Operational Utilisation of Absolute Quantum Gravimeters

Peter Rosenbusch

exail Quantum Systems

09/11/2023

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2011

2021

2023

SYRTE l'Observatoire de Paris | PSL

SYstèmes de Référence Temps-Espace

INSTITUT d'OPTIQUE GRADUATE SCHOOL ParisTech

µQUANS

kYLia

iXblue → exail

1500
EMPLOYEES

exail photonics > 20 years experience in Photonics & Quantum Technologies

Quantum Sensing | Quantum Communication | Quantum Simulation | Quantum Computing

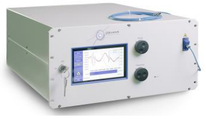
PASQAL

Welinq

Systems

ILS laser series

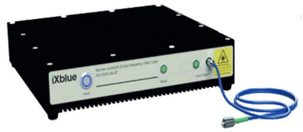
Intelligent Laser Systems



USML laser series

Ultra-stable Master Lasers

Sub-systems



iMOB series and **fiber lasers**

Micro-Optic Benches

Components

fibers, modulators, custom solutions

exail **Quantum Systems**

Quantum instruments from the lab => the field 2011 => 2023

absolute quantum gravimeter

($\Delta g/g \approx 10^{-9}$)

laser-cooled atom clock

($\Delta f/f \approx 10^{-15}$)

high-stability optical frequency transfer

($\Delta f/f \approx 10^{-20}$)

laser systems

($\Delta \lambda/\lambda \approx 10^{-10}$)

How to measure gravity ?

photo: wikipedia

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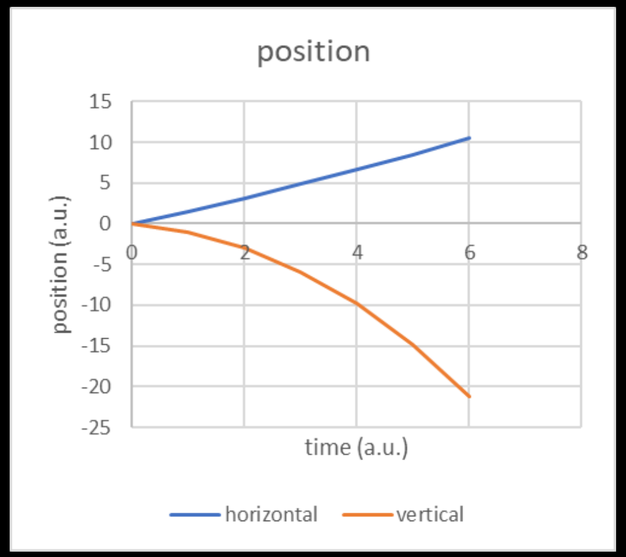
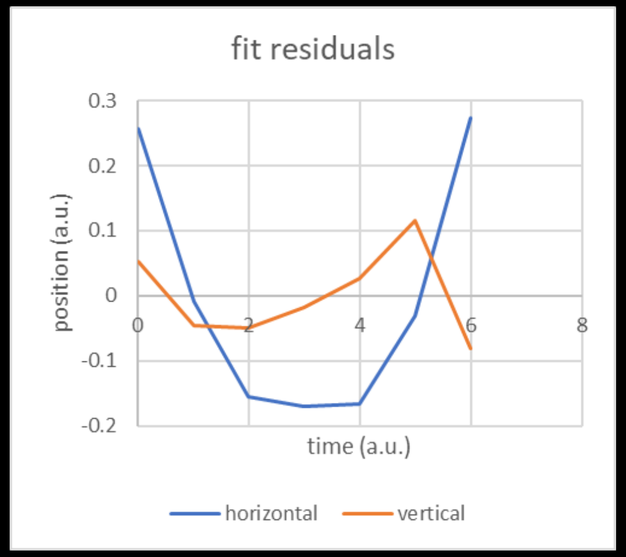
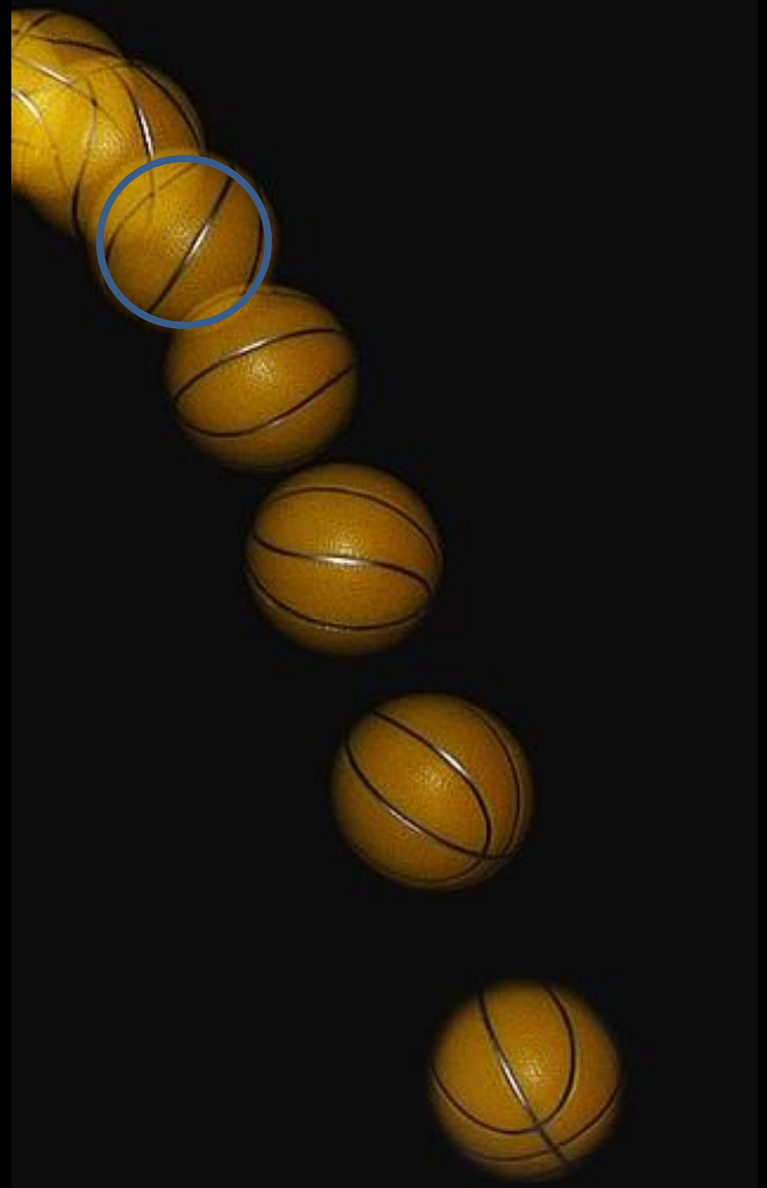
How to measure gravity ?





=> camera angle 100 mrad



Accuracy 5x 10^{-3} g

photo: wikipedia

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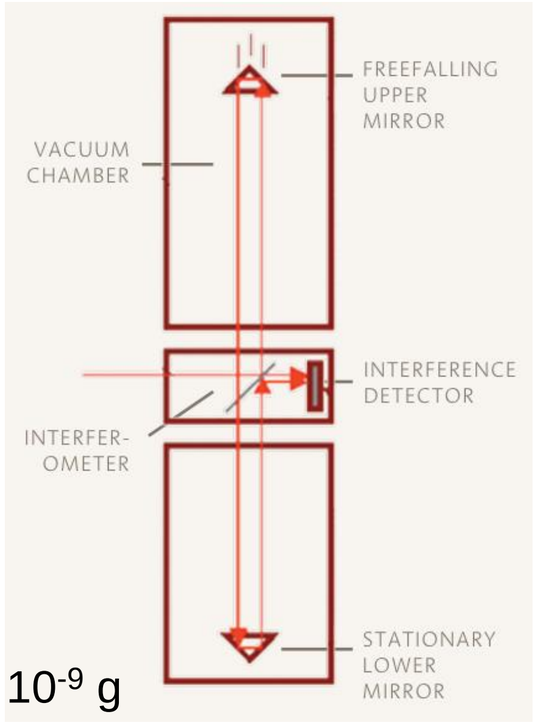
Absolute Gravimeters



Accuracy
5 10^{-3} g

2 10^{-9} g

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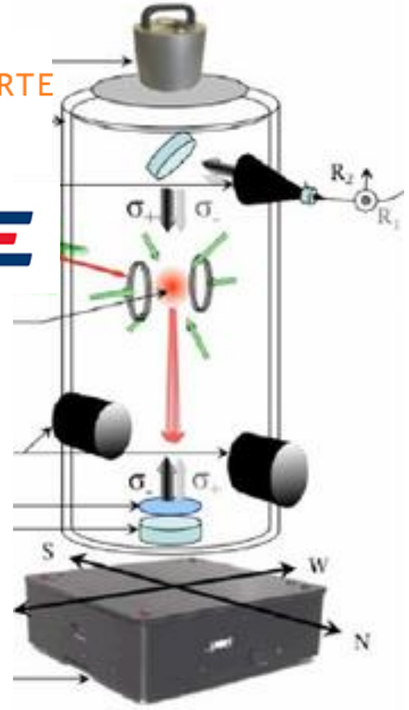
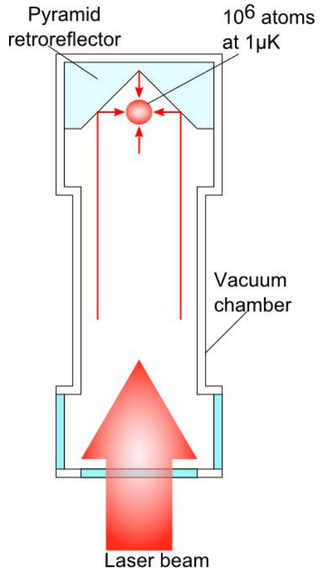
Systèmes de Référence Temps-Espace
LABORATOIRE NATIONAL DE MÉTROLOGIE ET D'ESSAIS — LNE



2 10^{-9} g



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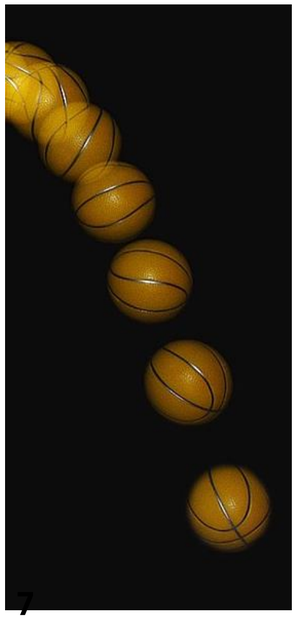
target
1-10 10^{-9} g



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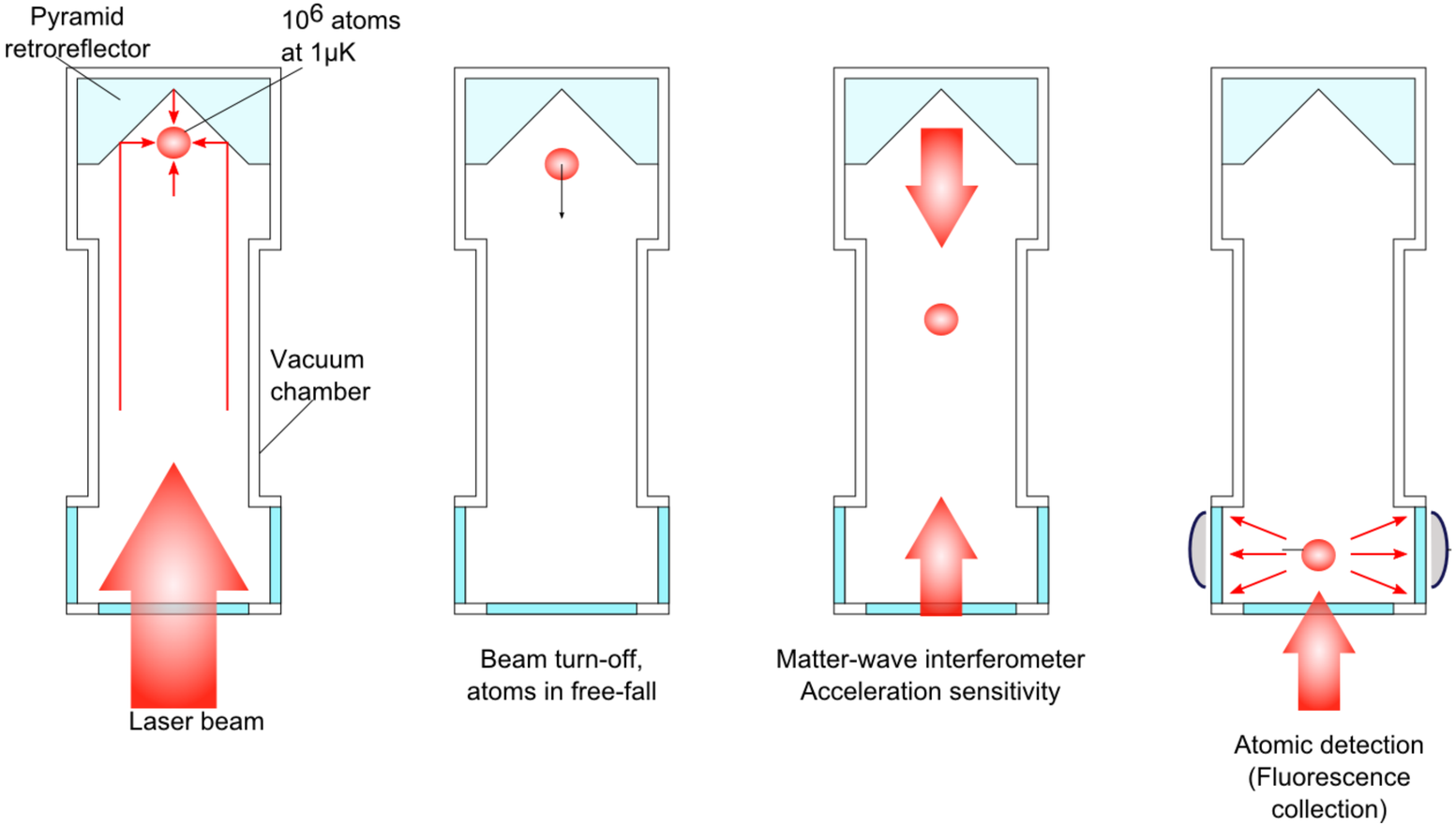
Absolute Quantum Gravimeter – Working Principle

laser-cooled Rb atoms are the test mass !



Ménoret et al, Sci Rep 8, 12300 (2018)

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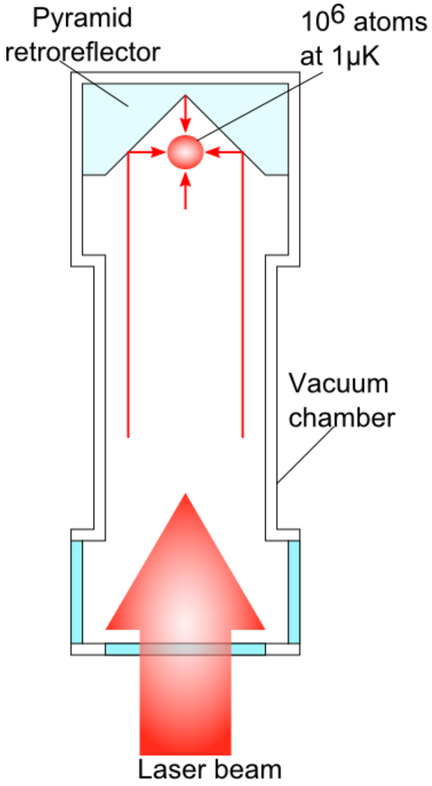
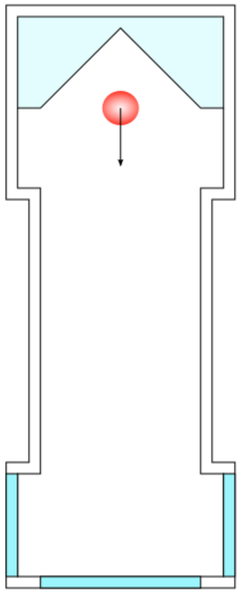
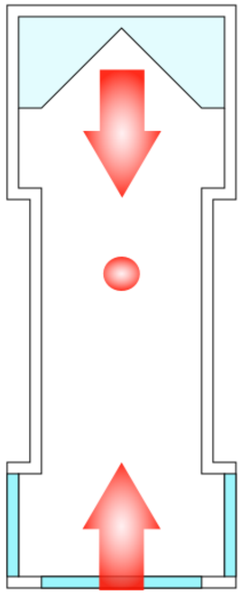
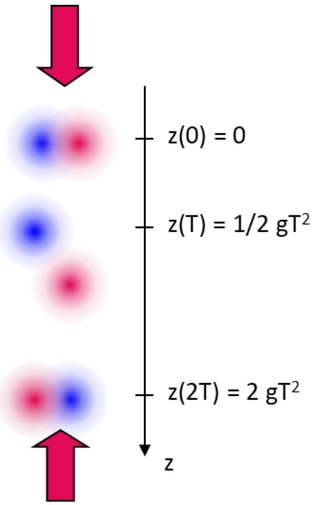


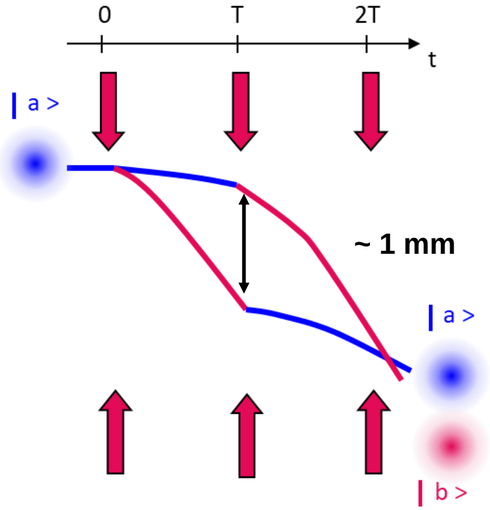


Beam turn-off,
atoms in free-fall



Matter-wave interferometer
Acceleration sensitivity





laser kicks open the matter wave interferometer !

Ménoret et al, Sci Rep 8, 12300 (2018)

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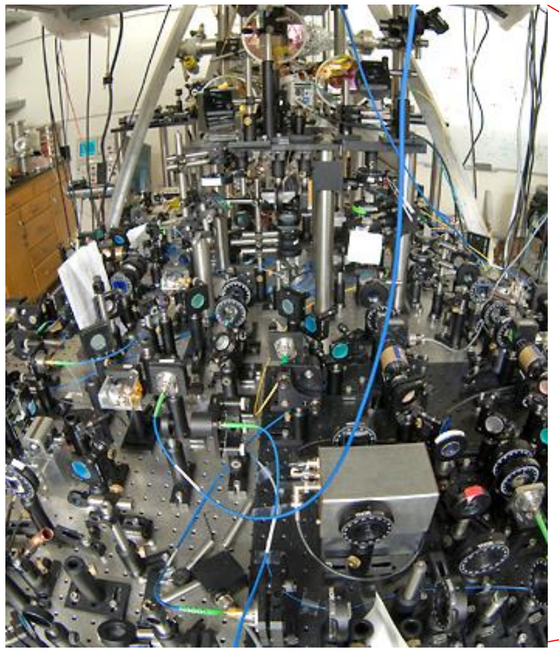
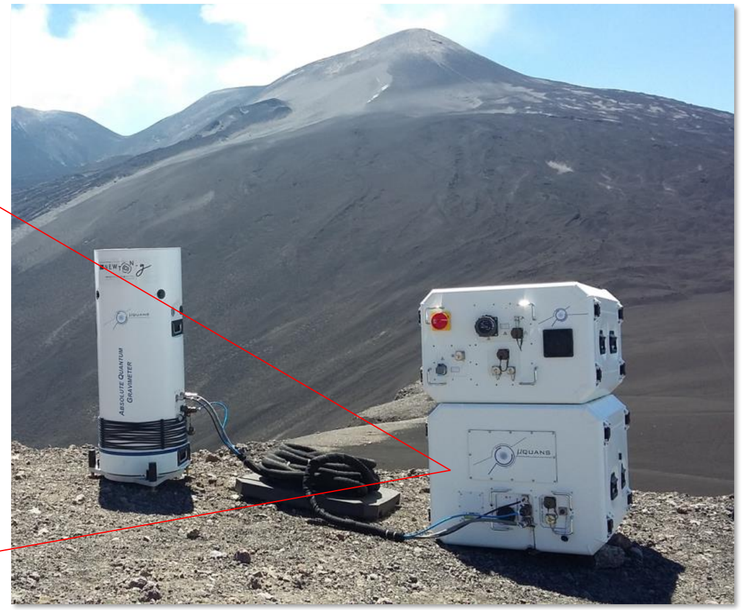
Absolute Quantum Gravimeter – Making it work !

squeeze a laser lab into a suitcase !

1665



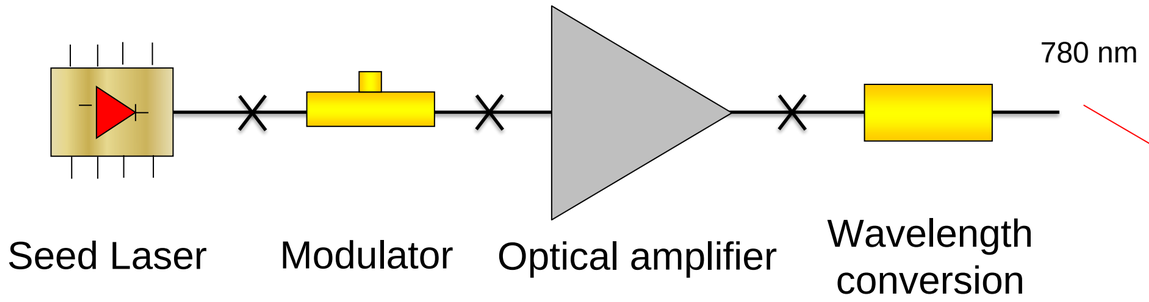
2010

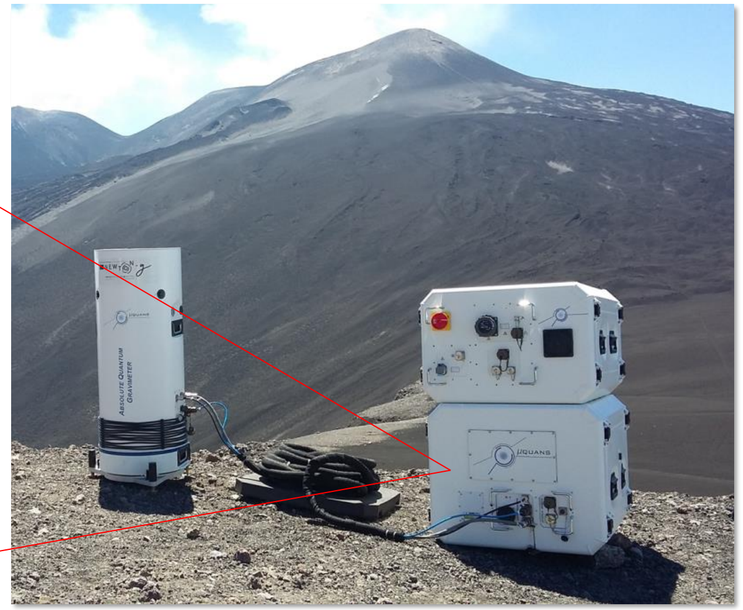


2020

Absolute Quantum Gravimeter – How does it work ?

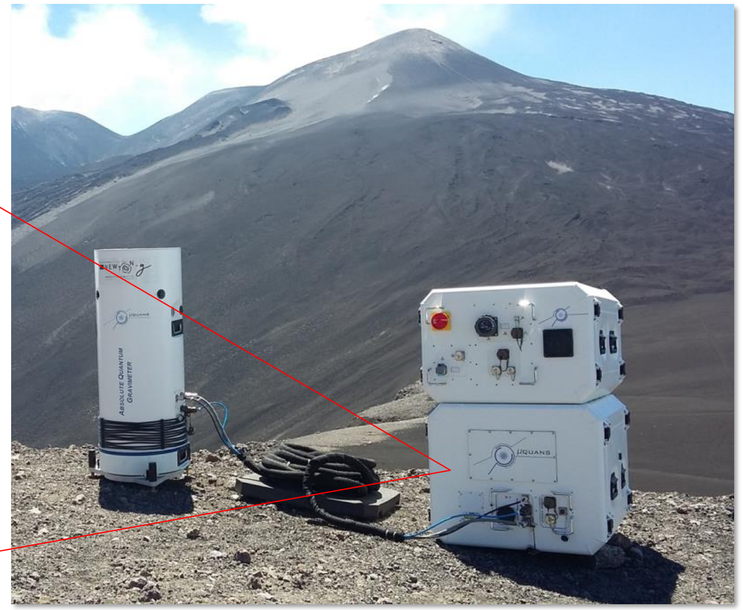
telecom laser technology and micro-optical benches





Absolute Quantum Gravimeter – Goes to the field !

braving the elements !



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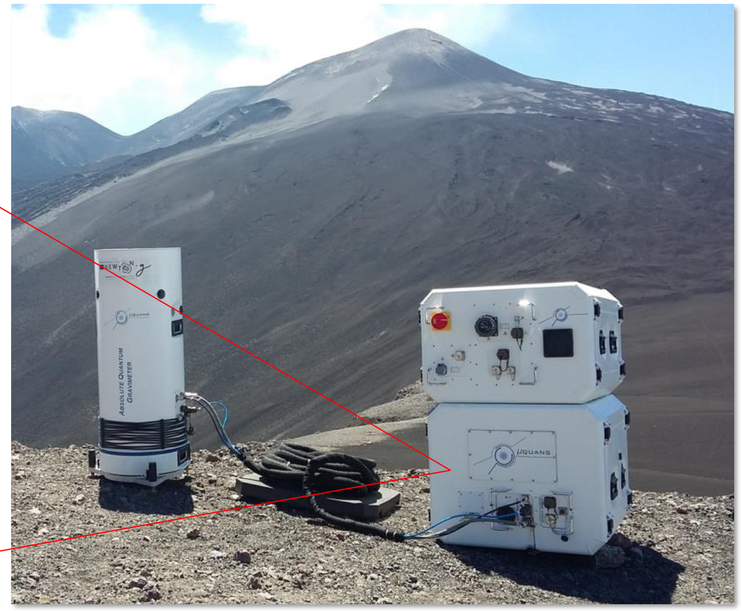
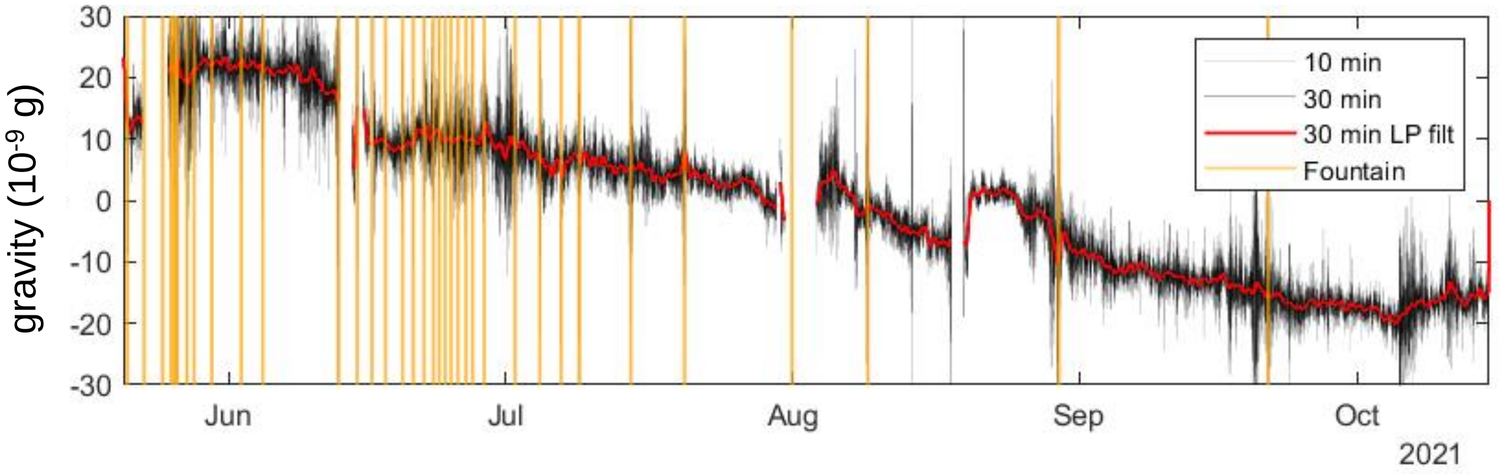
Absolute Quantum Gravimeter – Why it is so good !

thanks to (integrated) fibre optics, the AQG works despite strong volcanic tremor

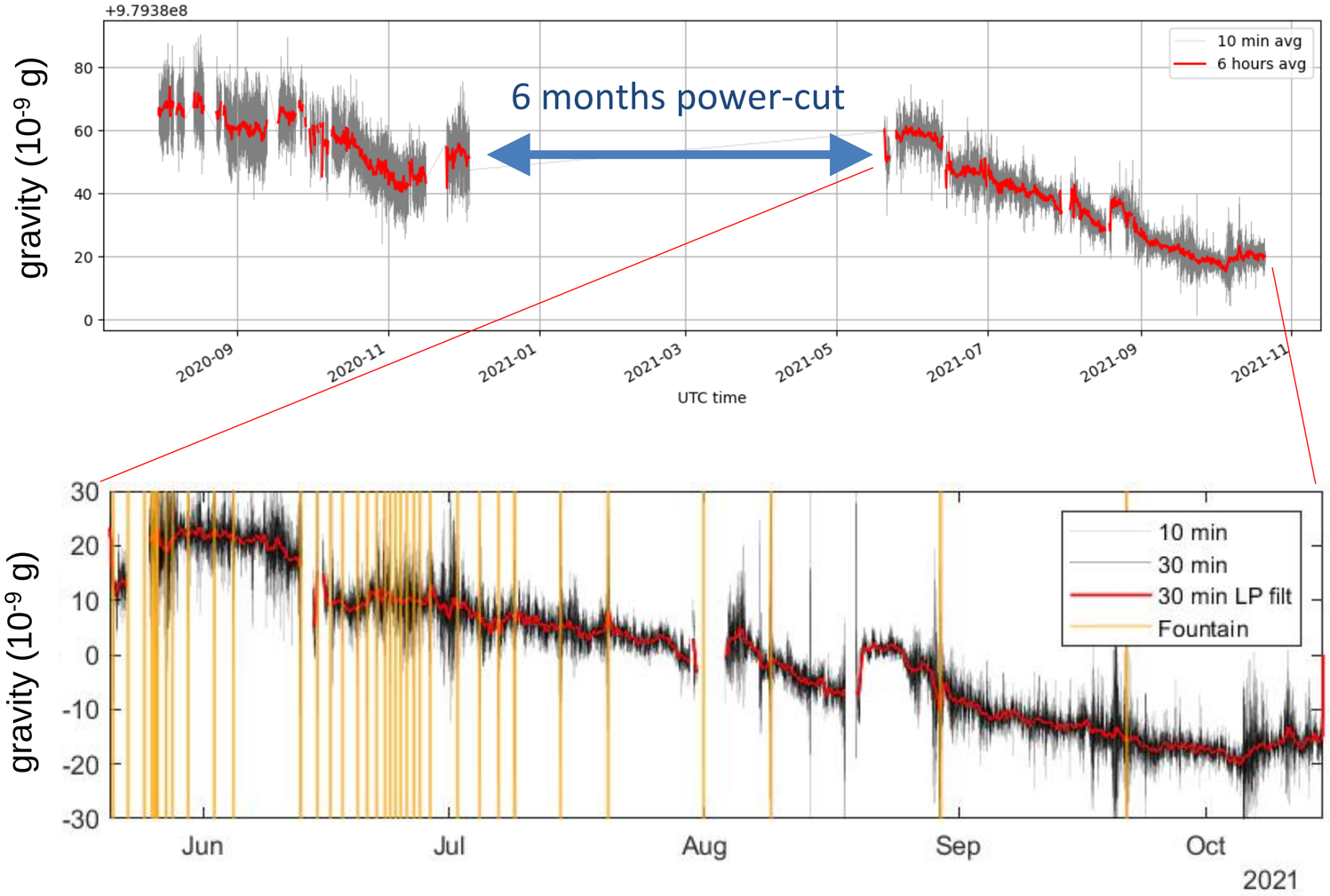




NEWTON-g

Absolute Quantum Gravimeter – Why it is so good !

robust optics and vacuum system survived 6 months power-cut



NEWTON-g

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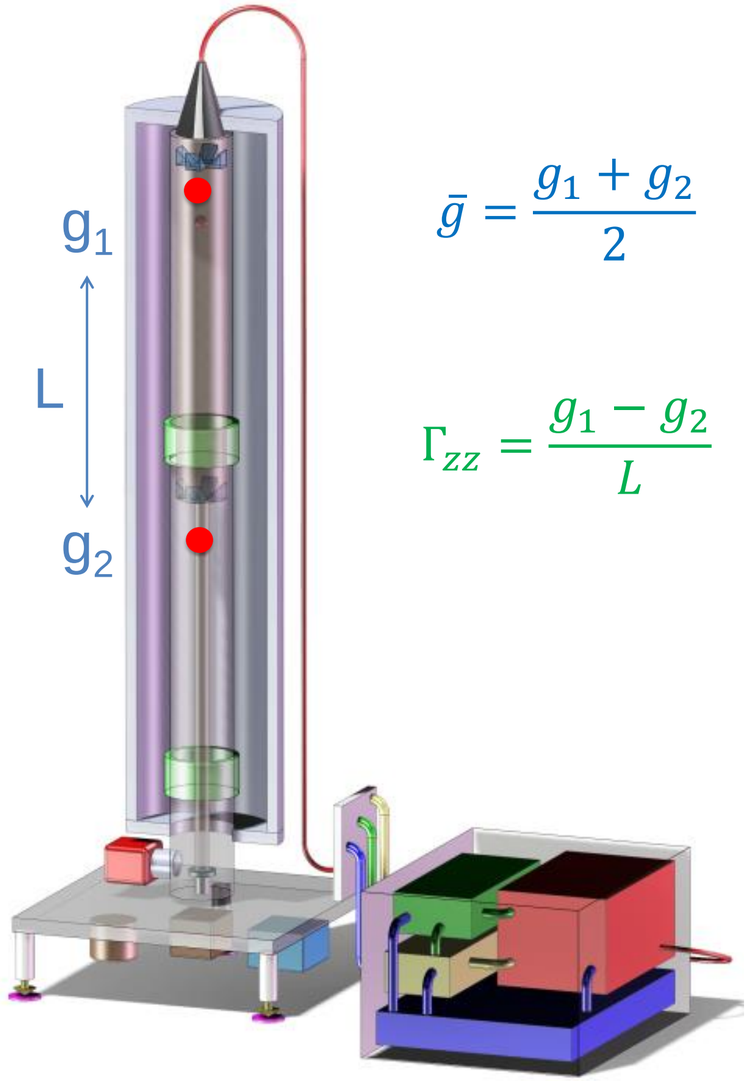
Next Generation Quantum Sensors

Differential Quantum Gravimeter

- **two vertically stacked gravimeters measure g and its gradient**
- **applications in**
  - civil engineering
  - resource monitoring
  - archaeology
- **soon a product**



$$\bar{g} = \frac{g_1 + g_2}{2}$$

$$\Gamma_{zz} = \frac{g_1 - g_2}{L}$$

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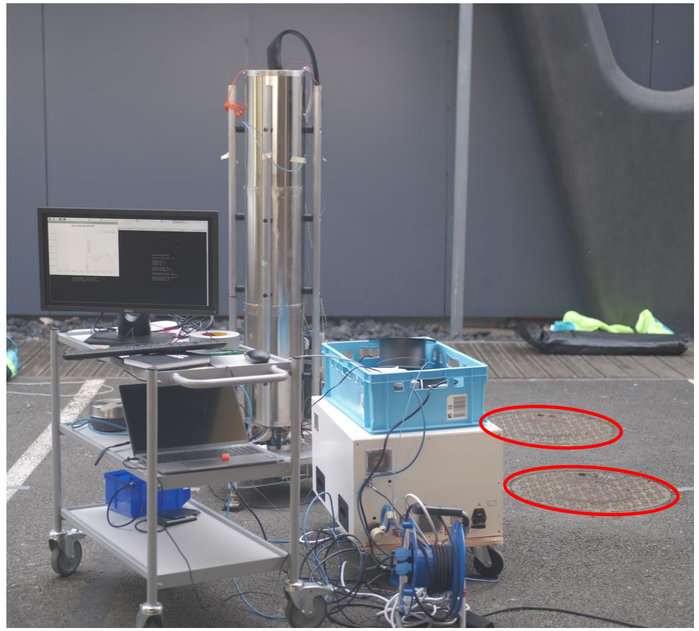
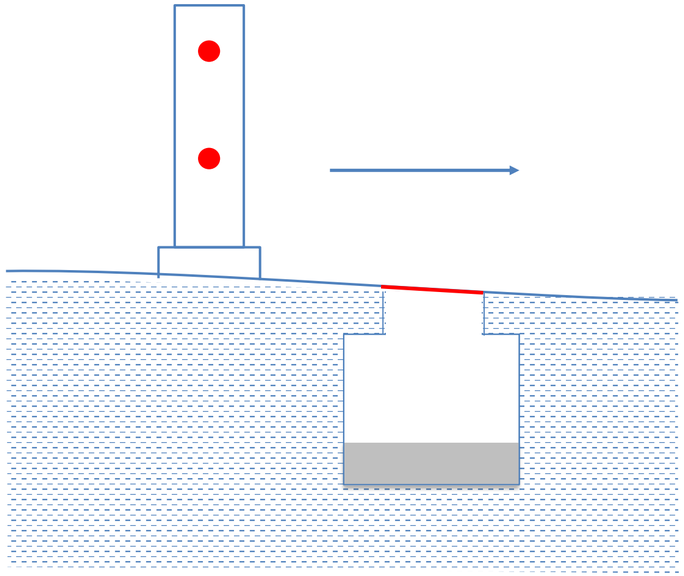
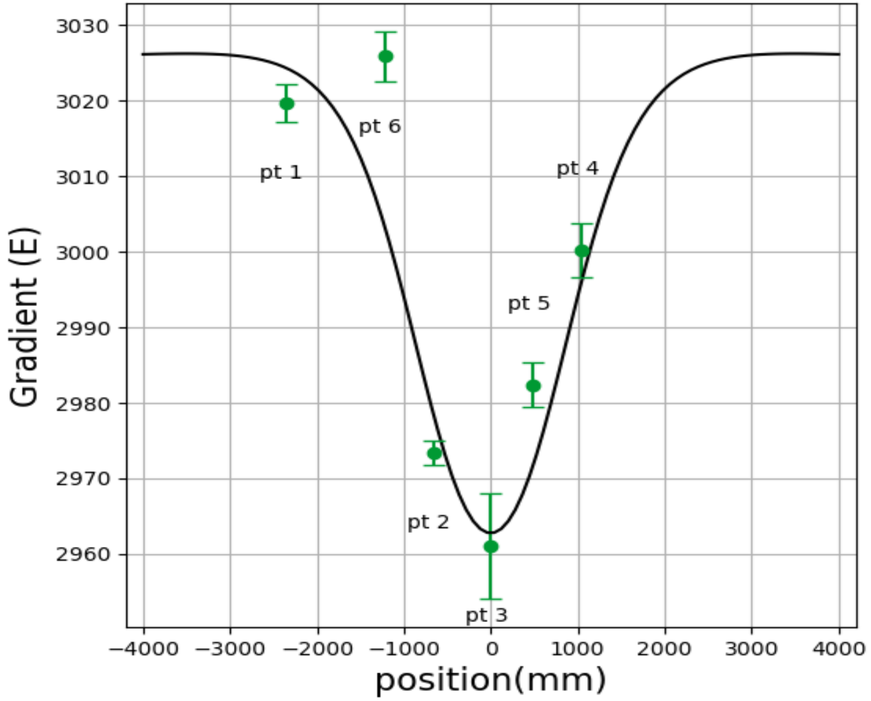
Next Generation Quantum Sensors

Differential Quantum Gravimeter

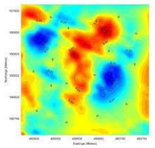






gravity gradient from a 1 m^3 cavity
0.5 m under the surface

- **applications in civil engineering**
- **follow-up project on a rover**



fiqus

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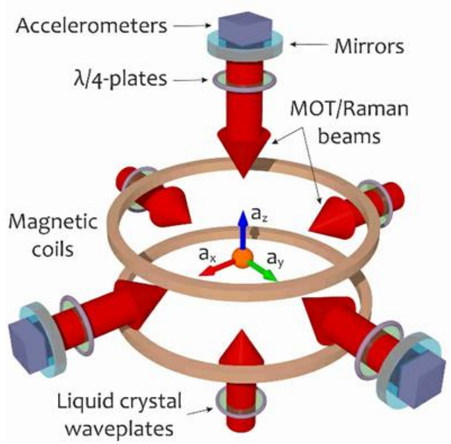
Next Generation Quantum Sensors

quantum sensors for moving platforms

IXATOM
Quantum technologies for high end Inertial Sensors



cnrs

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MINISTÈRE DES ARMÉES
Liberté
Égalité
Fraternité

SHOM

photo: SHOM

MINISTÈRE DES ARMÉES
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DGA

RÉPUBLIQUE FRANÇAISE
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ONERA
THE FRENCH AEROSPACE LAB

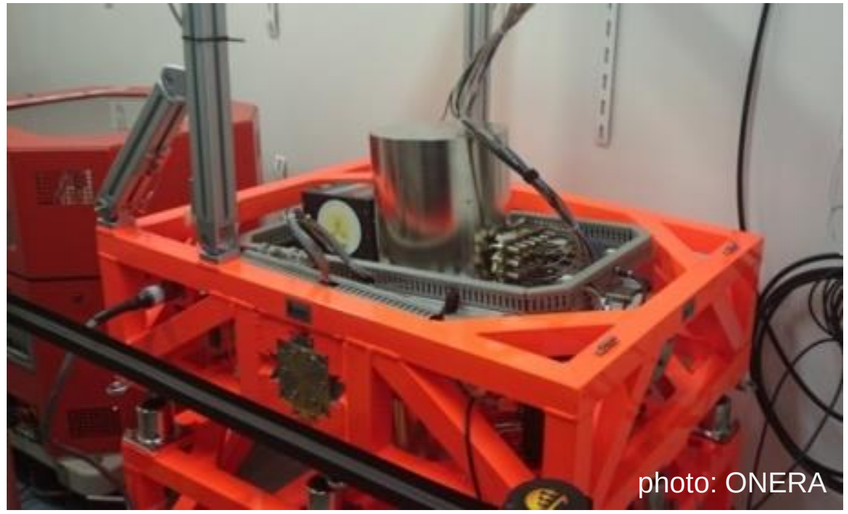
photo: ONERA

› **gravimeter on active gimbal**

› **strap-down 3-axis accelerometer**

Conclusion

- **exail** provides a broad range of components, sub-systems and systems for **photonics** and **quantum technologies**
- **exail Quantum Systems** has brought laser-cooled atom technology **from the lab to the field**
- **exail's Absolute Quantum Gravimeters** rival the best absolute gravimeters and surpass these in robustness
- **exail's next generation quantum sensors** will go to moving platforms including satellites
- email **Peter.Rosenbusch@exail.com**