University of Strathclyde Science

Compact, laser-cooled atomic clocks

Paul Griffin – University of Strathclyde

esa

EPSRC
Pioneering research and skills

UK National Quantum Technologies Hub in Sensors and Metrology

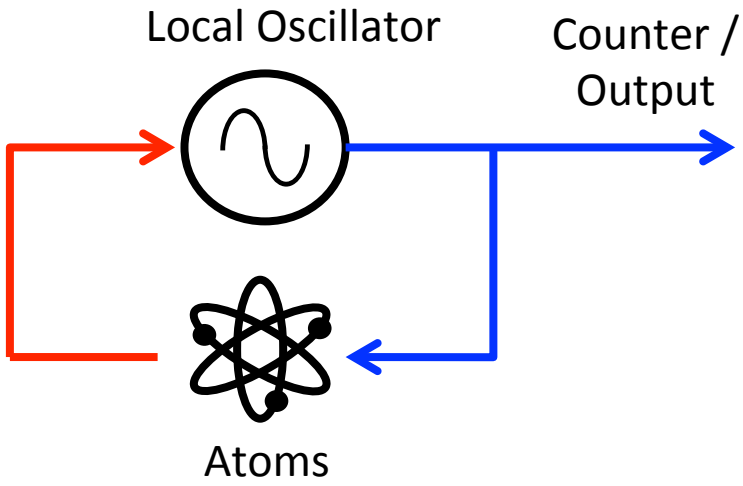
[dstl]

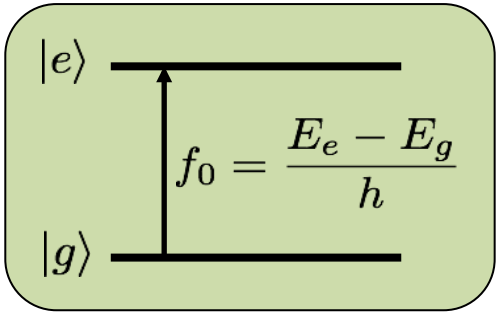
Innovate UK
Technology Strategy Board

The Royal Society of Edinburgh

ITSF2015 – Edinburgh 2015-11-04

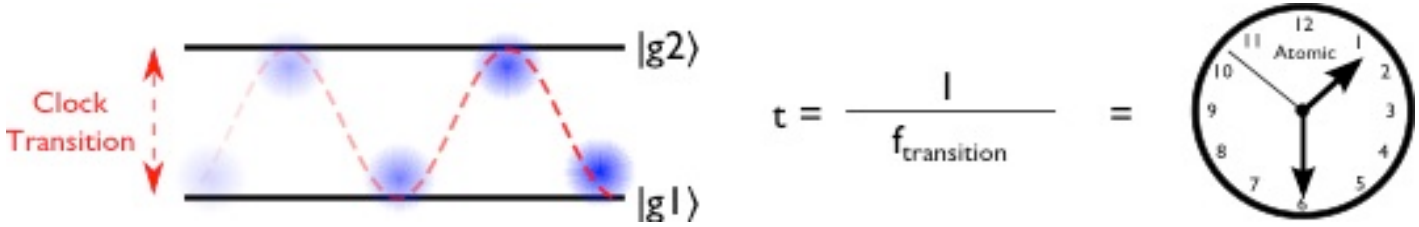
Clocks





The second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of caesium 133 atoms (1967)

A compact cold atom clock



$$\sigma_y(\tau) = \frac{\Delta f_a}{f_o\sqrt{N\tau}}$$

N: Number of atoms

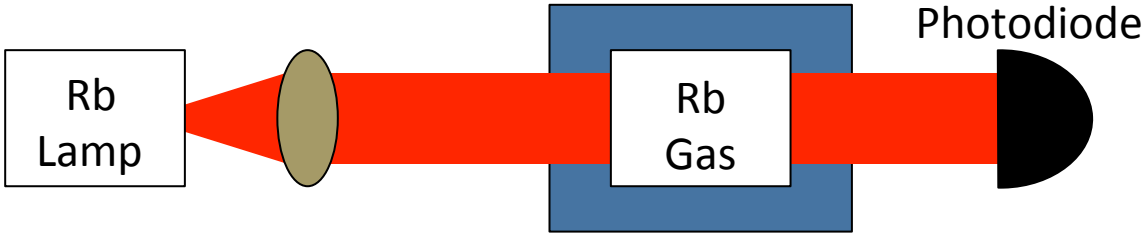
f_0: Resonance frequency

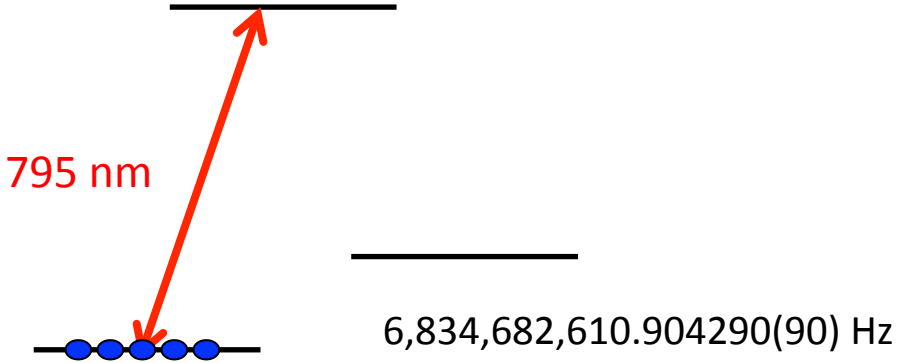
τ: Measurement time

Δf_a: Linewidth of transition

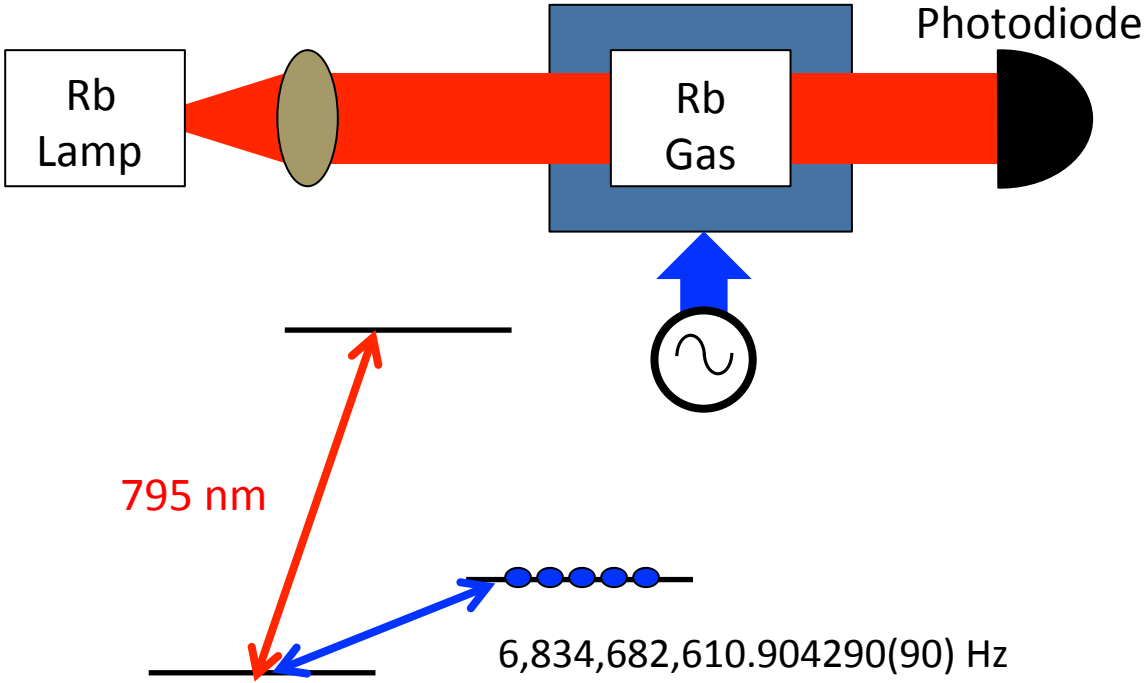
Proposed instability: $3\times10^{-13}/\tau^{1/2.}$

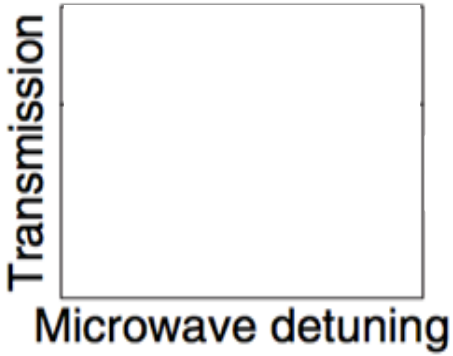
An atomic clock



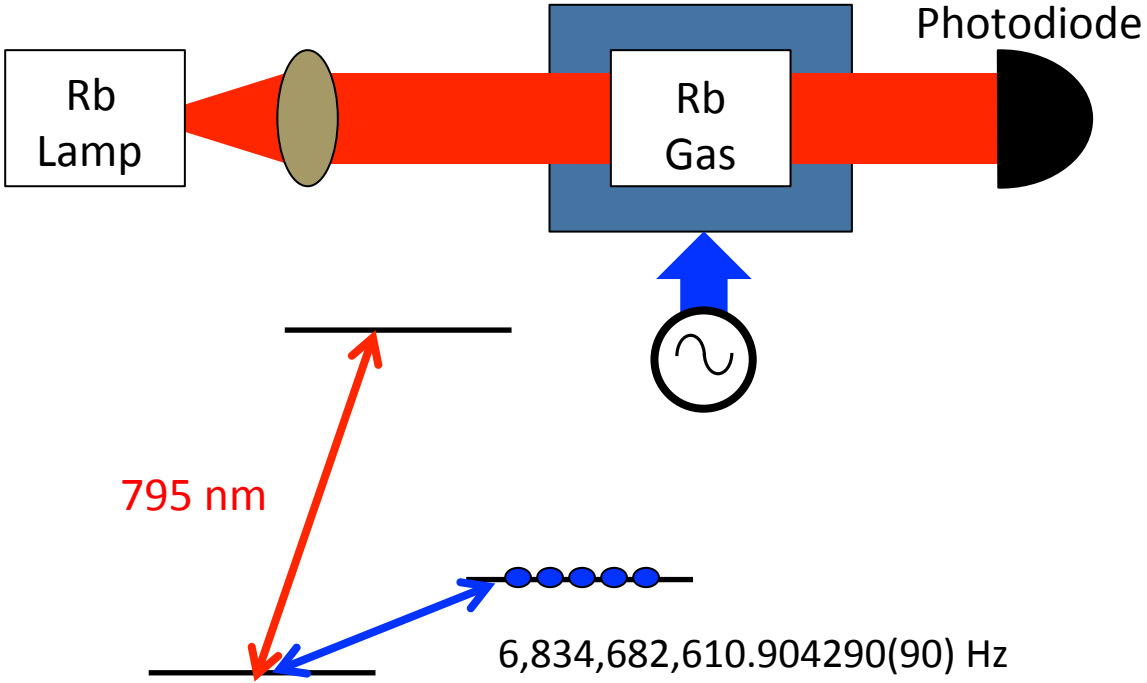


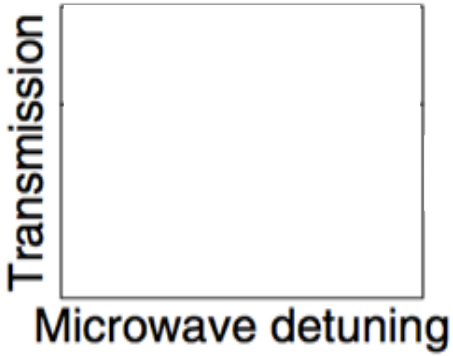
An atomic clock



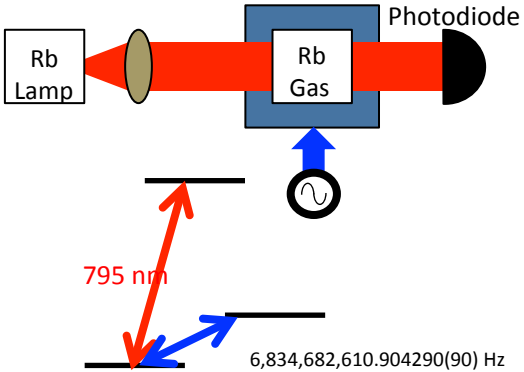


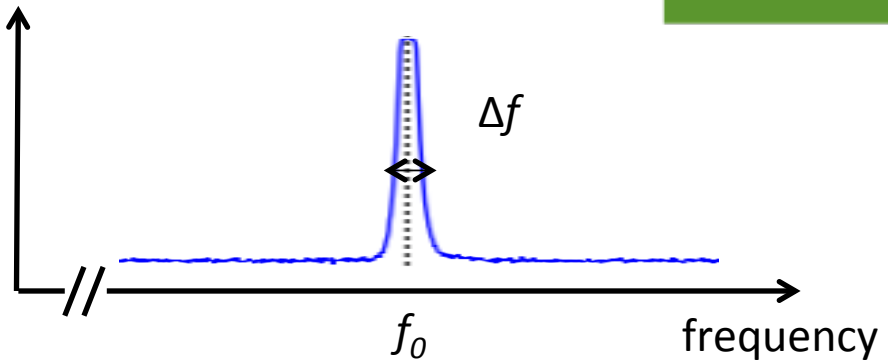
An atomic clock



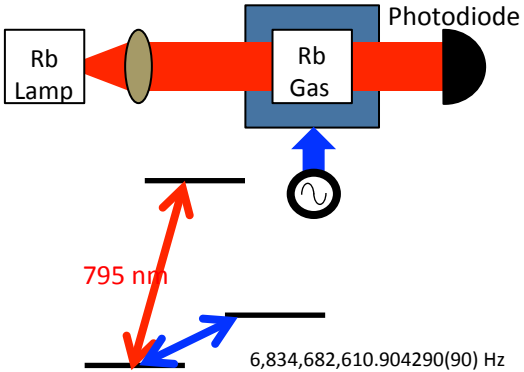


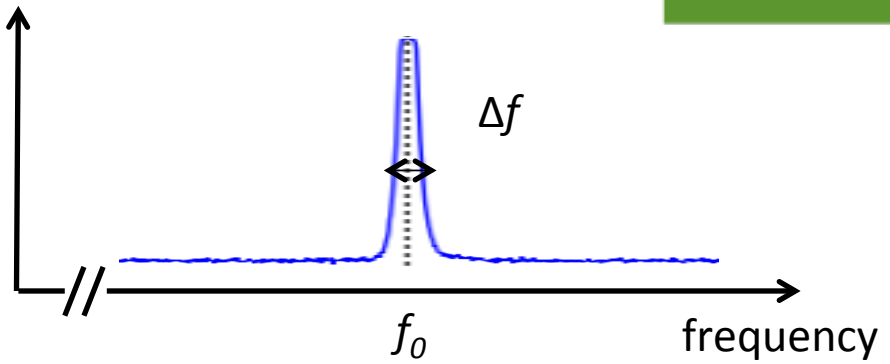
An atomic clock





An atomic clock



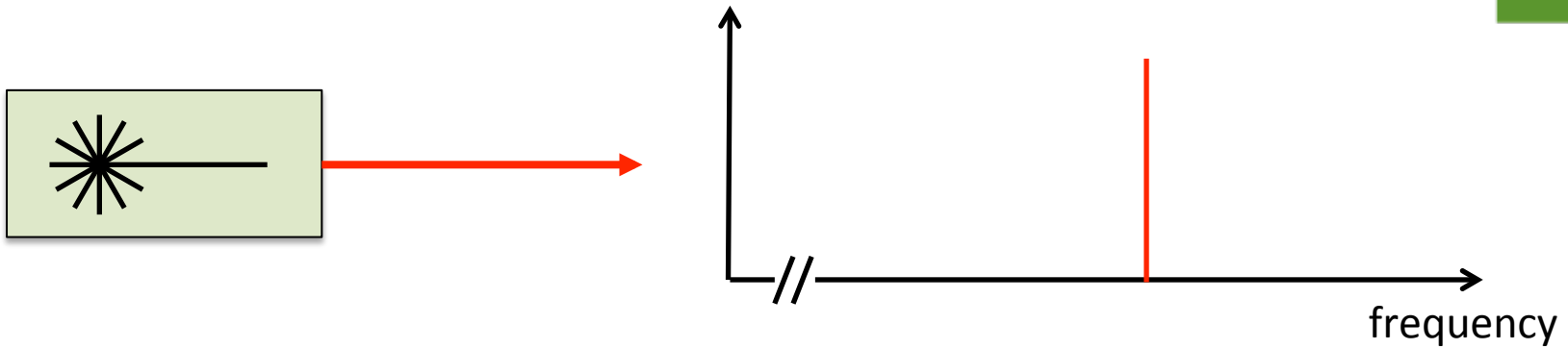


Not miniaturise-able

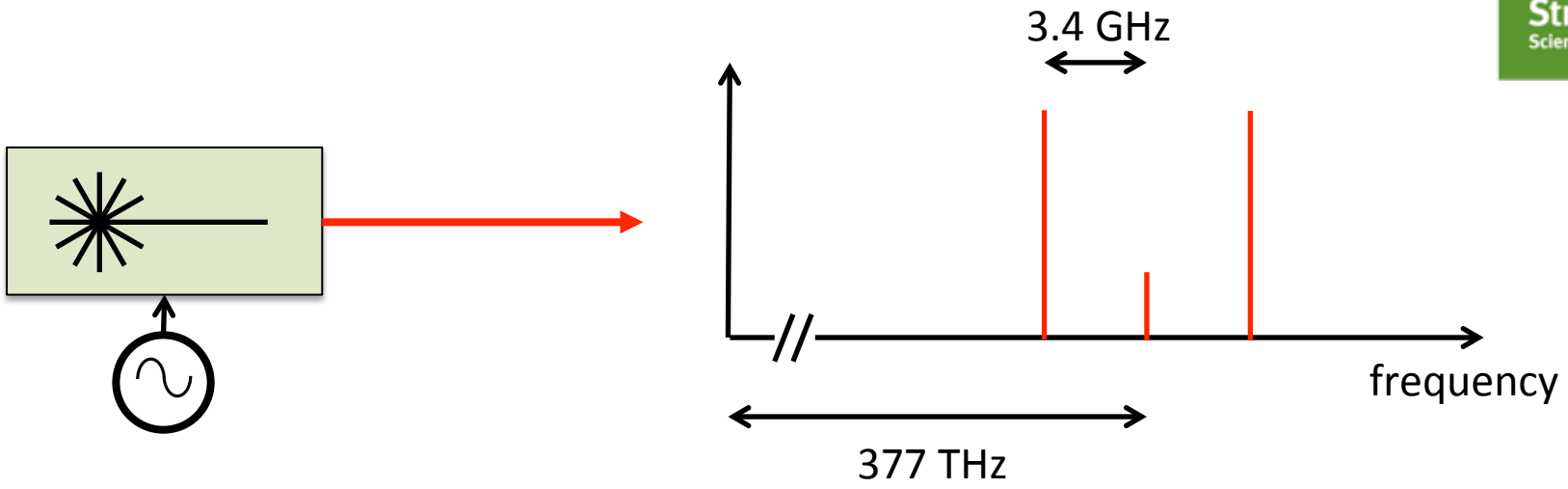
$$\lambda = \frac{c}{f_0}$$

= 4.4 cm

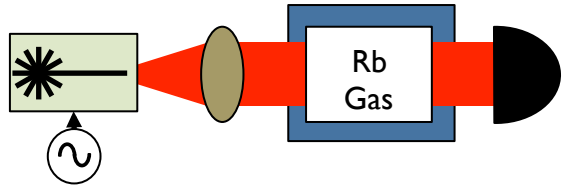
Getting past cavities

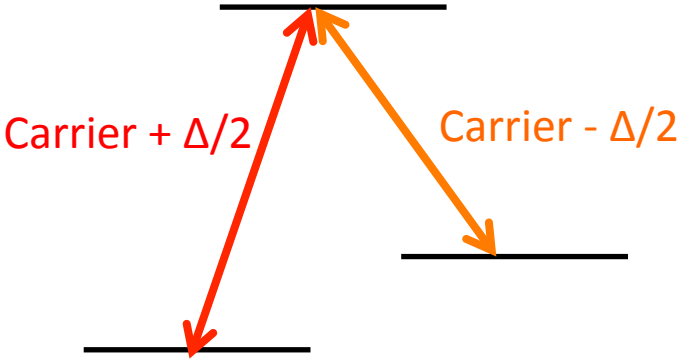


Getting past cavities



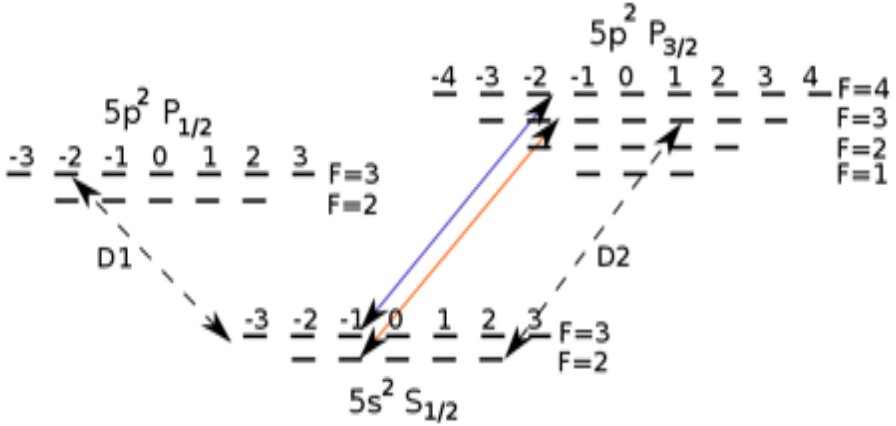
Getting past cavities

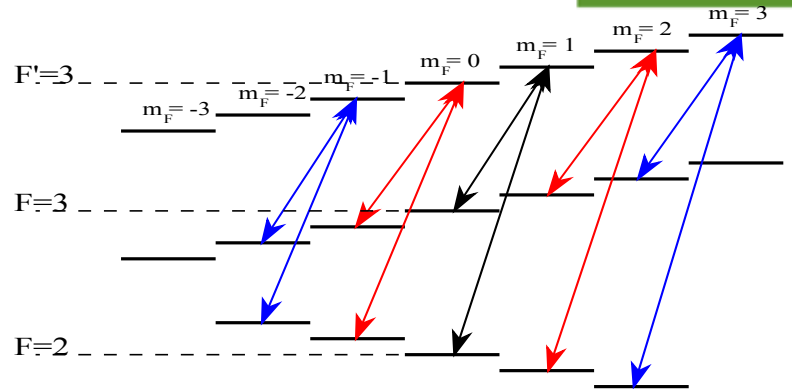


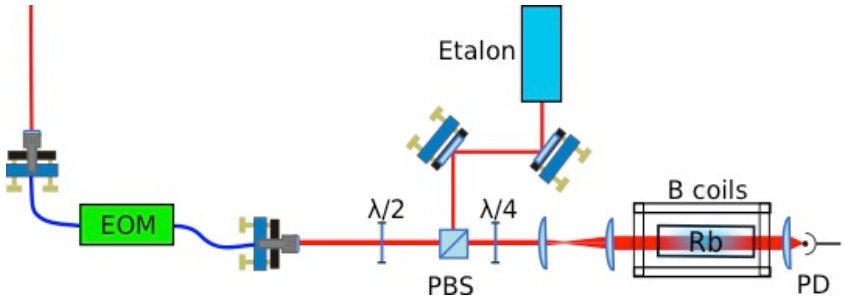


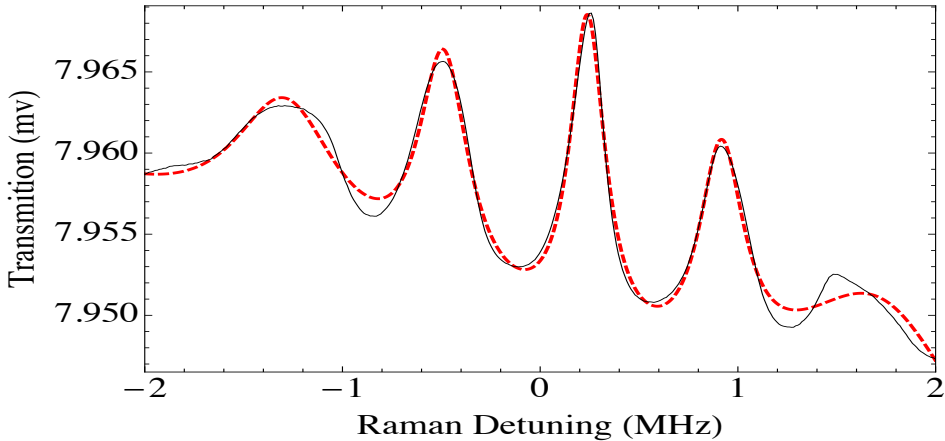
Coherent population trapping

Thermal atoms



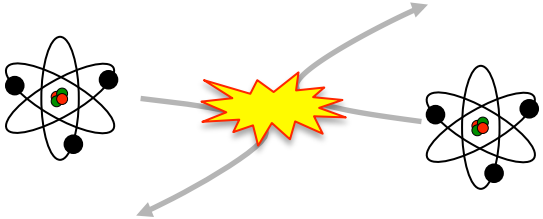




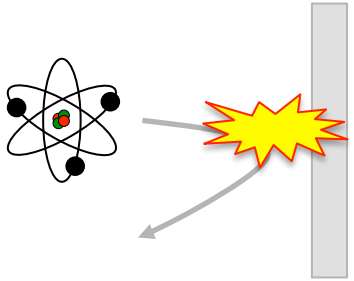


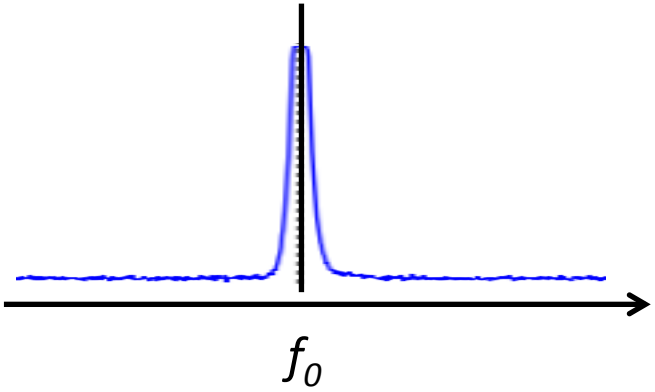
What about accuracy?

Atomic collisions are **bad**



Wall collisions are **bad**





Simple physics … or physicists

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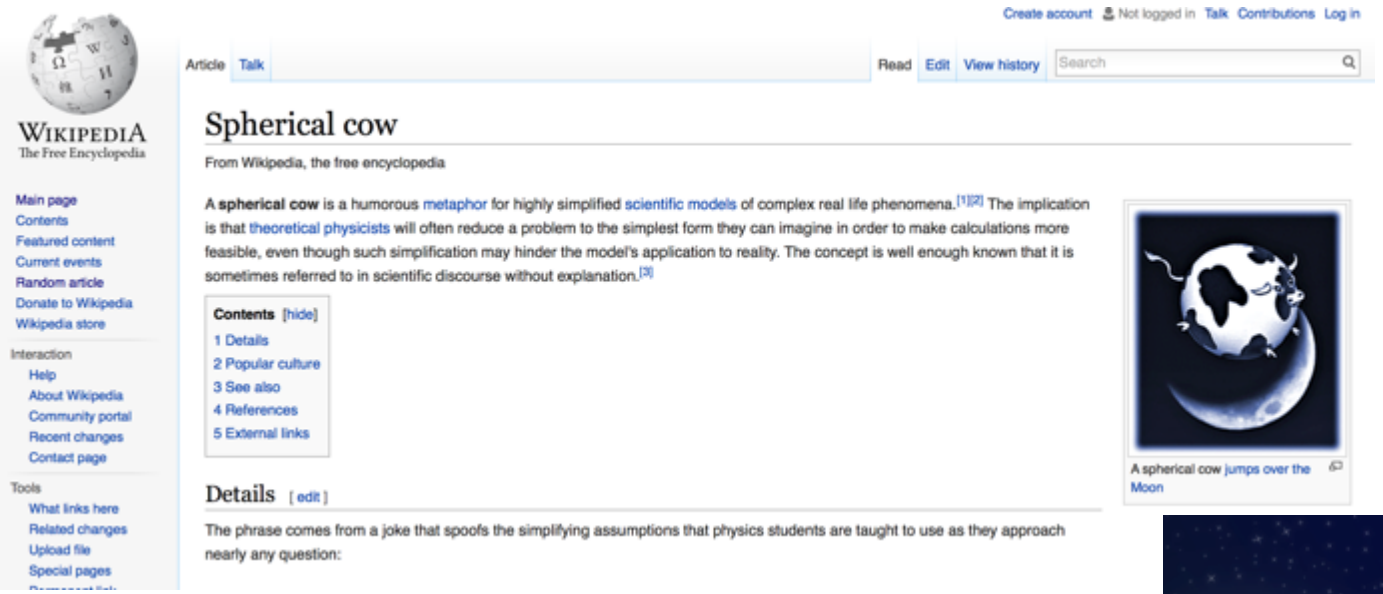

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Spherical cow

From Wikipedia, the free encyclopedia

A spherical cow is a humorous metaphor for highly simplified scientific models of complex real life phenomena.[1][2] The implication is that theoretical physicists will often reduce a problem to the simplest form they can imagine in order to make calculations more feasible, even though such simplification may hinder the model's application to reality. The concept is well enough known that it is sometimes referred to in scientific discourse without explanation.[3]

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3 See also
4 References
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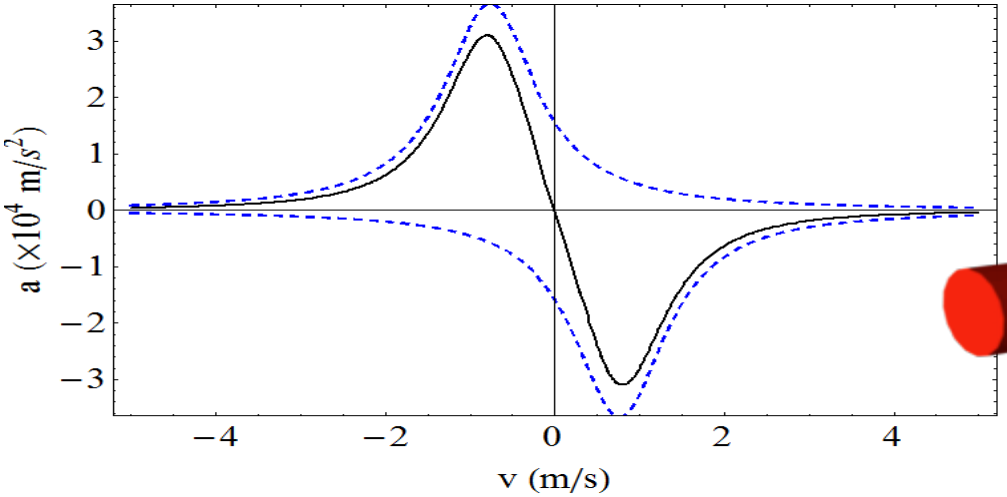
A spherical cow jumps over the Moon

Details [edit]

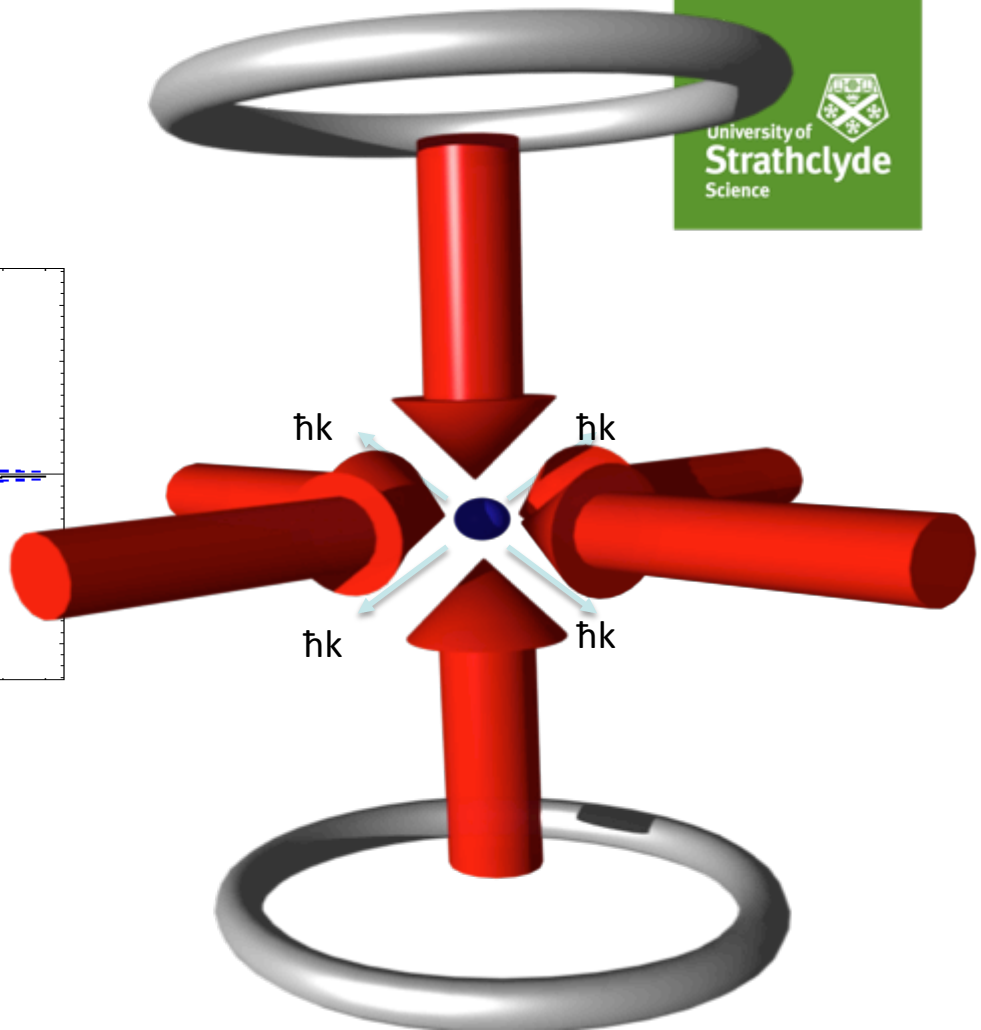
The phrase comes from a joke that spoofs the simplifying assumptions that physics students are taught to use as they approach nearly any question:

How to get cold

$$p = mv = \hbar k$$



$$< a >= \frac{\hbar k R(I,\nu)}{m}$$



Innovation in laser cooling

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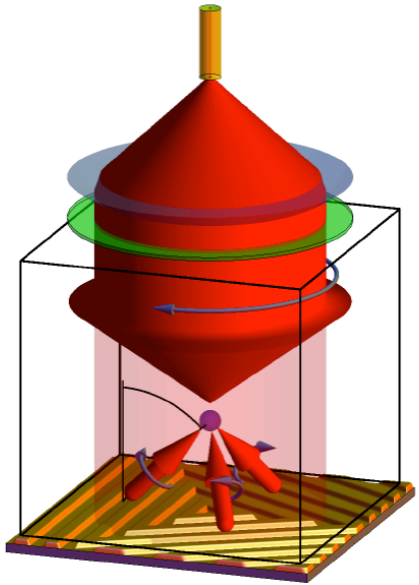
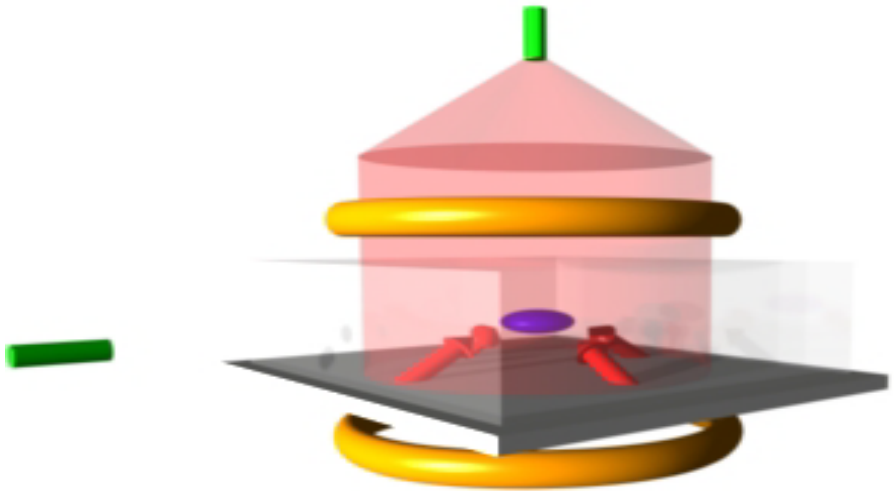
Micro-fabricated Grating MOT



Nature Nanotechnology **8**, 321–324 (2013)

Coherent population trapping

Cold atoms



Compact measurement device

Coherent population trapping

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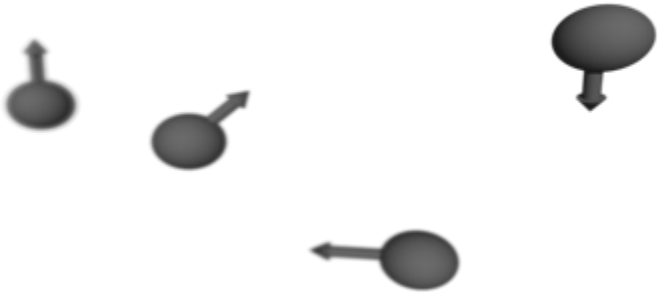
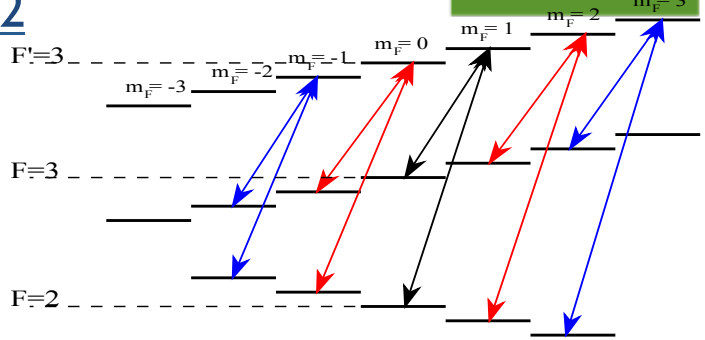
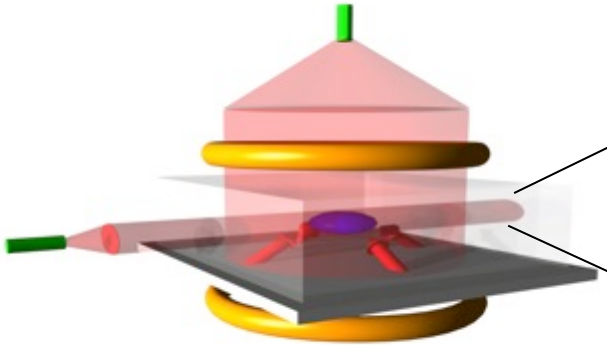
Step 1

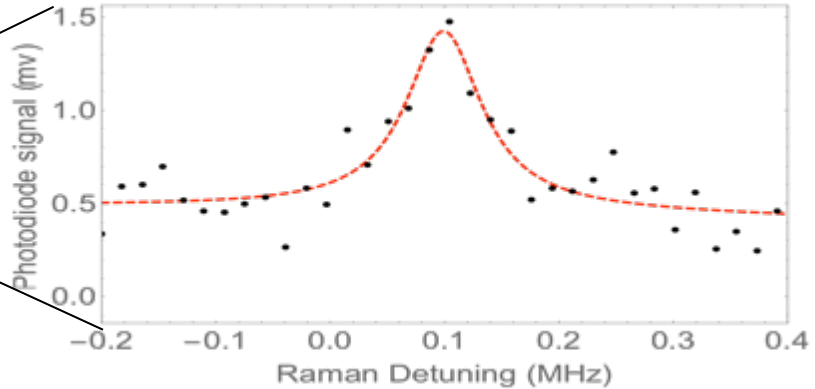


Step 2



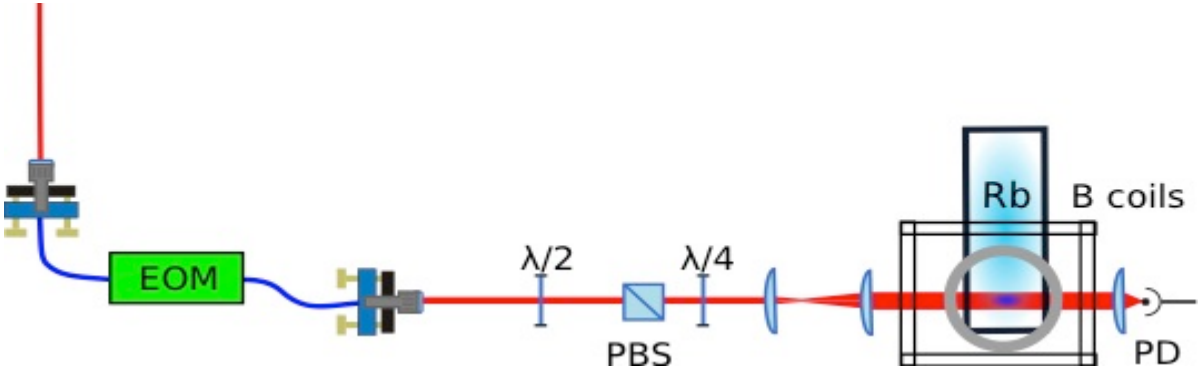
Step 3

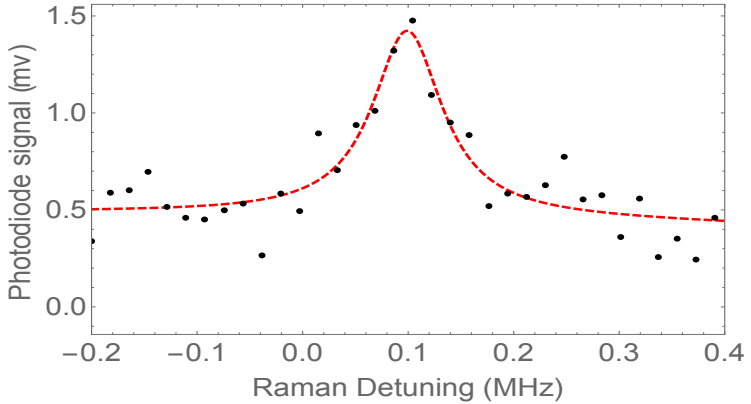




Coherent population trapping

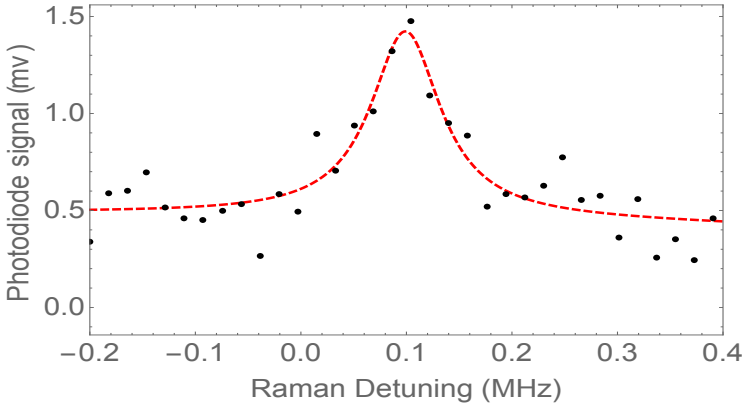
Cold atoms

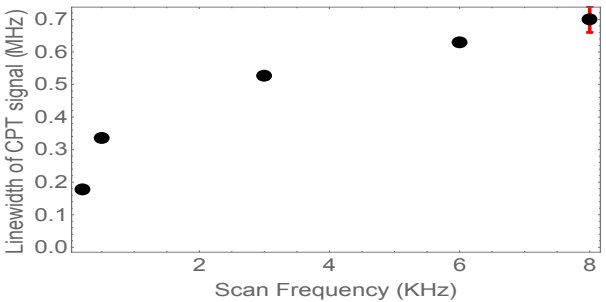




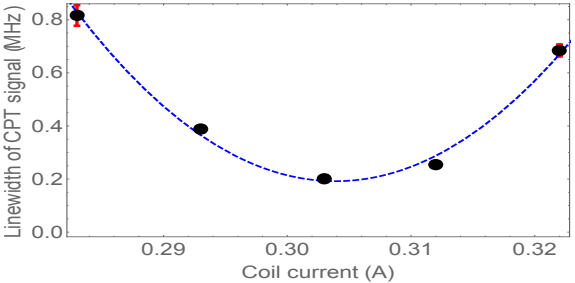
Coherent population trapping

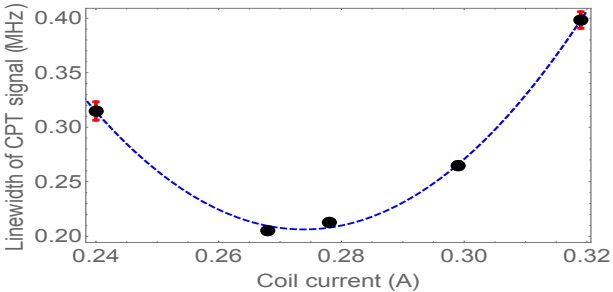
Cold atoms

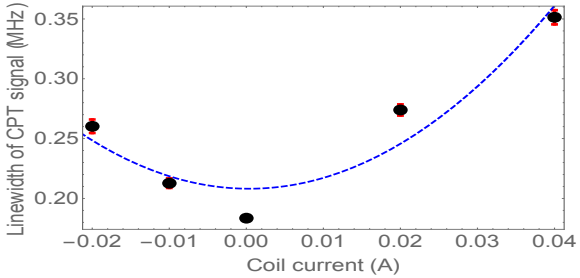




The parameters of the thermal system were studied along with new parameters in order to find the lowest FWHM

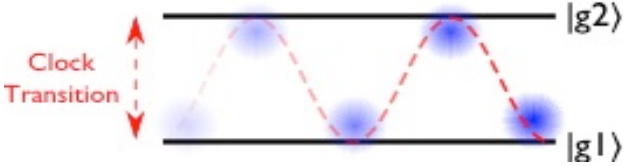




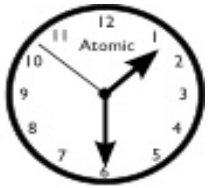


Compact quantum measurement:

Towards a compact cold atom clock



$$t = \frac{1}{f_{transition}} =$$



$$\sigma_y(\tau) = \frac{\Delta f_a}{f_o\sqrt{N\tau}}$$

N: Number of atoms

f_0: Resonance frequency

τ: Measurement time

Δf_a: Linewidth of transition

Current value: $10^{-9}/\tau^{1/2}$

Aim for coming year: $<10^{-12}/\tau^{1/2}$.

Proposal

Stability of 10^{13} in a sub-litre package within five years

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Obstacles:

- Ultra-high vacuum required
- Low-noise, medium-power lasers
- Robust against
  - vibrations
  - electrical noise
  - magnetic noise
  - external temperature

Solutions

Proposal

Stability of 10^{13} in a sub-litre package within five years

University of Strathclyde Science

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- Ultra-high vacuum required
- Low-noise, medium-power lasers
- Robust against
  - vibrations
  - electrical noise
  - magnetic noise
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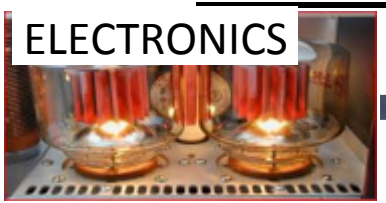
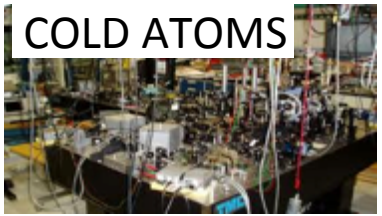
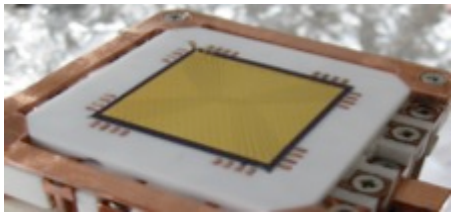
Solutions

ELECTRONICS



COLD ATOMS





UK National Quantum Technologies Hub in Sensors and Metrology

Team

Experimental Quantum Optics & Photonics

University of Strathclyde Science

PG

Erling Riis

Aidan Arnold

Ranjita Sapam

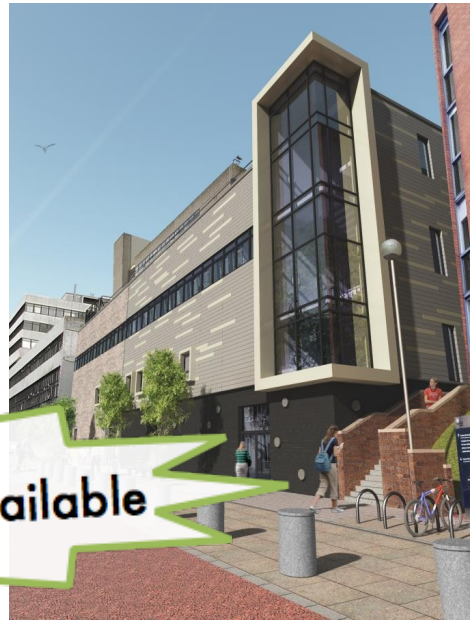
Stuart Ingleby

James McGilligan

Rachel Elvin

Mathieu Vangeleyn

Chidi Nshii



Postdoc Positions Available

http://photonics.phys.strath.ac.uk/