Resonant optical trapping in a 2D photonic crystal cavity

Ulagalandha Perumal Dharanipathy

Laboratory of Quantum Optoelectronics
École Polytechnique Fédérale de Lausanne (EPFL)
Switzerland
Photonic Crystals

1-D: periodic in one direction
2-D: periodic in two directions
3-D: periodic in three directions
Optical trapping: Classical & Integrated

Diffraction limit is reached when trapping smaller particles (< 1 µm)

Classical tweezers are bulky and are not practical

Plasmonics

Waveguides

Evanescent cavities
Optical trapping: Resonant cavity trapping

Inside a cavity:

- Size specific trapping
- Refractive index specific trapping
- Shape specific trapping
- Lower trapping power
- Smaller particles
- Fixed trap position

High Q, small V

Strong field gradients

- Lower trapping power
- Smaller particles
- Fixed trap position

Back action effects

- Size specific trapping
- Refractive index specific trapping
- Shape specific trapping

Particle induced perturbation

Photonic crystal cavities
Q in water > 1000 and Mode volumes < (λ/n)^3
A standard photonic crystal cavity

2D triangular lattice
Air holes in high index dielectric

Very limited field overlap with the particle
Hollow photonic crystal cavity

- Dimension: 700 nm diameter
- Estimated overlap ~20%
- $Q_{\text{COMSOL}} \sim 8000$ (air)
- $Q_{\text{COMSOL}} \sim 3000$ (water)
Adaptive meshing of the photonic crystal slab

Number of DOF: 1.5 million
Memory: 127GB
Time: 120 minutes
Investigations performed

• Effect of field on particle : Resonant Trapping

• Effect of particle on field : Dynamic resonance shift

• Particle – field coupling: Back-action
Effect of field on particle: Resonant Trapping - COMSOL
Effect of field on particle: Resonant Trapping - Experiment

Particle is optically trapped at a red detuned wavelength inside the hollow photonic crystal cavity until the input laser is turned off.

Ultra low trapping powers of 120 µW
Effect of particle on field: Dynamic resonance shift: COMSOL

- Detuning $\Omega$ (nm) vs. Displacement from centre (nm)
- Particle diameter: 100nm, 300nm, 400nm, 500nm

- Displacement from the center along X Axis (nm)
- Displacement from the center along Y Axis (nm)
Effect of particle on field: Dynamic resonance shift: Experiment
Particle – field coupling: Back-action: COMSOL

Regime 1

Regime 1

Regime 2

Regime 2
Particle – field coupling: Back-action: Experiment

Resonant excitation

Particle escapes

Estimated guided power (μW)

Regime I

Regime II

No trapping

Detuning from empty resonance wavelength (nm)

37 μW

99 μW

Laser diode output power (mW)
Conclusions

• **Ultra low power resonant optical trap** in a 2D hollow photonic crystal cavity with permanent trapping achieved at 120µW powers.

• **Dynamic resonance shift** resulting from the strong perturbation of single particle inside the cavity demonstrated.

• Presence of particle-cavity coupling is revealed and this **back-action** in the resonant trap leads to the existence of **two distinct trapping regimes**