Low-frequency high-resolution optical inertial sensors

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Abstract

Large-scale, high-end, scientific instruments see their performances significantly impaired by residual ground motion at low frequencies. Namely, recent development of gravitational wave detectors aims to detect gravitational waves whose strain is as low as 10^{-20} $Hz^{-1/2}$ in the sub-Hz frequency range [1], while seismic noise can be 9 times larger in this frequency range [2]. High performance active isolation strategy and seismic sensors are required to address this issue.

The Precision Mechatronics Laboratory, based in ULiège and ULB, Belgium, has a large experience in developing high-resolution optical inertial sensors intended to be used in active control [3]. Efforts have been spent in improving the resolution of these sensors in the low frequency range.

Currently, horizontal and vertical inertial sensors have been developed. These sensors are based on an Long-range, Michelson-type, optical readout with a sensitivity of $2{\cdot}10^{-13}$ m/√Hz at 1 Hz. The inertial sensors are characterized by a sensitivity of $2{\cdot}10^{-12}$ m/√Hz at 1 Hz, $1{\cdot}10^{-13}$ m/√Hz at 10 Hz and $3{\cdot}10^{-14}$ m/√Hz at 100 Hz [4].

The resolution of the inertial unit is limited by thermal noise below 20 Hz and photodetector noise above 40 Hz. Efforts are now spent in mitigating these limitations in our next generation of sensors. Thermal noise will be decreased by using low-dissipation flexures made in fused-silica, and placing the mechanics in a HV environment. Readout resolution is improved by means of high-performance InGaAs photodetectors. The sensors are also meant to be compact, and fit in a 10 x 10 x 10 cm^3 box.

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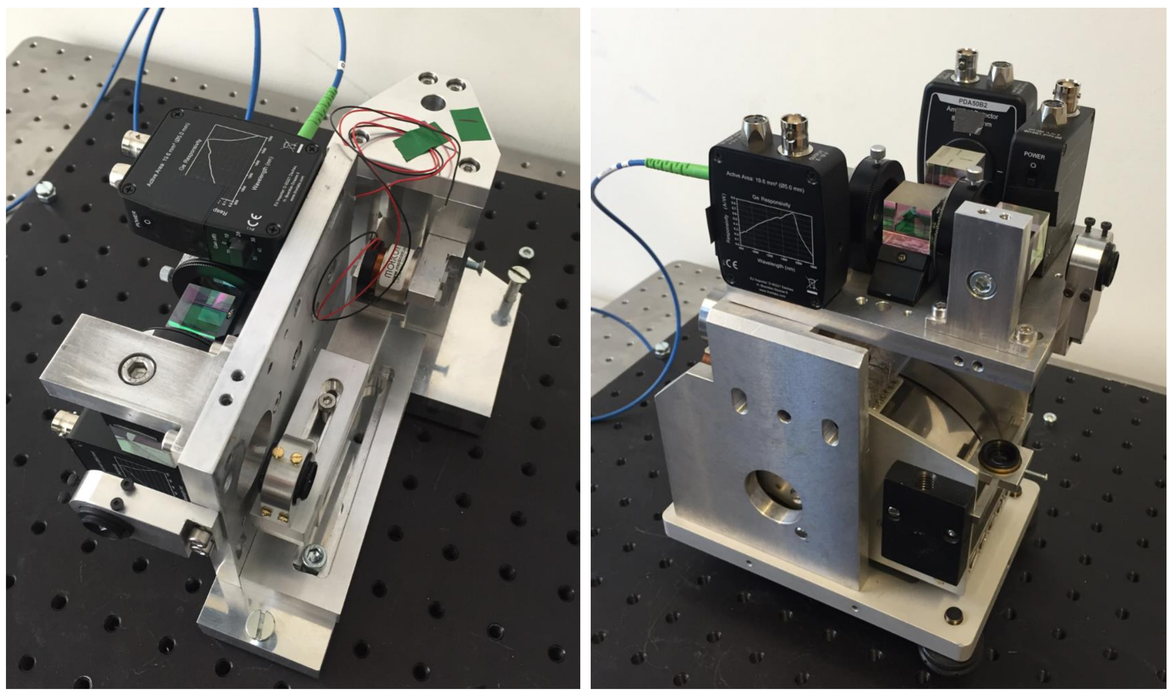

Fig. 1: Current Horizontal and Vertical Inertial Sensors.

Inertial unit resolution

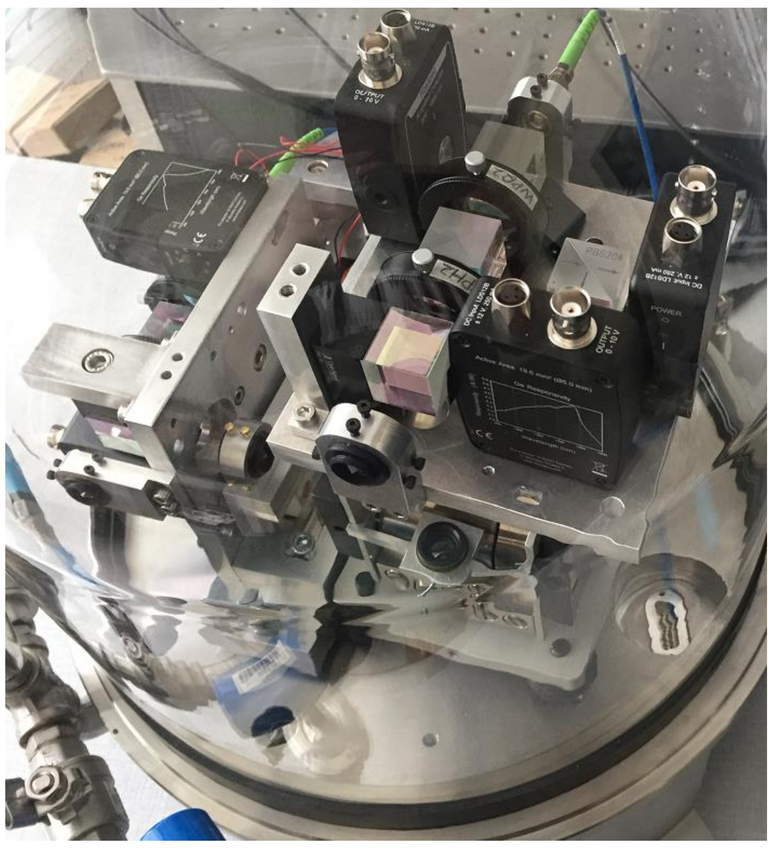

Fig. 2: Inertial unit. Three of them are available.

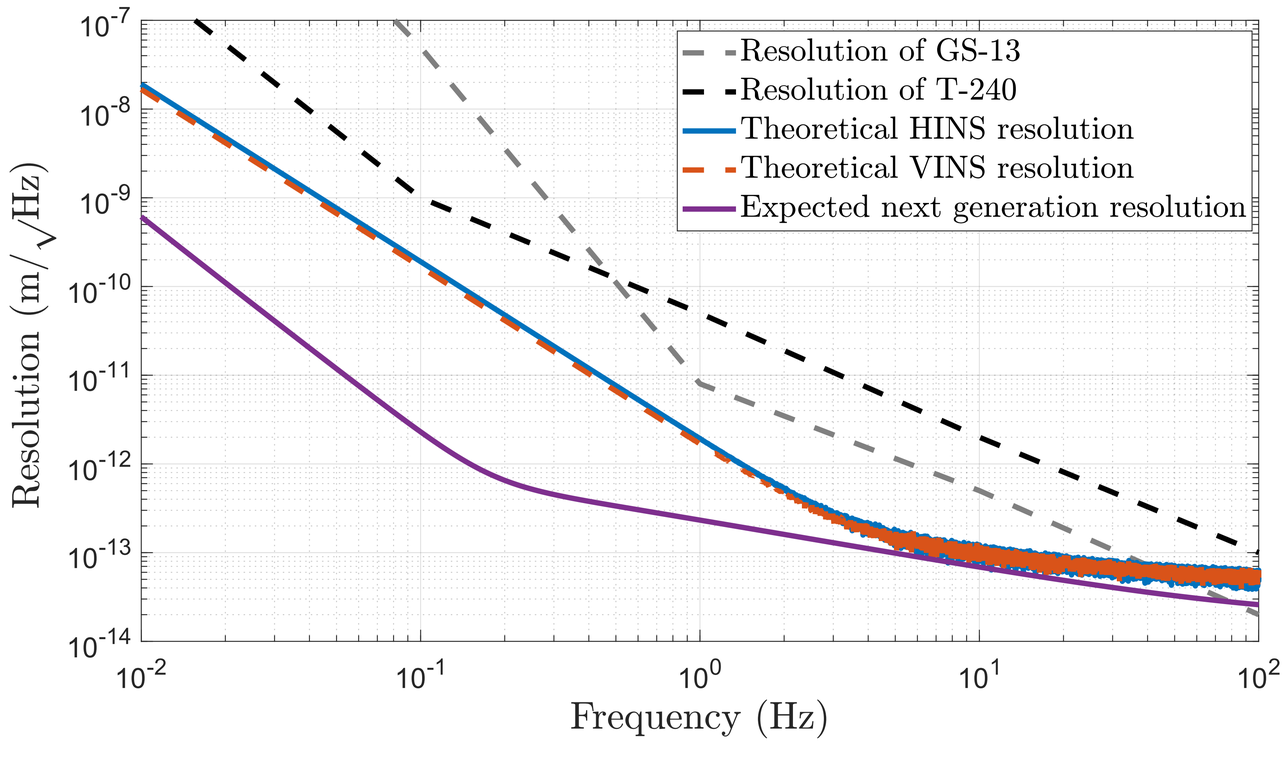

Fig. 3: Theoretical resolution of the inertial sensors.

Next generation

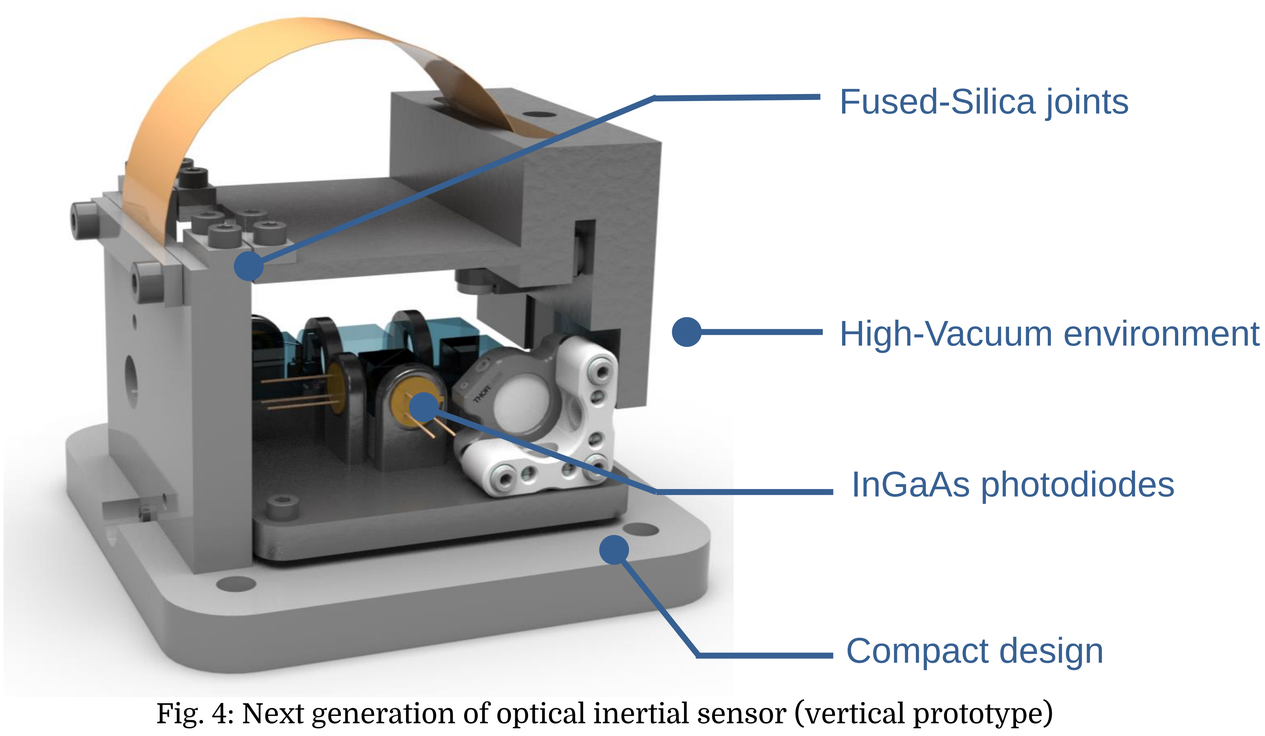

Fig. 4: Next generation of optical inertial sensor (vertical prototype)

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