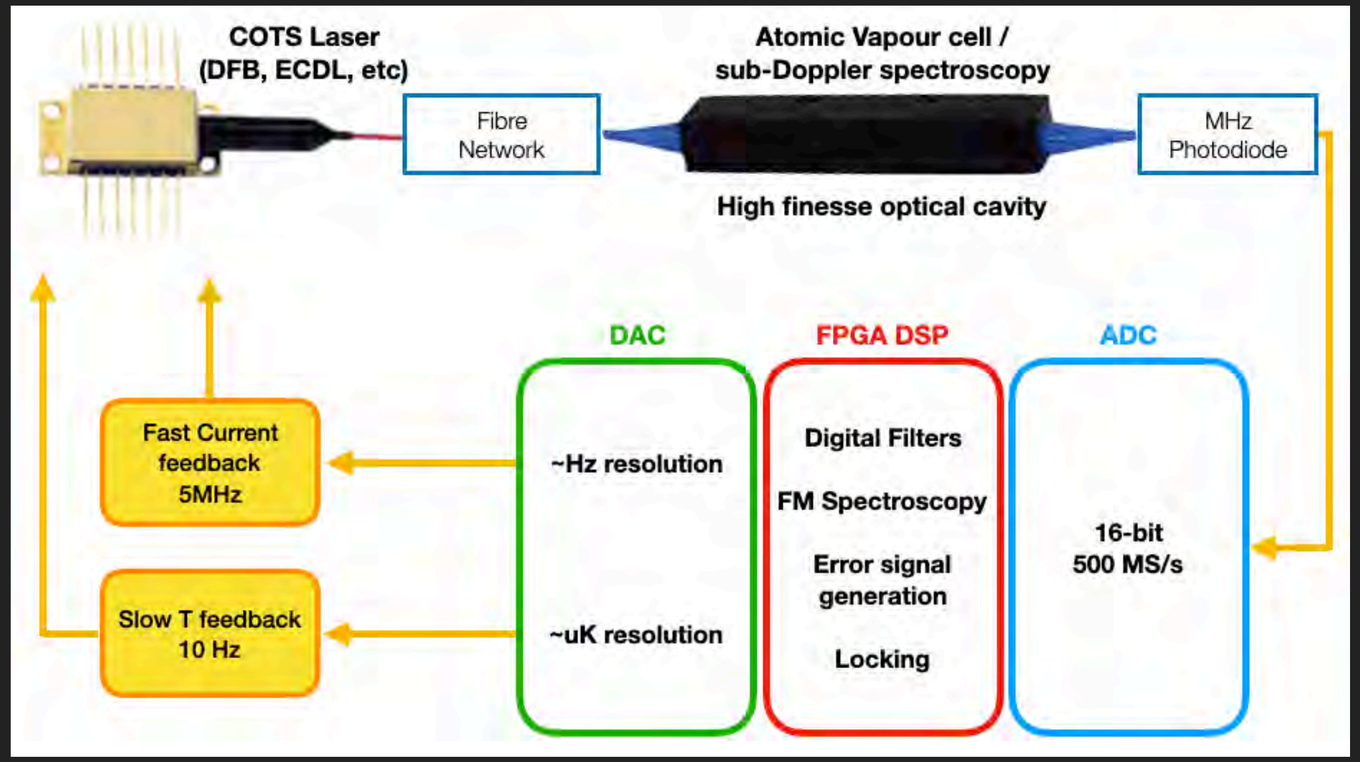
- Build a stabilised laser for a Gravimeter / Quantum sensor
  - Use 780nm Rb stabilised laser: Prove 10 kHz / 1 MHz stability/accuracy
  - With other laser diodes / references: Potential <100 Hz / 1 kHz stability/accuracy

Technology

- Low SWaP, cost: (1 liter, 0.5 kg, 10 W / SmallSat)
- All-digital control (FPGA), all "COTS" fibre-optics

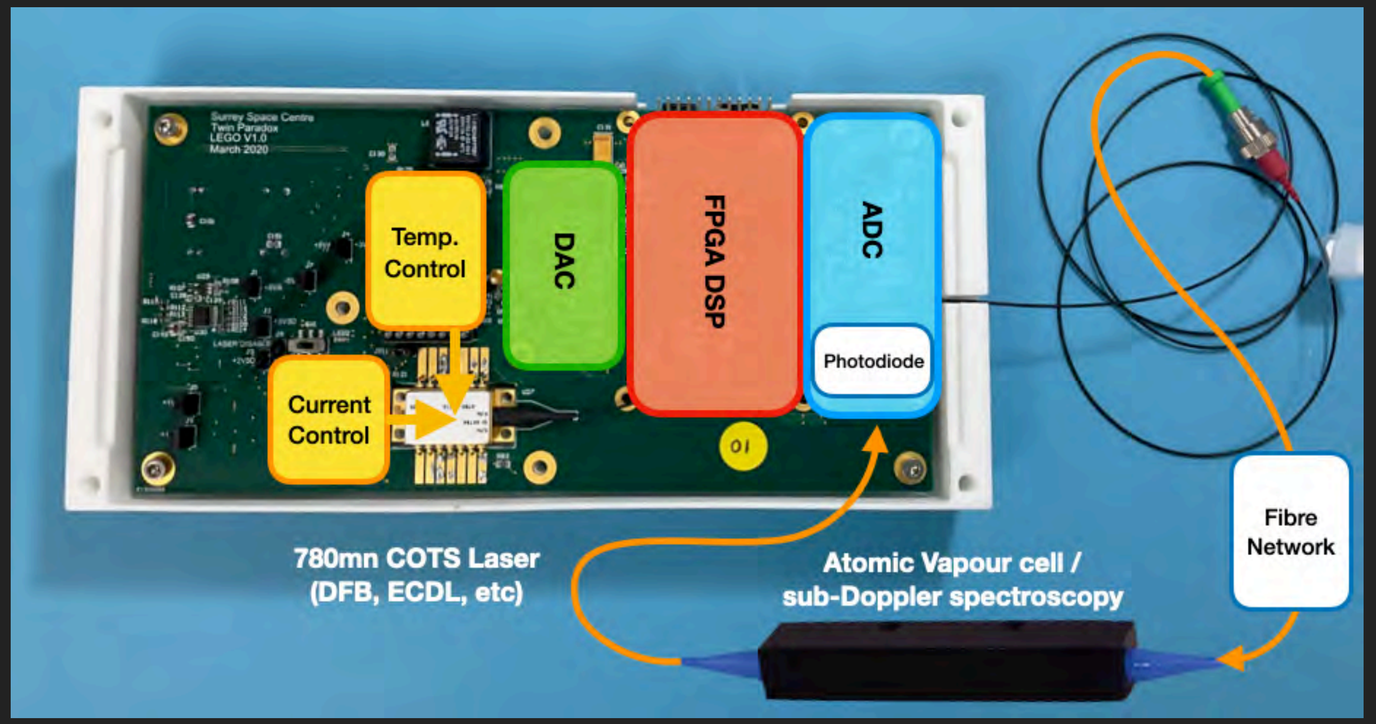
Technology Overview

- Put everything into software
  - ADCs/DACs & DSP from SDR research
  - High resolution / high speed
  - Optimised analogue front ends
  - FPGA control
- Put everything into fibre
  - **Any** diode laser
  - UV/VIS/NIR Fibre components
  - Telecordia standards / "Plug & Play"
  - Compatibility:
    Fraunhofer / Ferdinand Braun / JLIQS



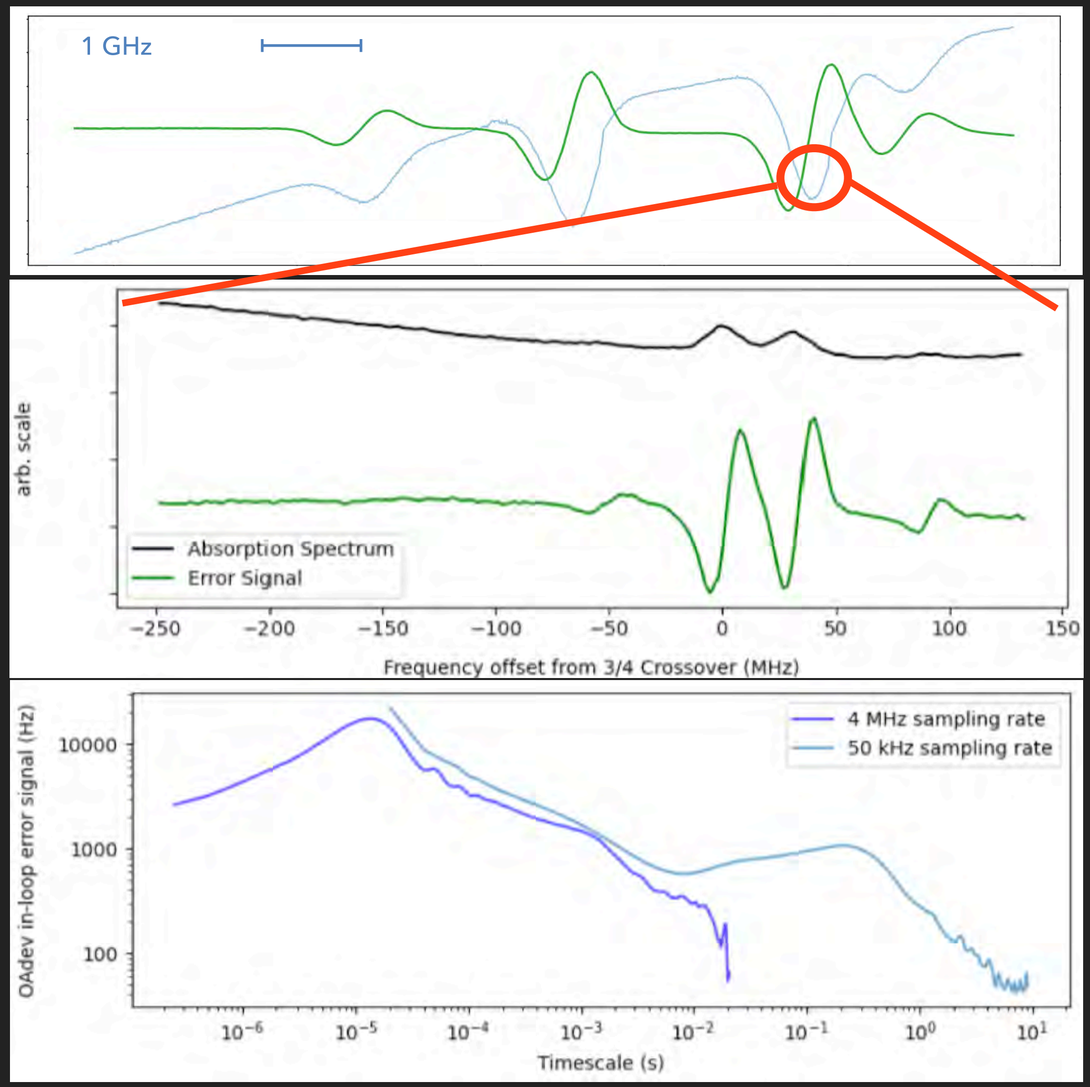
Technology

- All Digital control
  - Optimised VHDL → ~20% of Spartan 6
  - FIR, IIR filters
  - MHz bandwidth FM spectroscopy
  - Digital PID & control
- Single PCB module
  - Power, DSP, laser control, etc.
  - Overcurrent/voltage protections (SEU)
  - Telemetry & monitoring
  - USB / UART / CAN-FD



Science

- Opto-electronics
  - Flexible laser driver
  - **For this project:** 10mW output DFB
  - **Future?:** 500mW VHG/Hybrid-ECDL
  - All fibre sub-Doppler optics
- Rubidium Sat. Spectroscopy
  - FM / PDH spectroscopy
  - Polarisation control
  - 100MHz high-gain photodiodes
  - Mounted to enclosure lid



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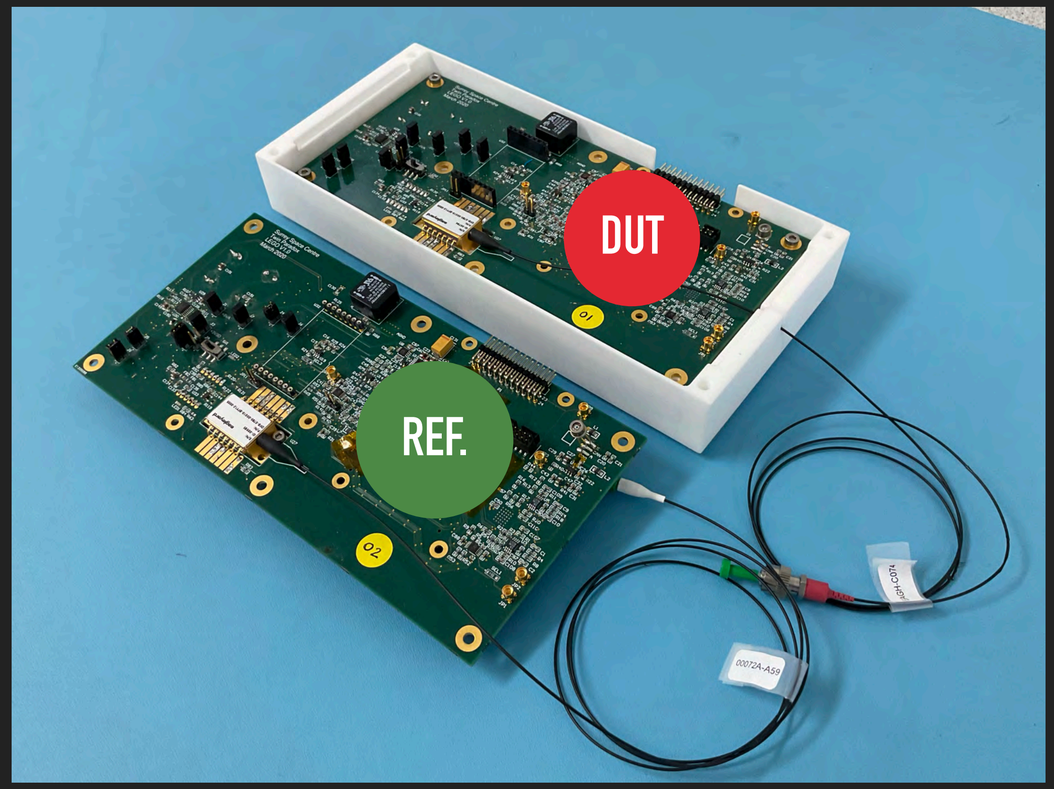
Current Status

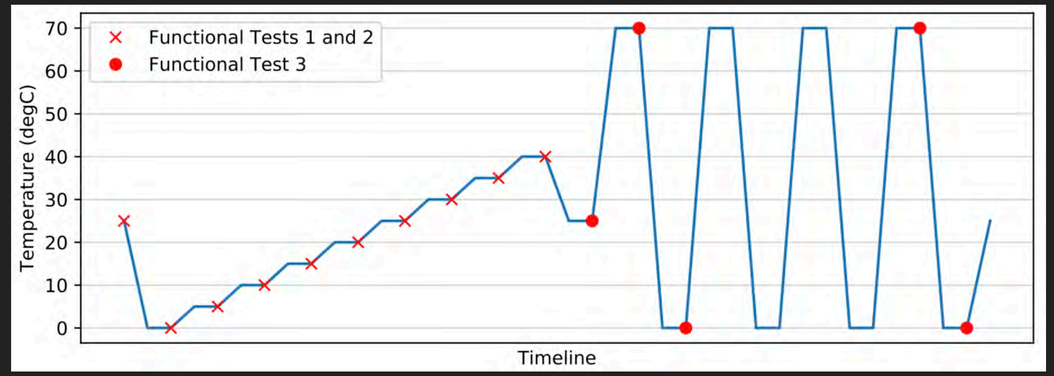
Science

- 10 kHz Db stability (in-loop estimate)
- 1 kHz sD stability (in-loop estimate)

Technology

- 1 liter (20 x 10 x 5 cm)
- 300 g
- 7 W (5V @ 1.4A)





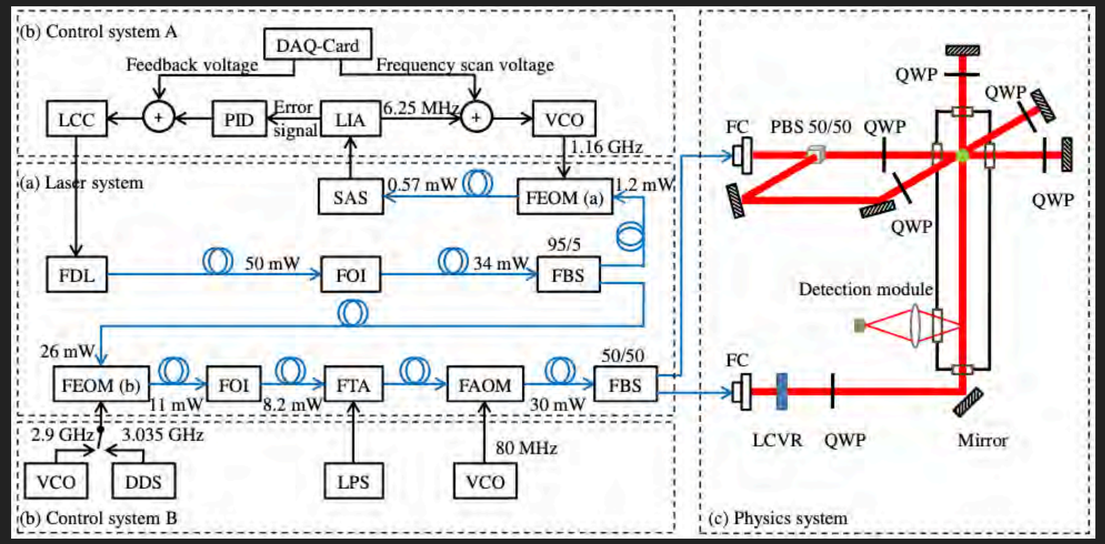
Where next?

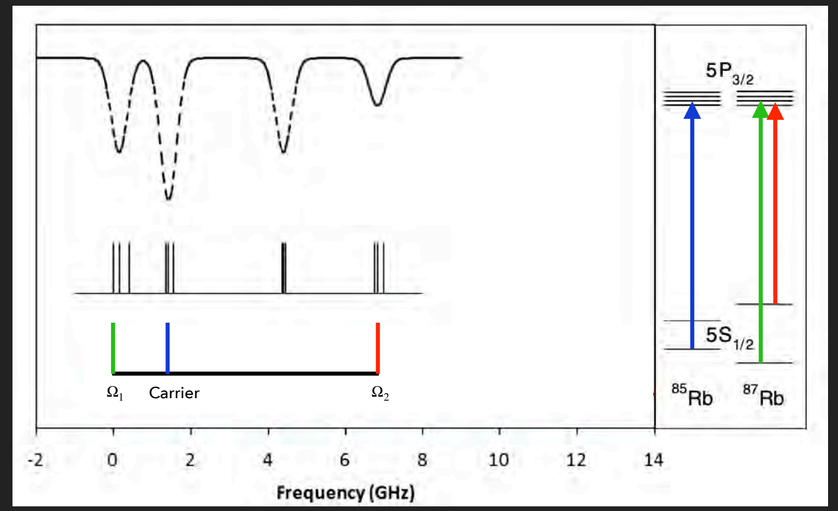
- Optimizations
  - Improve bandwidths, resolution, etc.
  - More SWaP reductions
- Frequency Agility
  - GHz tuning
  - Arbitrary spectrum generation
- **Applications**

  Atom Interferometer & Atomic Clocks (cooling & clock)

  → Open to collaborations

Fang, Opt. Expr. 26 1586 (2015)





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