A New Instrument for Direct Observation of Torsional Normal Mode Oscillations of the Earth.

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We describe the experimental effort underway at Washington University to measure directly from a single location, the rotational motions of the earth induced by seismic and other activity. This method described in detail elsewhere, consists in observing a long period torsion balance with a highly sensitive optical lever. Sensitivity to energy resident in these modes down to ~ 10^{15} Joules can be achieved with the balance operating at room temperatures and the sensitivity may be improved to ~ 10^{13} Joules by operating the torsion balance at cryogenic temperatures.

Torsion Balance

Cross of 4 arms equal in length

Moment of inertia: $I=1.02\times10^4 g\cdot cm^2$

Masses at end act as mirrors

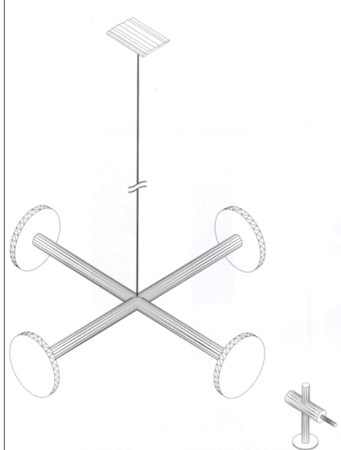
Suspended from SS-304 alloy strip of Cross section of 7µm x 110µm

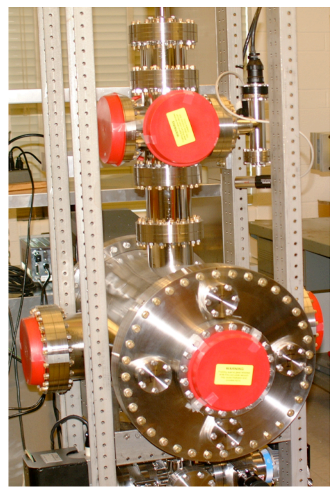
Torsional rigidity of $k_f=10^{-2}$ dyne·cm/rad

Angular frequency of natural oscillations $\omega_0 \approx 10^{-3}$ rad/s, $f_0 \approx 1.6 \times 10^{-4}$ Hz

$f_0 < f({}_0T_2)$ (lowest freq. torsional mode)

Housed in ultra high vacuum





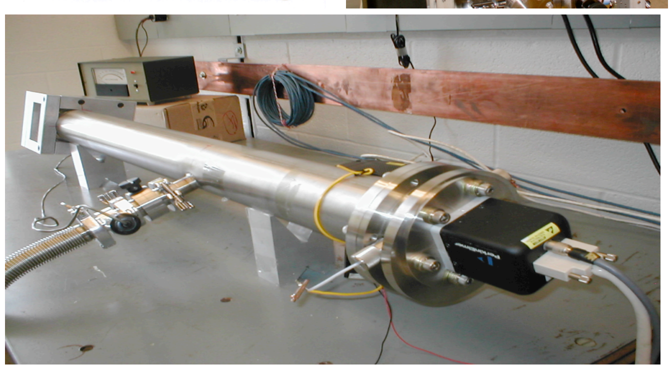
Autocollimator

Angular orientation measured by autocollimating optical lever

Autocollimator follows motion of Earth

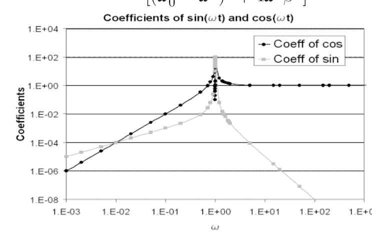
Angular resolution of 2×10^{-10} rad·Hz$^{-1/2}$

Dynamic Range of 3×10^6



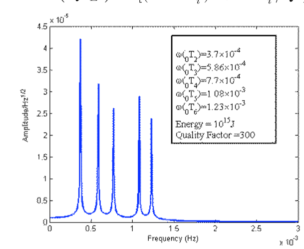
Response Function of the Balance

$$\alpha = \psi - \psi_L = a(\omega)\left\{\frac{\cos(\delta)}{[(\omega_0^2-\omega^2)^2+4\omega^2\beta^2]^{1/2}} - \frac{1}{\omega_0^2}\right\}\cos(\omega t) + a(\omega)\left\{\frac{\sin(\delta)}{[(\omega_0^2-\omega^2)^2+4\omega^2\beta^2]^{1/2}}\right\}\sin(\omega t)$$



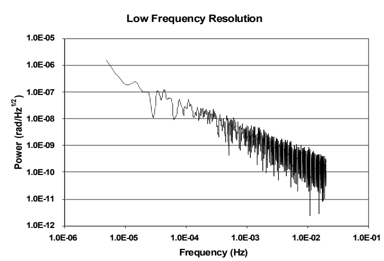
Response of the instrument to Rotational Normal Modes

$$\theta_E(\omega) = \left(\frac{2\omega E_i}{QI_E}\right)^{1/2} \frac{1}{[(\omega^2-\omega_i^2)^2 + w^2 w_i^2/Q^2]^{1/2}}$$



Resolution of the Autocollimator

$$\Delta\theta = 2 \times 10^{-10}(0.01 Hz/\nu)\,\mathrm{rad}\cdot\mathrm{Hz}^{-1/2}$$



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