The force of light

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I. INTRODUCTION

A world wide communication network like the internet relies on a global network of transparent optical fibers. These fibers are capable of transporting huge amounts of information and operate at large bit rates (Tb/s). However at the intersection of two or more of such fibers sometimes an optical signal propagating inside one fiber needs to be redirected into another fiber in order to reach its correct destination. This process is called routing or switching and is currently implemented by converting the optical signal to an electrical signal and performing the switching in the electrical domain. Finally the electrical signal is launched again into the correct fiber. This slow Optical-Electrical-Optical conversion limits the actual bandwidth so ideally the signal should maintain its optical character throughout the switching operation.

It is part of the mission of the Photonics Research Group Ghent to develop optical chips with this switching functionality. In particular it would be interesting if the switching could be triggered by the light itself and no external electrical pulse is needed anymore to control switching. One option to do this is to look into optomechanics.

II. OPTOMECHANICS

Optomechanics is about joining “optics” and “mechanics”. In very simple words we try to move objects using light induced forces. Light can be thought of as consisting of small particles called “photons”. When such a photon bumps into a macroscopic object an almost negligible force is exerted on this object (comparable with a small marble bumping into another big marble). However this picture changes dramatically when the object size is shrunk to nanoscale dimensions. In these circumstances light might displace considerably the tiny structures that can be found on a chip and even set or reset an optical switch on a chip.

III. DEVICE

On a silicon-on-insulator chip the light is propagating inside silicon nanowires (typically 400nm width x 220nm height, Figure 1 left).

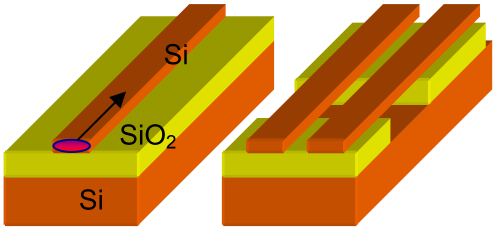

Figure 1: Silicon wire waveguide with light pulse propagating through (left); waveguide string pair (right)

By removing the SiO_2 locally under the nanowire we can create a silicon string which will vibrate when we exert a force on it. In our actual experiment we will work with two parallel waveguide strings (Figure 1 right) and create attractive and repulsive forces between them.

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In Figure 2 the device is shown. The region labeled “waveguide coupler” is in fact our parallel waveguide string pair with string length L. The light comes in at the right and is equally divided over two waveguides through the Multi Mode Interference coupler.

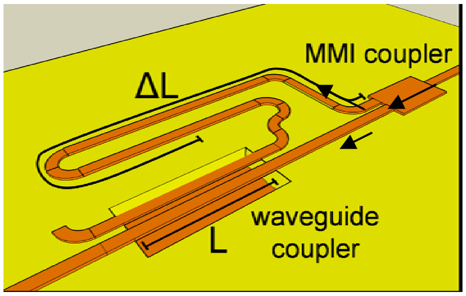

Figure 2: waveguide coupler (=parallel string pair) and the construction to control the power distribution over the waveguides

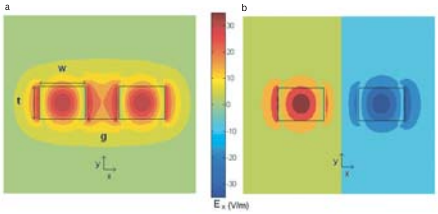

Figure 3: the electromagnetic fields can be distributed over the waveguides in a symmetric and anti-symmetric way

Both these waveguides lead to the entrance of the waveguide coupler.

However one route is ΔL longer than the other one, which allows us to alter the optical power distribution over the waveguide strings by sweeping the wavelength of the light.

IV. Experiment

Figure 3 shows that the electromagnetic fields can be distributed over both waveguides in a symmetric and anti-symmetric way. This is important because calculations show that the symmetric distribution gives rise to an attractive force, while the waveguides will repel each other with the anti-symmetric distribution [1].

Finally we found experimentally attraction and repulsion between both waveguides when sweeping wavelength (Figure 4) [2]. Logically at some intermediate wavelength the attractive and repulsive force cancel each other out and a zero force is found.

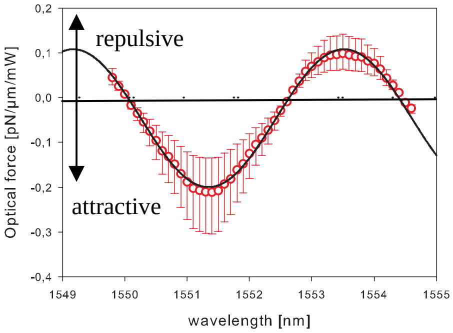

Figure 4: attractive and repulsive force in function of wavelength

V. Discussion and Conclusion

We have shown attractive and repulsive force between waveguides. The repulsive force was never observed before and makes this experiment a major breakthrough for fundamental physics. Nevertheless optical forces on a chip might also have implications towards practical applications. All optical switching could make an optical fiber based network like the internet much more efficient. The observed optical force could be used here as actuation mechanism for an optical switch, For this purpose however, the magnitude of the force should be upscaled even more. This is the aim of our current and future research.

References

[1] M. Povinelli et al., *Evanescent wave bonding between optical waveguides,* Opt. Lett., 30, 3042-3044 (2005)

[2] J. Roels et al., *Tunable optical forces between nanophotonic waveguides*, Nature Nanotechnology, 4, pp. 510-513, (2009)