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 10 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]. The latest inertial sensors, HINS and VINS, are based on an Long-range, Michelson-type, optical readout with a sensitivity of $2{\cdot}10^{-13}$ m/√Hz at 1 Hz. They have a resolution 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].

A new, compact, design of the sensors is being developed. The sensor is designed to fit a 10 x 10 x 10 cm box, reducing the original design of VINS by a factor of 8. The mechanics also features fused-silica joints for and reduced low-frequency thermal noise. Ringdown tests demonstrate a Q-factor of 2800 in open-air.

Compact Inertial Sensor

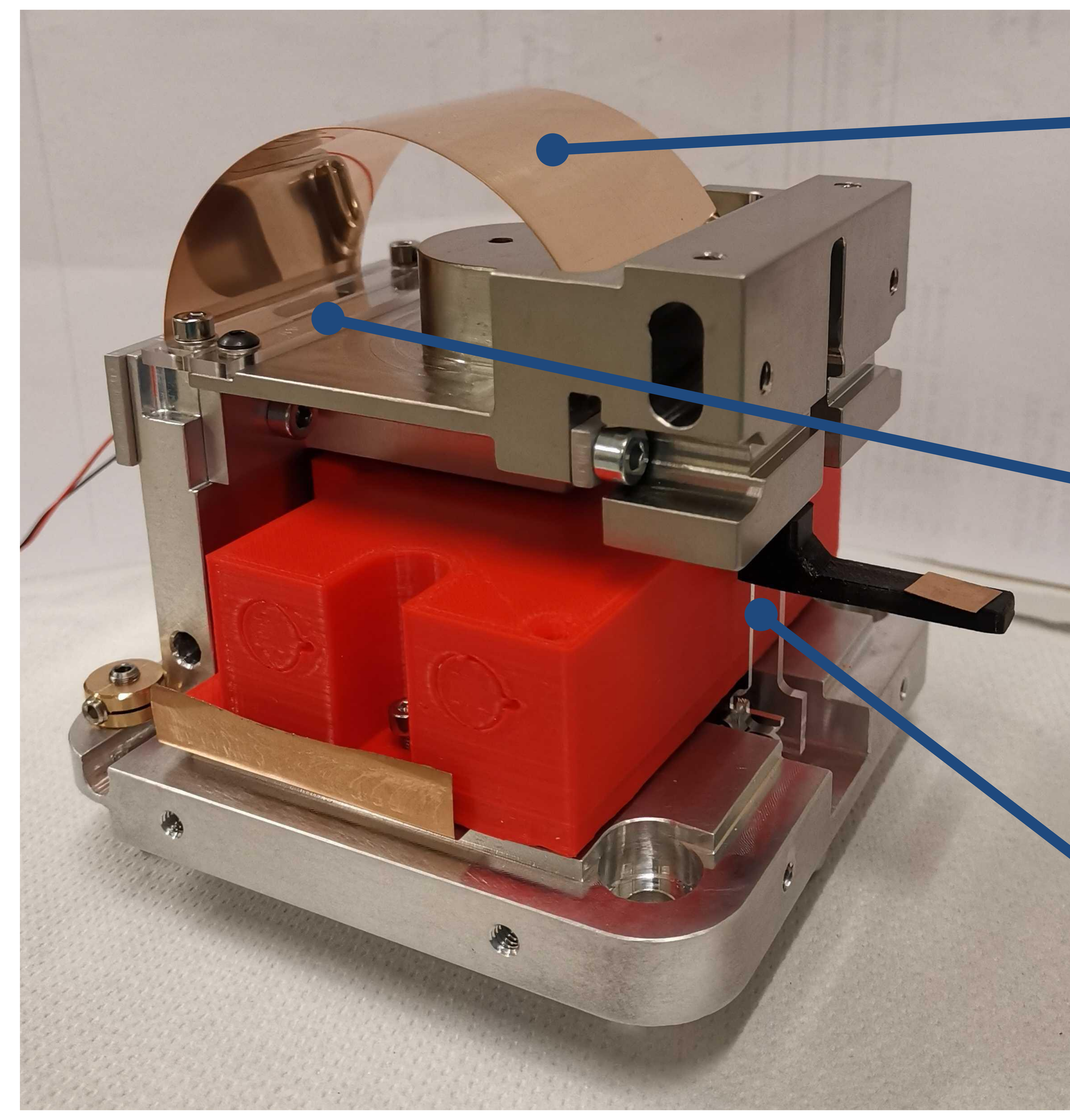

Fig. 1: Mechanics of the vertical inertial sensors with fused-silica joints.

Fused-Silica mechanical assembly

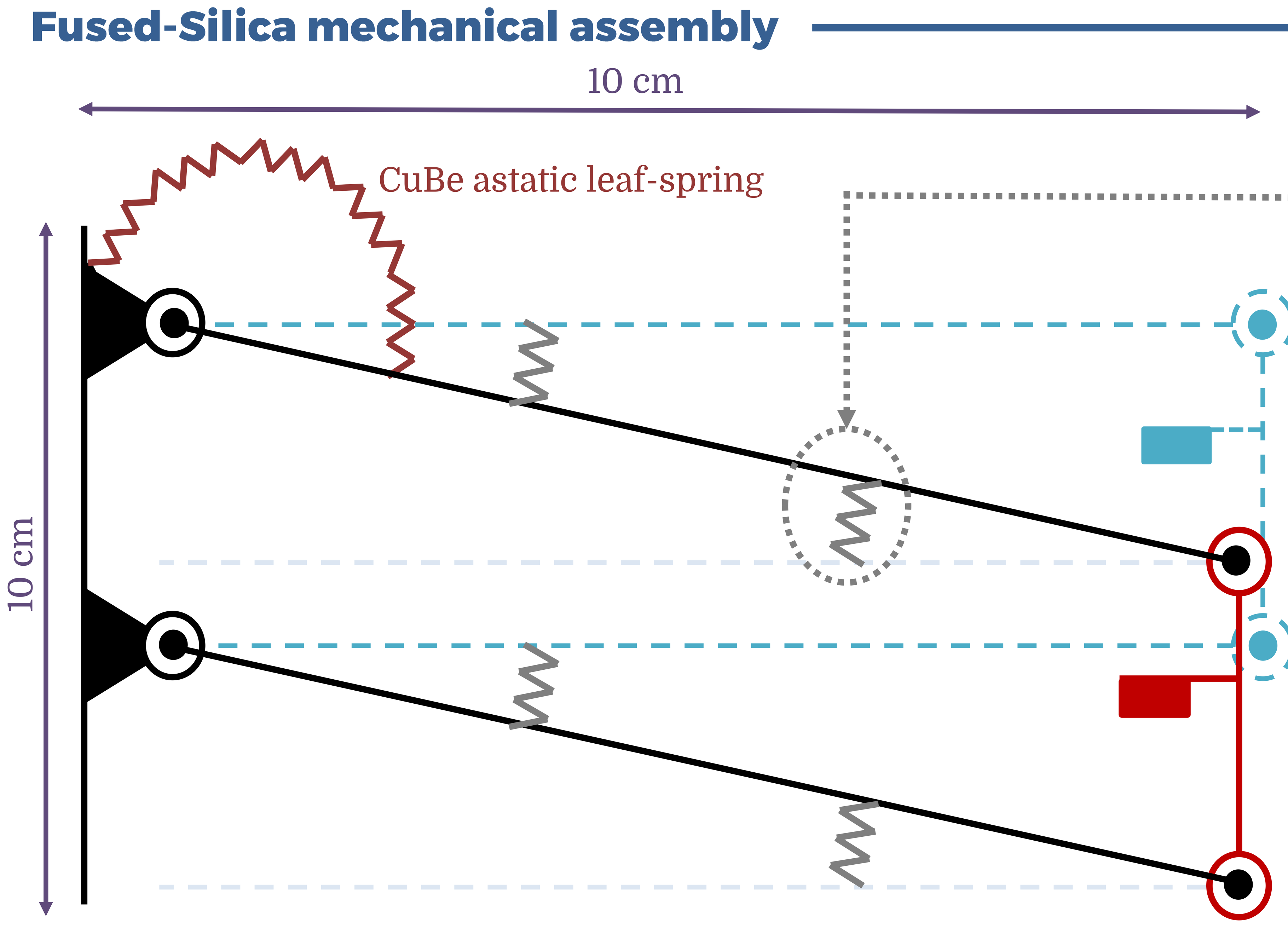

Fig. 2: Schematics of the mechanics of the sensor. The "four-bars" mechanism guarantee the translation motion of the mirror.

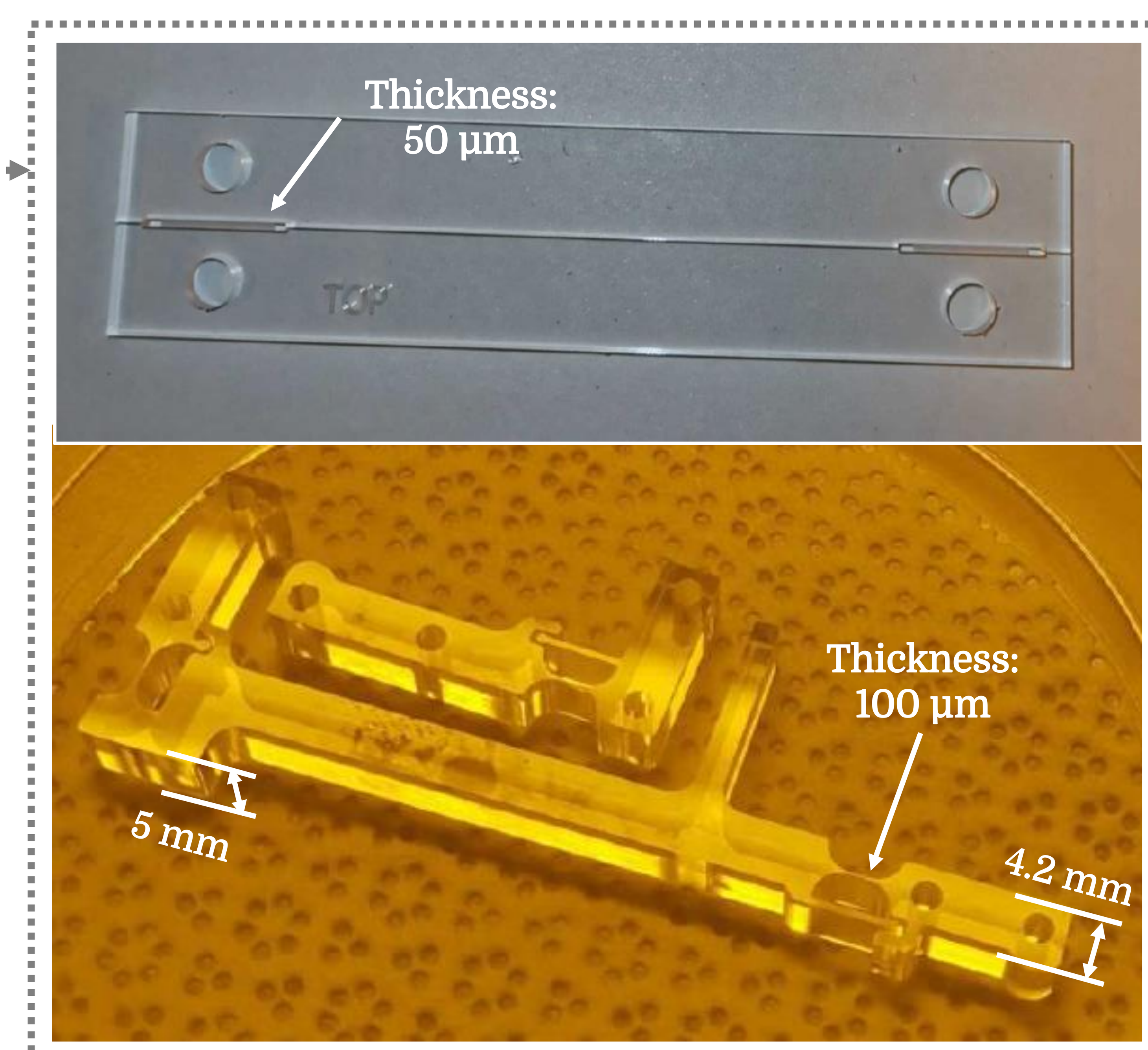

Fig. 3: Fused-silica joints.

Simulated performance & noise budget

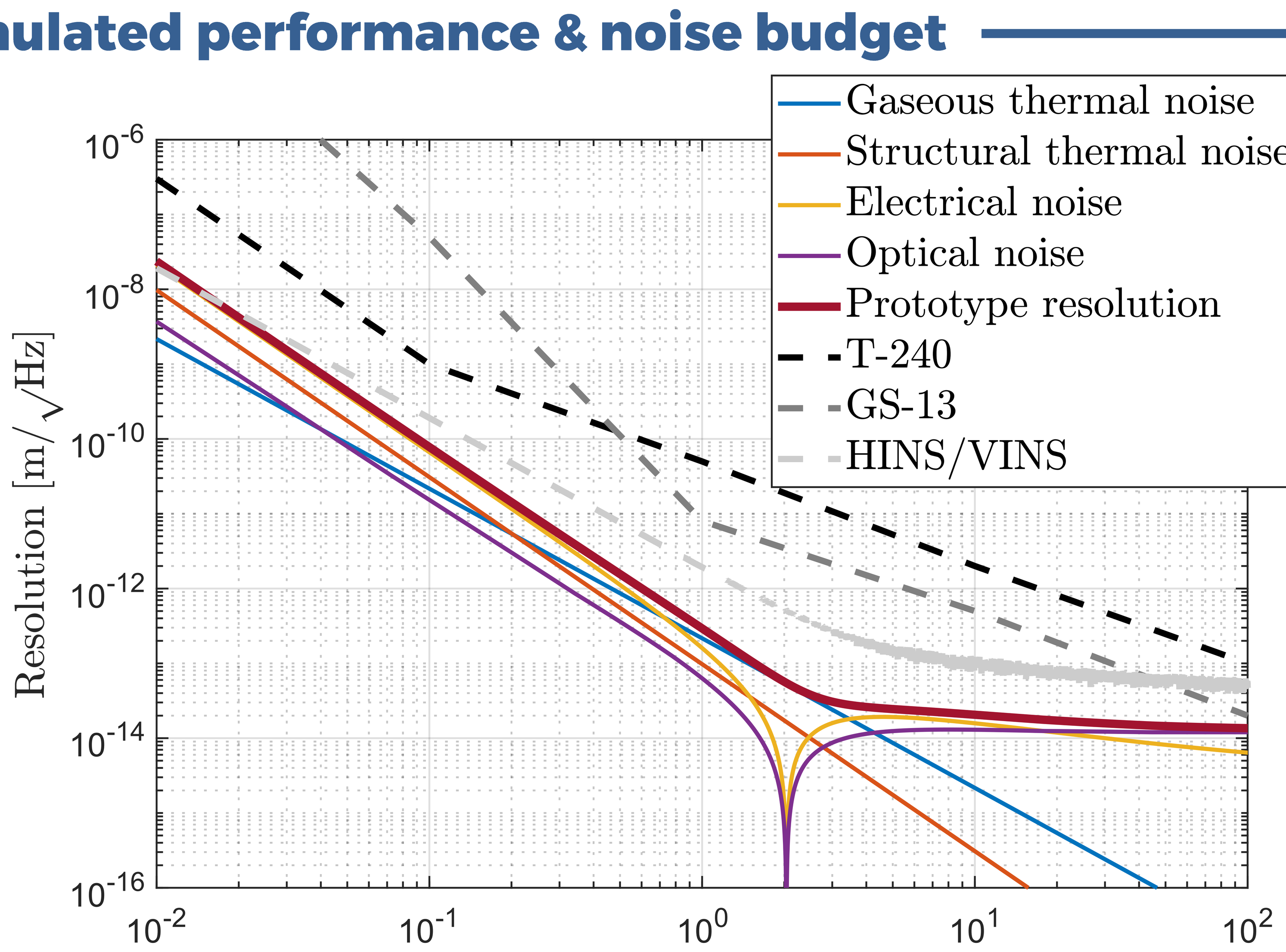

Fig. 5: Estimated noise budget of the prototype & comparison with previous sensors.

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