Calculating quantum vacuum forces in nanostructures

February 8 2013

(Phys.org)—One of the surprising predictions of quantum mechanics is that uncharged conductors can attract each other over small distances, even in empty space. While the resulting "Casimir force" has been accurately measured and calculated for simple flat conductors, researchers from the Department of Energy, Indiana University-Purdue University Indianapolis, and the NIST Center for Nanoscale Science and Technology have solved the much more complicated problem of calculating this force between metal plates with complicated periodic nanoscale structures on their surfaces.

This type of surface nanostructuring is currently being explored in order to control the Casimir force in microscopic mechanical sensors, actuators, and electrical relay devices.

The Casimir force has been notoriously difficult to calculate for complicated structures because an infinite number of electromagnetic quantum vacuum fluctuations have to be taken into account. Previous methods took weeks of computer time to carefully combine the results from numerically solving Maxwell's equations-a standard set of equations describing the physics of electromagnetism-thousands of times, and were prone to numerical errors.

The researchers have now analytically pre-calculated a series of eigenmodes, or exact solutions for specific cases, that can be combined much more simply to produce the force for any particular periodic nanostructure. This analytical calculation also gives simple insight into how the force behaves in various important situations.

The researchers expect the analytical techniques they have developed will have broader applications for calculating other forces induced by fluctuations, including thermal emissions and near-field heat transfer. They are now applying these techniques to understand the results of recent Casimir force experiments on nanostructured surfaces.

More information: Quasianalytical modal approach for computing Casimir interactions in periodic nanostructures, F. Intravaia, P. S. Davids, R. S. Decca, V. A. Aksyuk, D. López, and D. A. R. Dalvit, Physical Review A 86, 042101 (2012).
link.aps.org/doi/10.1103/PhysRevA.86.042101

Provided by National Institute of Standards and Technology