Numerical Analysis of the Casimir-Polder Force

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Problem description

The Casimir effect is one of the most striking discoveries of the quantum physics [1]. It was first described and observed as a weak attractive force between two uncharged metallic plates. The origin of this force is the vacuum fluctuations of the electromagnetic field - the constant appearance and disappearance of photons. In thermal equilibrium these vacuum photons will uniformly populate all the available states (eigenmodes). However, the number of accessible modes in the space between the plates depends on the distance and becomes smaller if the plates are closer to each other, whereas the number of accessible modes outside the plates is slightly larger. Skimming over the infamous infinity problem that plagues the quantum field theory, the resulting difference in the energy is what pushes the plates towards each other.

The Casimir effect, although weak, cannot be neglected on a submicrometer scale and may even be involved in such macroscopic phenomena as adhesion and sonoluminescence. Estimation of the Casimir force in the general case requires a numerical computation of the Local Density Of States (LDOS) as a function of position, which can be reduced to the numerical solution of a large but classical electromagnetic scattering problem [2]. As this well-studied problem is computationally very intensive there is plenty of room for improvement on the mathematical side, e.g. by preconditioning.

Approach

1. Literature review, starting with [2]-[4] of the numerical methods currently applied in this field
2. Computation of the Casimir force for a test object using one of the methods (e.g. in Matlab)
3. Identification of bottlenecks and suggestions for improvements

References

[1] http://en.wikipedia.org/wiki/Casimir_effect
[2] Rodriguez, A. W., Capasso, F., Johnson, Steven G. (2011). "The Casimir effect in microstructured geometries". *Nature Photonics* 5 (4): 211–221.
[3] S.G. Johnson, Numerical methods for computing Casimir interactions, http://arxiv.org/abs/1007.0966
[4] O. J. F. Martin, C. Girard, and A. Dereux, Phys. Rev. Lett. 74, 526 (1995).