Photonic Devices Based on Optical Forces

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A self-aligned photonic coupler, consisting of a 660nm tapered fiber and a 240x220nm suspended rectangular waveguide, is presented as a new approach for optical interfacing from SMF fiber domain to integrated photonic domain. The alignment occurs due to optical forces and a theoretical maximum transmitance of -1.4dB as well as significant attractive optical force range of 1.25μm for 1mW of input power are demonstrated. For this non-optimized geometry, this result already matches transmitance for typical approaches for this interfacing.

Introduction

Optical forces are widely used to trap, manipulate and propel micro- to nanoscale particles. This mechanism can be extended to evanescent waveguide modes and can provide positioning within optical devices[1]. We propose a coupler designed to exhibit self-alignment due to coupling forces.

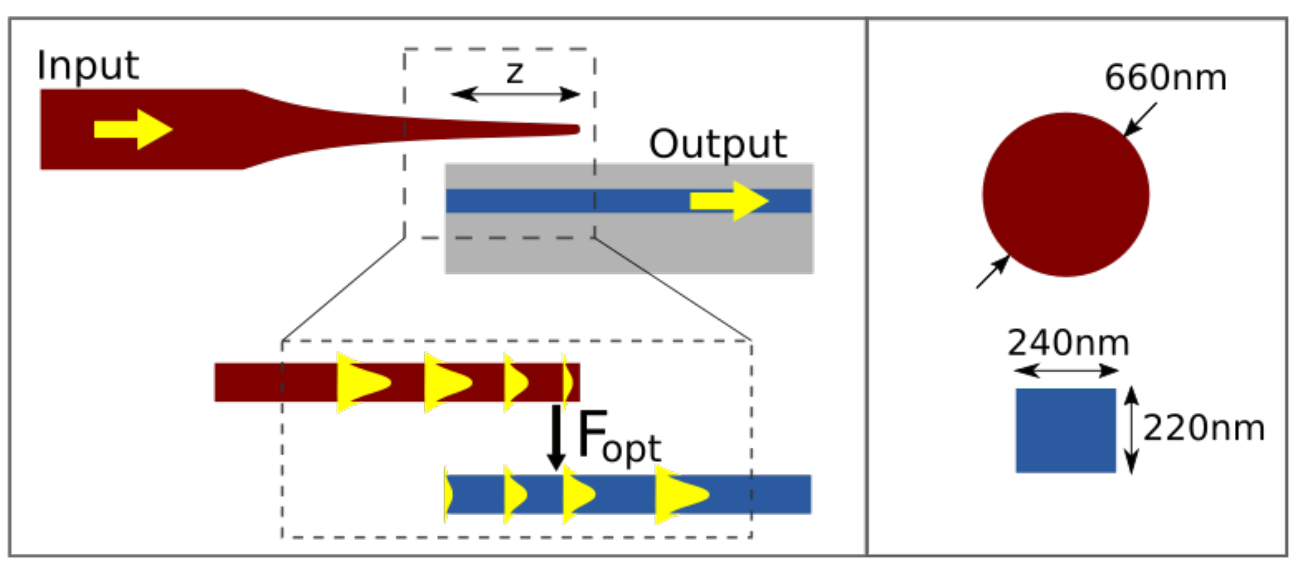

Figure 1: Schematic of the coupler concept. Blue represents silica, red, silicon and yellow, power and modal profile. Light is lauched in a 660nm diameter tapered fiber and coupled to an integrated waveguide with 240nm width and 220 nm height. The fiber is subject to an optical force that aligns the system.

Design

In order to achieve high coupling efficiency, the effective indexes of both waveguides should match. On the other hand, the wider the evanescent field, the wider the optical force range.

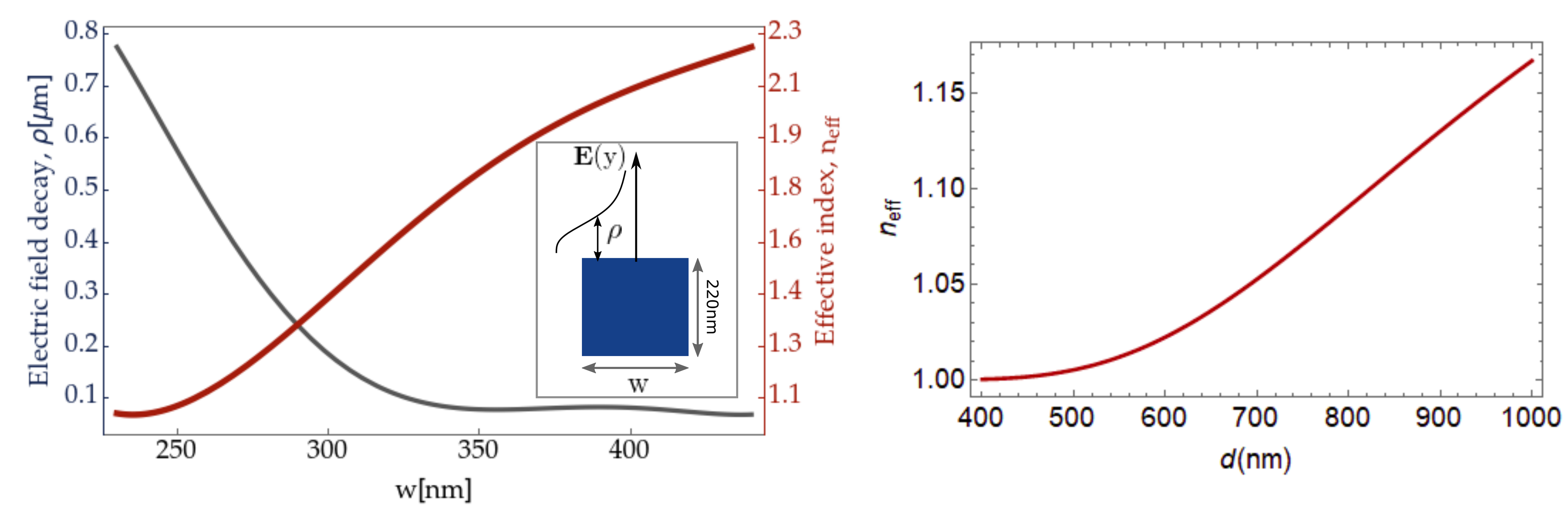

Figure 2: Left: electric field decay (position above the waveguide surface such that the field norm is half of its maximum value) as a function of width for the silicon waveguide. Inset: geometry and decay scheme. Right: effective index as a function of taper diameter.

For a 660nm taper diameter the effective index matches a 240 nm width waveguide.

Optical Force

The optical force can be calculated by the RTOF (Response Theory of Optical Forces) for multi-port systems[2].

$$\mathbf{F}_{opt} = \frac{Pz}{c} \sum_{i=1}^{M} |a_i|^2 \nabla_{\mathbf{q}} n_{eff,i}$$

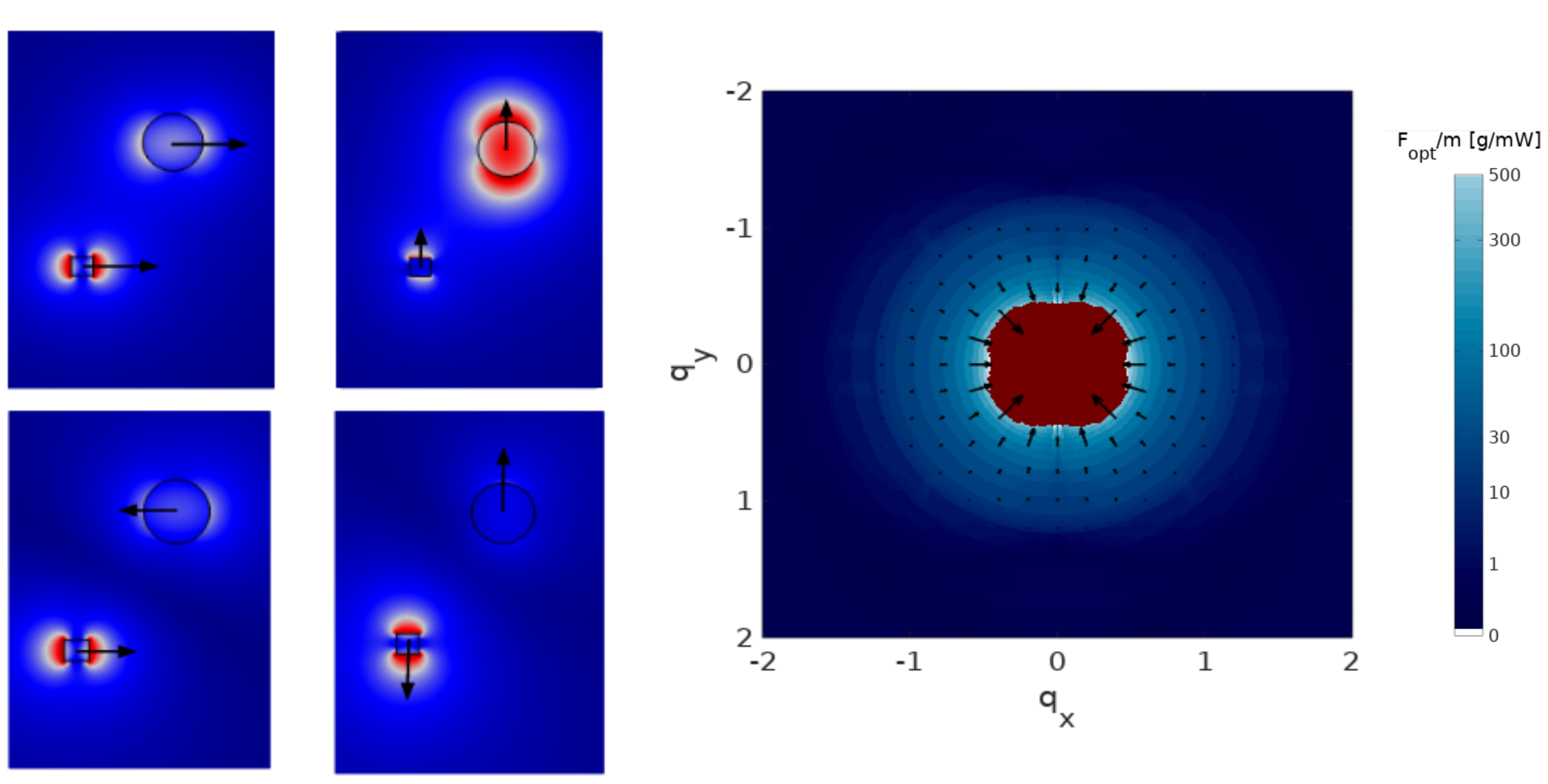

Figure 3: Left: Electric field norm profile for the eingenmodes of the two-waveguide system: TE and TM, symmetric and antisymmetric. Right: Acceleration in g's (g=9.8m/s²) for a silica cylindrical rod under the optical force for 1mW of input power. In red is represented positions not allowed for the fiber taper center due to the waveguide's presence at the origin. For a distance of 1.25μm the optical force corresponds to 1g and is rapidly increasing as q decreases.

Transmitance

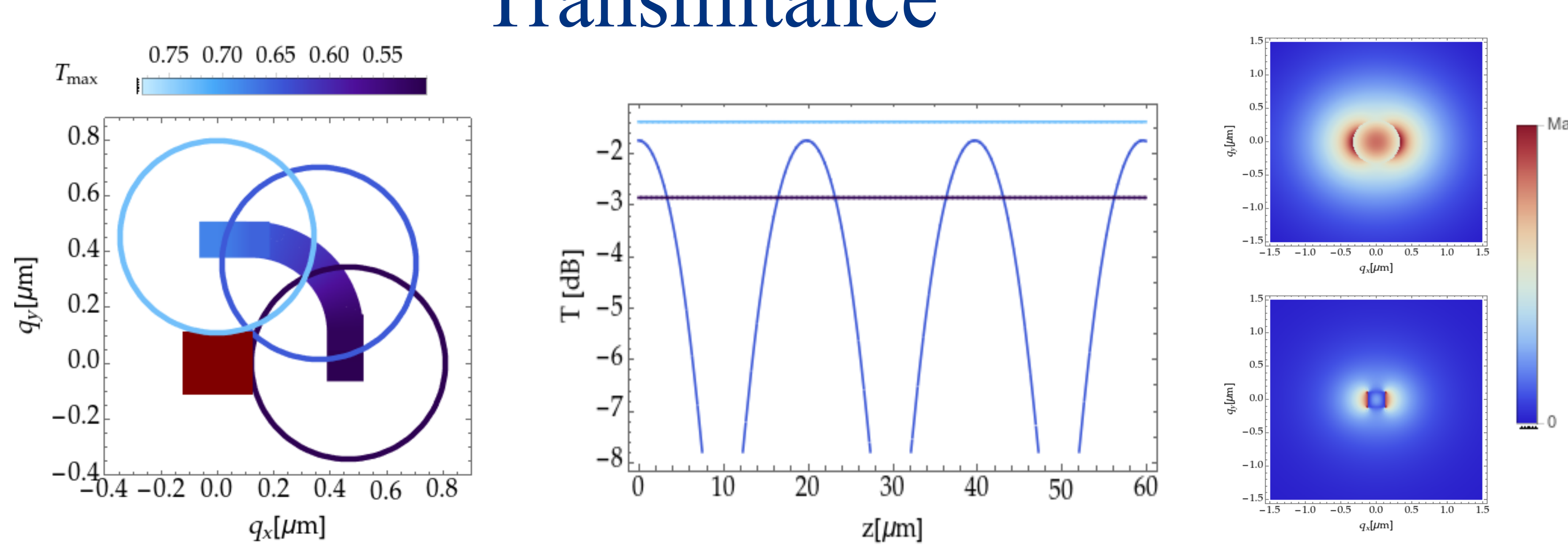

Figure 4: Device transmitance for final positions – taper touching the waveguide. Horizontally polirized input and TE output considered. Curve for taper center final positions with the trasmitance for z=0 represented by the color scheme (left). Transmitance as a function of interaction length for the three respective situations depicted on left (middle). Input and output modes (rignt). Color gradient: electric field norm.

Conclusion

Theoretical results show a self-aligned photonic coupler with optical force range of 1.25μm (for optical-induced acceleration of 1g/mW) and maximum coupling efficiency of -1.4 dB. Although the chosen geometry is not optimized, it shows better performance than grating couplers (-3.5 to -5 dB) [3] and comparable to edge coupling (-1dB) with the advantage of coarser alignment precision.

References:

[1]Povinelli, M.L., Lončar, M., Ibanescu, M., Smythe, E.J., Johnson, S.G., Capasso, F. and Joannopoulos, J.D., 2005. Evanescent-wave bonding between optical waveguides. Optics letters, 30(22), pp.3042-3044.
[2]Wang, Z. and Rakich, P., 2011. Response theory of optical forces in two-port photonics systems: a simplified framework for examining conservative and non-conservative forces. Optics express, 19(22), pp.22322-22336.
[3]Chrostowski, L. and Hochberg, M., 2015. Silicon photonics design: from devices to systems. Cambridge University Press.

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