μQUANS
PRECISION QUANTUM SENSORS

Absolute Quantum Gravimeter

A free-fall absolute gravimeter based on laser-cooled atoms

The Absolute Quantum Gravimeter (AQG) is the first commercially available gravimeter based on laser-cooled atoms. This unique solution is the **result of more than 15 years of research** conducted by our academic partners (LP2N and LNE-SYRTE). This ground-breaking instrument is based on the cold atom gravimeter developed at SYRTE that has successfully participated to several international key comparisons of absolute gravimeters since 2009[1].

The AQG measures the acceleration of a free-falling test mass in vacuum: the ballistic free-fall of an ensemble of laser-cooled atoms is accurately monitored, and the acceleration of gravity is then inferred[2]. This technique is one of the **ballistic free-fall methods proclaimed by the BIPM** (Bureau International des Poids et Mesures) as an official primary method for the measurement of gravity.

Based on this approach, the AQG offers very attractive features for high-precision gravity measurements both on operational and scientific levels:

- **absolute gravity measurement at the μGal level** in terms of stability and accuracy
- **continuous data acquisition** from a few seconds to several months
- **simple and fast operation:** automated data acquisition system and user-friendly interface, no optical alignment, no primary pumping
- **very low maintenance constraints and high reliability:** no moving part is used
- excellent robustness to ground vibration (without any spring-based mechanical isolation device).

This makes the AQG highly suitable for a wide range of applications in geophysics[3, 4], geodesy, metrology and sub-surface imaging for civil engineering, natural resources exploration and production.

Picture of the Absolute Quantum Gravimeter. The instrument is composed of the sensor head (right side of the image) where the gravity measurement is performed, and the control unit (left side of the image)

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AQG specifications

Sensitivity (at quiet site)	50 µGal/√Hz 5 µGal in 1.5 min 2 µGal in 10 min 1 µGal in 40 min
Cycling frequency	2 Hz
Stability	≤ 1 µGal
Repeatability	≤ 2 µGal
Accuracy	few µGal

Continuous absolute measurements from a few seconds to several months. Data averaging time can be changed at will by the user depending on the application and sub-µGal stability can be achieved with longer averaging time.

Key technologies

▸ Simple and compact architecture

The design of the AQG relies on a patented opto-mechanical architecture using a pyramidal retro-reflector. This configuration allows to perform the measurement sequence with a single laser beam instead of up to eight usually, leading to a drastic simplification of the instrument.

▸ High reliability, fibered laser technology

The laser system developed by Muquans relies on the use of lasers operating at 1560 nm. This approach therefore gives access to a wide variety of high performance fibered optical components, originally developed for high-bit-rate optical communication systems. Thanks to the technological efforts conducted over the last 20 years by the telecom industry, these components present unique features:

- fibered components: no optical alignment required
- extreme optical and electrical performances
- compliance with Telcordia qualification procedures (extended temperature range)
- high reliability (lifetime > 50 000 h).

▸ High tolerance to ground vibrations

The AQG efficiently rejects ground vibration noise with an active compensation technique that does not require any mechanical isolation device or superspring.

Examples of AQG data

The AQG is a flexible gravity sensor able to perform: surveys reaching a resolution of a few µGal with short integration time (Fig. 1), reference station and time-lapse measurements at 1 µGal (Fig. 2) and drift-free long-term continuous gravity monitoring with ultra-high sensitivity (Fig. 3).

Fig. 1. Example of gravity data provided by the AQG for a short averaging time in a urban environment. The standard deviation of the data-set is 2.2 µGal.

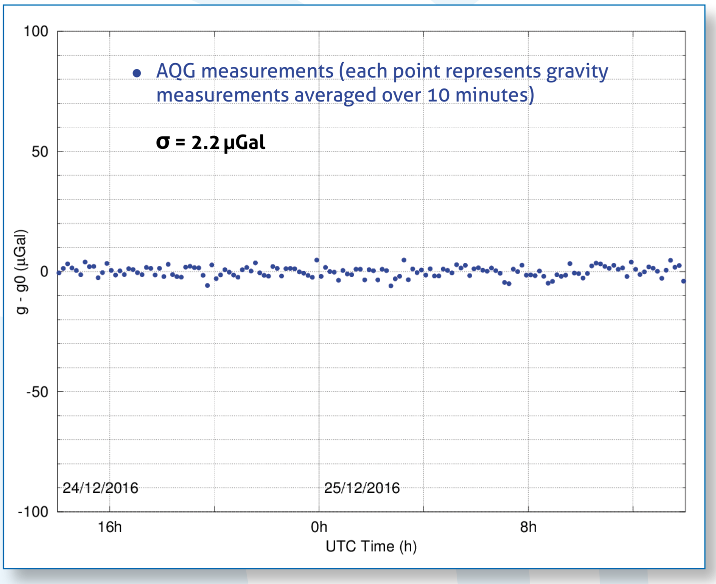
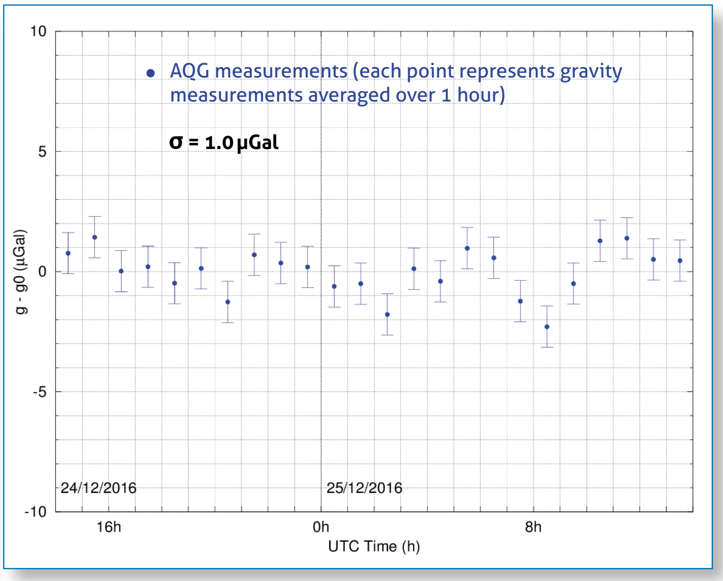
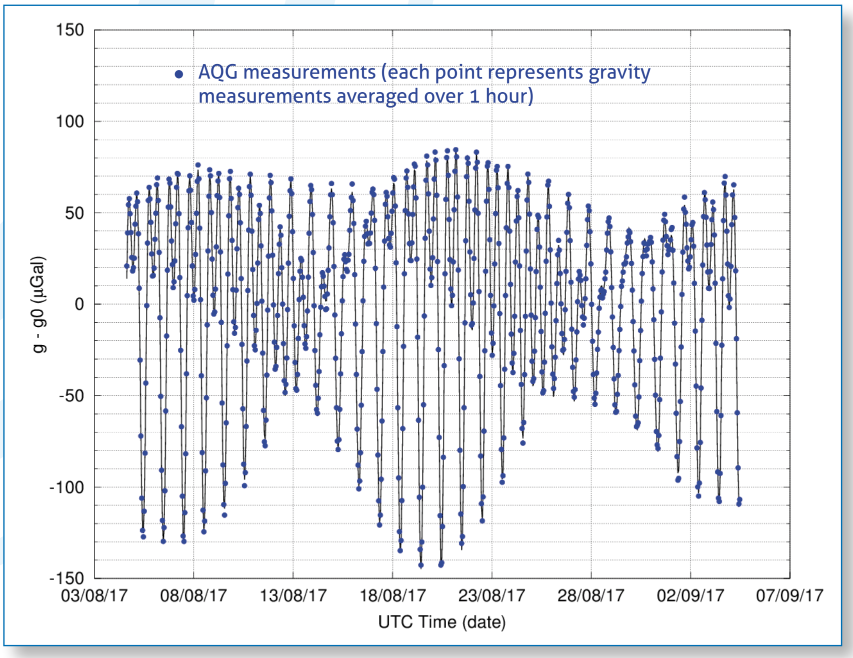


Fig. 2. Example of gravity data provided by the AQG for a long averaging time in a urban environment. The standard deviation of the data-set is 1.0 µGal.



These values of *g* are corrected from local tides, atmospheric pressure, tilt deviations and ocean loading. In Fig. 2, error bars correspond to the value of the Allan Deviation of the entire data-set calculated at one hour integration time, which corresponds to the statistical uncertainty of this measurement.

Fig. 3. Example of data provided by the AQG for long-term continuous absolute gravity monitoring.



This uninterrupted time series has lasted one month and shows local tides. When data are averaged over long durations, the AQG provides drift-free sub-µGal stability.

Instrument features

General features

	Control Unit	Sensor Head
Dimensions	95 cm x 60 cmx70 cm	Height: 74 cm Diameter: 37 cm
Floor footprint	1 m^2	0.25 m^2
Weight	85 kg	30 kg
Power consumption	300 W in total	
Number of flight cases	4 in total	
Operating temperature	[18 °C; 28 °C]	

Specific features of the AQG

Installation time	15 minutes (no optical alignment, no mechanical assembly, no pumping required prior to measuring) Ready to measure within 1 hour (includes warm-up time)
Maintenance	Low maintenance effort (no moving parts, no gasket nor belt to replace)
Robustness to ground vibration	Sub-µGal resolution even in urban environments (without spring-based mechanical isolation device)
Autonomy	Transport and storage for several days without any power supply will not affect measurement capability nor require additional pumping (sealed dropping chamber)
Software	Dedicated and user-friendly data acquisition and system controller software Automated starting procedure Automated self-calibration procedures Remote monitoring and real-time data retrieval
Data processing	Gravity data is real-time processed with corrections from local tides, atmospheric pressure, tilt variations, ocean loading and polar motion
Auxiliary sensors	The sensor head of the AQG houses a classical 3D accelerometer, a pressure gauge, tiltmeters, temperature sensors and a GPS receiver

References

1. P. Gillot, O. Francis, A. Landragin, F. Pereira Dos Santos and S. Merlet, "Stability comparison of two absolute gravimeters at their best capabilities: optical versus atomic interferometers", Metrologia 51, L15-L17 (2014).

2. F. Pereira dos Santos, S. Bonvalot, "Cold-atom absolute gravimetry", Encyclopedia of Geodesy, pp 1-6 (2016).

3. M. Van Camp, O. de Viron, A. Watlet, B. Meurers, O. Francis, C. Caudron, "Geophysics from terrestrial time-variable gravity measurements", Rev. Geophys. (2017).

4. D. Carbone, M. P. Poland, M. Diament, F. Greco, "The added value of time-variable microgravimetry to the understanding of how volcanoes work" Earth-Science Rev. 169, 146 – 179 (2017).

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