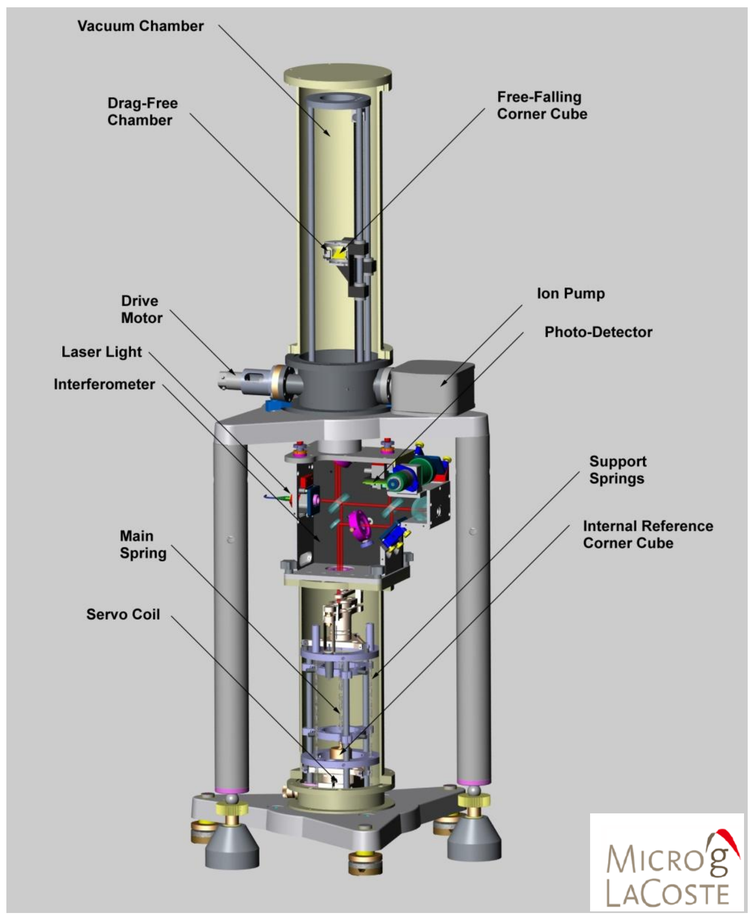
Federal Agency for Cartography and Geodesy

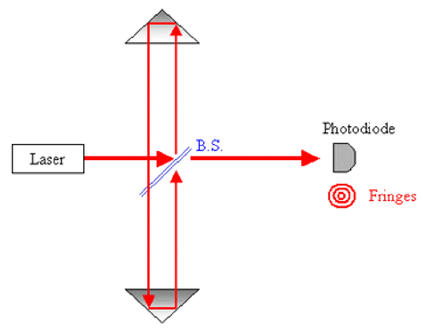
The FG5 absolute gravimeter

State of the art in absolute gravimetry



Theory of operation

The principle of the ballistic FG5 absolute gravimeter is to observe the free-falling of a repeatedly dropped corner cube reflector.
This test mass is contained in a co-falling servo-controlled motor-driven drag-free chamber and falls over 20 centimeters in 0.2 second inside a vacuum chamber.
The position of the mass is measured as a function of time by laser interferometry.



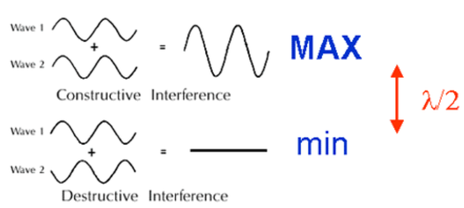
Michelson's interferometer

FG5-227 at TIGO/Concepcion (Chile)

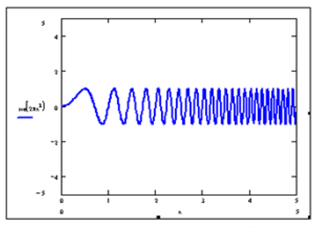
Measuring Principle

One arm of a Mach-Zender interferometer traverses a path up to the free-falling retro-reflector. This "Test" beam is reflected back down to another corner cube contained in the proof mass of an active long-period seismometer (free period of about 60 seconds) which provides an inertial reference frame. The other interferometer arm ("Reference" beam) recombines with the first test beam.
As the object falls, interference fringes are formed at the optical output.
The fringe signal is detected using an avalanche photo-diode and the time of occurrence of the fringes is measured by a rubidium atomic clock. The length standard is provided by an iodine-stabilized laser.

The absolute gravity measurements are therefore directly tied to the **time and length SI units**.



fringe signal sweeps in frequency as test mass falls under influence of gravity



time recorded (w.r.t. rubidium oscillator) at each minimum creating (t,d) pairs at every λ/2

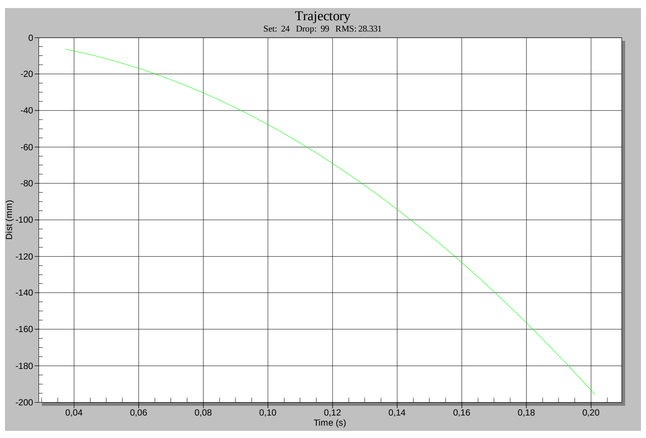
g Determination

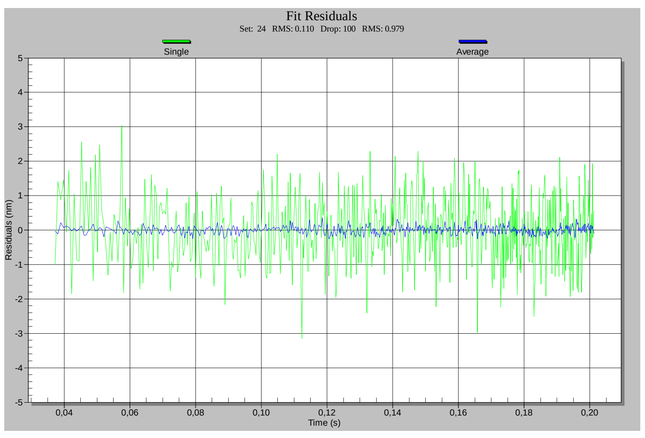
- Fringe = 1/2 x_i
- For each x_i, a measured time t_i
- The following function is fitted to the data x_i, t_i :

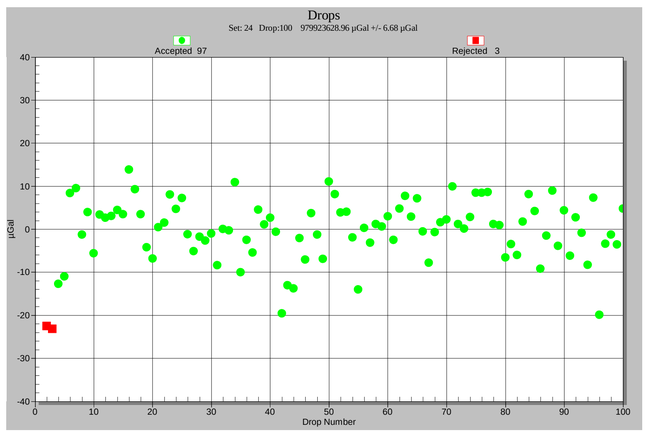
$$x_i = x_0 + v_0\tilde{t}_i + \frac{g_0\tilde{t}_i^2}{2} + \frac{\gamma x_0\tilde{t}_i^2}{2} + \frac{1}{6}\gamma v_0\tilde{t}_i^3 + \frac{1}{24}\gamma g_0\tilde{t}_i^4 \qquad \tilde{t} = t_i - \frac{(x_i - x_0)}{c} \qquad x_i,\ t_i,\ i = 1, \ldots, 700$$

- γ is the vertical gravity gradient (~3 µGal/cm),
- c the speed of light
- x_0 the initial position
- v_0 the initial velocity
- g_0 the initial acceleration

MICRO g LACOSTE



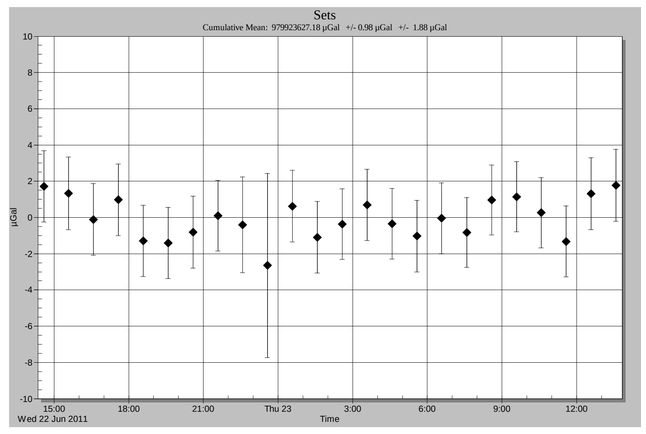




Data acquisition and reprocessing using g-software of Micro-g LaCoste.

A total of 700 time-position points are recorded over the 20 centimeters length of each drop. In routine operation the drops are repeated every 10 seconds, 100 times per hour.
The average of these 100 drops is a "set", which exhibits standard deviations of 4 to 15 µGal under normal conditions.
Measurements usually consist of one set per hour with the average of 24 sets providing a "gravity value".

The final gravity value is obtained after applying corrections for Earth tides, ocean loading, local atmospheric effects and polar-motion effects.
The instrumental accuracy of the FG5 is about 2 µgal as proven by several international comparisons of absolute gravimeters (e. g. at the BIPM).
FG5-227 was connected to the International Gravity Reference by comparisons at the German gravity reference station in Bad Homburg in 2005 and by verification with the FG5-101 of the BKG in 2010 at TIGO.



Department G4 – National Reference Systems Gravity

Federal Agency for Cartography and Geodesy (BKG)
Richard-Strauss-Allee 11, 60598 Frankfurt/Main, Germany