Quantum Gravimeter

DATASHEET

Quantum Sensing Gravimetry

GRAVITY SENSING USING MATTER WAVE INTERFEROMETRY

M SQUARED

Quantum Gravimeter

The quantum gravimeter, the first commercial device of its kind in the UK, uses quantum interference of matter waves to measure the local value of gravitational acceleration, or 'g', with very high precision. Objects with different mass cause small fluctuations in the value of g measured on the surface of the Earth. The quantum gravimeter can be used to sense these objects hidden under the surface in a non-intrusive and undetectable way.

APPLICATIONS

- Geodesy and earth observation
- Archaeology
- Surveying
- Mineral prospecting
- Underground infrastructure assessment
- Navigation

FEATURES

- Transportable system
- Single Equinox pumping two SolsTiS lasers
- Flexible laser system generates all beams required for both laser cooling and atom interferometry
- Low-noise phase locked laser system allows precise manipulation of atomic states
- Flexible and intuitive

CORE SYSTEM COMPONENTS & MODULES

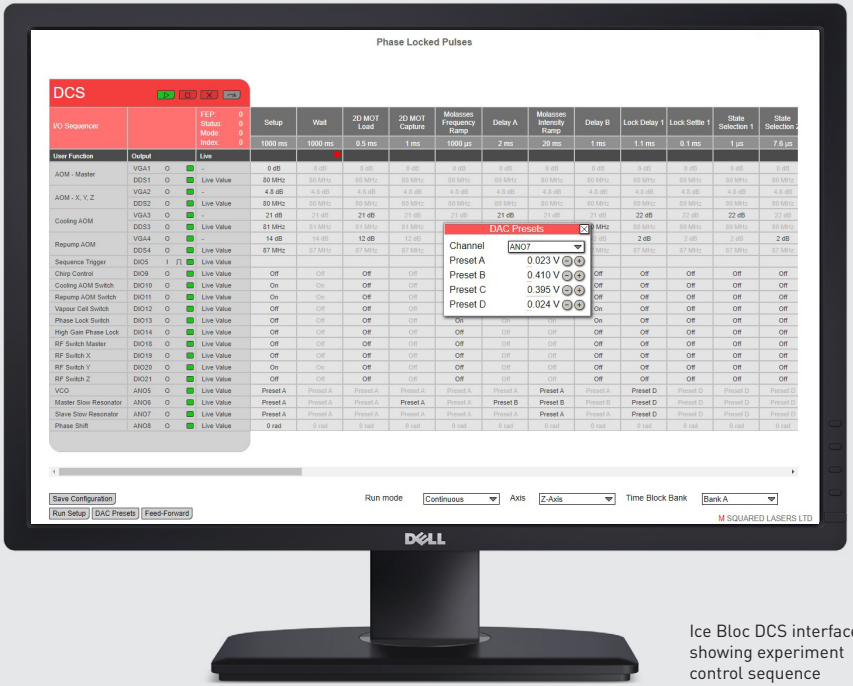
Photonics package:

- Equinox 18 W (pump)
- Dual SolsTiS lasers (laser cooling, atom interferometery)
- Vapour Cell Lock (frequency reference)
- Ice Bloc DCS (experiment control)
- Ice Bloc Phase Lock (laser frequency control)

Physics package (first generation):

- Compact vacuum chamber
- Vacuum chamber weight < 20 kg
- Background vapour-loaded 3D MOT
- Magnetic field nulling
- 150 ms atom interrogation region
- Low noise atom detection
- Vibration isolation and MEMS feedback available

M Squared's Quantum Gravimeter



Ice Bloc DCS interface showing experiment control sequence

SYSTEM CONTROL

- Full optical control with intuitive software
- Laser tuning, frequency generation, light shuttering, data collection and triggering control via Ice Bloc DCS
- Phase lock controlled with Ice Bloc PL
- Lasers controlled with standard SolsTiS and Equinox interface
- Remote control via TCP/IP

HOW IT WORKS

Atom interferometry uses a sequence of finely tuned, retro-reflected laser pulses to manipulate the quantum states of a cloud of cold atoms. The atoms accumulate a phase due to accelerations experienced during interferometry along the axis probed by the lasers. Precise measurements of accelerations use the laser system as an optical reference to measure the atomic quantum phase. The laser system must therefore have excellent phase noise properties and be extremely stable.

Our quantum gravimeter measures changes in acceleration due to local gravity. Measurements are made by firstly capturing and laser cooling a cloud of 10^8 rubidium atoms close to absolute zero. After turning the cooling lasers off, the cloud falls under gravity and atom interferometry takes place using three pulses of light along the direction of the falling cloud. The first laser pulse splits the cloud into two momentum states. After a duration, T, a second pulse is applied to reverse these momentum states. The clouds recombine after a further duration T, where the final pulse is then applied to create interference of the atomic cloud. The accumulated phase is then measured with a final set of pulses to detect the output states of the atoms, and hence the local gravity at the device.

The interferometer is highly sensitive to vibrations on the retro-reflecting mirror as it 'jumps' the phase of the laser light observed by the atoms. To mitigate this, we use a MEMS accelerometer mounted on the mirror to measure the vibrations during interferometry. The data can then be post-corrected using this information to account for vibrational phase shifts to get an accurate measurement of gravity. This approach allows our system to operate without the need for a vibration isolation platform, giving the gravimeter the versatility for for applications in field testing.

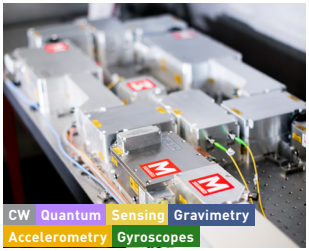
SPECIFICATIONS

INTERFEROMETER	FIRST GENERATION	SECOND GENERATION (EXPECTED)
FOOTPRINT	0.7 m x 0.7 m	0.7 m x 1 m
ATOMIC SPECIES	^{87}Rb	^{87}Rb
ATOM NUMBER	>1 x 10^7	>1 x 10^9
3D MOT LOADING RATE	10^7 atoms per second	>5 x 10^9 atoms per second
INTERFEROMETER TIME	T = 50 ms	T = 60 ms
CLOUD TEMPERATURE	15 µK	5 µK
REPETITION RATE	> 0.5 Hz	2 Hz
PRECISION	1.3×10^{-7} g	1 x 10^{-8} g

SPECIFICATIONS

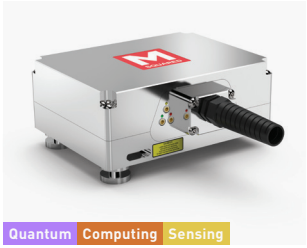
LASERS AND ELECTRONICS	
POWER CONSUMPTION	< 500W
FOOTPRINT	1 m x 0.7 m
PUMP LASER	Equinox 18 W
LASERS	2 x SolsTiS
SPECTROSCOPY LOCK	Tunable Vapour Cell Lock with 1-2 GHz offset from ^{85}Rb spectroscopy feature
PHASE LOCK	Tunable 6.8 GHz phase lock, with < 11 mrad phase noise
LASER TUNING RATE (Lasers locked)	~1 GHz per ms
CONTROL SYSTEMS	
EQUINOX	1 x Equinox Ice Bloc (double-sized)
SOLSTIS	2 x SolsTiS Ice Bloc
VAPOUR CELL	Expansion card for SolsTiS Ice Bloc, tuning via DCS Analogue Output
PHASE LOCK	1 x Ice Bloc Phase Lock. 6.8 GHz version with fast photodiode module, tuning via Ice Bloc DCS
EXPERIMENTAL CONTROL (Timing, Trigger, AOM Control, DIO)	1 x Ice Bloc DCS
DATA COLLECTION	Photodiode with low noise amplifier - 14-bit Analogue Input

RELATED PRODUCTS



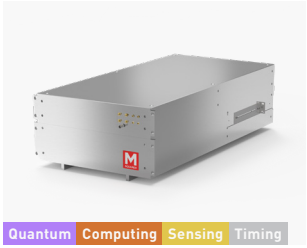
SOLSTIS - PHASE LOCKED

A complete system based on two phase-locked SolsTiS lasers. The high power and extremely low phase noise light provides an excellent platform for atom interferometry.



VAPOUR CELL LOCK

A compact fibre-coupled solution for laser locking to alkali vapour cells - easily integrated into existing SolsTiS set-ups and with simple operation using our Ice Bloc user interface.



SOLSTIS - RACK MOUNTED

The award-winning SolsTiS and Equinox pump laser in an integrated 19-inch rack system. An ideal solution for portable experiments and space-saving in the laboratory.

ICE BLOC DCS

A highly versatile sequencing system with multiple high-speed digital I/O, analogue outputs and a four-channel digital synthesiser.

CONTACT

Whether you are looking for information or would like a question answered, reach out to us by phone or email.

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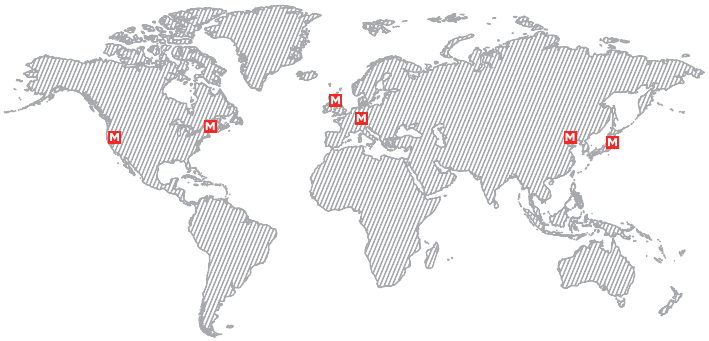

A complete list of our global locations is available on our website.

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