MEMS Gravimeters

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Institute for Gravitational Research

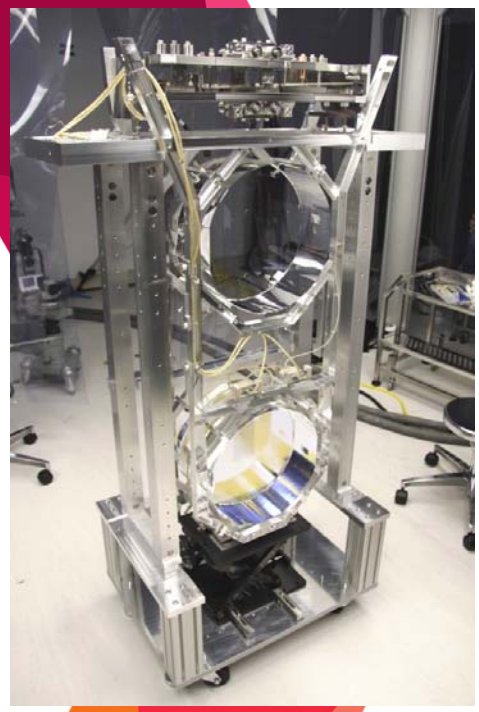
SUPA, University of Glasgow

APPEC Technology Forum 2018, Eindhoven

Outline

- Gravitational waves – MEMS Gravimeters
- Gravity imaging applications
- Wee-g: the Glasgow MEMS gravimeter
- Industry projects
- Future directions

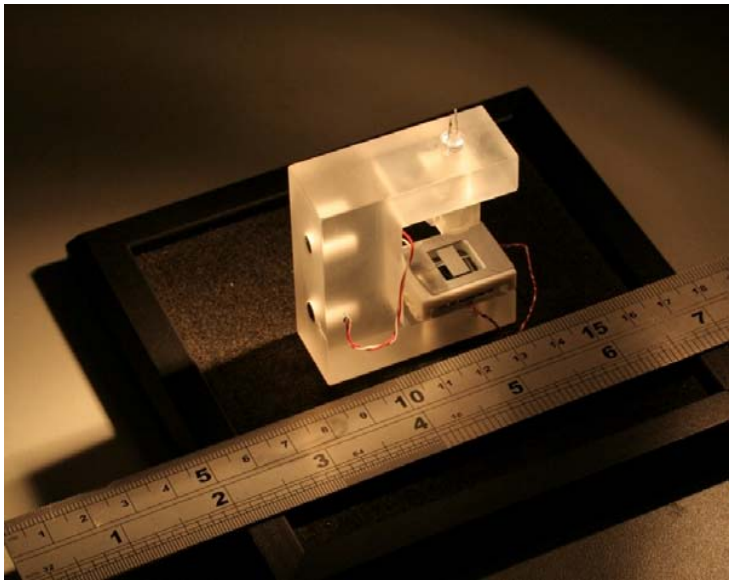
Gravitational Waves - MEMS



Institute for Gravitational Research
(https://www.physics.gla.ac.uk/igr/)

Fundamental research

Applied research



QUANTIC

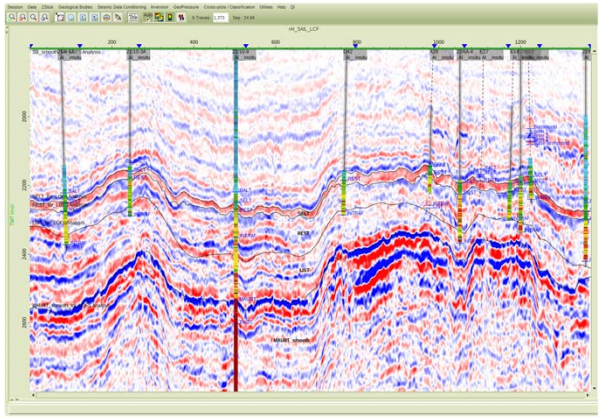
UK Quantum Technology Hub in Quantum Enhanced Imaging (https://quantic.ac.uk)

Gravity Imaging Applications

Oil & gas prospecting

Navigation

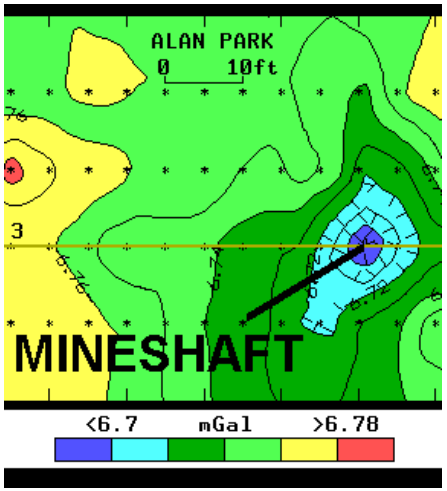
Seismic surveys



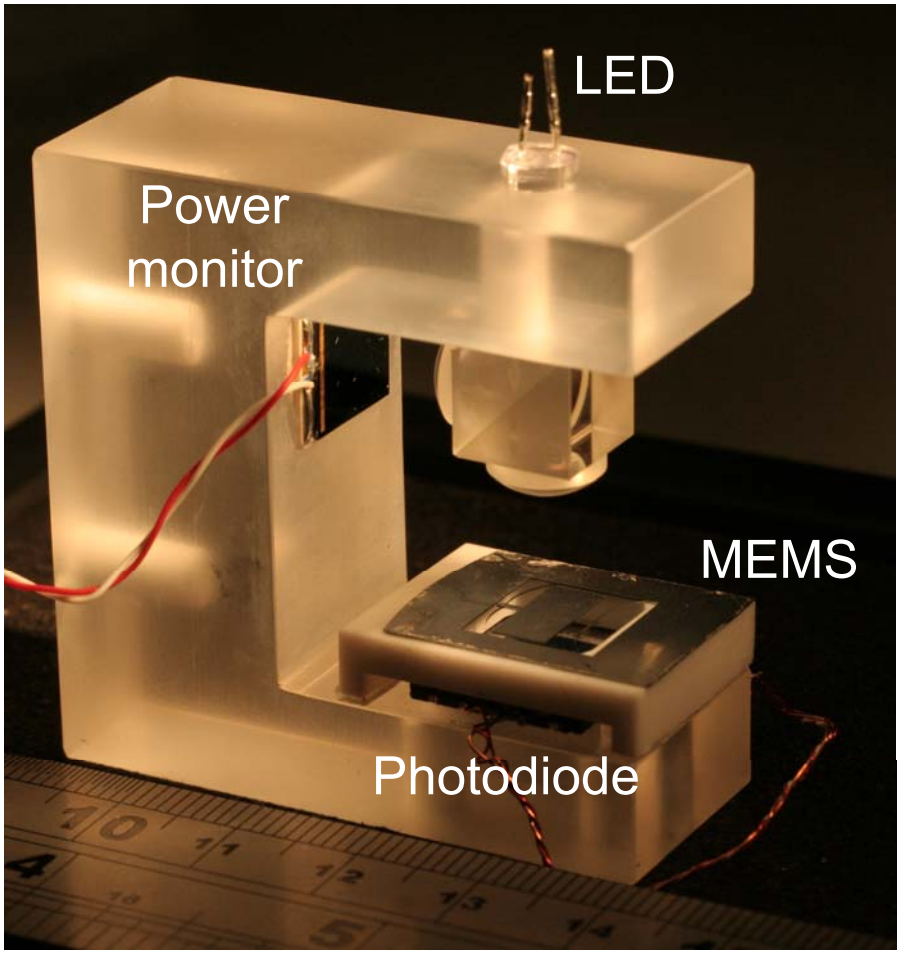
Security & Defence

Environmental monitoring

Sink hole detection

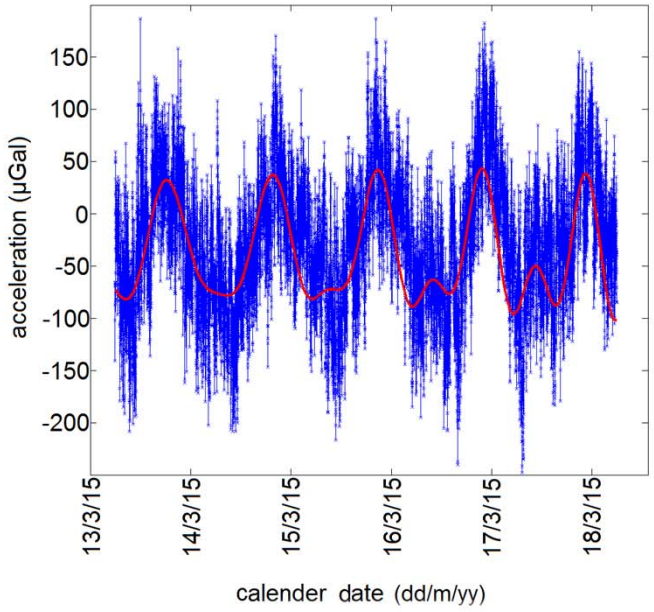


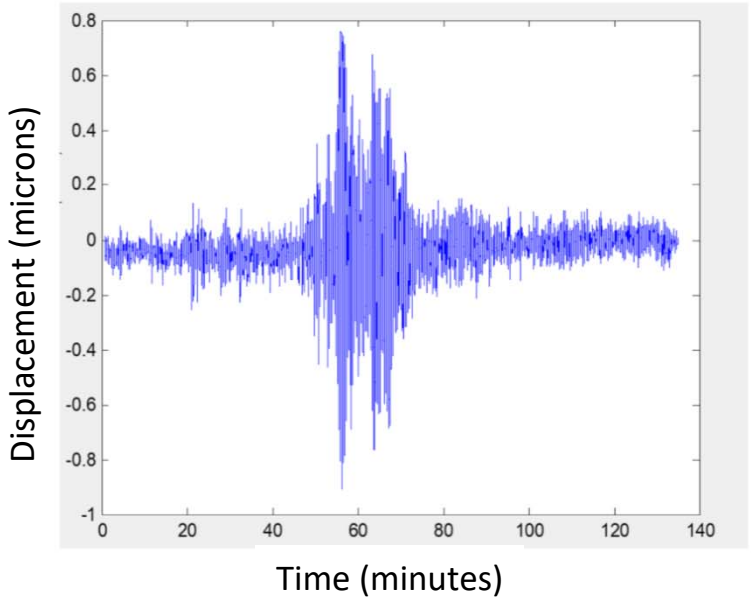
Glasgow MEMS Device (Wee-g)



R.P. Middlemiss et al. Nature 531, 614, 2016
Toninelli et al. Optics Express 25 (18), 2017
Bramsiepe et al. IEEE Sensors 18 (10), 2018
R.P. Middlemiss et al. MDPI Sensors, *17*(11), 2571, 2017

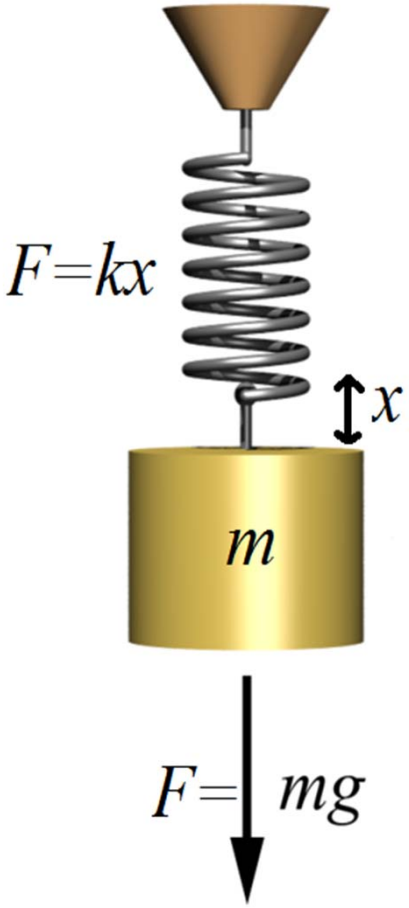
- Earth tides

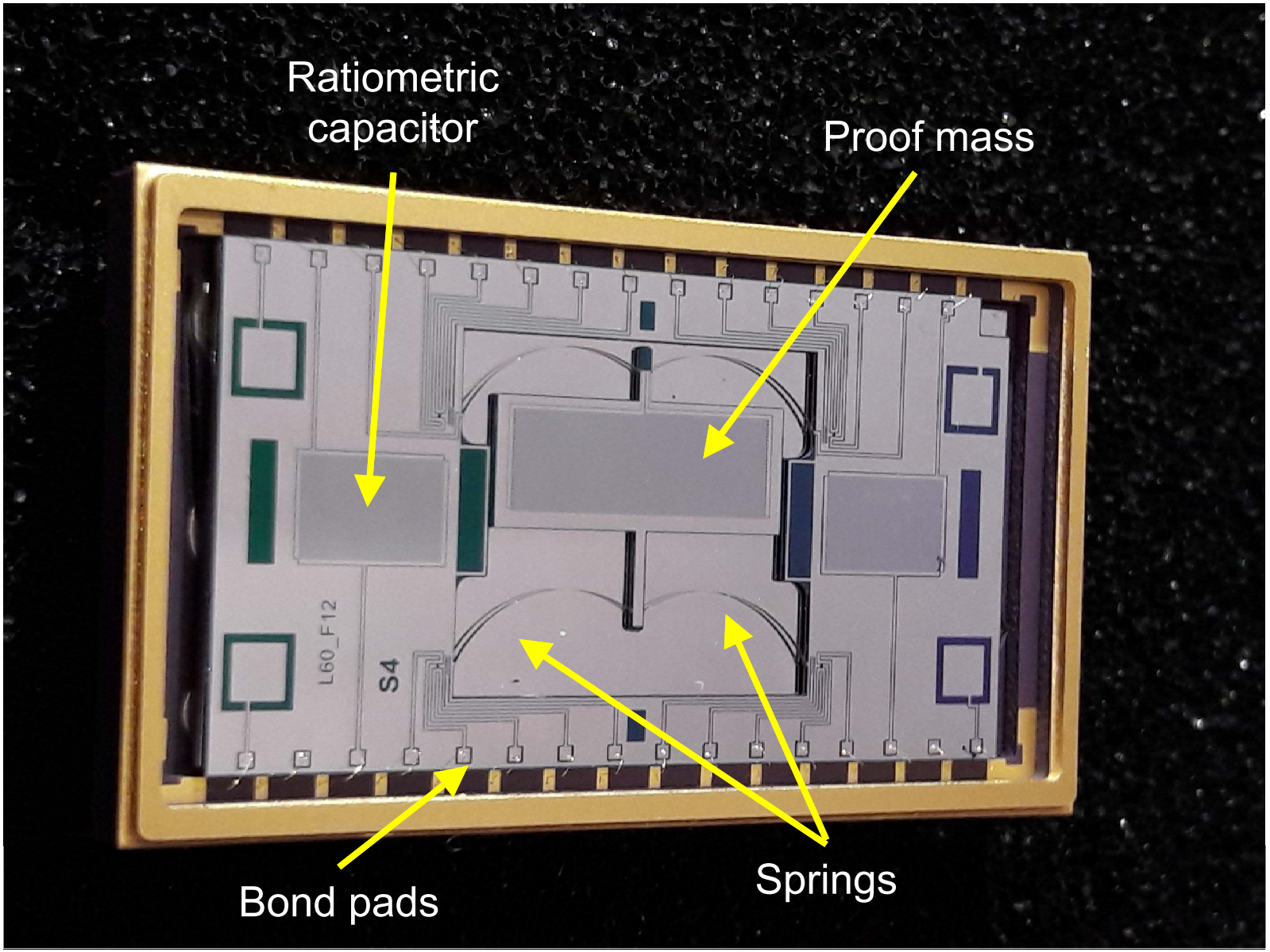




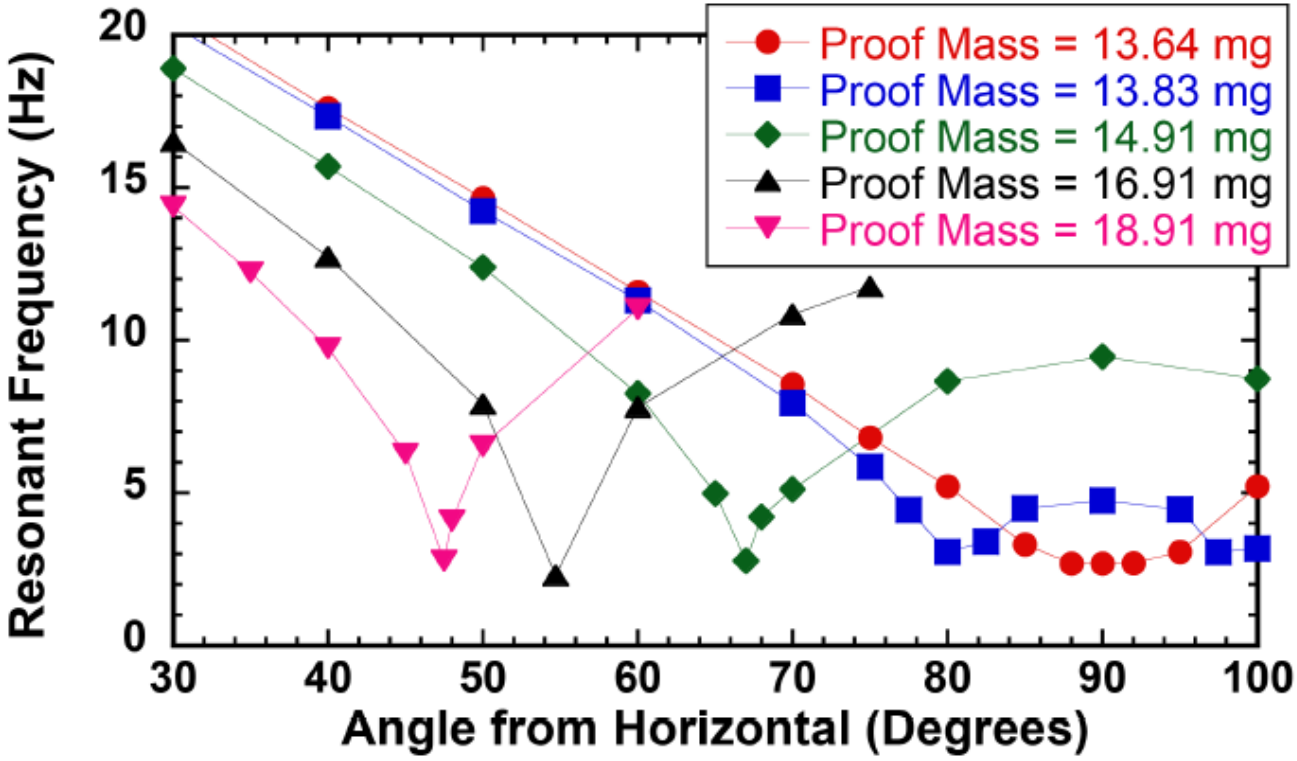
- Seismic noise (earthquakes)

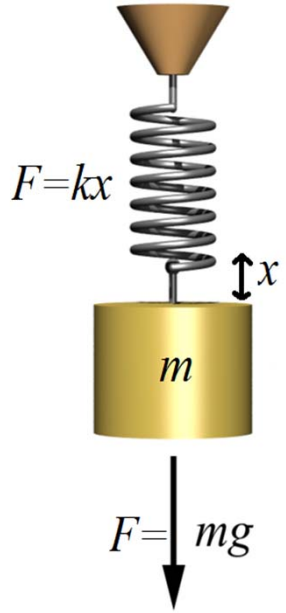
Glasgow MEMS Device (Wee-g)

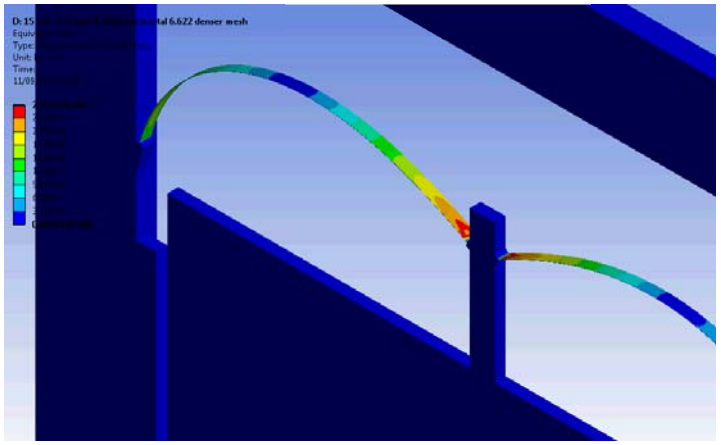




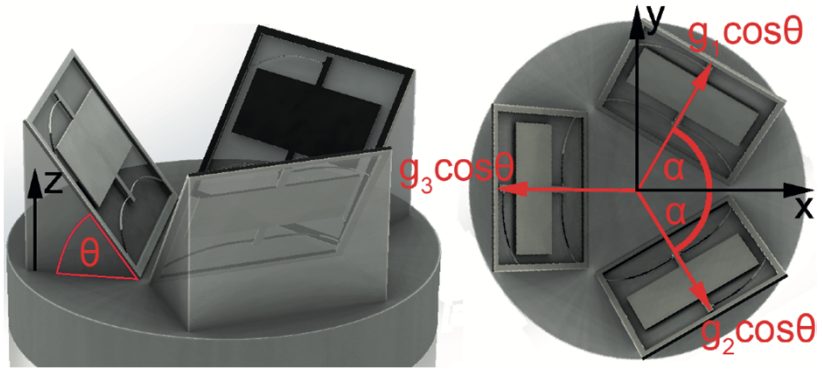
Spring Topology



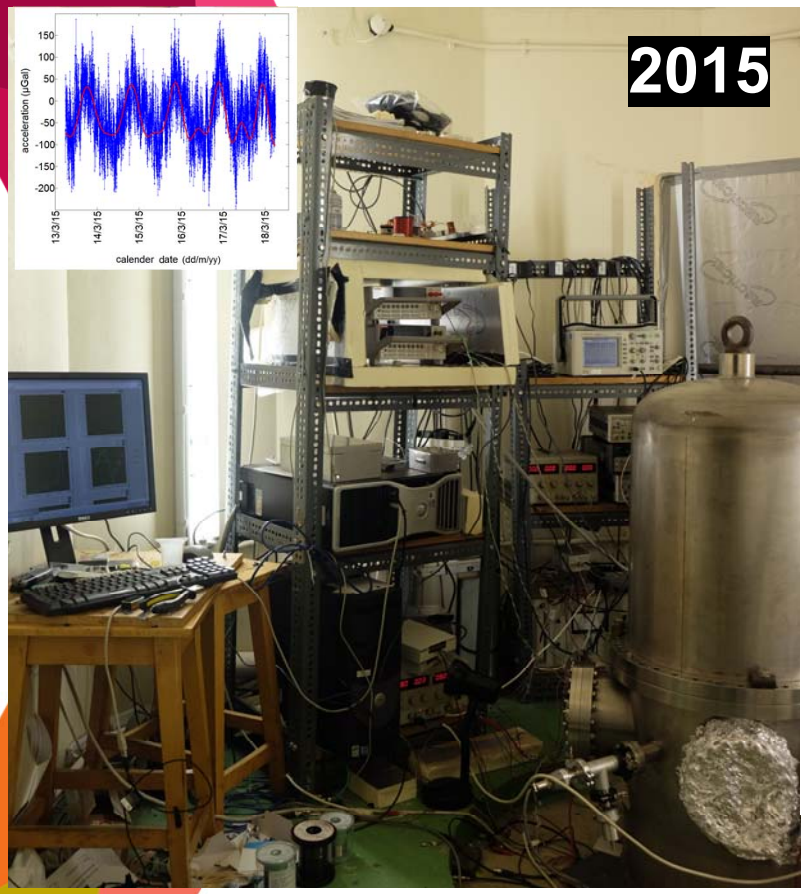




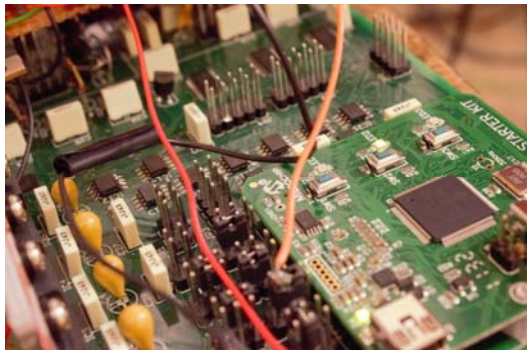
- We can build >1 Hz resonators which are stable, with minimum frequency at a wide variety of angles => 3 axis devices



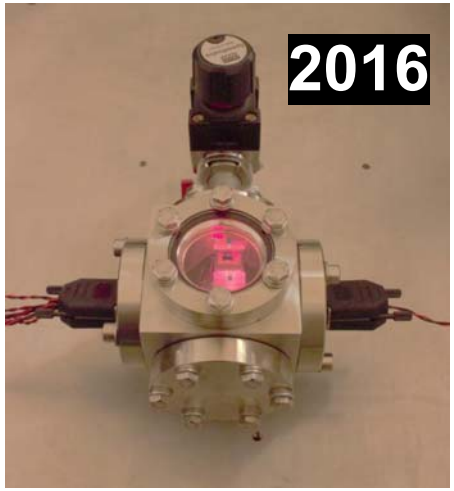
Device Development



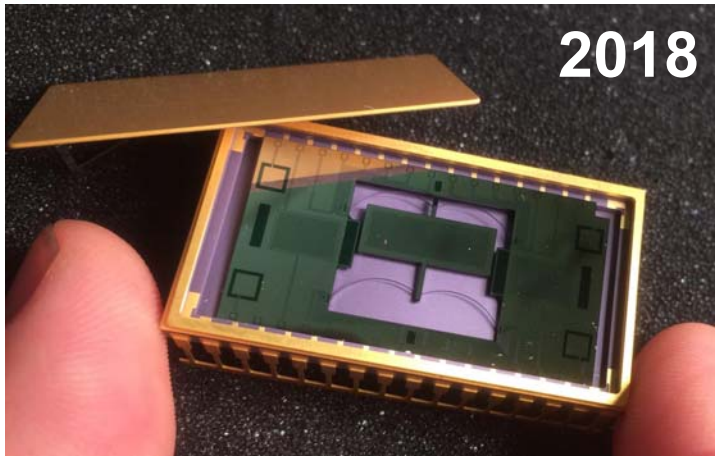
Lab based system with mains power, rack mount electronics



Packaged device with FPGA readout

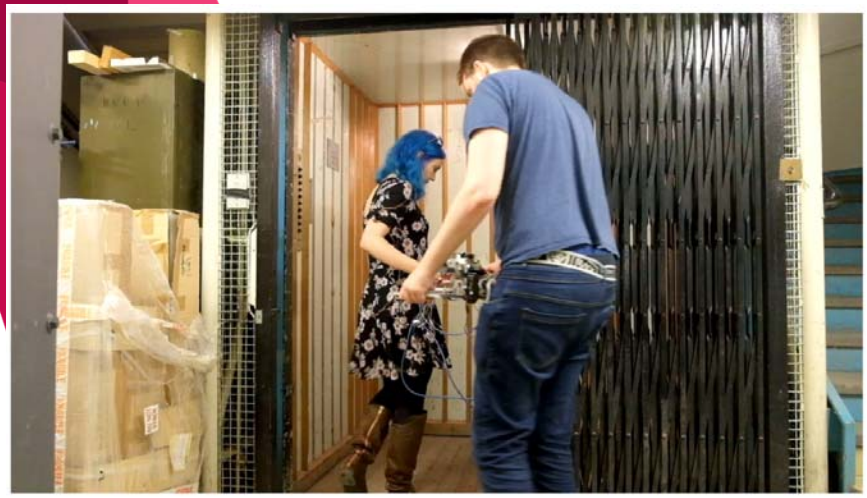


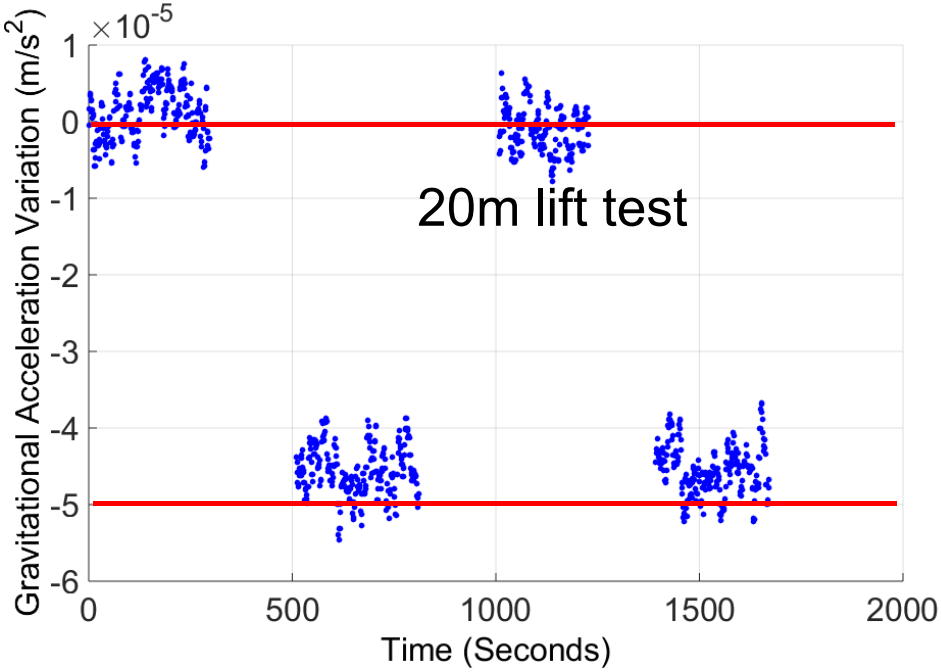
Shoebox sized field demonstrator, battery power



2017 Field Tests: In a Lift

R. P. Middlemiss et al, Sensors **2017**, 17, 2571.



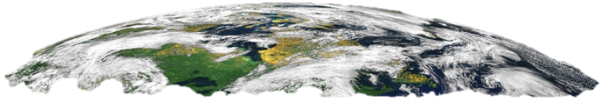


9.80994m/s^2

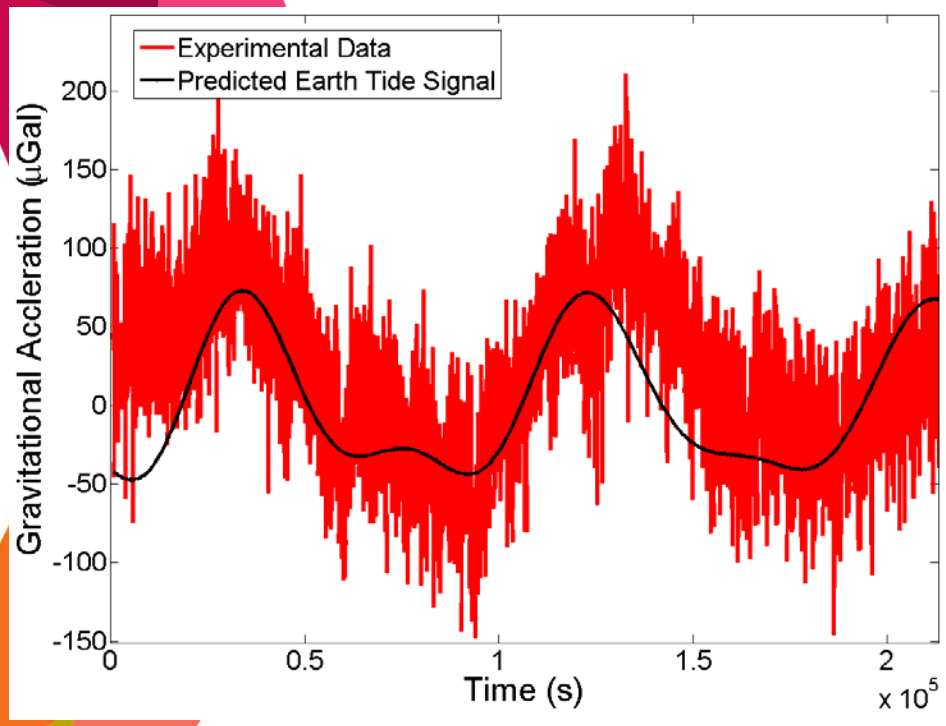
20m

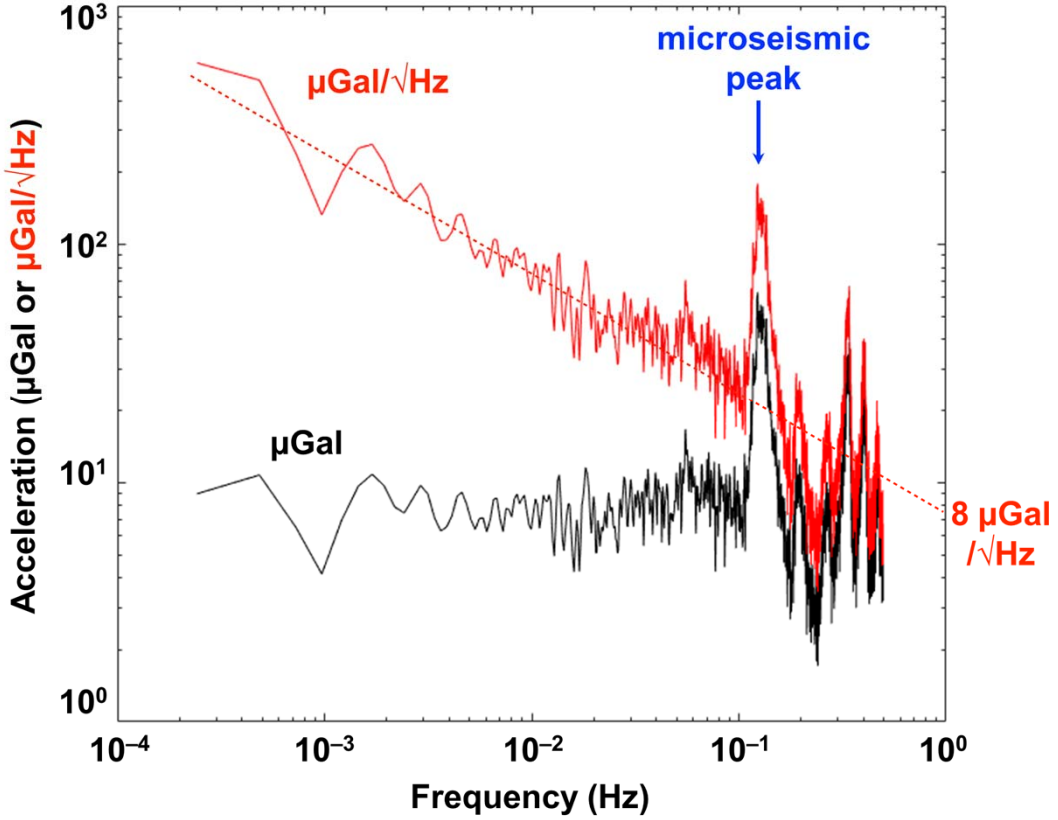
$$g = \frac{GM}{R_{Earth}^{\ 2}}$$

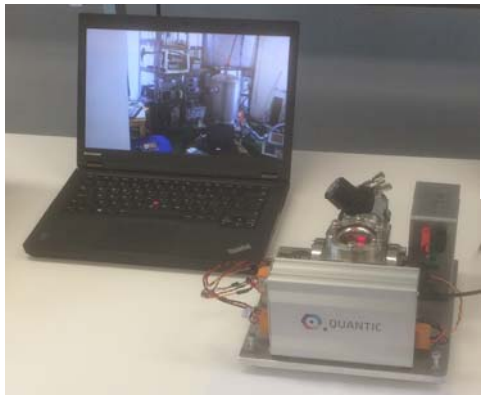
9.810000m/s^2



Tides on the Portable System

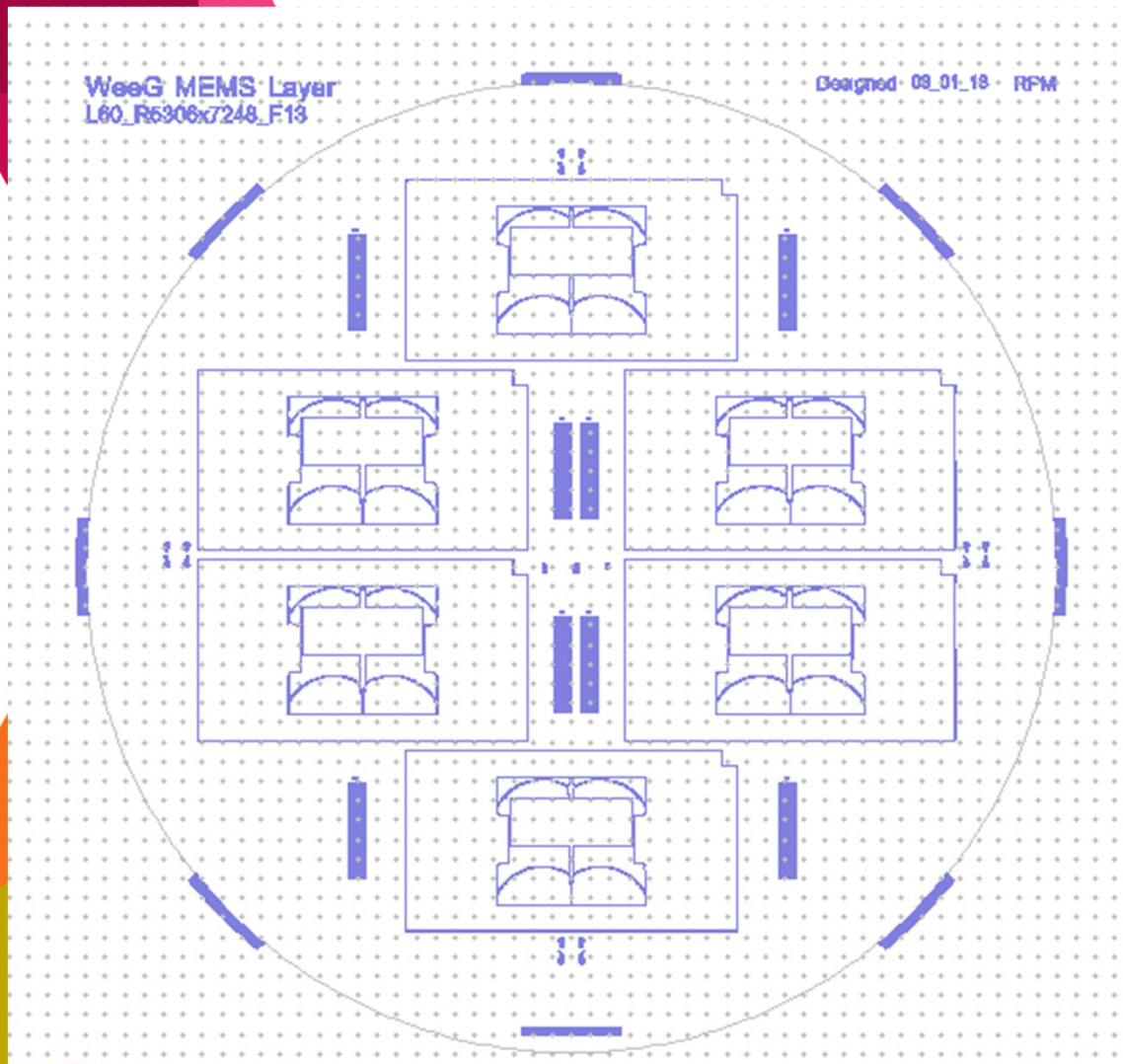


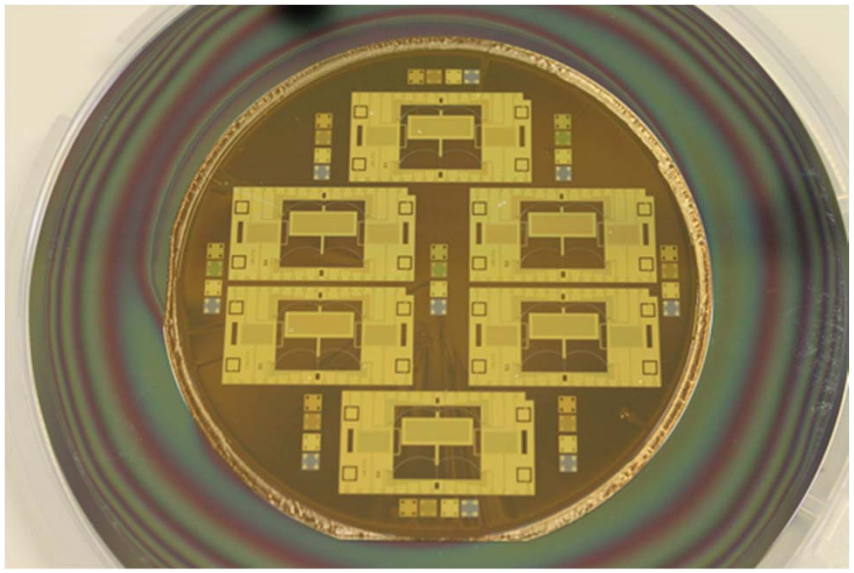


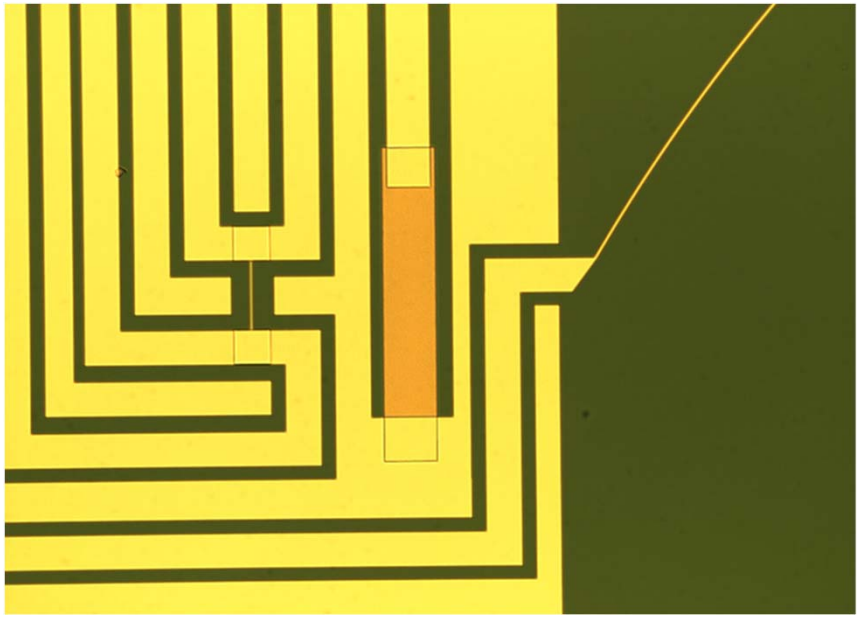


10 kg, 3.2 W, 15 hours battery
± 2 mK temperature control,
dsPIC μcontroller & SD card

Fabrication of the Device







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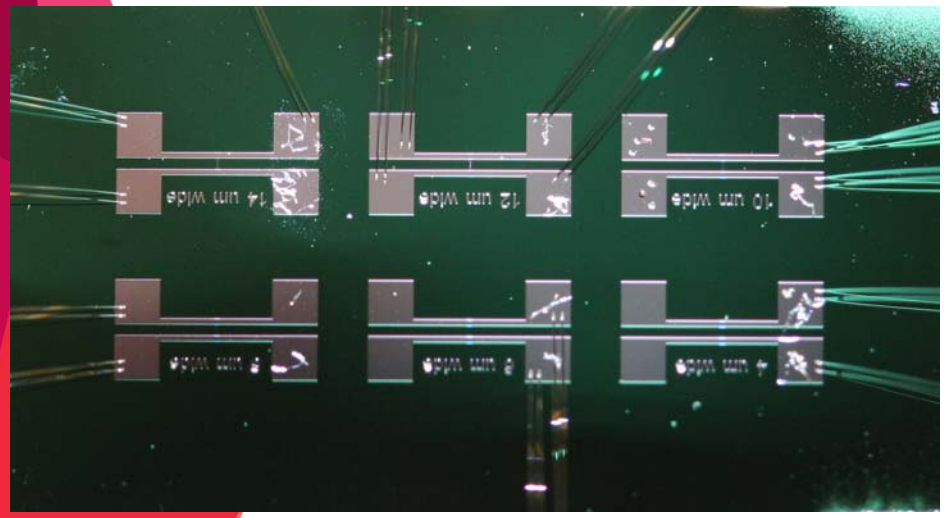
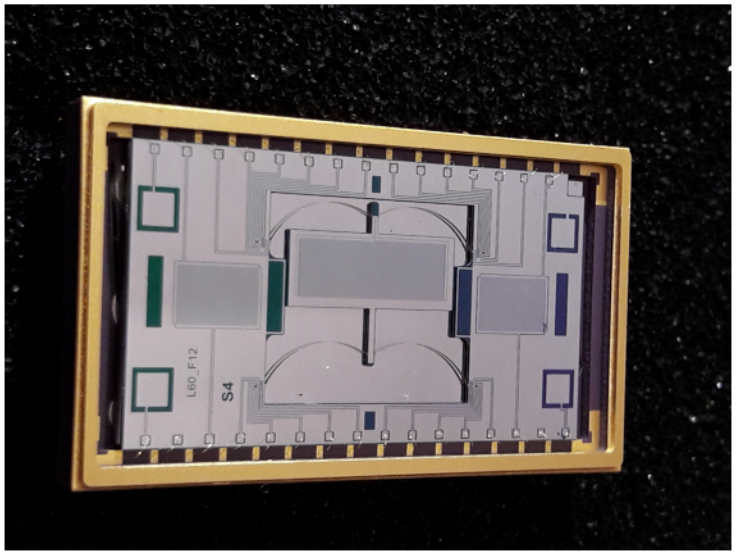
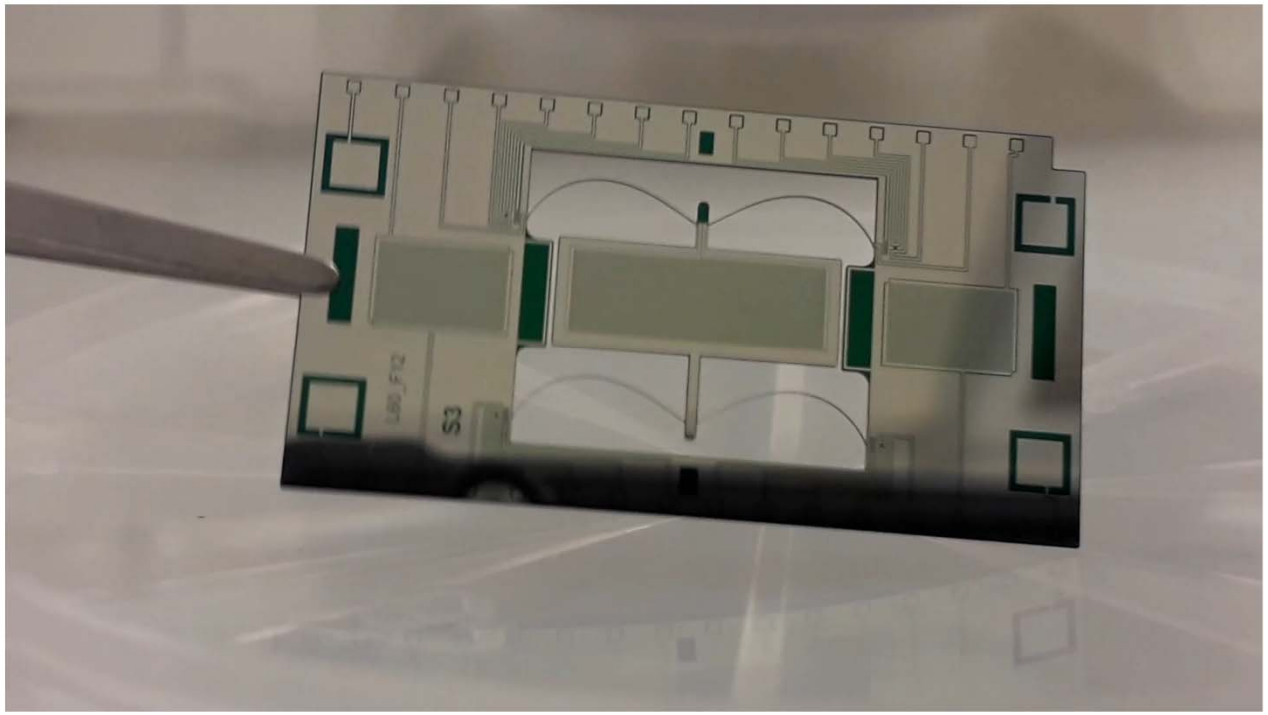
Fabrication of the Device





- Wire bonding/packaging at Optocap



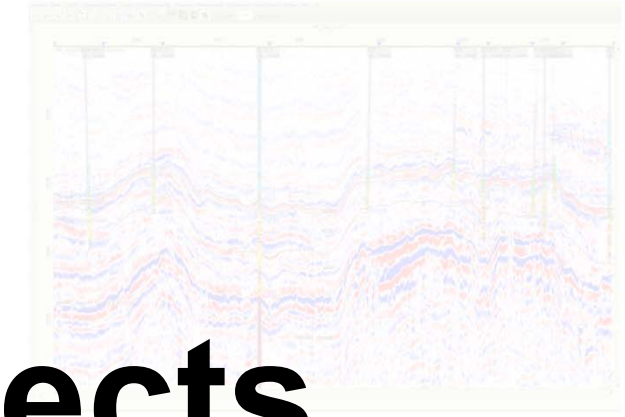
KELVIN NANOTECHNOLOGY

Industry Projects

Oil & gas prospecting

Navigation

Seismic surveys



Security & Defence

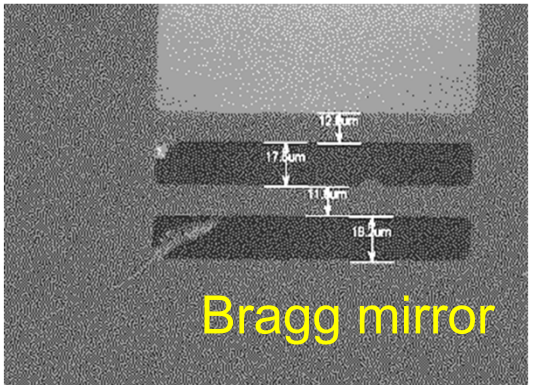
Environmental monitoring

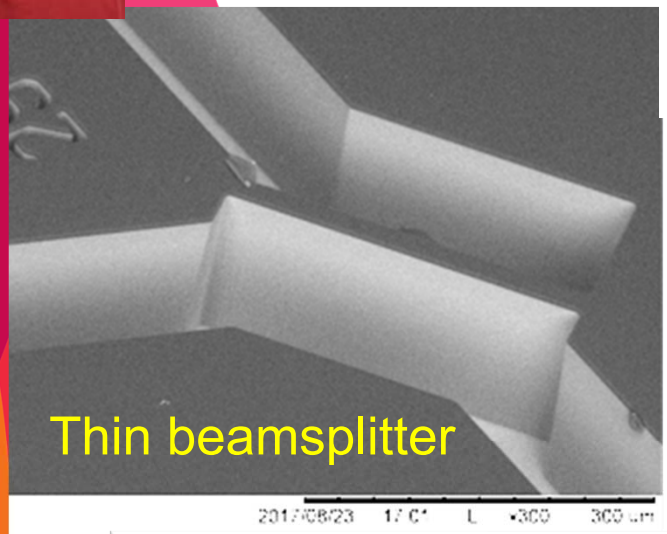
Sink hole detection

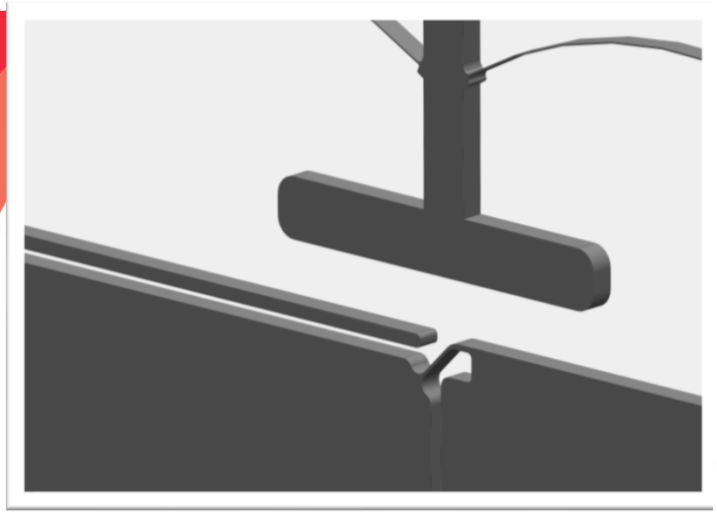
A. Noack
PhD Student

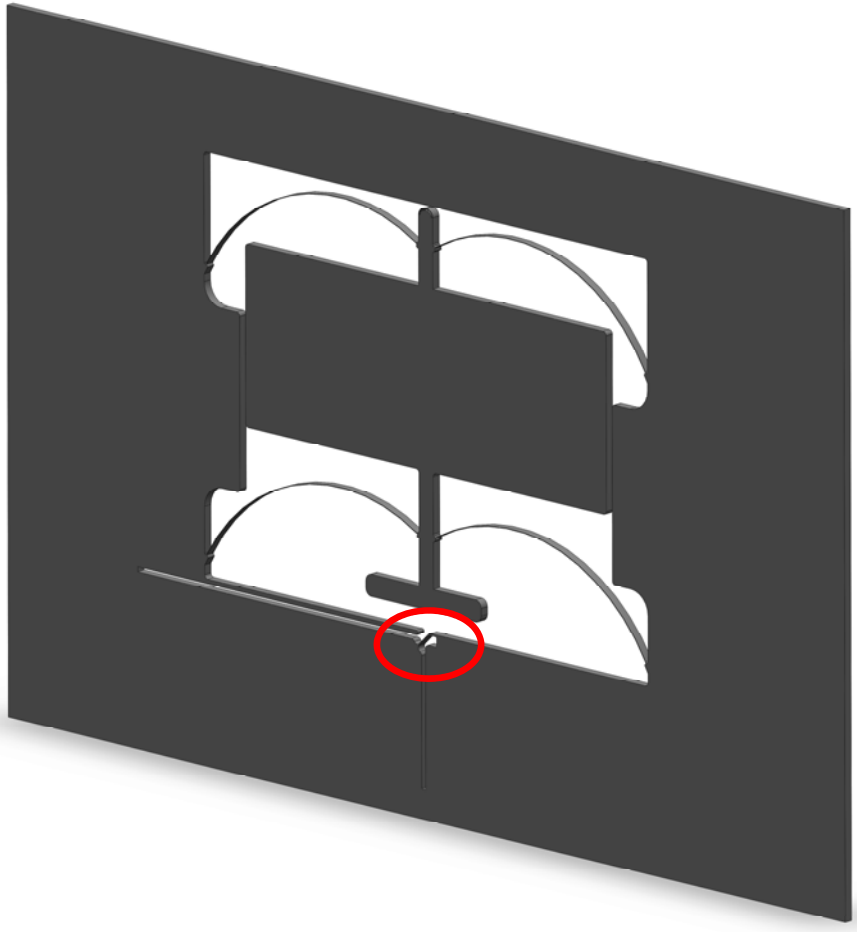
Schlumberger

- Developing optical readout for MEMS
- On-chip Michelson interferometers







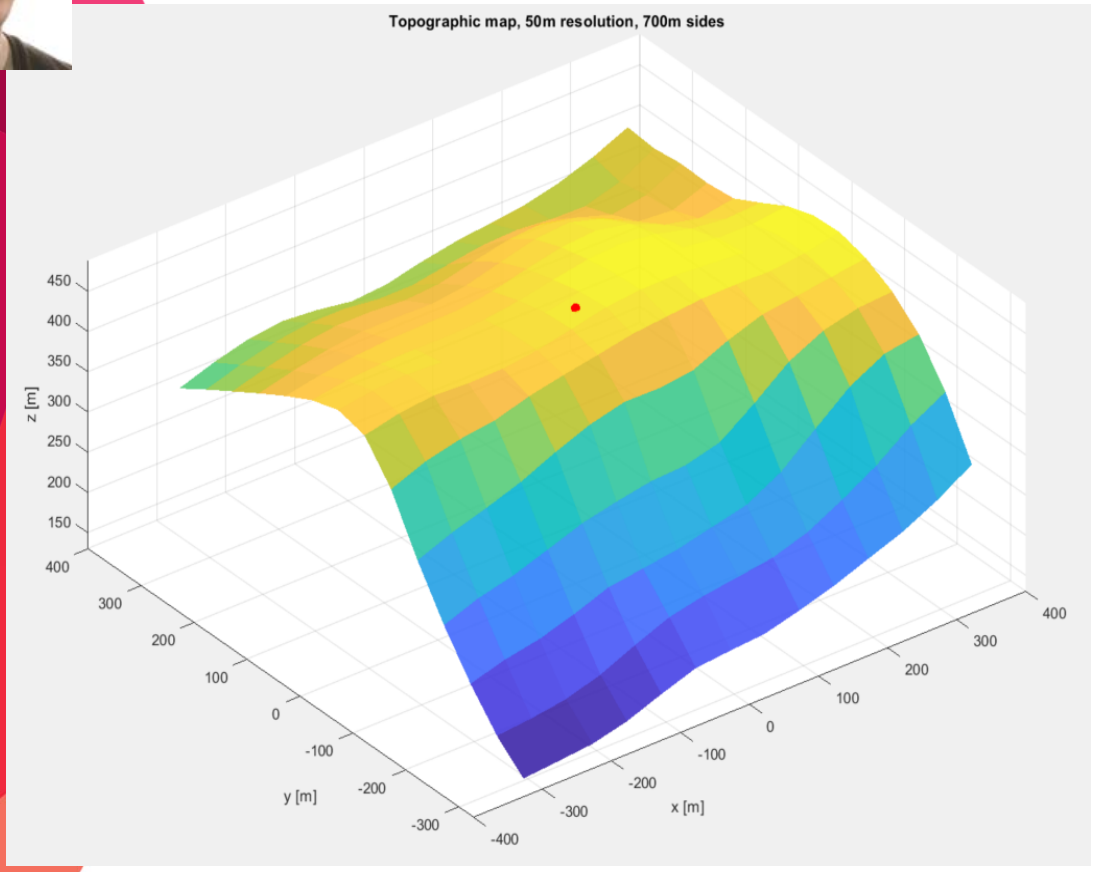


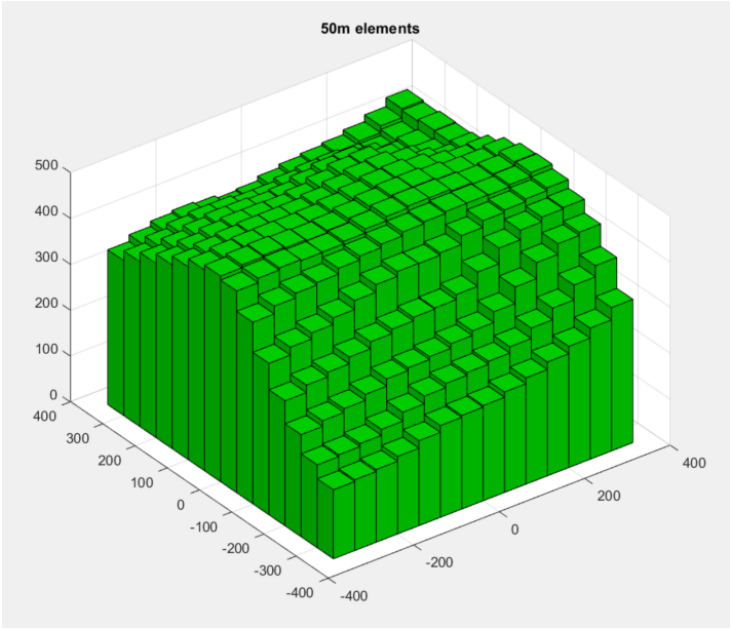
e

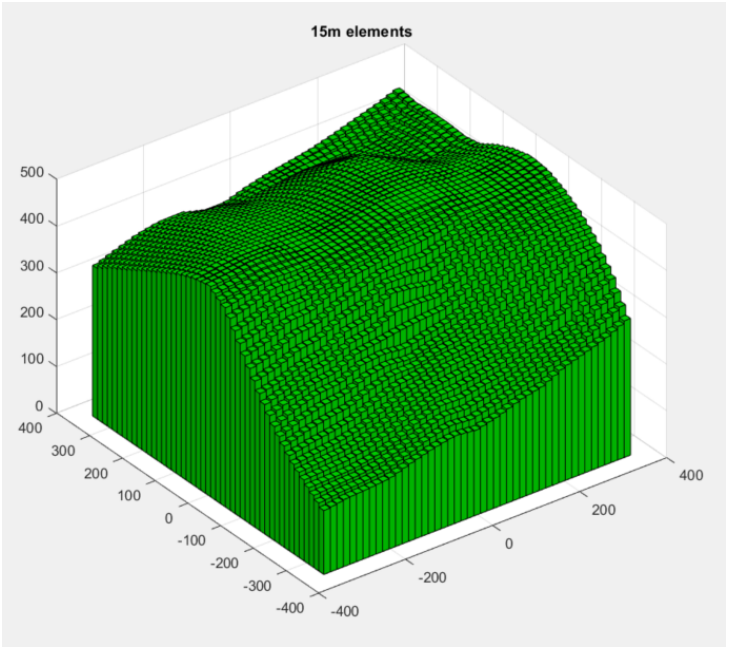
Schlumberger

M. Aftalion
PhD Student

QinetiQ





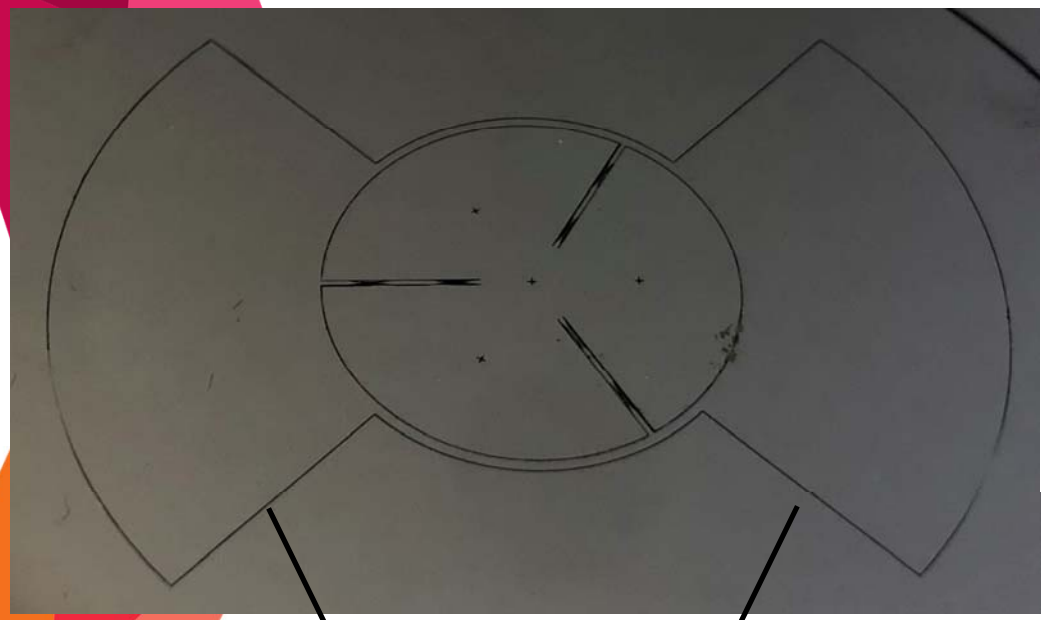


- Developing tools for terrain/gravity modelling
- Hybrid meshing shows topology limits accuracy to few uGal

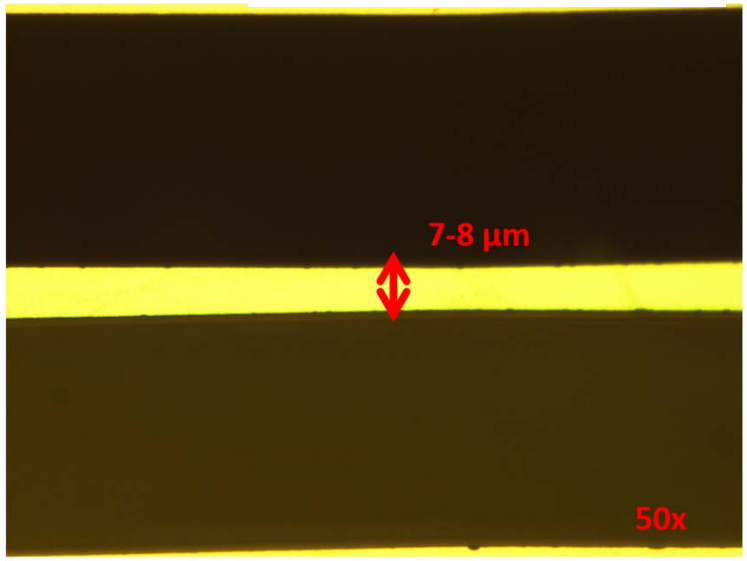
QinetiQ

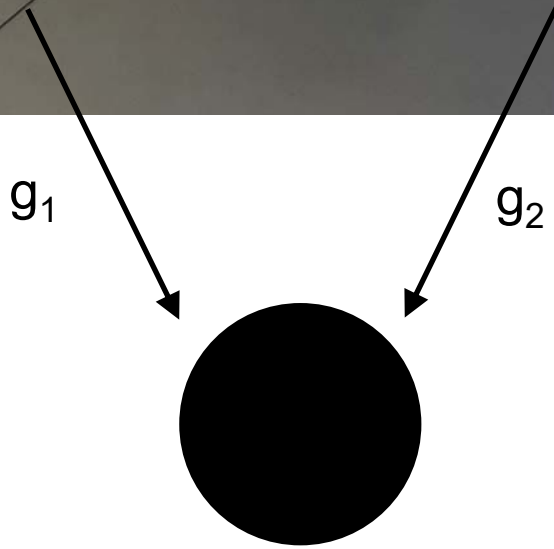
G. Marocco
PhD Student

ClydeSpace



Flexure

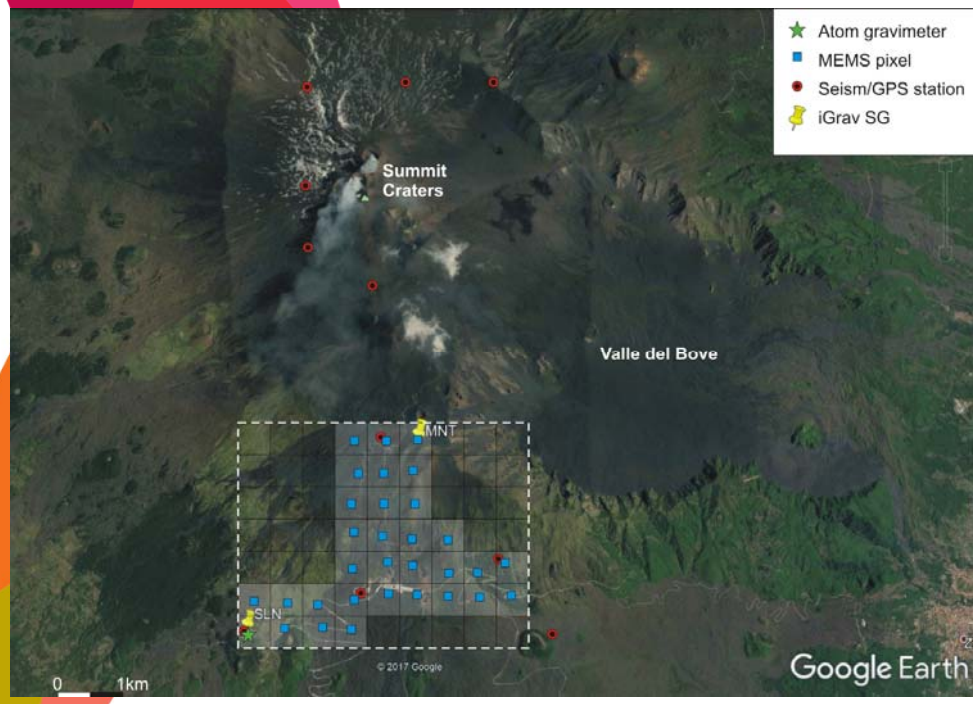




- Developing MEMS gradiometers for space applications (attitude control of Cubesats)

Future Directions

- Studentship with Bridgeporth to test MEMS in Boulby mine
- Packaging devices (KNT/OptoCap) in late 2018 for engagement with end users



- FET-OPEN H2020 grant to deploy 70 MEMS onto Mt Etna by 2022 (€800k to Glasgow, €3.5 million total)

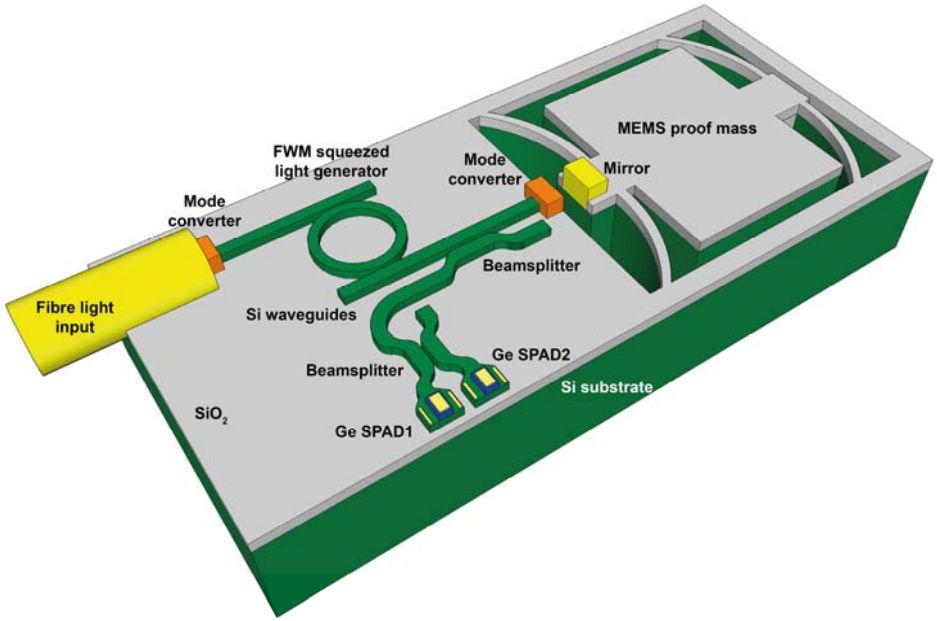
European Commission

- DSTL tender secured to deliver gradiometers for drone deployment

Future Directions

Innovate UK

IQE



- Innovate UK funded project to develop on-chip interferometer

bp

- Proposal for 100km line survey of gravimeter / gradiometer on drone-based platforms (BP Proof of Concept)

- Discussing possible spin-out opportunities with investors
- Looking for opportunities to develop ASIC's for the device readout

The Team

G. Hammond

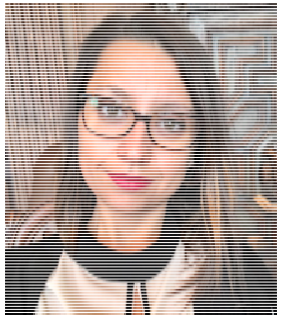
D. Paul
(Engineering)

R. Middlemiss (RA)

A. Prasad (RA)

S. Bramsiepe
PhD Student

A. Noack
PhD Student



G. Marocco
PhD Student

M. Aftalion
PhD Student

E. Ghisetti
(Engineering RA)

K Anastasiou
PhD student

R. Walker
PhD student

KELVIN NANOTECHNOLOGY

bridgeporth

Schlumberger

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[dstl]

optocap

European Commission

KAIAM

QinetiQ

CLYDE SPACE