Computing Casimir Forces in Complex Nanosystems

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Quantum and thermodynamic fluctuations give rise to a wide range of effects on nano- and micro-systems, including Casimir forces between neutral objects that are believed to cause nano-devices to fail in a process known as “stiction”. Recent developments in nano-fabrication are pushing devices to smaller and smaller scales, making the Casimir force an important component in their fabrication and operation. Although the first prediction of Casimir forces was made in 1948, in a geometry consisting of perfectly conducting parallel plates in which the force was shown to be attractive and monotonically-decaying as a function of plate–plate separation, only recently have numerical tools capable of computing the force in more complicated geometries been developed.

I will describe how one can compute the Casimir force in nanosystems of arbitrary complexity using sophisticated, free and widely available numerical software based on standard and well-established tools and techniques from classical nanophotonics [1–2]. Decades of work in the field of computational electromagnetism paved the way for the rapid growth and exploration of nanophotonic systems and have in the last few years also allowed us to study a number of geometries exhibiting interesting and unusual Casimir phenomena, illustrated in Fig. 1, including repulsive forces between designed metallic geometries in vacuum, stable suspensions and orientation transitions between objects in fluids, and stiction effects in complicated opto-micromechanical devices.

Figure 1: Schematic of recently proposed geometries exhibiting unusual Casimir phenomena, including: a non-monotonic dependence of the force between two waveguides as a function of their separation from two adjacent slabs; a repulsive force between an elongated object and a plate with a hole; an orientation transition between two finite “hokey pucks” suspended in a fluid; the actuation of Casimir stiction via optomechanical forces on a photonic-crystal single-membrane suspended above a layered substrate.

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