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Optically Levitated Microspheres as a Probe for New Interactions

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We have demonstrated a novel technique for measuring microscopic forces acting on optically levitated dielectric microspheres. The radiation field at the focus of a laser beam is used to levitate a microsphere in a harmonic trap where the displacement of the microsphere can be determined by the pattern of scattered light. Optical levitation isolates the microsphere from the surrounding environment at high vacuum, making exceptionally sensitive force measurements possible. We have demonstrated a preliminary sensitivity of $5 \times 10^{-17}\ N/\sqrt{Hz}$ for forces acting on $5\mu m$ microspheres and expect to be able to improve this by several orders of magnitude by eliminating non-fundamental sources of noise. The electric charge of a microsphere can be determined by applying an electric field and measuring the resulting force. We have demonstrated the ability to control the charge of the microspheres with single electron precision, which eliminates the main component of the electrostatic backgrounds from force measurements. As a demonstration of this technique we have searched for the presence of unknown charged particles with charge $> 5 \times 10^{-5}e$ in bound in our microspheres, and for the presence of screened interactions associated with dark energy. Here we discuss the apparatus, our previous results, and outline our plans for future measurements that will include the investigation of gravity at short distance.

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