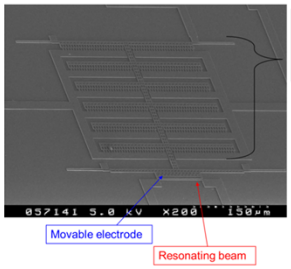
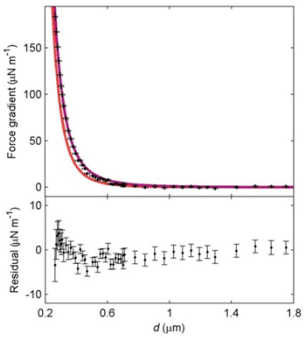
CNMS User Project Highlight

Casimir Forces On A Silicon Micromechanical Chip



SEM of the micromechanical structure. The separation *d* between the suspended doubly clamped beam and the movable electrode was controllably reduced so that the Casimir force could be detected

Upper panel: Measured force gradient between the beam and the movable electrode as a function of separation *d*. The red line represents the calculated Casimir force gradients between an electrode and a beam made of silicon. The purple line includes possible contributions from patch potentials.
Lower panel: Deviations of the measured force gradient from the purple line in the upper panel.



Achievement

The Casimir force between micromachined components with nanoscale separations within a silicon chip, in the absence of external objects, has been demonstrated and measured.

Significance and Impact

A compact and integrated actuation and detection on-chip platform is realized for the first time in measuring Casimir forces. Understanding interactions between micromachined elements in integrated chips is of great technological importance. The successful demonstration of the Casimir force between micromachined elements in such systems is a breakthrough that will help with problems of stiction and friction in micro- and nano-machinery fabricated using wafer-based technology.

Research Details

- **CNMS Capability**: Advanced e-beam lithography system in combination with advanced proximity correction software package.
- A magnetomotive transduction measurement technique was utilized to measure interaction forces. .
- Two interacting planar surfaces are automatically aligned as a result of the nanofabrication process.

Work was performed at the CNMS- ORNL, University of Florida, Harvard University, MIT, and Hong Kong University of Science and Technology.

J. Zou, Z. Marcet, A. W. Rodriguez, M. T. H. Reid, A. P. McCauley, I. I. Kravchenko, T. Lu, Y. Bao, S. G. Johnson, H. B. Chan. *Nature Communications* **4,** 1845 (2013).

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Highlight Narrative Text

It has been shown that the Casimir force can be the dominant interaction between silicon micromechanical components on an integrated micromechanical chip, in the absence of external objects. By creating two interacting surfaces via nanofabrication, the problem of aligning two planar surfaces has been circumvented. The paper results represent the first step towards on-chip exploitation of the Casimir force. The compact and integrated actuation and detection platform provides new opportunities of tailoring the Casimir force using geometry effects. Structures are defined by electron-beam lithography, making it possible to create surfaces with complex shapes that are automatically aligned after fabrication. Furthermore, the design can be integrated with suspended planar waveguide elements so that classical optical gradient forces and Casimir forces associated with virtual photons can be simultaneously utilized in these optomechanical systems.

Figure 1. SEM of the entire micromechanical structure. Planar comb actuator is suspended and anchored by squares in the corners. The separation d between the beam and the movable electrode was controllably reduced so that the Casimir force can be detected by measuring the shift in its resonance frequency.

Figure 2. Measured force gradient between the beam and the movable electrode as a function of separation d after compensating for the residual voltage. Upper panel - The red line represents the calculated Casimir force gradients between an electrode and a beam made of silicon. The purple line includes possible contributions from so called patch potentials that is manifestation of no charge conductive surface being equipotential. Such surface potential variations are results of local changes in surface crystalline structure, strains in the surface, chemical impurities, etc. giving rise to varying work functions.

Lower panel - Deviations of the measured force gradient from the purple line in the upper panel. Error bars represent plus and minus one standard deviation.

Reference:

"Casimir forces on a silicon micromechanical chip"

J. Zou[1,2], Z. Marcet[1,2], A. W. Rodriguez[3,4], M. T. H. Reid[5], A. P. McCauley[6], I. I. Kravchenko[7], T. Lu[2], Y. Bao[1] , S. G. Johnson[4] & H. B. Chan[2]

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