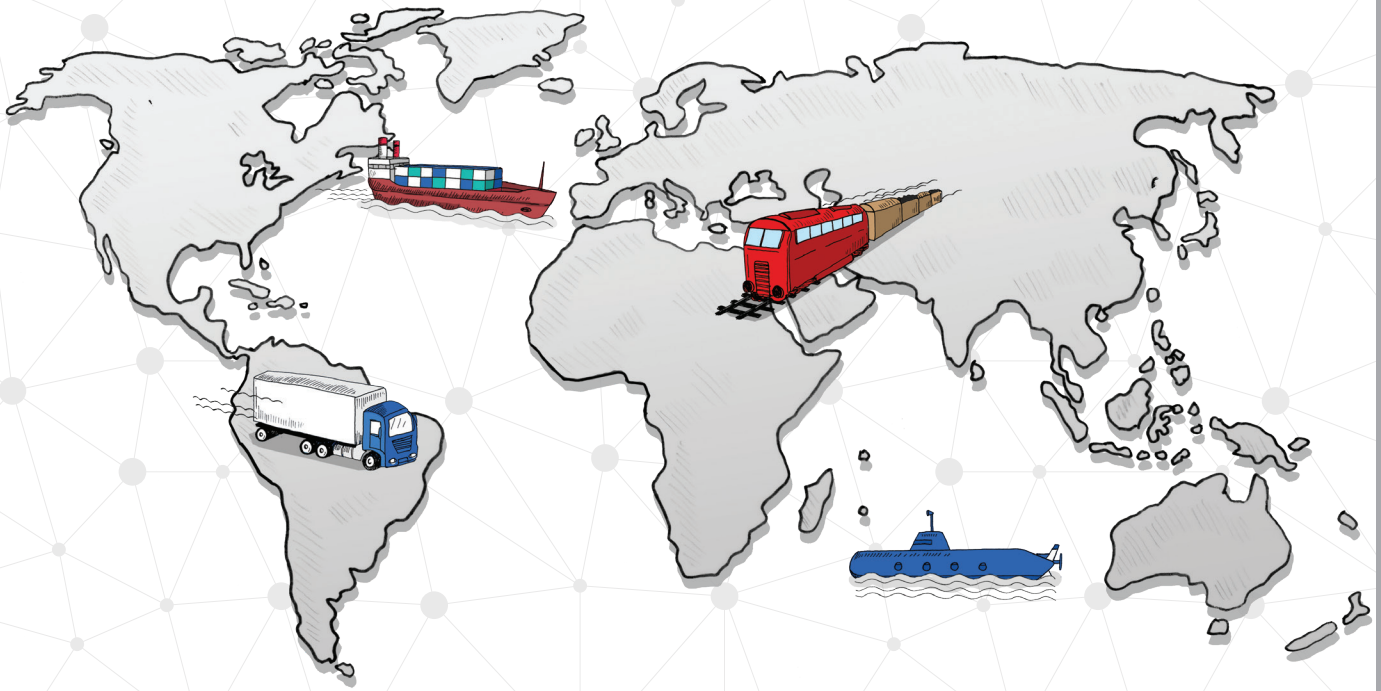
Imperial College London



M SQUARED

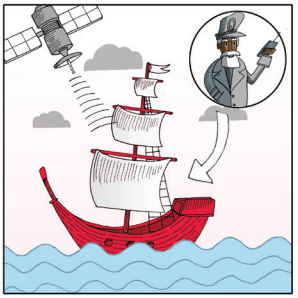
QUANTUM NAVIGATION

UK'S FIRST COMMERCIAL QUANTUM ACCELEROMETER FOR NAVIGATION

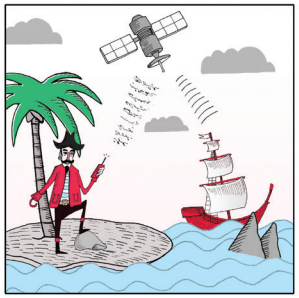
M Squared and Imperial College London are developing quantum sensors for real world applications. Our accelerometer uses quantum interference of matter waves to measure horizontal accelerations with no bias and ultra-high accuracy. The purpose of this is to navigate ships and submarines, and perhaps other vehicles in the future.

WHY QUANTUM NAVIGATION IS USEFUL

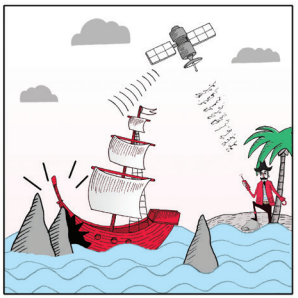
Today the world relies on the global navigation satellite system (GNSS). However, GNSS is susceptible to denial, jamming and imitation with an economic impact to the UK of £5.2 billion for a five-day disruption[1]. Quantum sensors, including our accelerometer, offer a new way to achieve accurate navigation without the need to send communications back and forth to satellites.



Ships can currently use GNSS to navigate at sea, relying on sending radio signals back and forth between satellites



But these signals are subject to outages, interference and jamming...

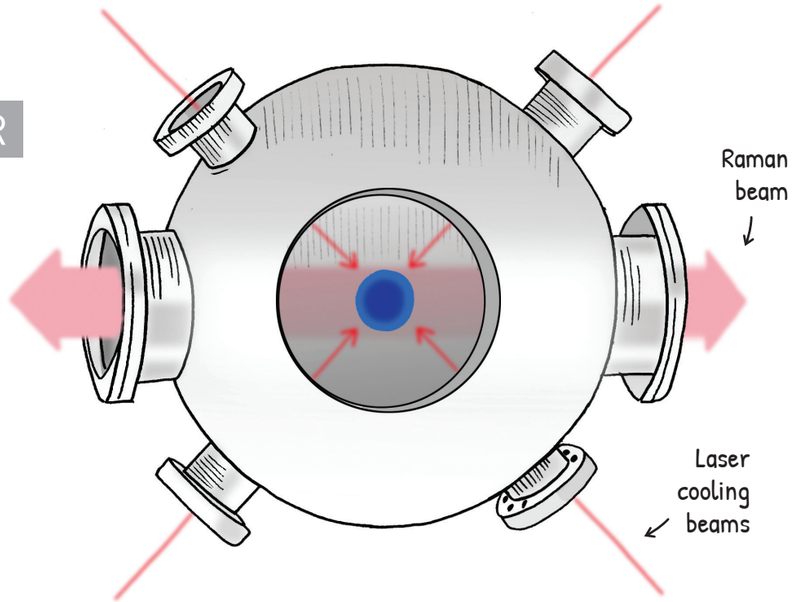


...which can result in costly navigational errors...

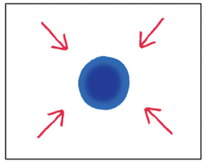
...much to the gain of our scheming pirate and the detriment of our noble sailor.

[1] "The economic impact on the UK of a disruption to GNSS," London Economics: https://londoneconomics.co.uk/blog/publication/economic-impact-uk-disruption-gnss/

HOW THE QUANTUM ACCELEROMETER WORKS



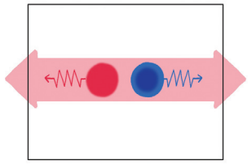
STEP 1



Atoms cooled and released

A combination of magnetic fields and laser light cools atoms close to absolute zero. The atoms are then allowed to fall freely to measure the acceleration of the vehicle as shown in the next steps.

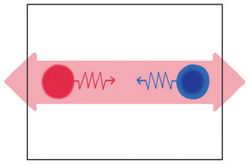
STEP 2



Matter-wave splitter

A pulse of laser light (travelling both left and right) splits each atom into two quantum waves (here red and blue) which move apart.

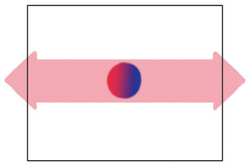
STEP 3



Waves reversed

A second laser pulse reverses the kick and the two parts come back together.

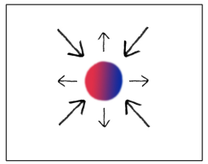
STEP 4



Waves interfere

A third laser pulse allows these waves to interfere with each other. The probability of ending up "red" or "blue"depends on the constructive or destructive interference of the waves, which depends on the acceleration of the vehicle.

STEP 5



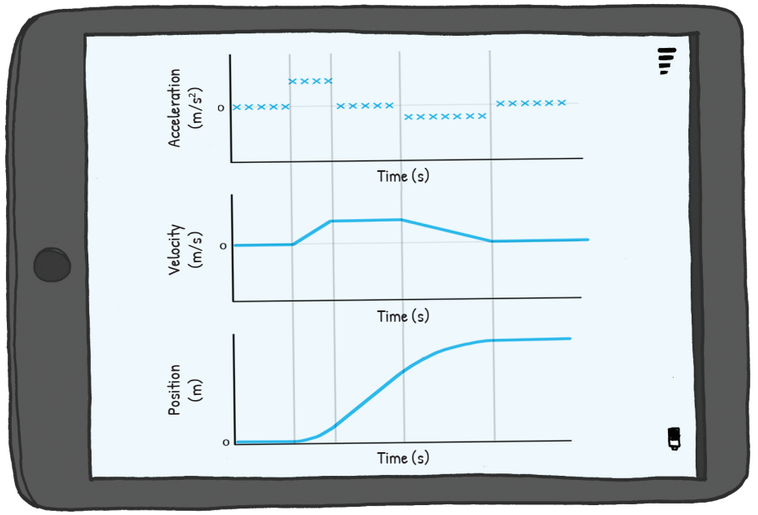
Detection

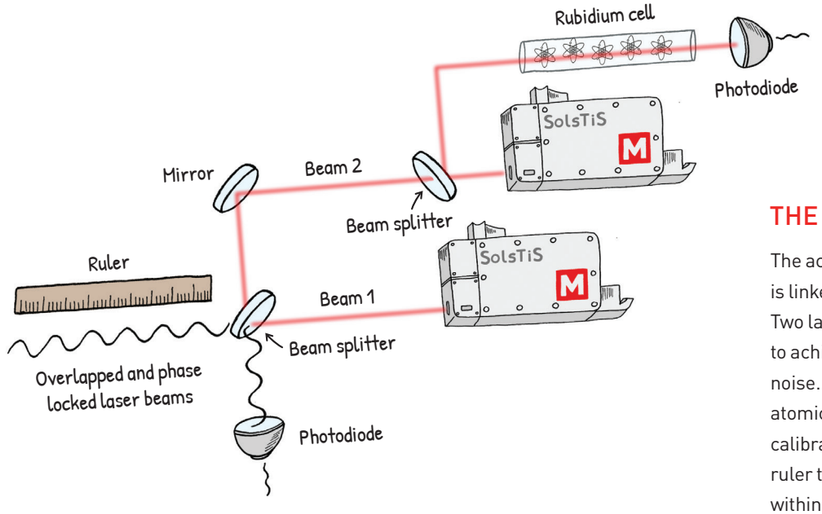
Laser light is scattered from the atoms to measure how many are "red" and how many are "blue". From this we determine the acceleration of the vehicle.

STEP 6

Measurement

By tracking the acceleration over time, we can calculate the velocity and position of the vehicle. A classical accelerator has measurement bias, and drifts in this bias result in errors when calculating position from acceleration. Quantum accelerometers do not have a measurable bias, so can be used to navigate accurately.





THE LASER

The accuracy of the quantum accelerometer is linked directly to that of the laser system. Two lasers are phase locked to each other to achieve an optical ruler of very low phase noise. The lasers are referenced to an atomic transition to guarantee accurate calibration. Each atom uses this optical ruler to sense the changes of its position within a few millionths of a hair's breadth.

REAL-WORLD APPLICATIONS

M Squared and Imperial College are developing a commercial quantum navigation system. We aim for the highest possible sensitivity, in order to provide accurate positioning, even after a long journey. The present noise figure corresponds to a positional accuracy of 2 km after 1 month, which is a substantial improvement in the state of the art.

APPLICATIONS

Submarines

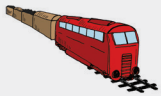
Submarines need to be able to navigate without communicating externally.

Cargo ships

Cargo ships also need to make long journeys without risk of GNSS denial.

Underwater vehicles

Autonomous underwater vehicles are another future market.



Trains

Train services that are not reliant on GNSS could be more frequent and reliable.

Future applications

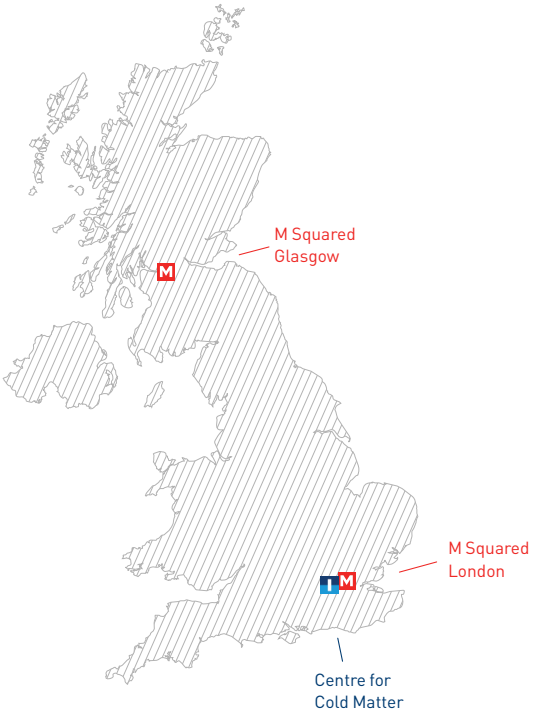
Further in the future, a wide range of vehicles could navigate using quantum sensors, such as planes and spacecrafts.

CONTACT

M Squared and Imperial College are collaborating to develop quantum navigation systems. If you would like more information, please contact the M Squared innovation team or the Centre for Cold Matter at Imperial College at the addresses below.

T: +44 (0)141 945 0500
E: innovation@m2lasers

m2lasers.com | @m2lasers



UK HEADQUARTERS

M Squared
1 Kelvin Campus, West of Scotland
Science Park, Glasgow,
G20 0SP
United Kingdom

UK – LONDON

M Squared
14 East Bay Lane, The Press Centre,
Here East, Queen Elizabeth Olympic Park,
Stratford, London E15 2GW
United Kingdom

UK – LONDON

Centre for Cold Matter
The Blackett Laboratory,
Imperial College London,
Prince Consort Road,
London SW7 2BW
United Kingdom

E: ed.hinds@imperial.ac.uk

Imperial College London

M SQUARED