Cryogenic Casimir Force Measurement with a Superconducting Torsion Balance

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We present preliminary results demonstrating the potential for measuring the Casimir Force in the plane-plane geometry at Liquid Helium (LHe) temperature. To achieve this, we use a novel levitating superconducting torsion balance which allows us to control the stiffness of the levitated object in all six degrees of freedom, and in particular, to give the object a very high frequency in five out of six degrees of freedom, while allowing it to act as a sensitive detector in the sixth, 'torsion balance' mode. Combined with our passive electrostatic damping, this means that we can bring two flat surfaces with area of order 10 cm^2 together, with a tilt stability corresponding to a variation in gap of about 0.1 micron at the edge while having the sensitivity to be able to observe the Casimir Force at gaps of order 5 microns, with accuracy limited by electrostatic systematics.

While one mass foil is suspended on the superconducting levitation system, the other is manipulated by an arrangement of micropositioners, with the relative position and orientation between them measured by a capacitance readout system. We demonstrate how this can reproducibly align and centre the mass foils in a cryogenic environment.

The torsion balance mode of the levitated object is measured with a heterodyne laser interferometer with a sensitivity better than 1 nRad/√Hz at a frequency of 0.05 Hz.

We demonstrate the feasibility of the levitation system, and show how seismic noise terms can be reduced by our novel electronic methods of tuning the effective centre of mass of the torsion balance in situ at 4 K.

We show how novel techniques for the transfer of lithographically produces source- and test-mass foils allow us to control the stress in the foils so that their flatness can be maintained in cryogenic conditions.