Constraints On Spin Independent Forces At The ∼100 Nm Range By Means Of A Micromechanical Oscillator

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Preliminary data from improvements made in our experimental setup are presented. Forces measured with our setup are presented and possible origins for the systematics observed are discussed. The observed signal is most likely induced by an impulsive oscillation of the motor.

1. Introduction

Experiments searching for corrections to Newtonian gravity[1–3] by a direct measurement of the interaction between a source and a test mass are faced with systematic signals arising from electrostatic and Casimir interactions between the masses. While in some cases it is possible to screen the masses by using a shield, when the separation between them is small, this task becomes infeasible. Some experiments have developed a so called 'isoelectronic' approach, where the effect of the mean electrostatic contribution and the Casimir interaction are nullified by design,[2,3] by measuring differences between signals with the same mean electromagnetic distribution (for a discussion on the effect of the variance of electrostatic contributions see Ref. 4) but different gravitational signature.

In the experiment published in 2005,[3] the limits obtained in spin-independent contributions to hypothetical forces were limited by the

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presence of a spurious signal. This signal was likely associated with a Casimir residual due to the fact that the distance between the test and source mass was not kept constant as the test mass was moved over regions where the source mass had different density. This motivated a development of a new system, where the variations in height of the source mass are uncorrelated with the variations in density.

Results

The experimental setup is schematically shown in the inset of Fig. 1. The sample is made of sectors of Au and Si defined on a Si waffer. This is glued to a flat glass surface, the Si waffer is etched and the whole sample is covered with ~200 nm of Au. This sample is then rotated in close proximity to an Au-coated sapphire sphere, which in turn is glued to a microelectromechanical torsional oscillator. The actual sample has different regions with alternating Au-Si sectors, each subtending the same angle. Each region, which has a radial extent of 200μm, is separated by a solid Si region of 250μm from a different alternating Au-Si region with a different number of 'spokes.' The number of Au-Si regions varies from a minimum of 50 to a maximum of 250, in increments of 25.

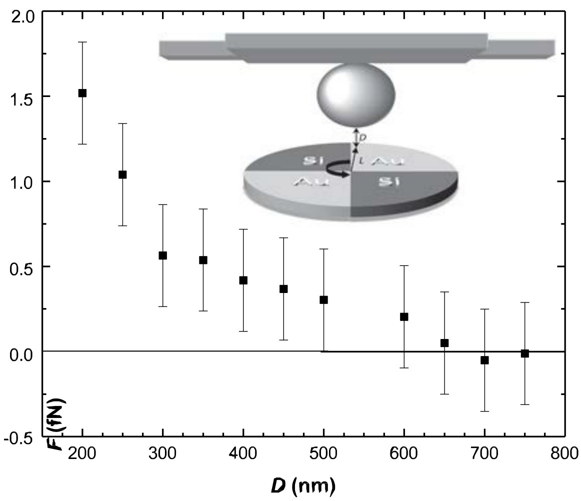

Fig. 1. Measured force as a function of separation. Inset: schematic of the experimental setup. The Au layer that covers the structured Au-Si test source mass is not shown.

With the sphere positioned over a structured Au-Si part of the sample, the system is rotated at $f = fr/n$ where fr is the resonant frequency of the oscillator plus sphere system and n is the number of Au-Si sectors. In this way, if there is a signal associated with the changes in mass in the source mass, the signal will be more easily detectable by the force sensitive mechanical oscillator.

The results obtained with the system are shown in Fig. 1. This signal, however, is not due to the mass density variation, since it appear also when the sphere is placed on top of the unstructured part of the rotating source mass. It can also be concluded that it is not associated with finite size effects,[5] or spatial fluctuations in the surface potential of the masses.[4] The fact that the observed signal is independent of f between 1 and 1000 Hz and increases with the distance L from the apex of the sphere to the axis of rotation indicates it is most likely associated with an impulsive motion of the axis of rotation of the system. If this is the explanation, the angular amplitude of the motion is smaller than 2 μrad.

2. Outlook

The results obtained will allow more stringent limits on spin independent contributions to hypothetical corrections to Newtonian gravity. These limits will improve by about three orders of magnitude existing limits at the ~100 nm range. A similar setup can be used with a spin polarized mass replacing the Au. In this case the experiment would also provide the best limits for the monopole-dipole couplings at $\lambda \sim 100$ nm.

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