THE CASIMIR FORCE AS A DRIVER IN MICROMECHANICS

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1. Introduction

In modern practice, the micromechanical devices play a broad spectrum of roles and find expanding application in engineering and industry. With schrinking device dimensions to submicrometer level, in addition to mechanical and electric forces, the Casimir force induced by the electromagnetic fluctuations comes into play. This attractive force is of entirely quantum nature. It acts even between uncharged material surfaces and far exceeds typical electric forces for devices of size below a few hundred nanometers [1]. Experts in micromechanics have long been aware [2] that the Casimir force may play a detrimental role in the functionality of a micromechanical device leading to a jump of the moving part of it to a fixed piece. This phenomenon was called a *pull-in* or *stiction*. It was also demonstrated [3] that the Casimir force can be used for actuation of a micromechanical oscillator. This device was refined and found numerous applications in precise measurements of the Casimir interaction and in micromechanics [1, 4]. What is more, the possibility of frictionless transduction of mechanical motion through a vacuum gap using the lateral Casimir force [5, 6] was proposed [7].

2. Optical chopper driven by the Casimir force

It is well known that the standard mechanical choppers exploit the wheels of various shape which should have a highly stable rotating speed. Here, we demonstrate that it is possible to create the micromechanical optical chopper with no rotating wheels driven by the Casimir force. The key element of this device is the Fabry-Pérot microfilter schematically shown in Fig. 1. The length of its resonator cavity a should be made only slightly larger than the half wavelength $\lambda/2$ of the incidence laser beam $I_{\rm in}$. When the laser is switched off, the top of the right mirror, under an action of the attractive Casimir force $F(a)$ and mechanical electric force, will become for Δa closer to the top of the left mirror. The balance of both forces is given by

$$k\Delta a = \frac{1}{2}P(a)S, \qquad (1)$$

where k is the spring constant of the 5 μm thick wall, $P(a) = F(a)/S$ is the Casimir pressure expressed by the Lifshitz formula [1], and $S = 50 \times 50\,\mu\text{m}^2$ is the common area of the wall and of the cube side. Note that detection of the mechanical deformation of a macroscopic object induced by the Casimir force can be observed by means of an adaptive holographic interferometer [8].

When the laser is switched on, the effective resonator length over an area of the light beam becomes equal to $\lambda/2$, i.e., the resonance condition is obeyed [9]. This leads to a cyclic process. First, the amplitude of a standing wave in the resonator will instantaneously increase resulting in a detection of relatively high intensity $I_{\rm tr}$ of the transmitted light. Then, the repulsive force due to the light pressure in the resonator will compensate the Casimir force and the right mirror will become vertical. This means that the effective resonator length becomes larger than $\lambda/2$ in violation of the resonance condition, and the wave amplitude in the gap falls down leading to an almost zero level in the transmitted light I_{tr}. Finally, the Casimir force, which is not balanced by the repulsive force due to the light pressure any more, will work against the mechanical elastic force and return the

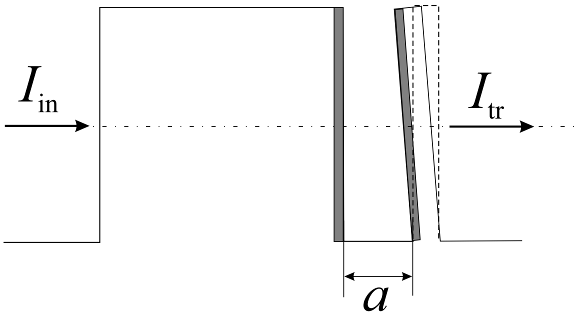

Figure 1: Two thin metallic mirrors marked by dark-grey deposited on the side of a SiO_2 cube and on a thin SiO_2 wall form a microresonator.

right mirror in its initial inclined position where the resonance condition is again obeyed. Thereafter, the next working cycle of a micromechanical chopper starts.

Detailed computations of the mechanical elastic, Casimir and light-pressure forces and their balance for the CW Nd-YAG laser (with $\lambda = 532.0$ nm and 7 mW power) and Ag mirrors of 1.175 nm thickness, presented in the talk, demonstrate feasibility of the proposed microdevice.

3. Conclusions

Various micromechanical devices are of considerable current use in both fundamental science and technological applications. We emphasize that in microdevices of next generations with sizes below a few hundred nanometers the role of a driver will be played by the fluctuation-induced Casimir force. One device of this type, an optical chopper, is proposed in this presentation.

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