Optomechanical interactions between nanophotonic wires on a Silicon-on-Insulator-Chip

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We present modeling, fabrication and characterization of a device which enables us to demonstrate optical in plane forces between nanophotonic structures. Hence our device makes part of a novel class of integrated optomechanically tunable devices.

I. Introduction

Recently significant progress has been made to control gradient optical forces on a chip [1]. Optomechanics provides an exciting and promising way to realize various optically tunable integrated devices. Furthermore better understanding and controlling of on-chip optical forces might have important consequences in the field of optical cooling of micromechanical resonators. In this proceeding we present optomechanical interactions between nanophotonic wires in silicon-on-insulator.

II. Device fabrication

A directional coupler (=two closely spaced nanophotonic wires) with S-shaped input and output bends is defined in the top layer of a SOI wafer (top layer monocrystalline Si: thickness t=220nm + buried oxide layer: thickness h=2µm) using CMOS-compatible Deep-Ultra-Violet lithography. Afterwards a resist mask is applied to define a freestanding region in the directional coupler (Figure 1). The underetch is performed with wet buffered HF and the samples are dried afterwards using a CO_2 Critical-Point-Drying process to prevent damage due to surface tension.

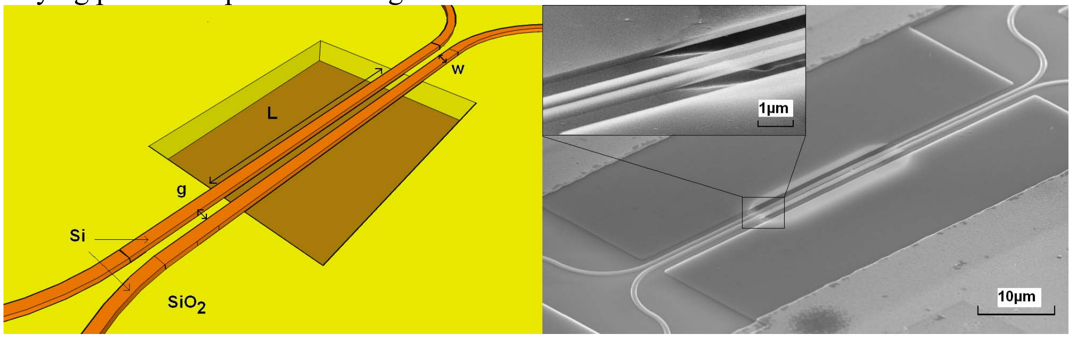

Figure 1: device concept (left) and SEM-picture (right)

III. Working principle

When light is sent through this device an attractive force arises between the two nanophotonic wires which results in a displacement of the freestanding part of the waveguides. This force can be explained through an adiabatic change in the energy carried by the waveguide eigenmodes when the spacing between the waveguides

978-1-4244-2382-8/09/$25.00 ©2009 IEEE

changes [2]. In our experiment a pump signal and a probe signal are simultaneously inserted into the device. The pump induces the optical force while the probe simply detects the induced displacement. The pump optical power is modulated such that an AC-force is created. Furthermore the experiment is carried out in vacuum such that both underetched waveguides respond resonantly to the applied force ($Q_{MECH}\approx 2000$). The natural frequency for our beams (length=21µm, width=380nm) is around 6.1MHz. The obtained signal is calibrated using the thermomechanical “Brownian” noise of the suspended waveguide beams.

IV. Optical force characterization

The measured and fitted responses (for different pump powers) are shown in Figure 2. The traces have been calibrated using the lower trace (Brownian displacement noise), also a thermo-optical background signal was fitted and subtracted from the signal. Two resonance peaks are visible in the vibration spectrum since the two underetched parts have not exactly the same dimensions. Also the extracted optical forces are shown (Figure 4, right). The experimentally obtained values (0.1pN/µm/mW, per µm beam length per mW optical power) differ slightly from theoretically expected values (0.15pN/µm/mW, most probably because the exact power inside the freestanding part of the waveguide can only be estimated quite roughly.

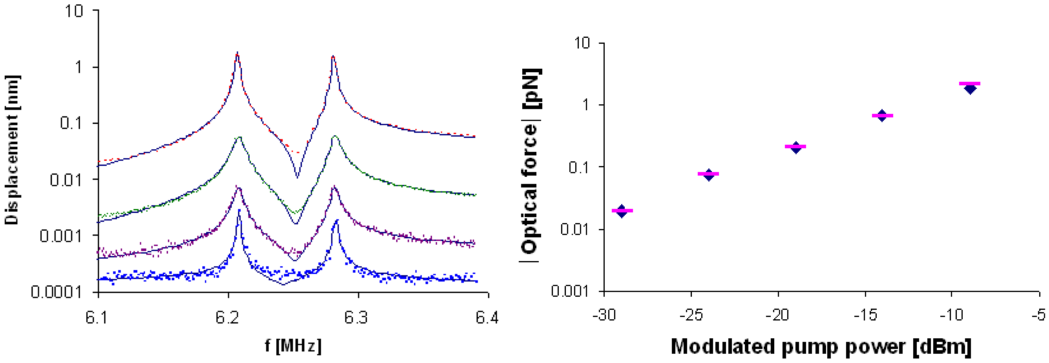

Figure 2: Measured vibration spectra for different optical pump powers (left) and extracted optical forces (right)

V. Discussion

We demonstrated in plane optical force on a chip. Relatively large gradient forces per photon are induced. Since no optical resonator is involved the type of component we describe here is potentially interesting for broadband optically tunable components.

VI. Acknowledgement

This work was supported by the Research Foundation Flanders (FWO-Vlaanderen).

References

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