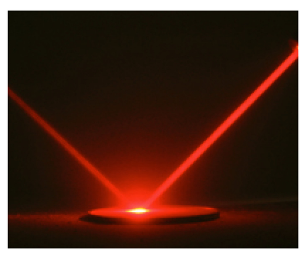
Tunable mechanical monolithic horizontal accelerometer for low frequency seismic noise measurement



F.Acernese[a,c], R.De Rosa[b,c], G. Giordano[b,c], R. Romano[a,c], F. Barone[a,c]

[a] Università degli Studi di Salerno, Fisciano (SA), Italy;
[b] Università "Federico II" di Napoli, Napoli, Italy;
[c] INFN Sezione di Napoli, Napoli, Italy;

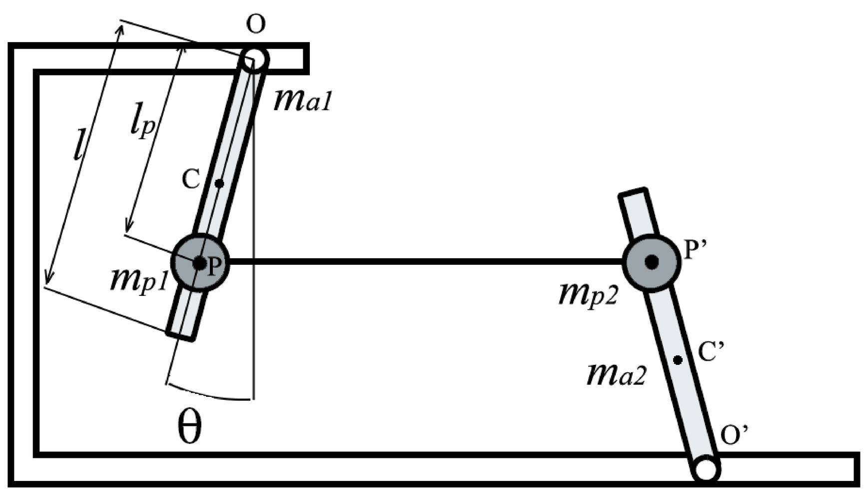
Motivations

Future experimental apparatus require the improvement of the performances of the accelerometers and displacement sensors to increase the sensitivity at low frequency. This means the development of sensors with a band extended to the very low frequencies. Following these directions we are developing and testing a mechanical monolithic sensor at the University of Salerno. The instrument is basically a monolithic tuneable folded pendulum that can be used both as seismometer and, in force-feedback configuration, as accelerometer.

The Sensor

Main design goals:

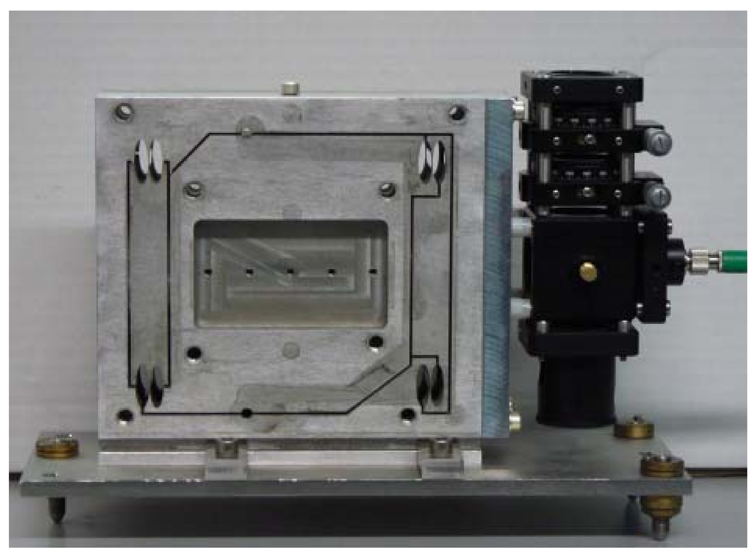
- Resonant frequency reduction → increase the resolution and the frequency band.
- Monolithic design implementation → high Q, low hysteresis and dissipation, low thermal noise, low coupling between different degrees of freedom.
- Optical readout system development → low noise, high resolution and low coupling with electromagnetic noise.



$$\frac{x_p - x_s}{x_s} = \frac{(1-A_c)\omega^2}{\omega_0^2 - i\frac{\omega_0\omega}{Q} - \omega^2}$$ where x_p is pendulumdisplacement and x_s is the grounddisplacement

$$A_c = \frac{\left(\frac{l}{3l_p}\right)(m_{a_1} - m_{a_2})}{(m_{a_1} - m_{a_2})\frac{l^2}{3l_p} + (m_{p_1} + m_{p_2})}$$

$$\omega_0^2 = \left(\frac{g}{l_p}\right) \cdot \frac{(m_{a_1} - m_{a_2})\frac{l}{2l_p} + (m_{p_1} - m_{p_2}) + \frac{k}{gl_p}}{(m_{a_1} + m_{a_2})\frac{l^2}{3l_p^2} + (m_{p_1} - m_{p_2})}$$

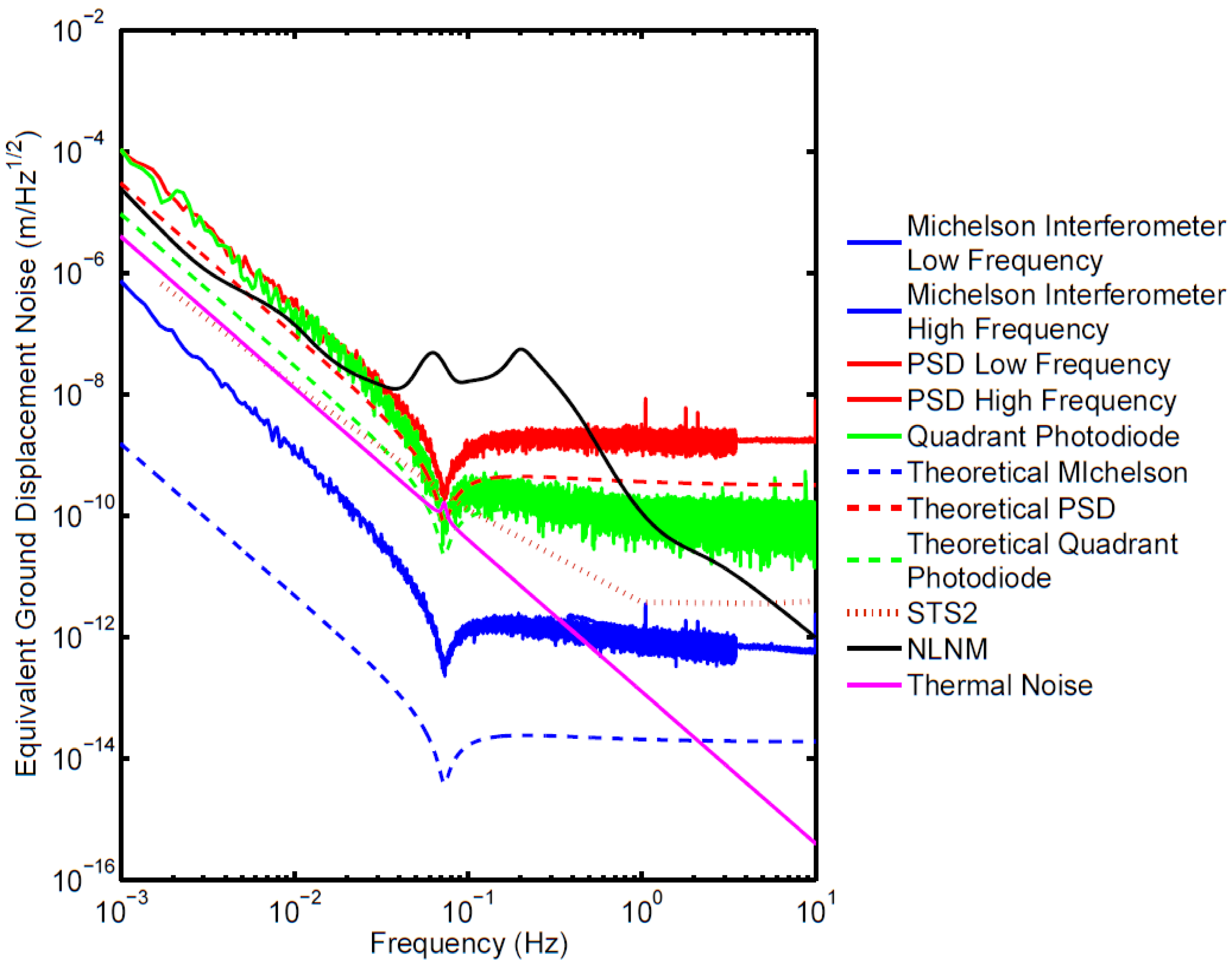


Main characteristics:

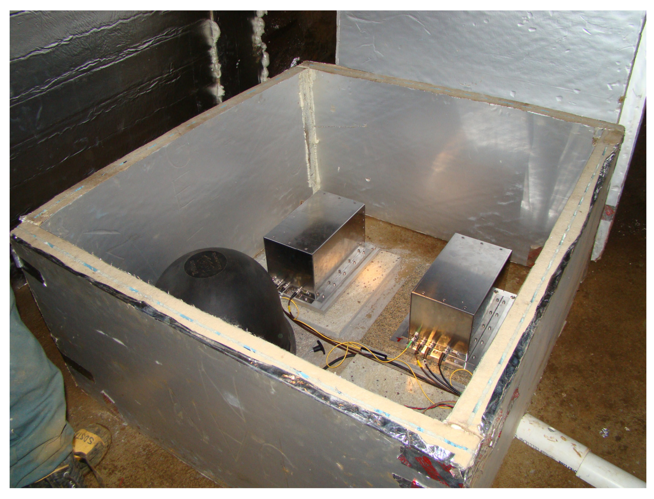
- Single block of Alloy 7075-T6 of 140x134x40 mm machined with an electro discharge machine with a 250 μm thick wire.
- Eight 50 mm thick notch elliptical hinges (ε=16/5) for torsional flexures.
- Optical Lever and/or Michelson Interferometer readout system and Coil-Magnet actuator system.
- Natural Resonant Frequency: **f_0≈700mHz** with **Q≈140** in air and **Q≈500** @ P=0.1 mbar
- Using calibration procedure: **f_0≈70mHz** with quality factor **Q≈10** in air

Equivalent ground displacement readout noise

The developed readout system has a noise spectrum lower that the NLNM. A little improvement in the resolution of the readout system will allow us measuring the thermal noise of the sensor above 1 Hz.



Installation of two sensors in Homestake mine, South Dakota, USA—2100ft level underground



Data taken started in December 15, 2008.
Data Analysis in progress...

Future developments

- Realization and test of a piezoelectric system for a more accurate calibration of the resonant frequency.
- Design of the control loop using the optical readout error signal (interferometer and optical lever).
- Measurement of the sensitivity curve in closed loop configuration.
- Test the sensor noise in the frequency band 0.01mHz - 1Hz.

Acknowledgments

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