Enhancement of optical forces using slow light in a photonic crystal waveguide: supplementary material

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SUPPLEMENTARY NOTE 1

We used the Finite Difference Time Domain (FDTD) methods (MEEP [1]) to simulate the forces acting on a 490 nm particle in 3D. For the photonic crystal we used a period of $a = 420$ nm, radius $r = 0.316a$, slab thickness 220 nm and a grid size of $\lambda/90$. The polystyrene particle was assumed to have a refractive index of 1.57. The simulated force enhancement (shown in Fig. 5 of the main text) was computed using force regions surrounding the particle, and was normalized to the same bead on top of a waveguide of width $\sqrt{3}a$ (i.e. the same width as a W1 waveguide, but without the surrounding mirror holes). The corresponding transmission spectrum, also simulated in MEEP with the same parameters and normalized to a waveguide, is shown in Fig. S1a.

In addition to the MEEP simulations, the simulated group index was computed using MPB [2] in 3D using the same parameters as the MEEP simulations and is shown in Fig. S1b.

A simulation of a 200 nm particle was also performed. The results are shown in Fig. S2. Fig. S2a shows the force normalized to a 200 nm bead on top of a waveguide, whilst Fig. S2b shows the force relative to a 490 nm bead on top of the same photonic crystal.

SUPPLEMENTARY NOTE 2

The force enhancement in an air filled photonic crystal was also modeled relative to a waveguide. In this case the hole radius was reduced to $r = 0.295a$ to give operation around 1550 nm. The results are shown in Fig. S3.

SUPPLEMENTARY NOTE 3

We investigated the particle dynamics with the particles of two different sizes (400 nm and 600 nm in diameter) and with

Fig. S1. Simulated slow light profile for a photonic crystal waveguide. a) Simulated transmission spectrum (MEEP). b) Simulated group index (MPB).

two guided optical powers of 2.5 mW and 4 mW, respectively (Fig. S4). As the scattering force scales with $\sim r^6$ while the Stokes drag force scales linearly with r , where r is the radius of the particle, the terminal velocity will increase with the particle size [3].

First we observe that the particle velocity scales with the guided optical power. The maximum velocities were measured at around 1560 nm for all cases. The larger particles of 600 nm gained more velocity for every wavelength probed due to the higher scattering forces relative to the Stokes drag force.

Fig. S2. Force enhancement simulation for a 200 nm bead. a) Normalized to a 200 nm bead on top of a waveguide. b) Normalized to a 490 nm bead on top of a photonic crystal.

Fig. S3. Modelling of particle on top of an air filled photonic crystal waveguide. a) Simulated transmission spectrum (MEEP) in air filled photonic crystal. b) Corresponding simulated force enhancement relative to a waveguide.

Note that in Fig. S4 the guiding velocity appears to rise again after 1561 nm. This rise is also mirrored in the corresponding trap stiffness measurements shown in Fig 4 within the main text. This rise may be due to variations in the waveguide transmission relative to the simulations as a result of fabrication errors and stuck particles from the earlier experiments.

REFERENCES

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Fig. S4. Particle velocities for different particle sizes and optical powers. a) 400 nm size particles b) 600 nm size particles.

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