UNIVERSITY OF BIRMINGHAM

EPSRC
Pioneering research and skills

UK National Quantum Technology Hub
in Sensors and Metrology

Activities of Birmingham and the Hub

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Toulouse, 09/12/2015

UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME

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Outline

- What does cold atom quantum technology look like?
- Overview of UKNQT Hub in Sensors and Metrology
- Frequency sensing activities in Birmingham
- Atom interferometry activities in Birmingham

What does cold atom quantum technology look like?

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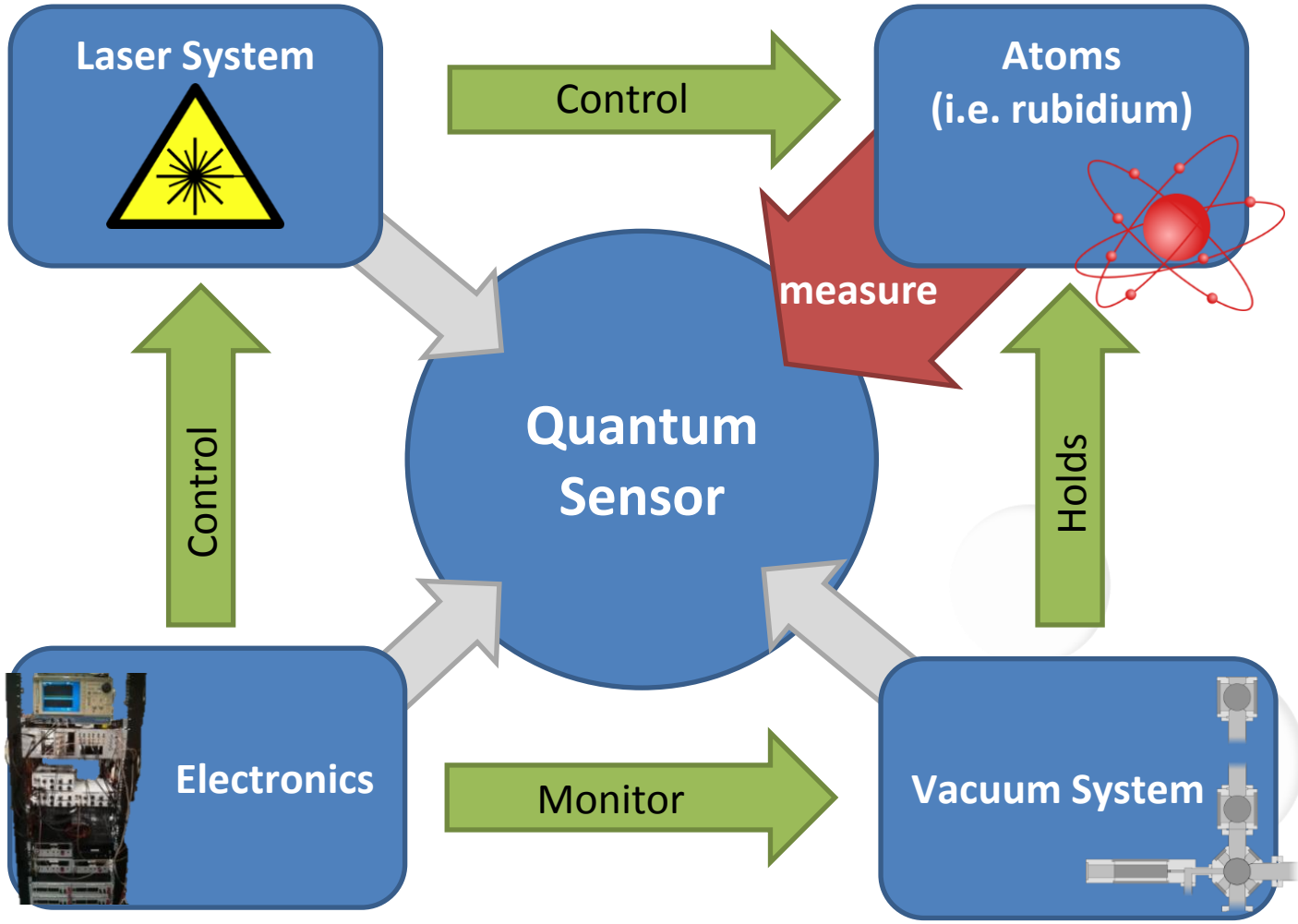
PROGRAMME

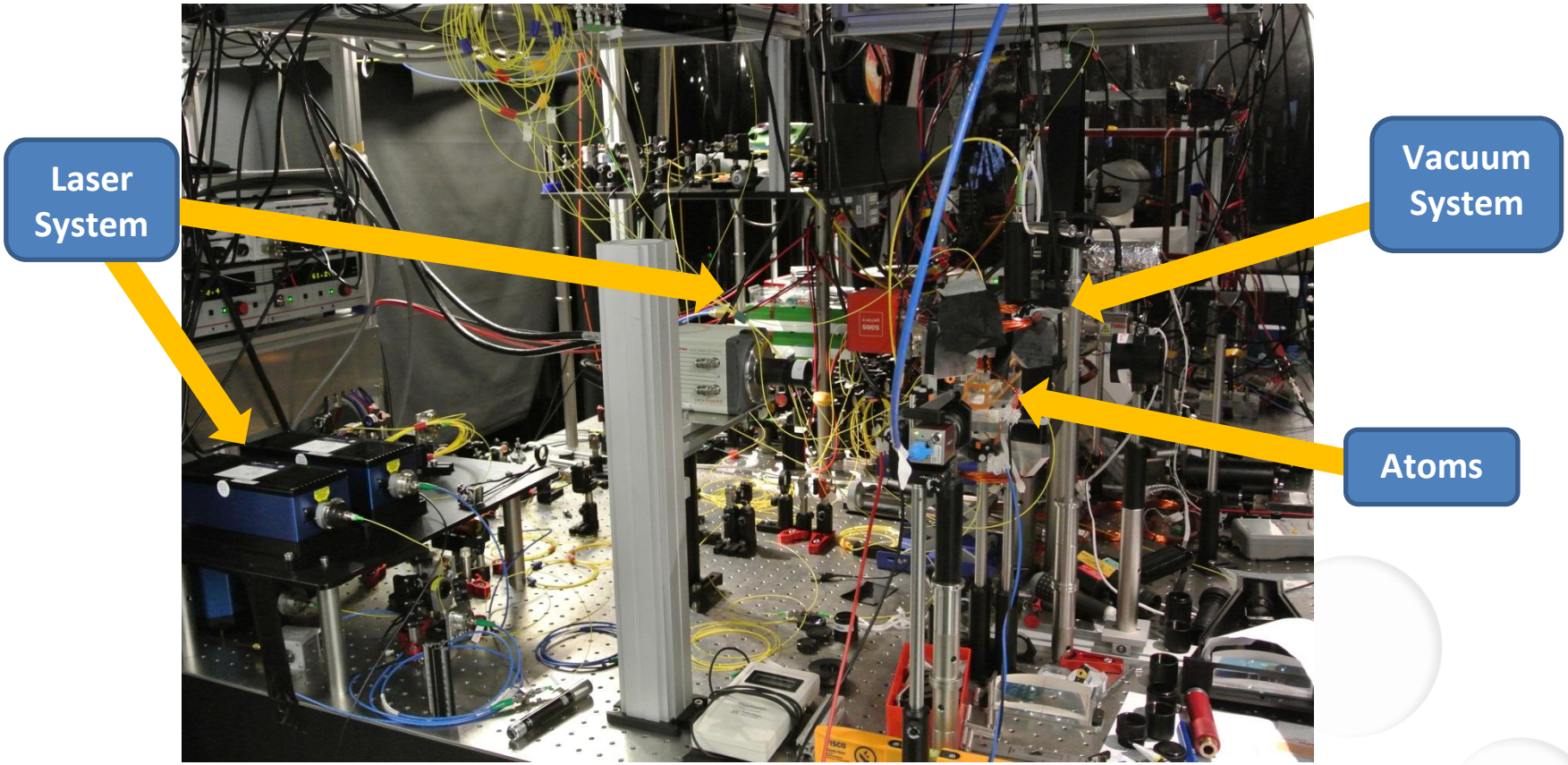
Anatomy of a cold atom QT sensor



- Offer extreme performance, but…

Anatomy of a cold atom QT sensor

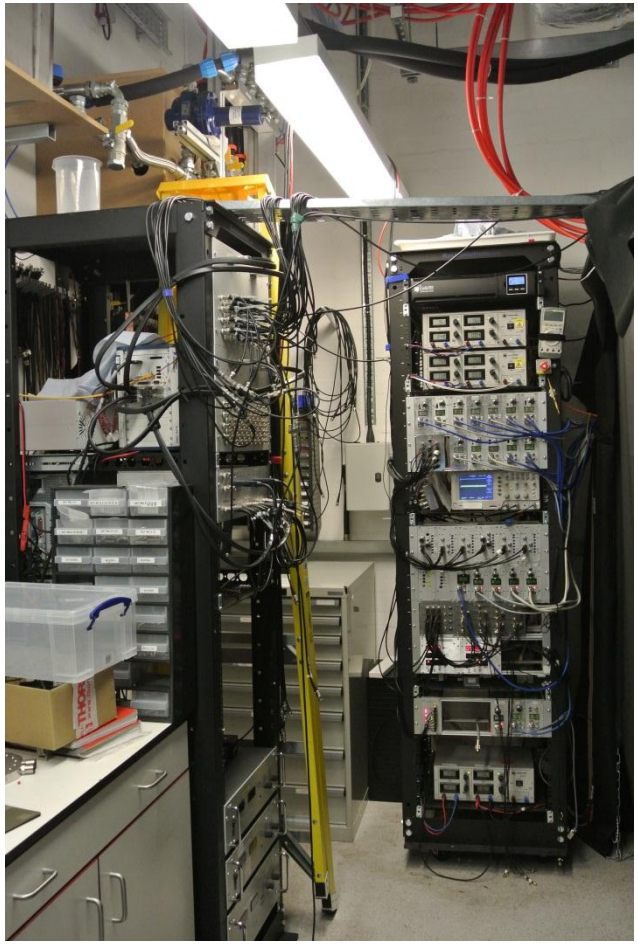
- Apparatus typically fills 1-2 optical tables:

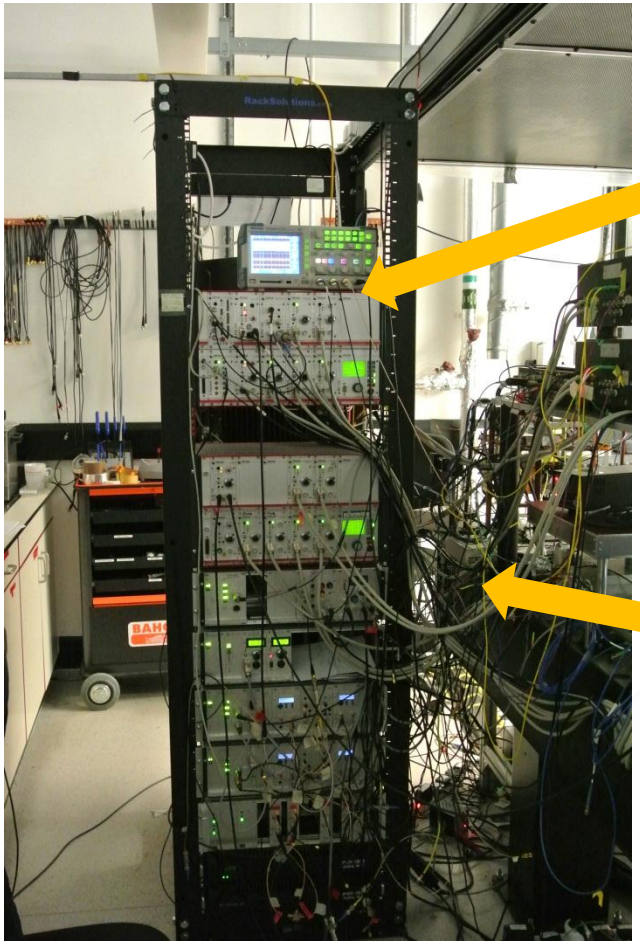


- And the electronics…

Anatomy of a cold atom QT sensor

- Typically fill 1-2 server racks:





- Other issues: robustness, cost…

Why should anyone be interested?

Cold atom based QT sensors:

- Already "outperform" classical counterparts
- Have huge potential
- Have disruptive benefits
- Globally, lot of good work has already been performed

However:

- To untap full potential need to reach wider markets
- Needs improved:
  Size, Weight, Power, **Cost, Confidence, Usability**

- Requires translation from "research" into "technology"

Overview of the UKNQT Hub in Sensors and Metrology

UK National Quantum Technology Hub

in Sensors and Metrology

UNIVERSITY OF BIRMINGHAM

University of Glasgow

The University of Nottingham

UNITED KINGDOM · CHINA · MALAYSIA

University of Southampton

University of Strathclyde Glasgow

University of Sussex

EPSRC Pioneering research and skills

NPL National Physical Laboratory

M SQUARED

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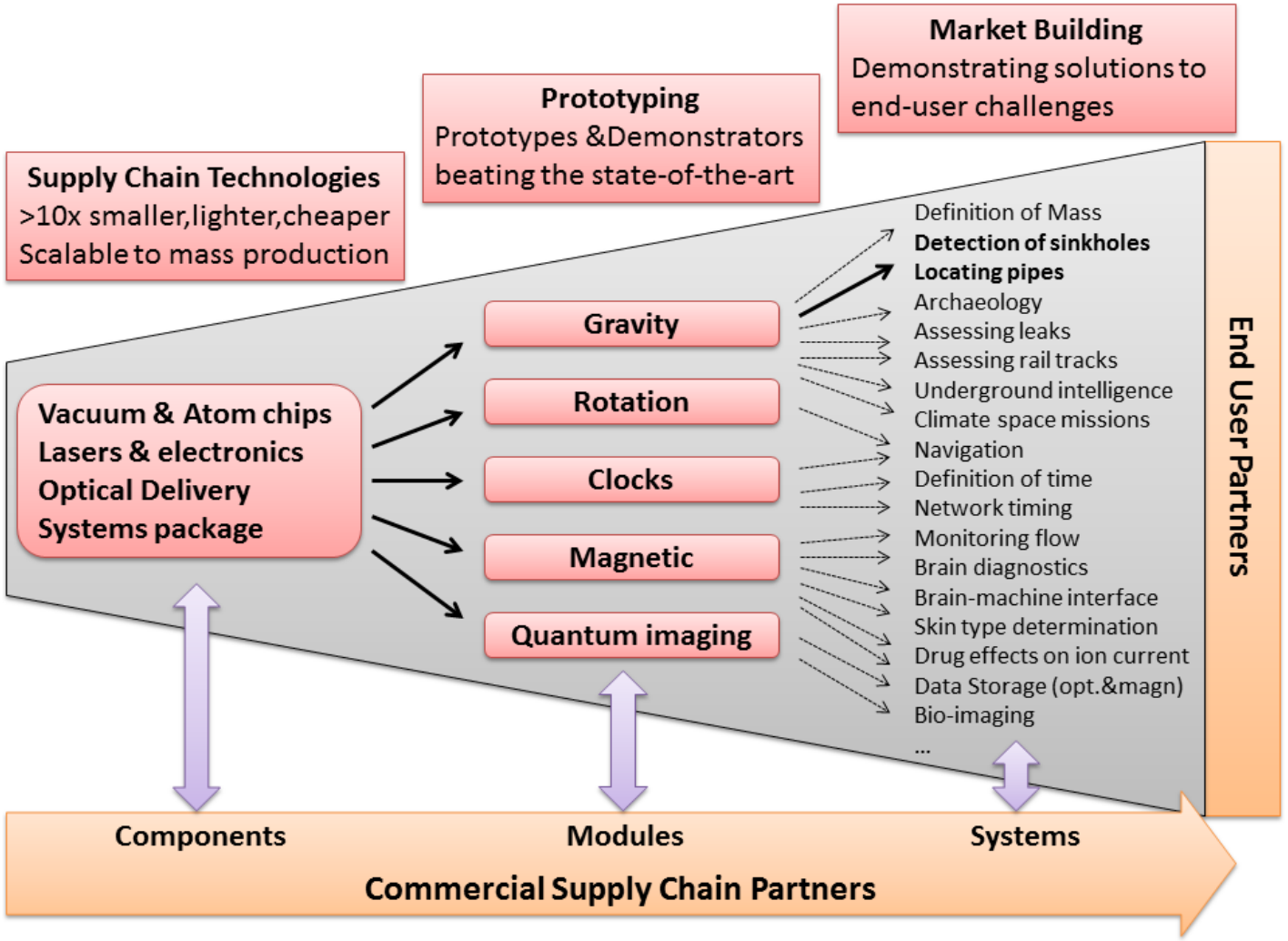
[dstl]

+ 70 industrial partners

Introduction to the Hub

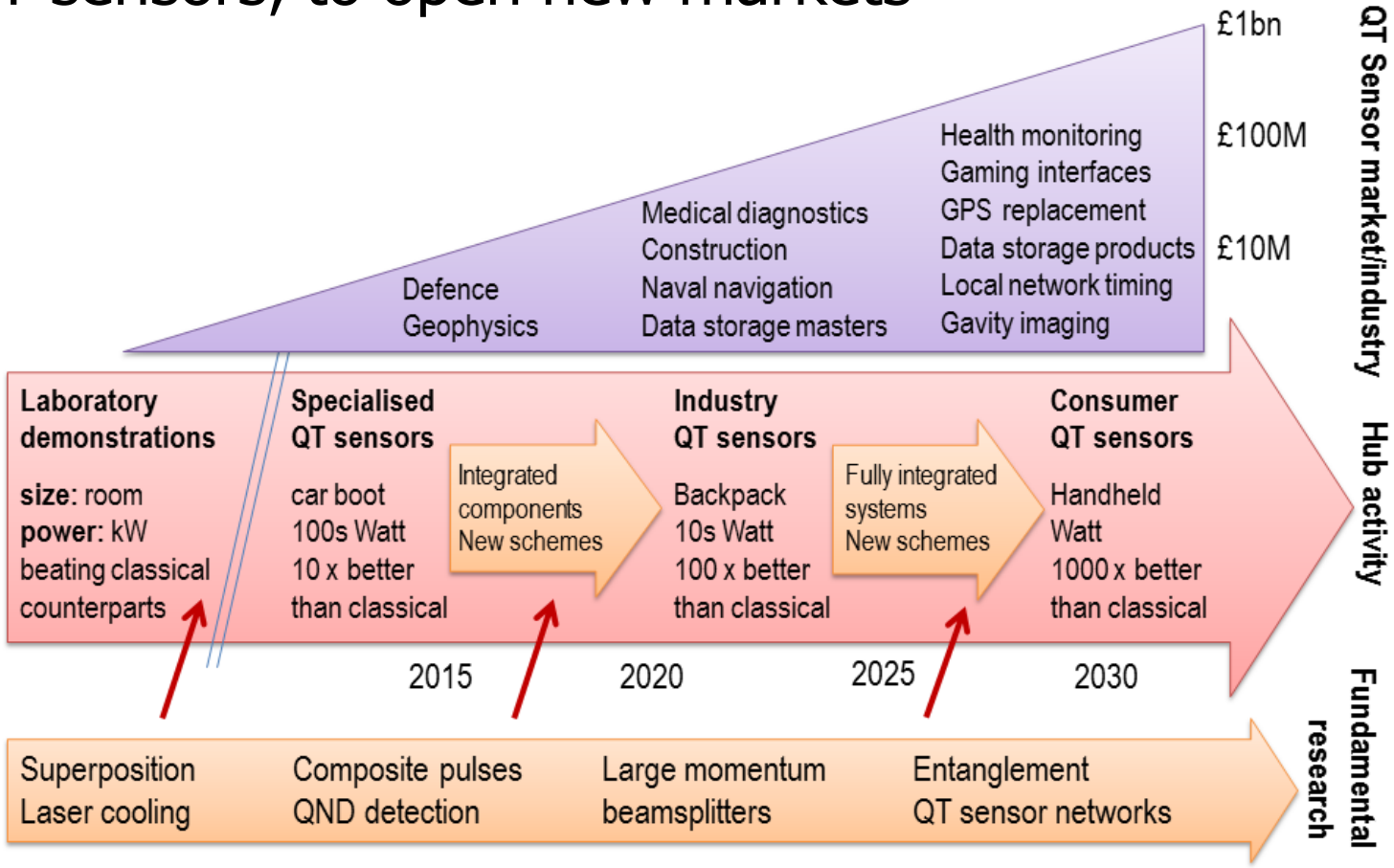
- Part of the growing UK QT programme
- Investment from government and industry to enable emergence of QT market
- Create an environment in which QT can flourish: mixture of academics, suppliers and end-users
- Develop supply chain and aid commercialisation
- Demonstrate key applications to build market interest

Vision of the Hub



Goals of the Hub

- Improve technology readiness, and performance of QT sensors, to open new markets



Frequency sensing demonstrators in Birmingham

UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME

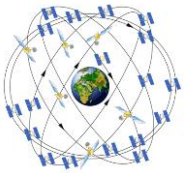
Applications of precision clocks

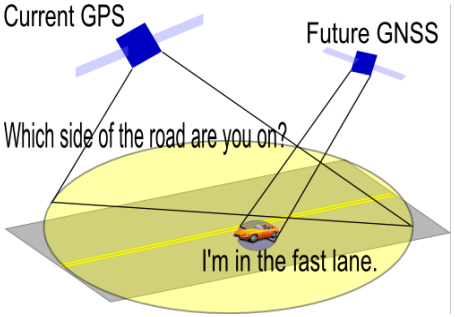
Network synchronisation

Financial time-stamping

Time references for data encryption

Next generation GNSS





Geodesy applications

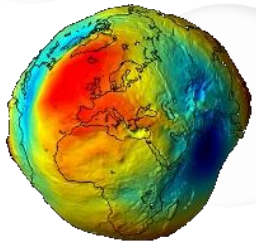
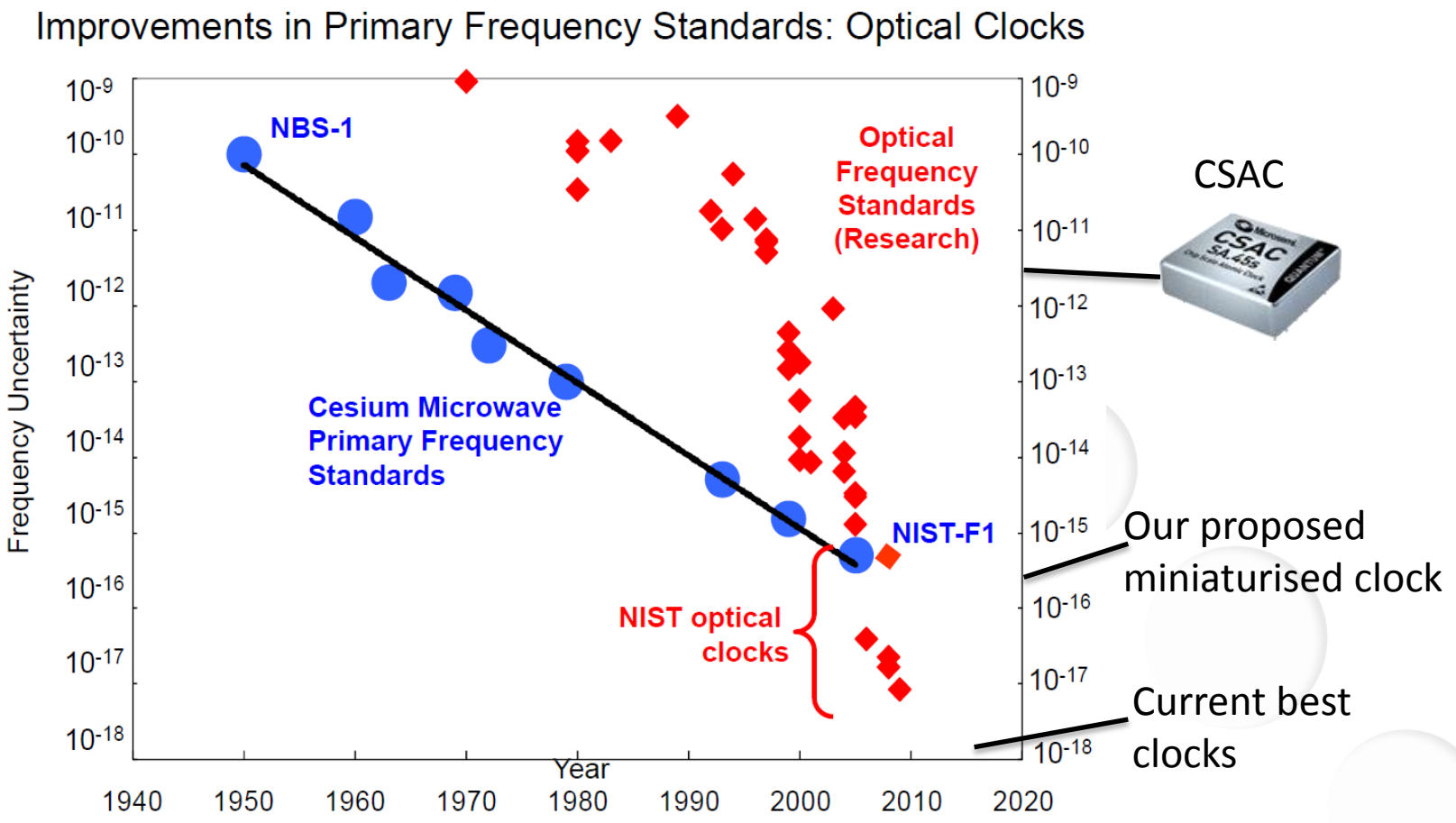


Photo: ESA/GOCE

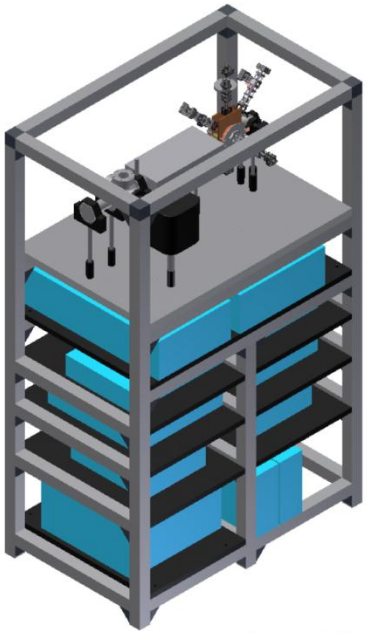
Motivation for cold atom based clocks

- Optical clocks overtaking primary standards

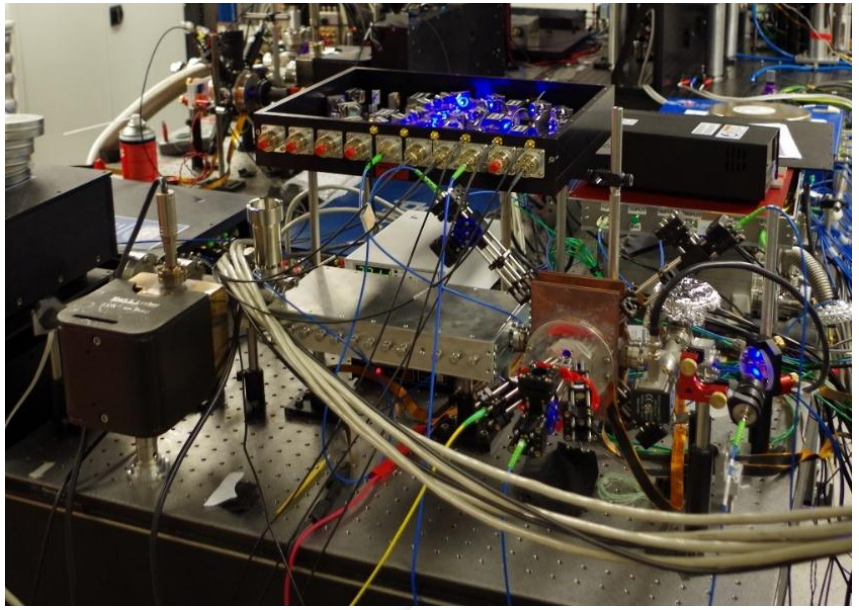


Current demonstrators at UoB

- SOC2 – Space optical clock 2 (strontium based)



- Portable housing of 970 l and 300 kg
- Mobile apparatus can be tested against other clocks
- System now deployed in PTB, Germany



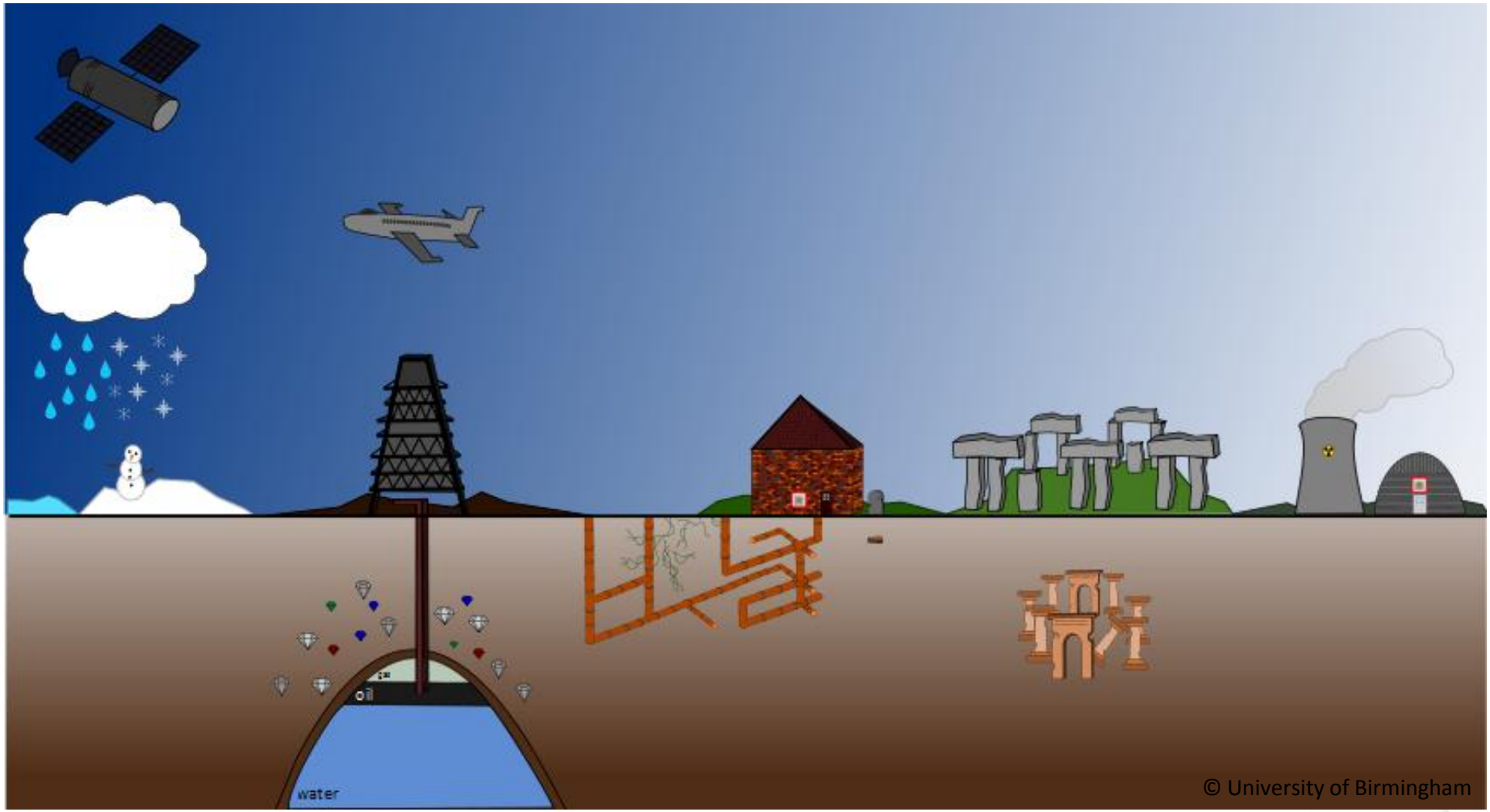
- Blue MOT: 1x10^7 atoms
- Red MOT: ~25% transfer at temperature ~1μK.
- Current status: Atoms in lattice, integrating clock laser

- New UoB project: 20L Sr lattice clock, NPL making portable stable cavity

Atom interferometry demonstrators in Birmingham

UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME

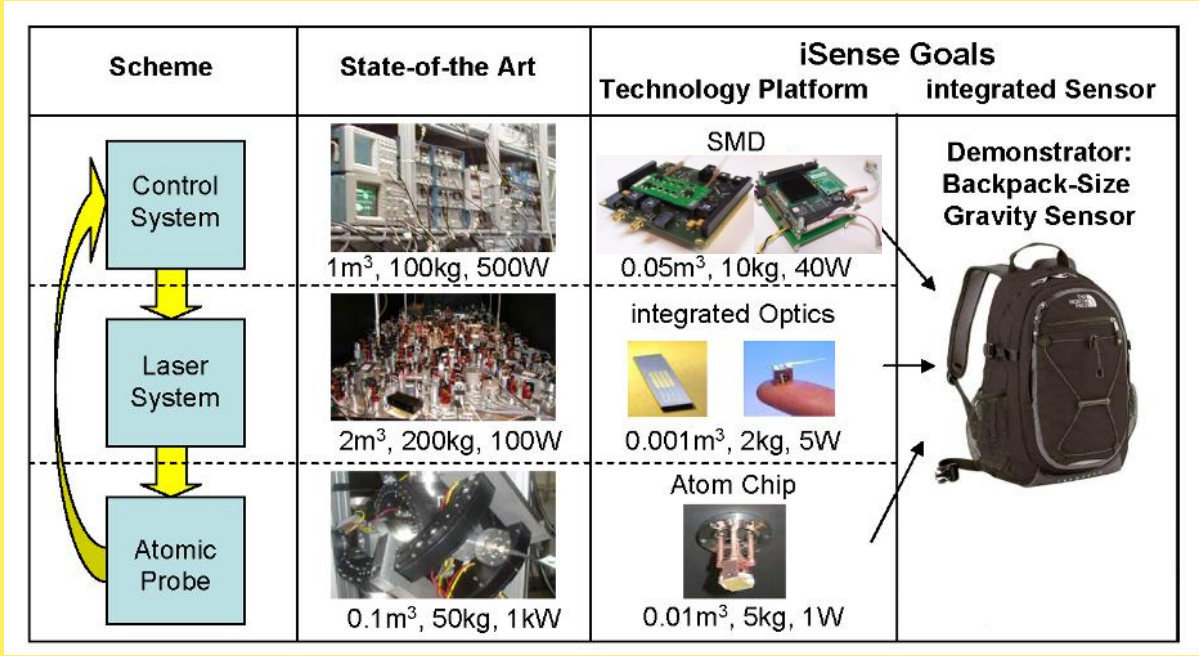
Applications of precision gravity sensing



iSense gravimeter

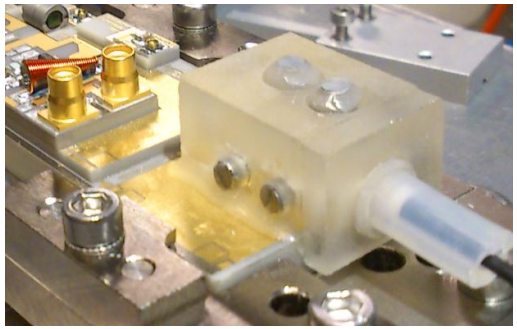
EU consortium to create a quantum technology platform to overcome the bottleneck in cold atom applications, and demonstrate it in Brussels.

Technology development areas

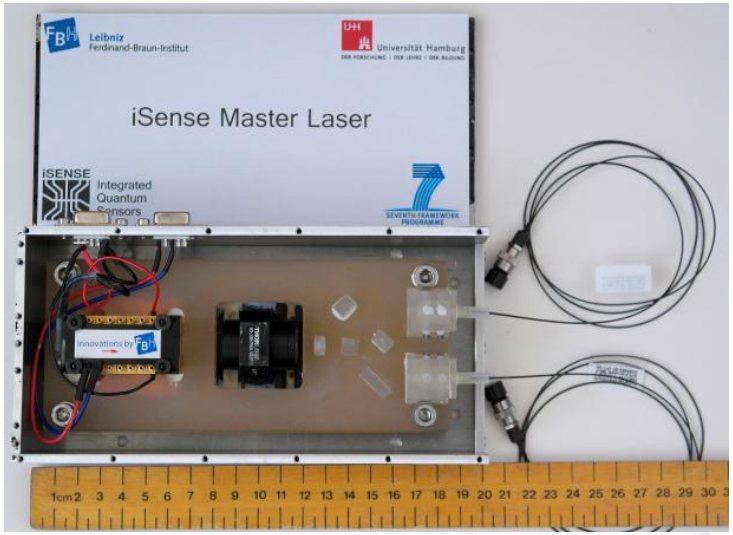


iSense gravimeter

- Light sources
  - Micro-integrated lasers from FBH
  - Packaging by Hamburg
  - Micro-spectroscopy unit, still in fabrication



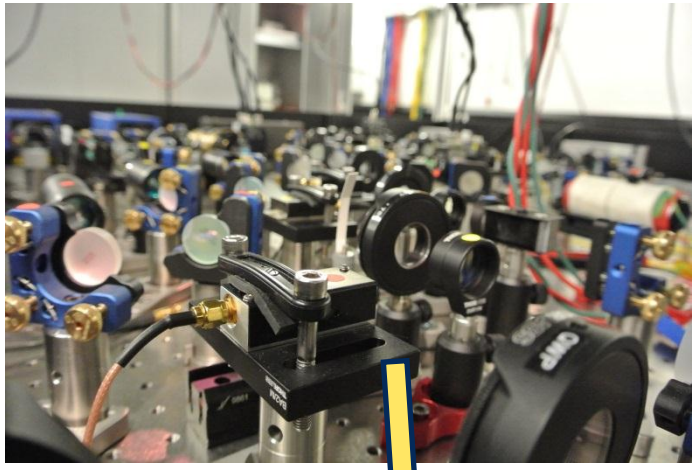
On-board ZERODUR fibre coupler

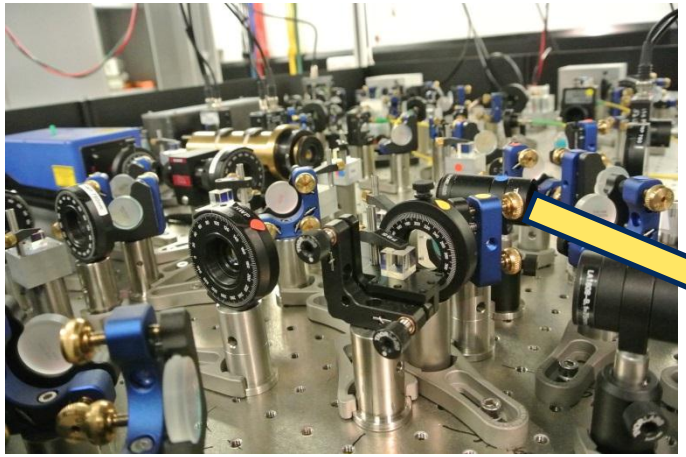


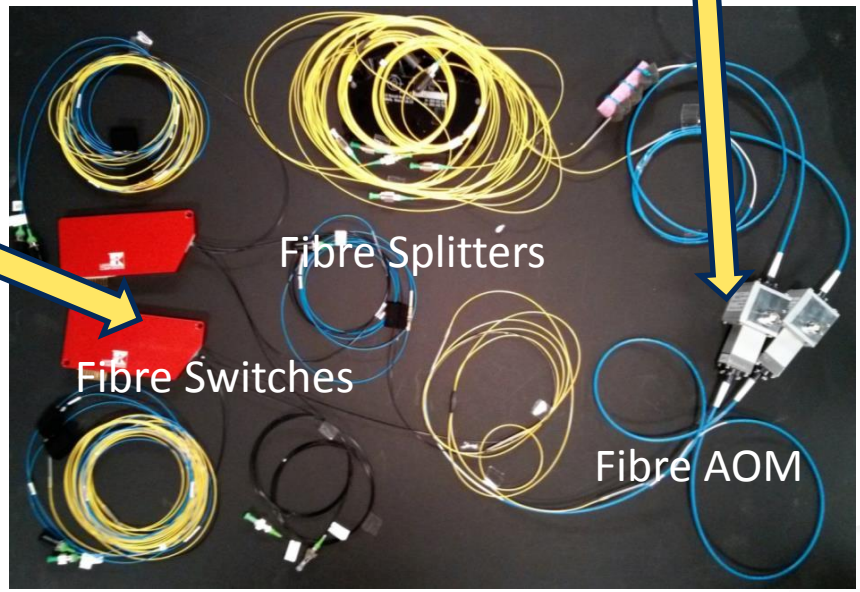
DFB

iSense gravimeter

- Light delivery
  - Free space to fibre optics
  - Reduced volume
  - Improved alignment stability

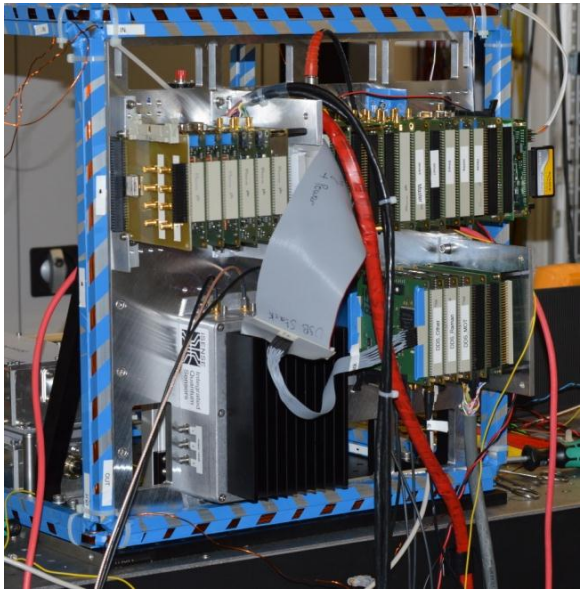


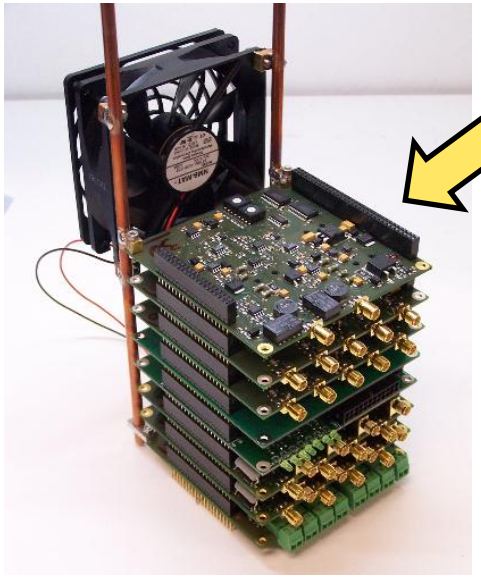


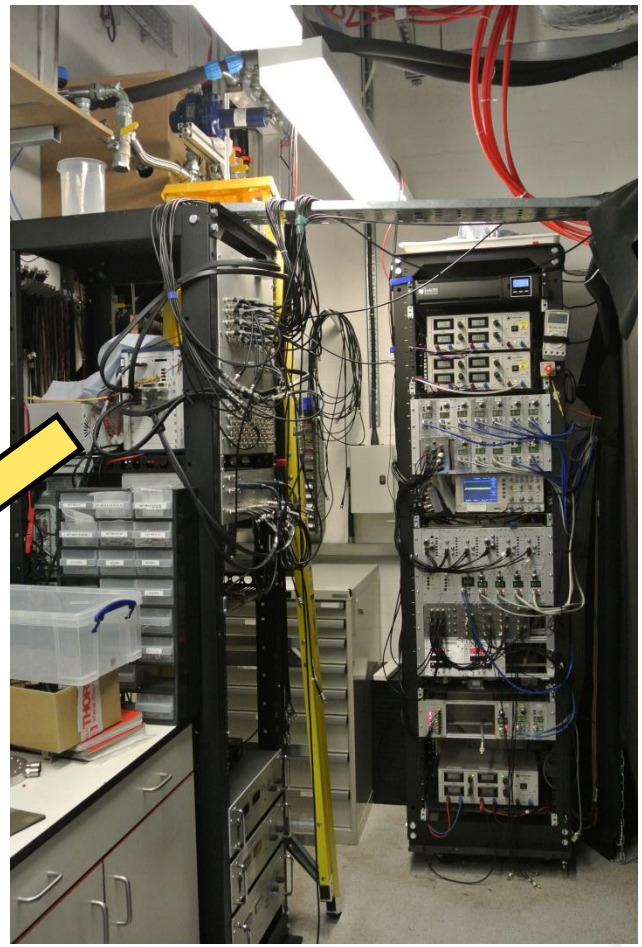


iSense gravimeter

- Electronics
  - Compact control from Hannover
  - PC104 form factor
  - FPGA, flexible programming
  - Microwave chain from CNRS

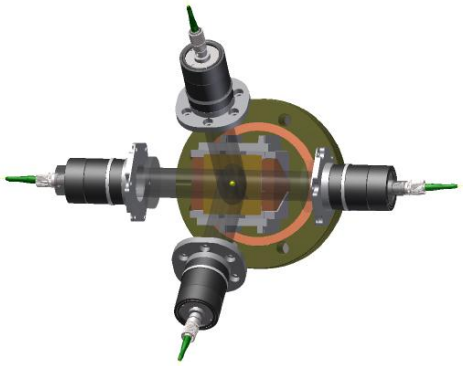






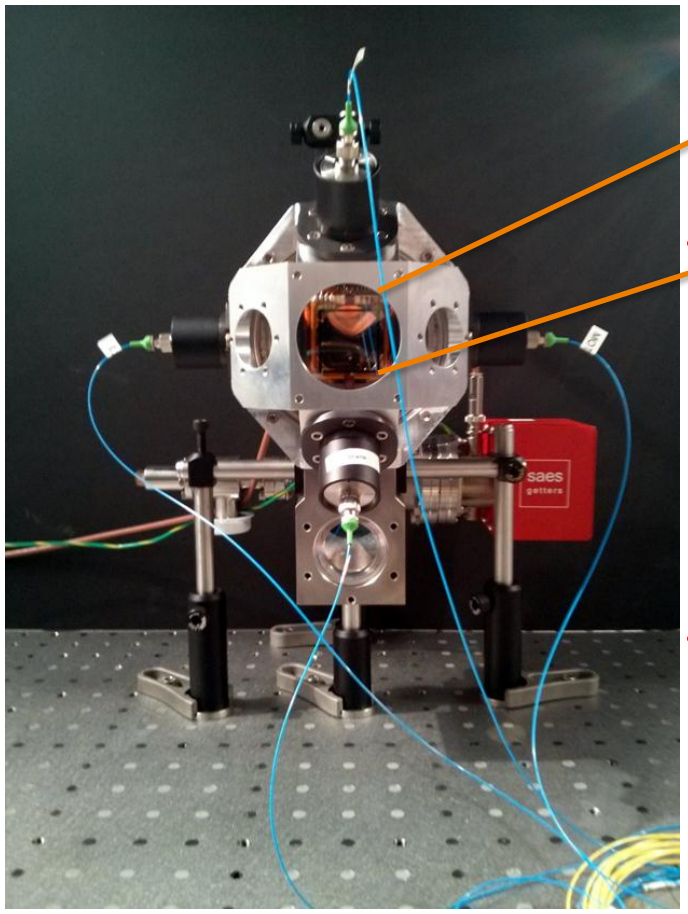
iSense gravimeter

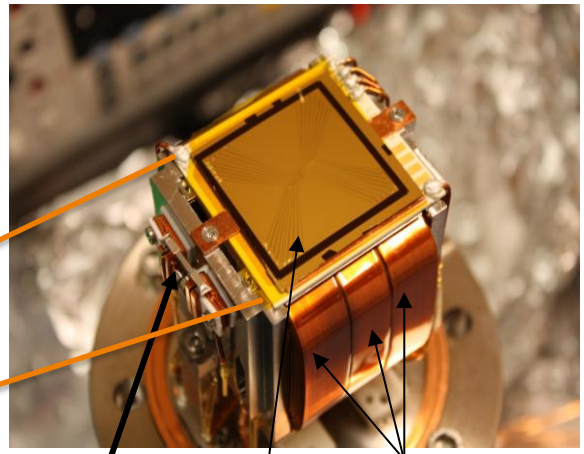
- Vacuum system
  - Low power atom chip from Nottingham



External volume 3.5l
Evacuated vol. 0.9l
Weight 8kg

Indium sealing

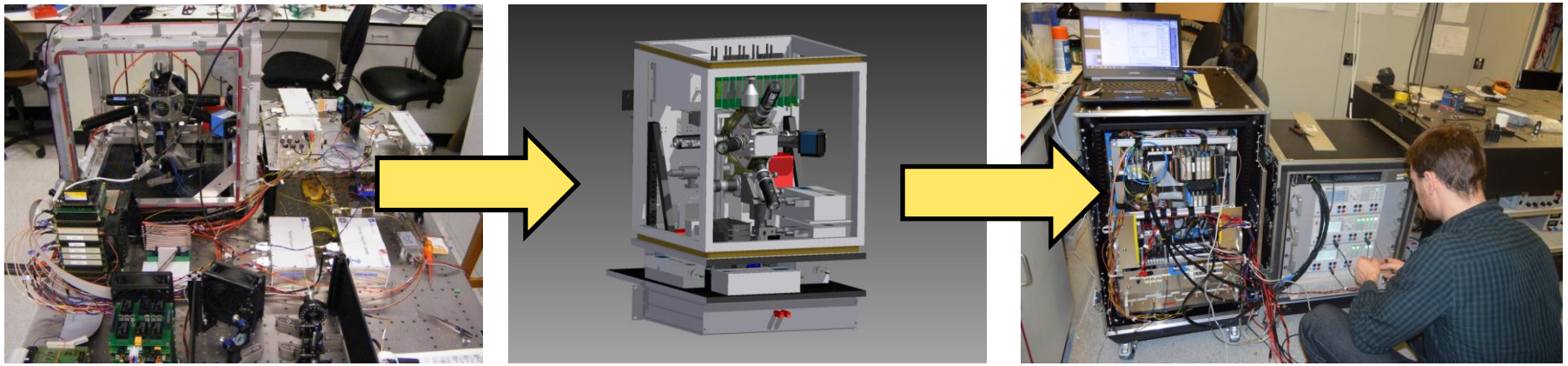


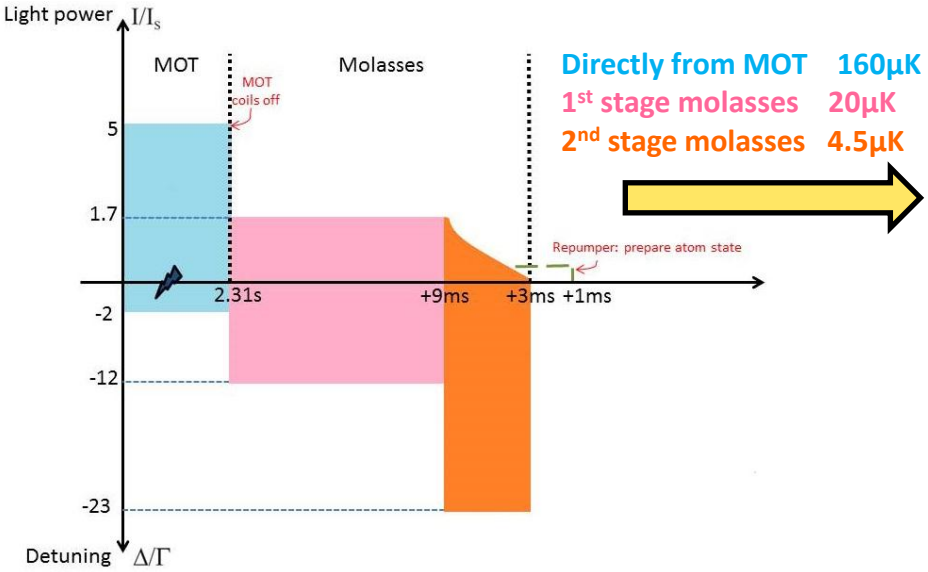


- Quadrupole coils:
  - 20 windings
  - Copper strips
  - 10G/cm @ 5mm @7A

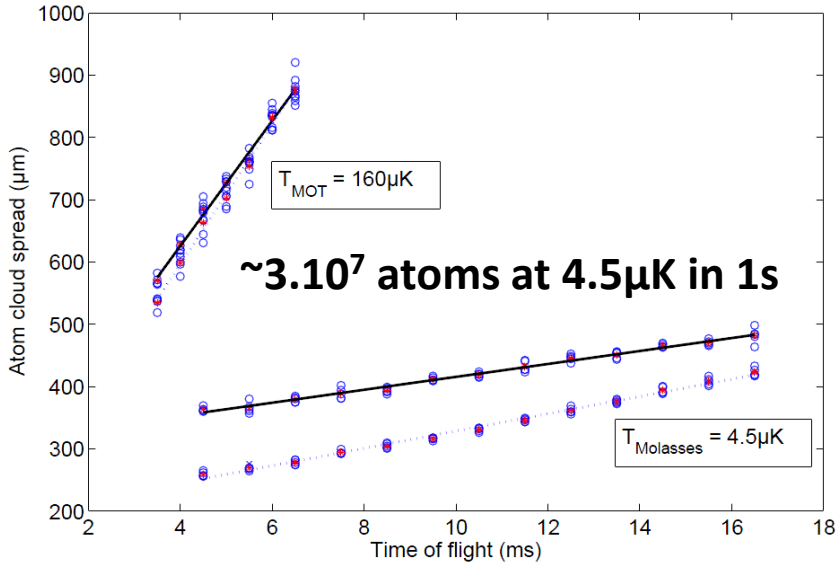
iSense gravimeter

- Integration and optimisation at UoB





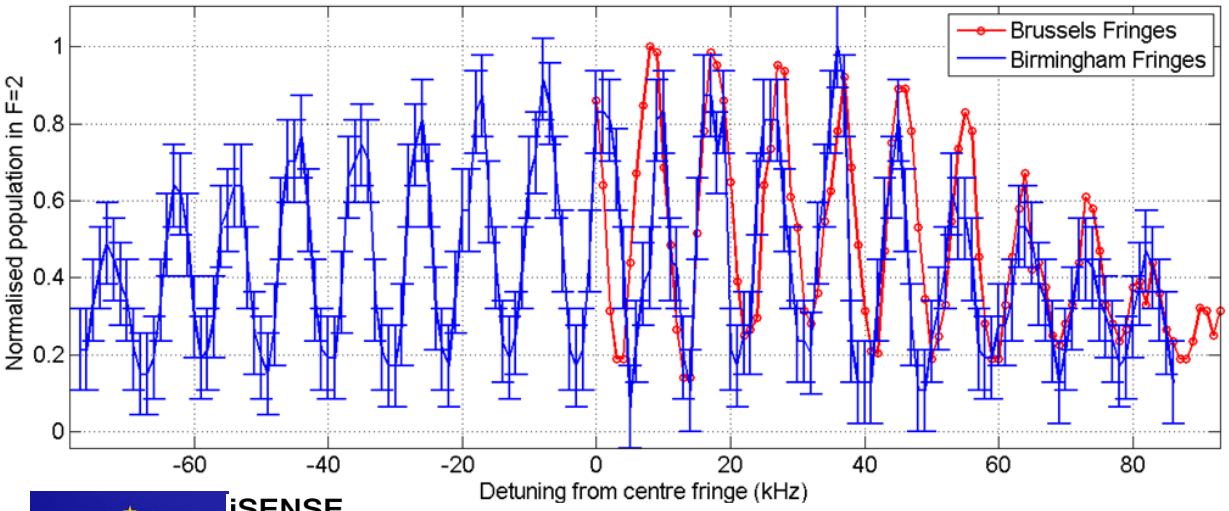
Directly from MOT 160μK
1st stage molasses 20μK
2nd stage molasses 4.5μK

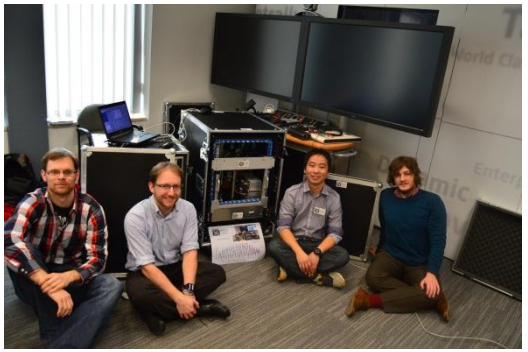


iSense gravimeter

- Atom interferometry
  - System operational in lab
  - February 2015 system visited Brussels and demonstrated atom interferometry.
  - Current specs (excluding case):

120L ext, 53kg, 240W, ~1Hz

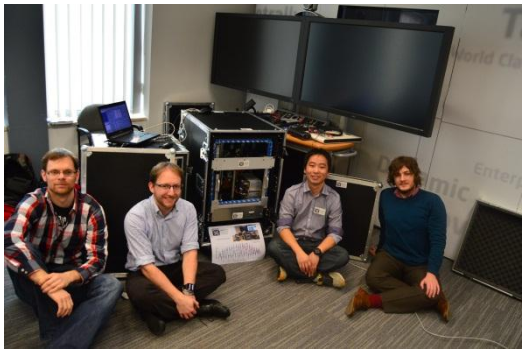


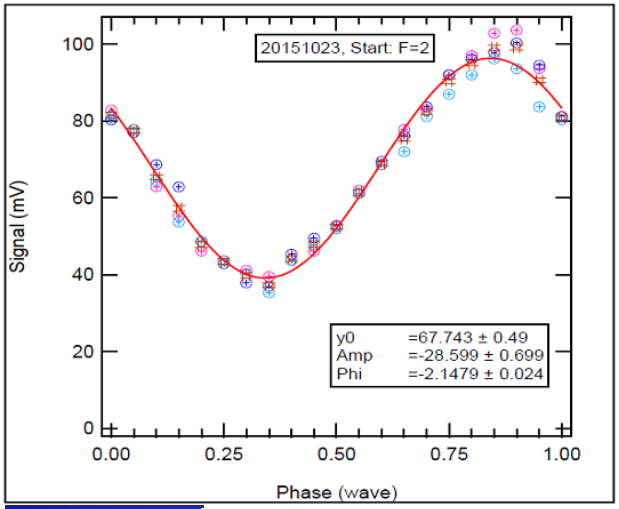


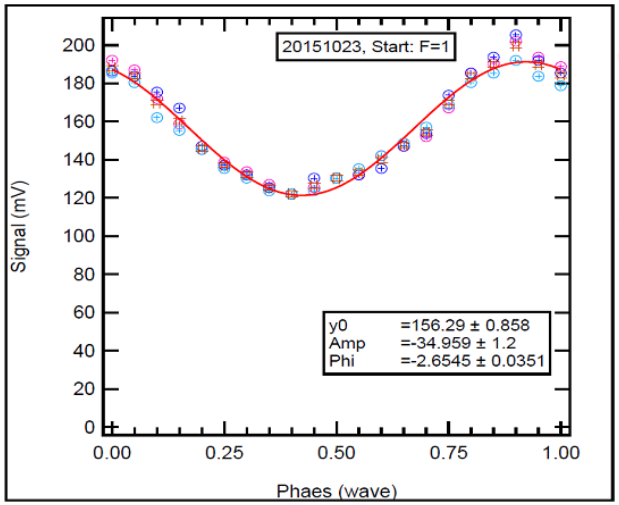
iSense gravimeter

Atom Interferometry

- Test-bed system operational as gravimeter, currently under optimisation
- Initial sensitivity ~10^{-5}g for T=1-2ms with detection after 170ms drop. Max T~65ms.
- Currently improving vibration isolation and the magnetic shielding

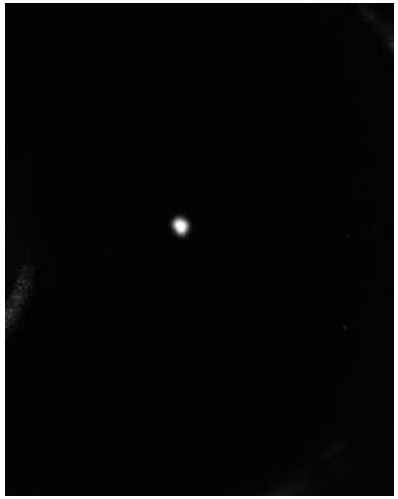




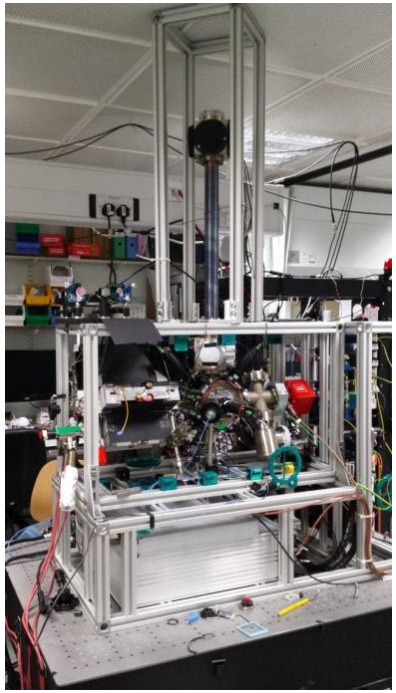


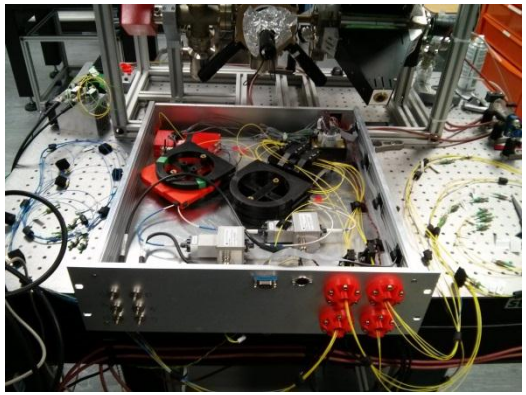
Current demonstrators at UoB

GGTOP project – prototype gradiometer



- Close liaison between cold atomic physicists, civil and electrical engineers and archaeologists
- Gain better understanding of user needs and relevant environments for quantum sensors
- Includes microgravity surveying with existing technology
- Current status: launch and interferometry achieved
- Future: science and technology test bed for testing new supply chain technology and new scientific techniques





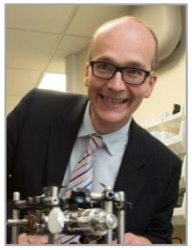
Summary

- The hub aims to bring QT devices to market, through supply chain development and demonstrators
- Enable close overlap of suppliers, academics and users
- Birmingham working in two areas of quantum sensing:
  - Strontium clocks
  - Atom interferometry for gravimetry

UoB Atom Interferometry

UNIVERSITY OF BIRMINGHAM MUARC

QT Hub Director



Prof Kai Bongs

Dr Vincent Boyer

Hub PM

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Space Projects

Prof Mike Cruise

Dr Simon Plant

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KTS

Jon Malcolm

AI lead

Dr Michael Holynski

Gravity Imager

Dr Aisha Kaushik

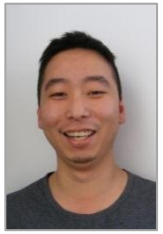
Alexander Niggebaum

Dr Artur Stabrawa

S&T Test bed

Dr Yu-Hung Lien

Clemens Rammeloo



Lingxiao Zhu

Andrew Hinton

Georgios Voulazeris

Demo

Dr Marisa Perea

[dstl]

PhD Prog.

Andrew Lamb

To engage with the Sensors and Metrology Hub: j.c.smart@bham.ac.uk

Recruiting: **PhD students**
Post-docs