Design and Analysis of Electro Static Drive (ESD) for the AEI 10 M Prototype

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Abstract

One of the key experiments in Albert Einstein institute (AEI) 10 m sub-SQL interferometer prototype is to surpass the Standard Quantum Limit (SQL) of sensitivity [1] using methods for noise reduction. The mirrors of the interferometer are suspended by using triple pendulum suspension and are actuated in the longitudinal degree of freedom by using an Electro Static Drive (ESD). The ESD allows for contact-free actuation, and a large free aperture for suppressing of Brownian noise [2].

The setup was proposed in AEI consisting of ESD plates, placed above and below the mirror as shown in Figure 1. The mirror actuation, with plate dimensions of 50 x 50 x 5 mm, was initially done with Ansys [3]. However the dimensions were recently modified to 90 x 23 x 3 mm, to ensure that the suspension wires does not contact with the ESD.
The present simulations are done using macros present in the Electrostatics (es) interface of COMSOL Multiphysics software. A 3D model of the electro static drive was built by assigning voltages to one of the plates of ESD and considering a sphere of radius 13 cm to account the fringing fields. The force on the mirror is given by surface integral of T.n, with T being the Maxwell stress tensor and n being the unit normal vector of surface A.
To actuate the mirror, the force acting on it should be greater than the restoring force. Figure 2 shows the force acting on the mirror as a function of voltage applied to the ESD plates, for the mirror placed at the tip of the ESD.
The maximum force acting on the mirror in longitudinal degrees of freedom is found to be -0.5 μN, in a direction opposite to the pendulum restoring force at 700 V. Figure 3 shows the force acting on the mirror at various positions along the ESD plates for the old and new dimensions.

Reference

[1] Kawazoe, Fumiko, et al. "Designs of the frequency reference cavity for the AEI 10 m Prototype interferometer." Journal of Physics: Conference Series. Vol. 228. No. 1. IOP Publishing, 2010.
[2] Gräf, Christian, et al. "Optical layout for a 10 m Fabry–Perot Michelson interferometer with tunable stability." Classical and quantum gravity 29.7 (2012): 075003.
[3] Wittel, H., et al. "New Design of Electrostatic Mirror Actuators for Application in High-Precision Interferometry." arXiv preprint arXiv:1411.3853 (2014).

Figures used in the abstract

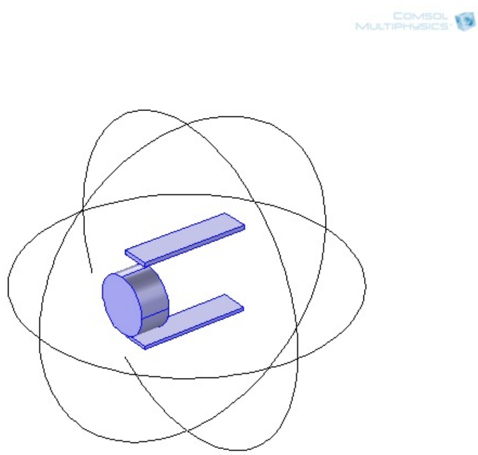

Figure 1: 3D view of the Electro Static Drive with the test mass being suspended using 50 micron steel wires from the penultimate mass.

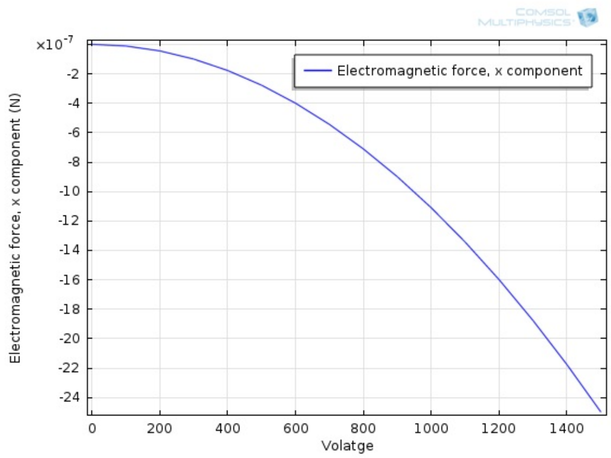

Figure 2: Variation in the force acting along the longitudinal degree of freedom as a function of the voltage applied to the ESD plates.

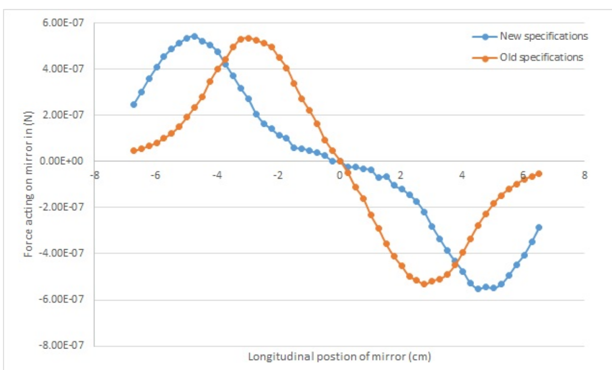

Figure 3: Force acting along the length of the ESD plates relative to the position of the mirror for different dimensions of the ESD plates.

Figure 4