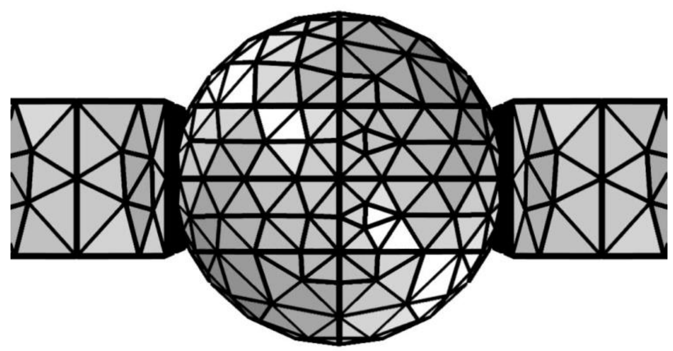
Resonant optical trapping in a 2D photonic crystal cavity



COMSOL CONFERENCE ROTTERDAM2013

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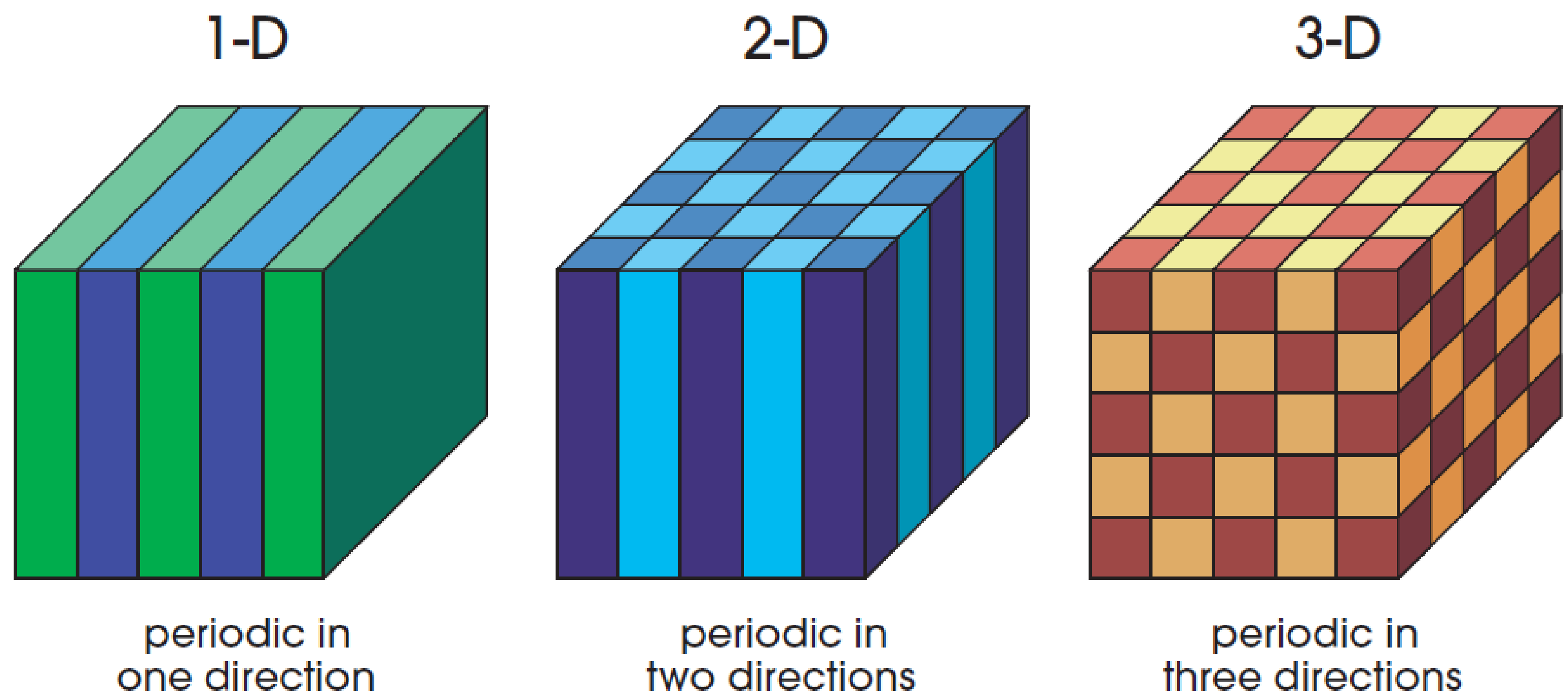
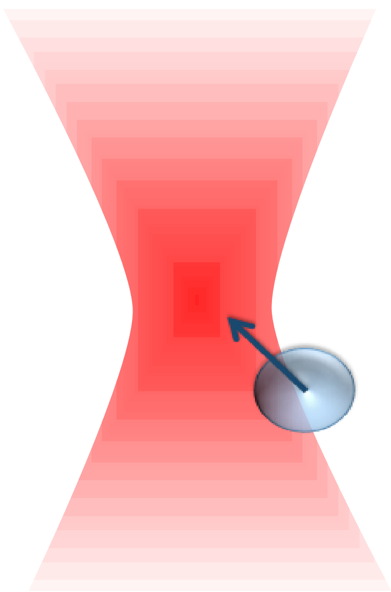
Photonic Crystals



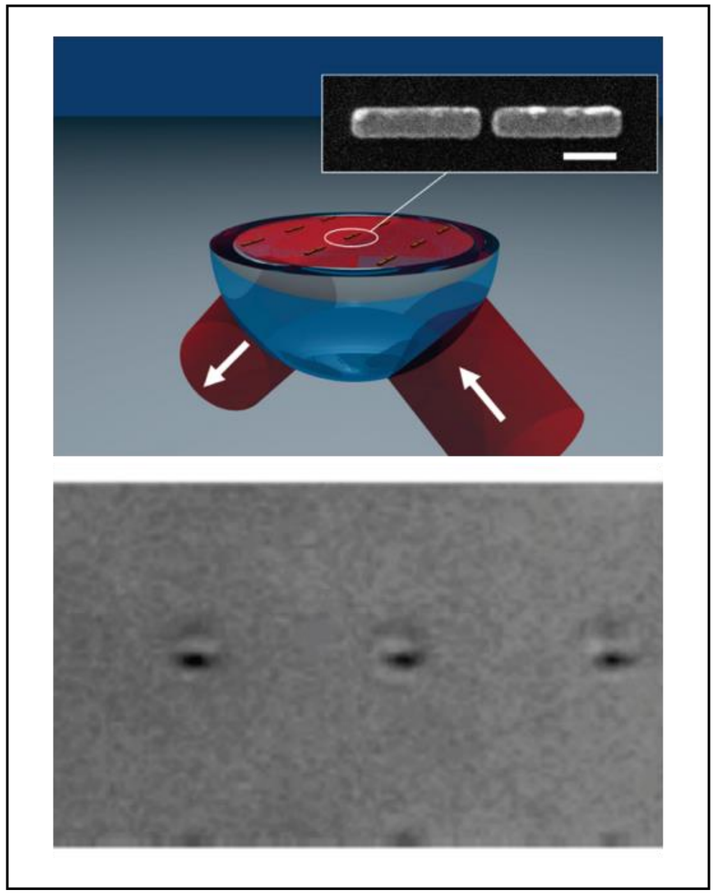
Optical trapping: Classical & Integrated

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

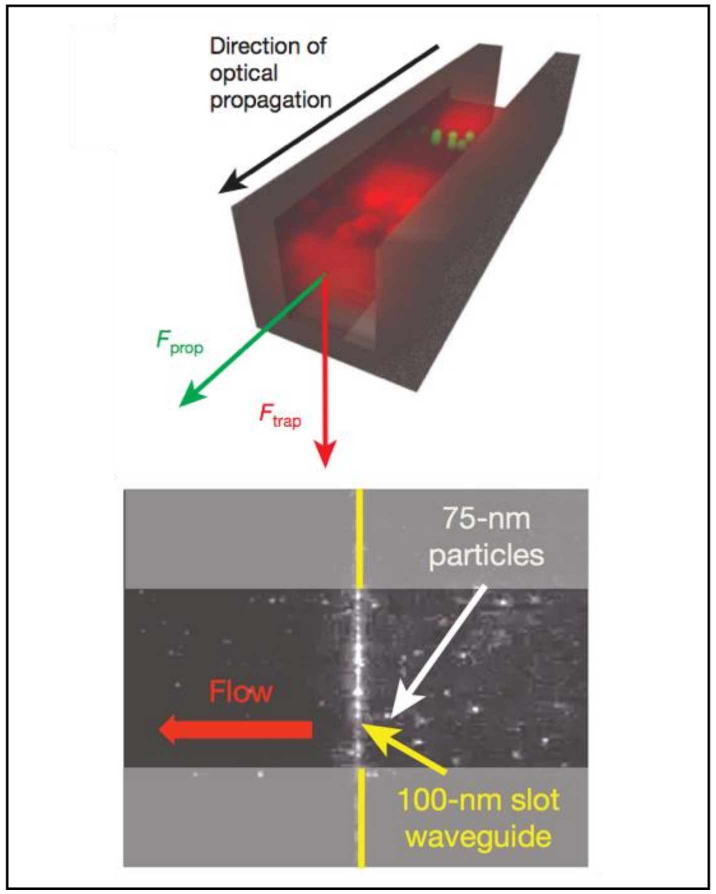


Classical tweezers are bulky and are not practical

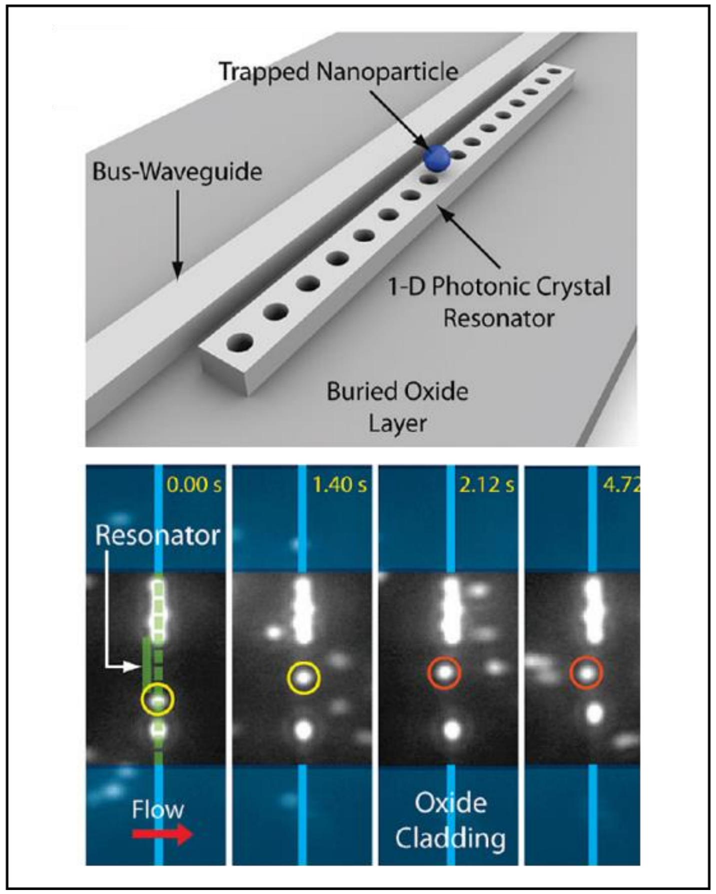
Plasmonics



Waveguides

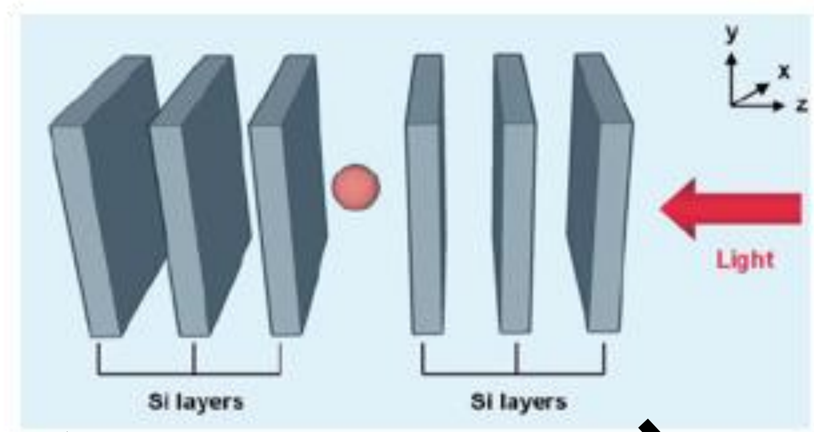


Evanescent cavities



Optical trapping: Resonant cavity trapping

Inside a cavity:



High Q, small V

Particle induced perturbation

Strong field gradients

- Lower trapping power
- Smaller particles
- Fixed trap position

Back action effects

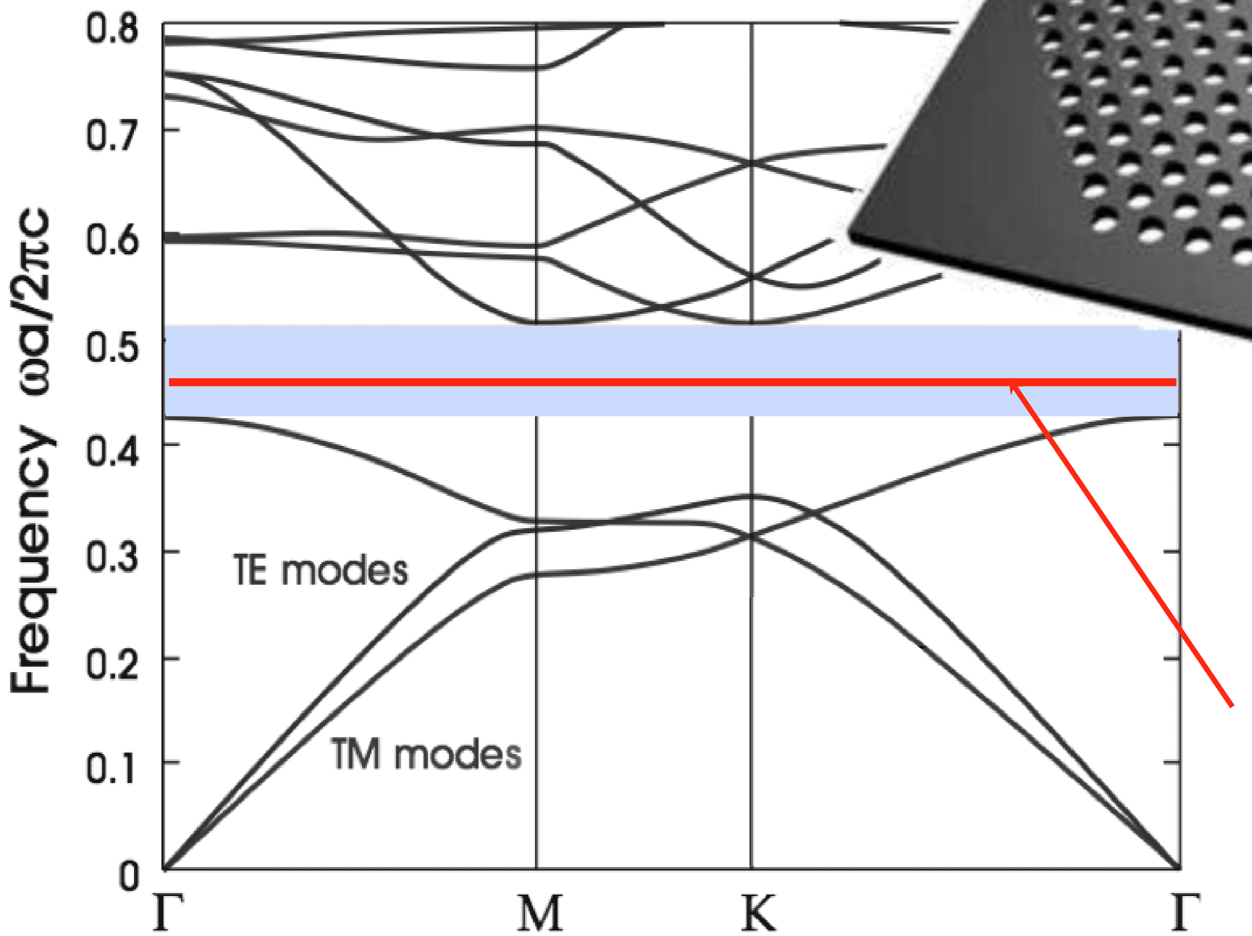
- Size specific trapping
- Refractive index specific trapping
- Shape specific trapping

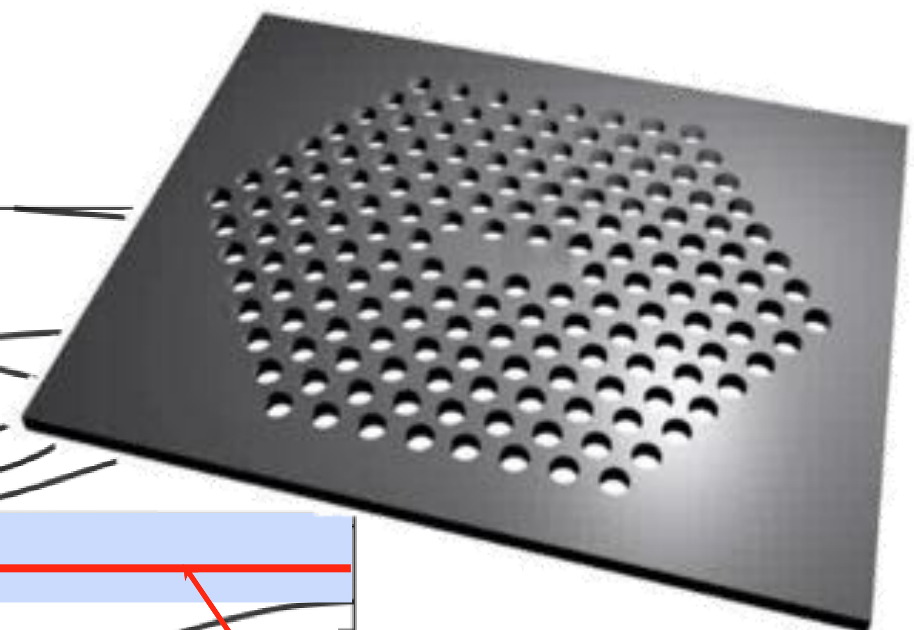
<u>Photonic crystal cavities</u>

Q in water > 1000 and Mode volumes < $(\lambda/n)^3$

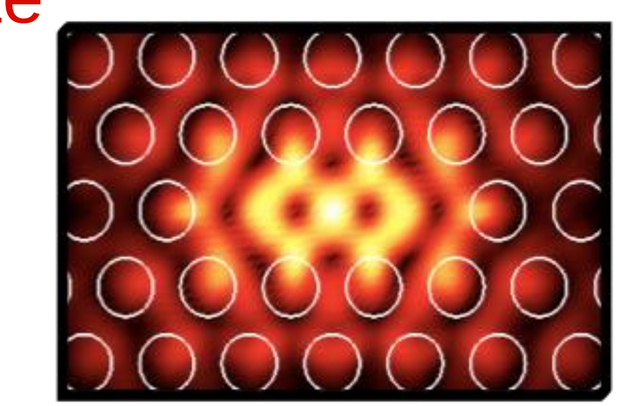
A standard photonic crystal cavity

2D triangular lattice
Air holes in high index dielectric



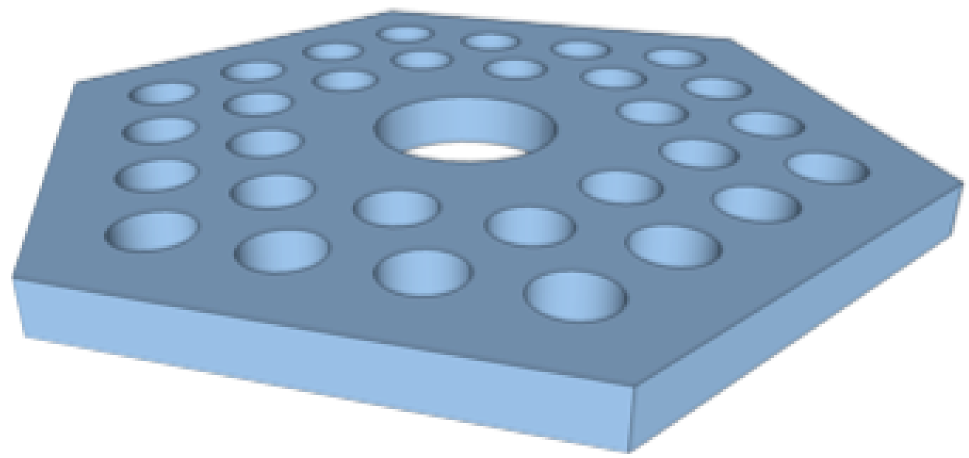


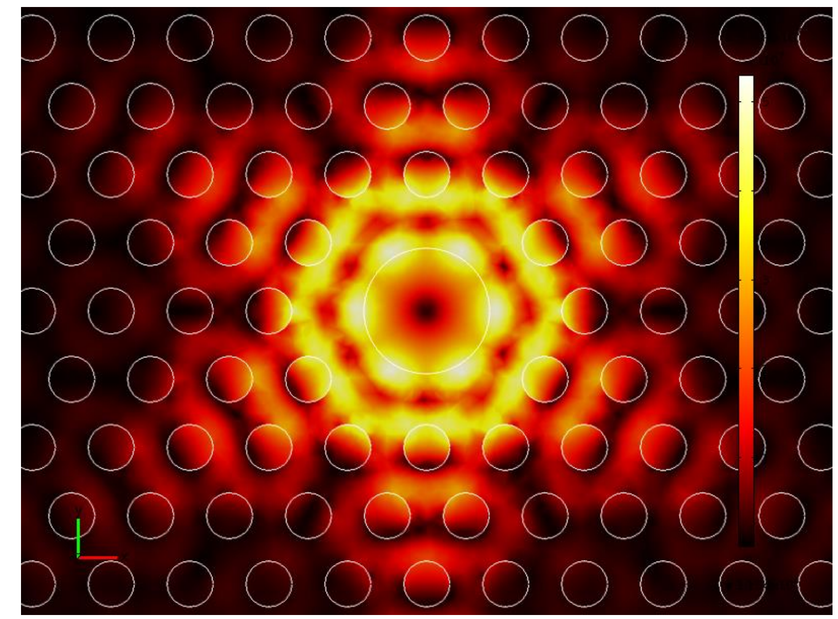
$|E_{x,y}|$ field distribution

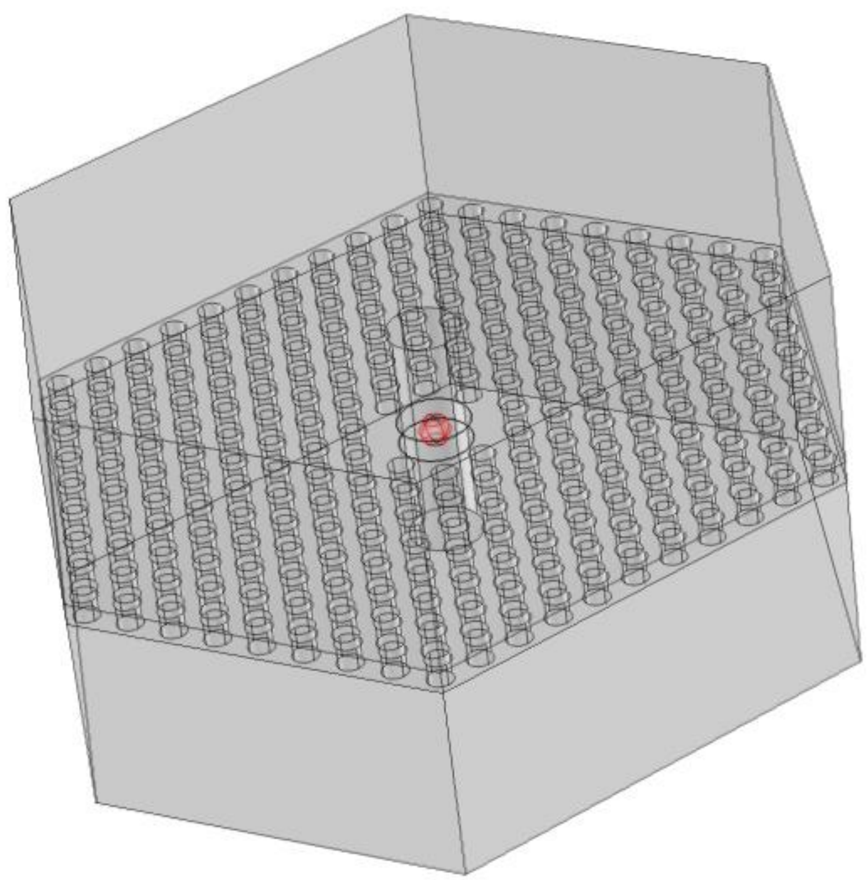


Very limited field overlap with the particle

Hollow photonic crystal cavity







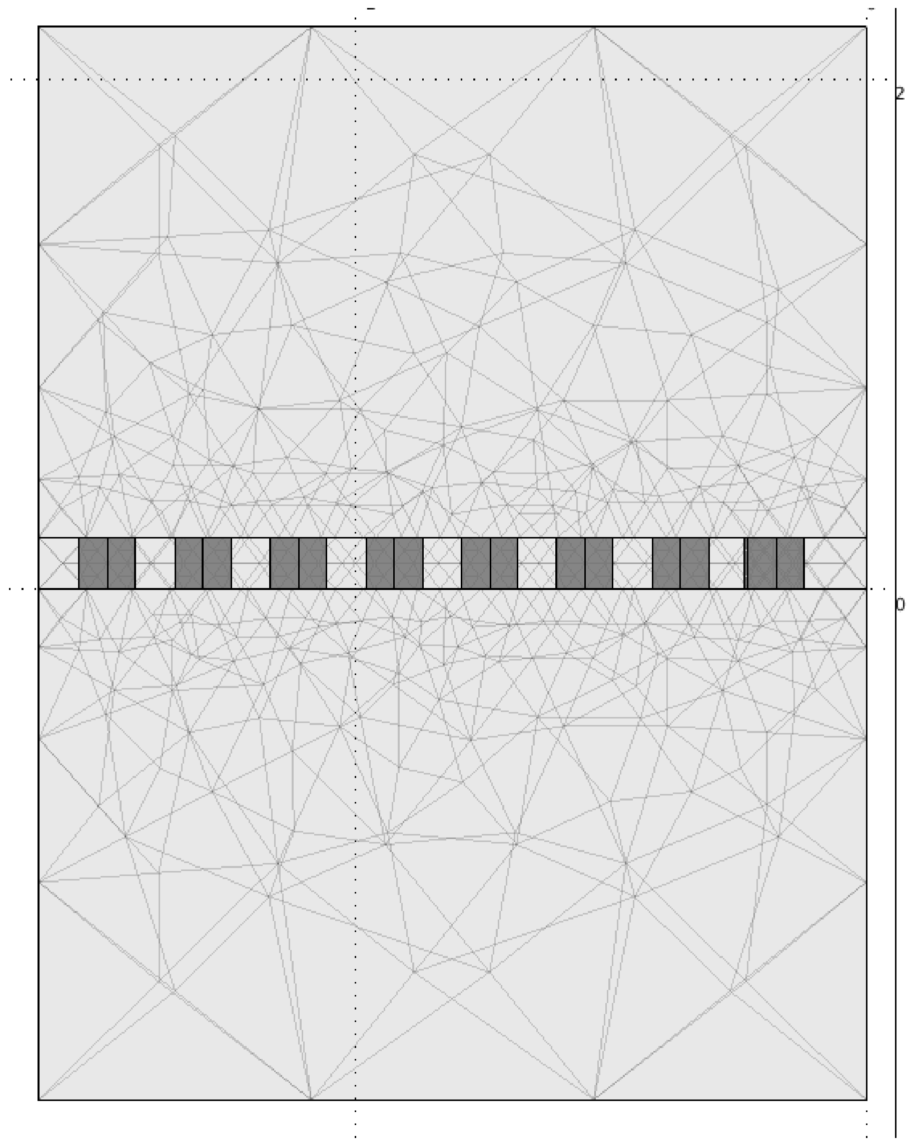
Dimension: 700 nm
liameter

Estimated overlap ~20%

Q_{COMSOL} ~ 8 000 (air)

Q_{COMSOL} ~ 3 000 (water)

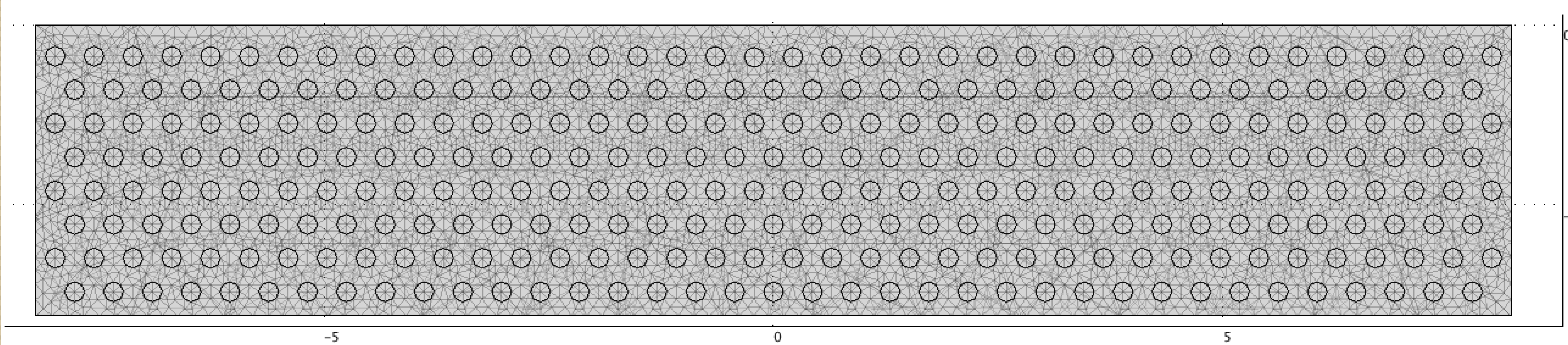
Adaptive meshing of the photonic crystal slab

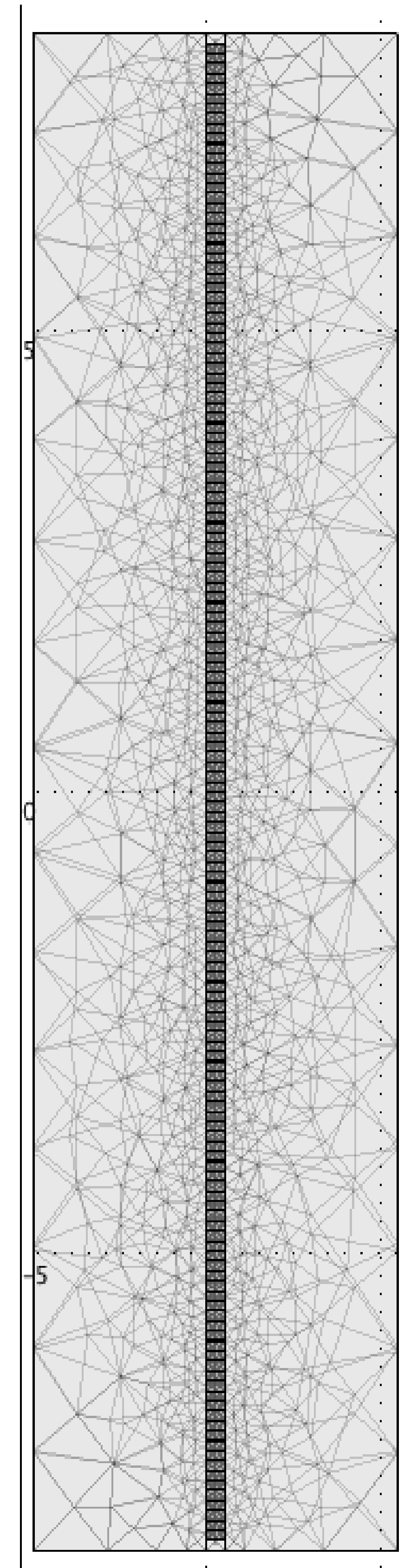


Number of DOF:
1.5 million

Memory: 127GB

Time: 120 minutes





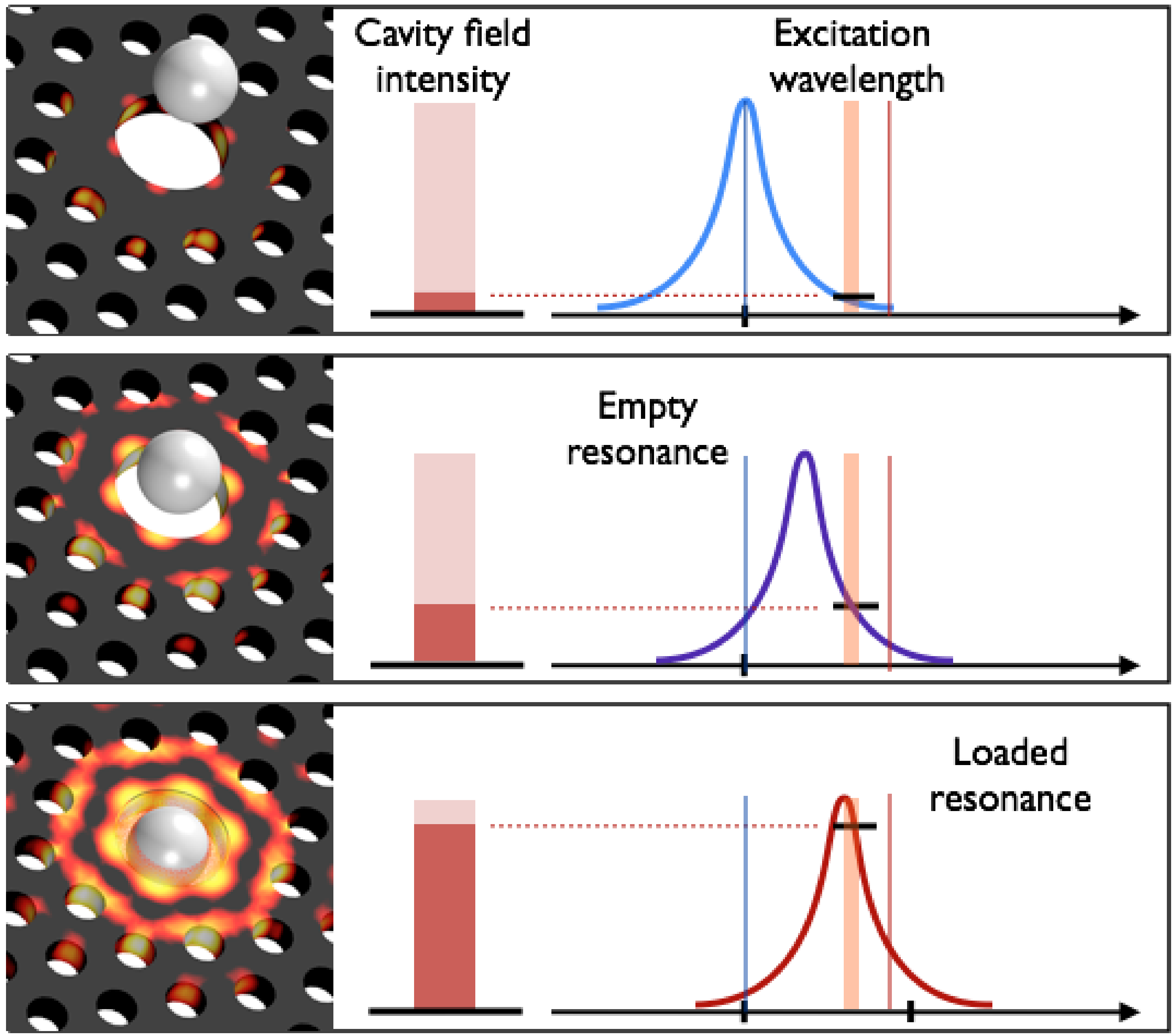
Investigations performed

- Effect of field on particle : Resonant Trapping

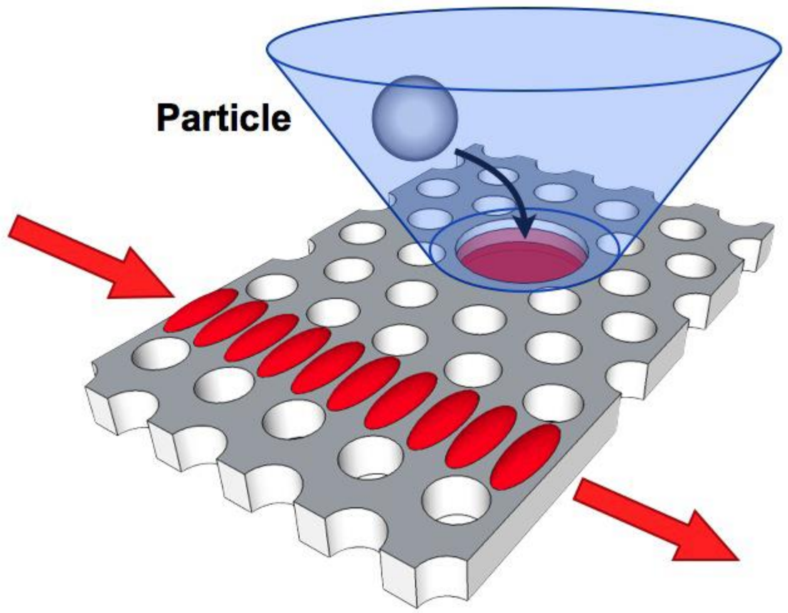
- Effect of particle on field : Dynamic resonance shift

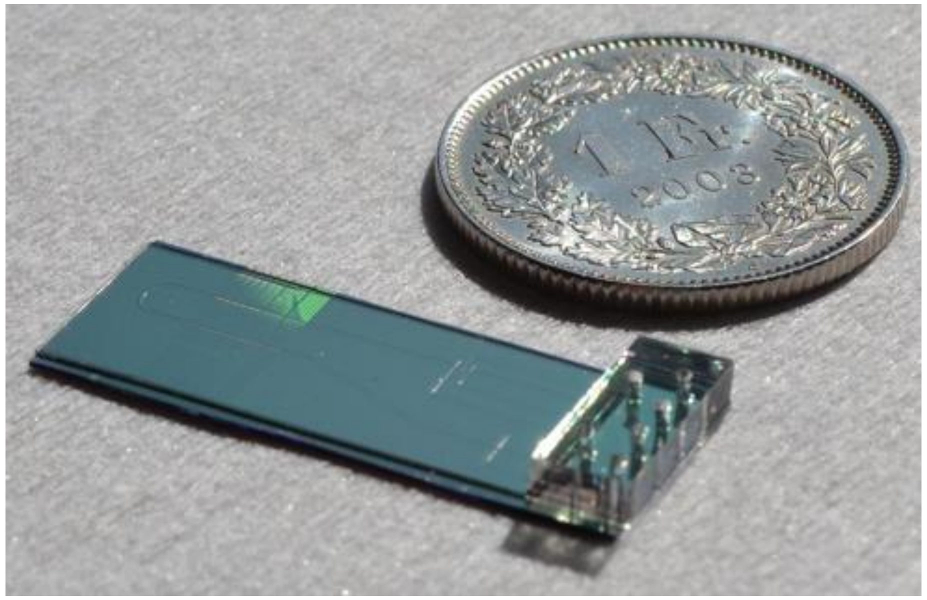
- Particle – field coupling: Back-action

Effect of field on particle: Resonant Trapping - COMSOL



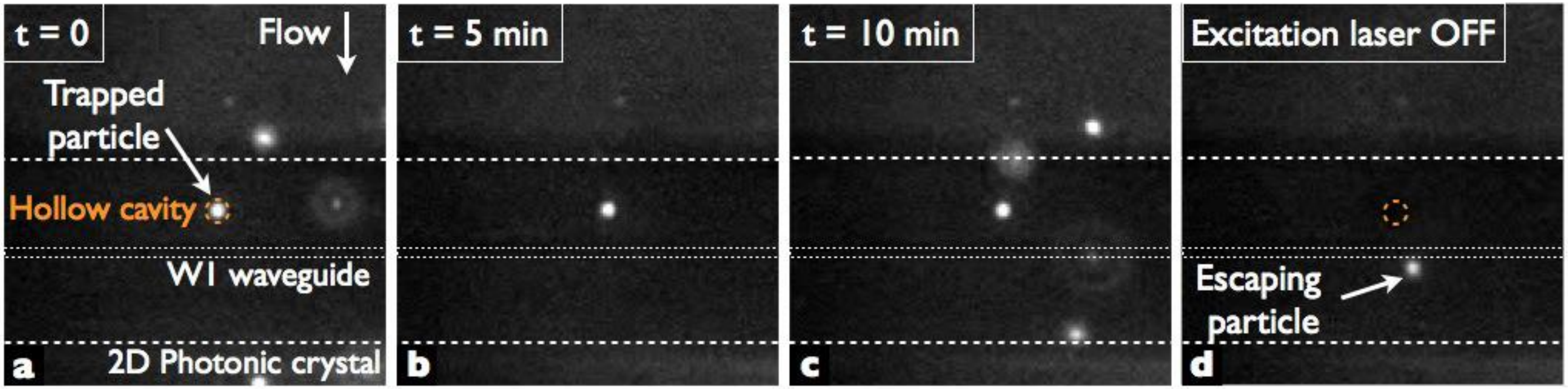
Effect of field on particle: Resonant Trapping - Experiment



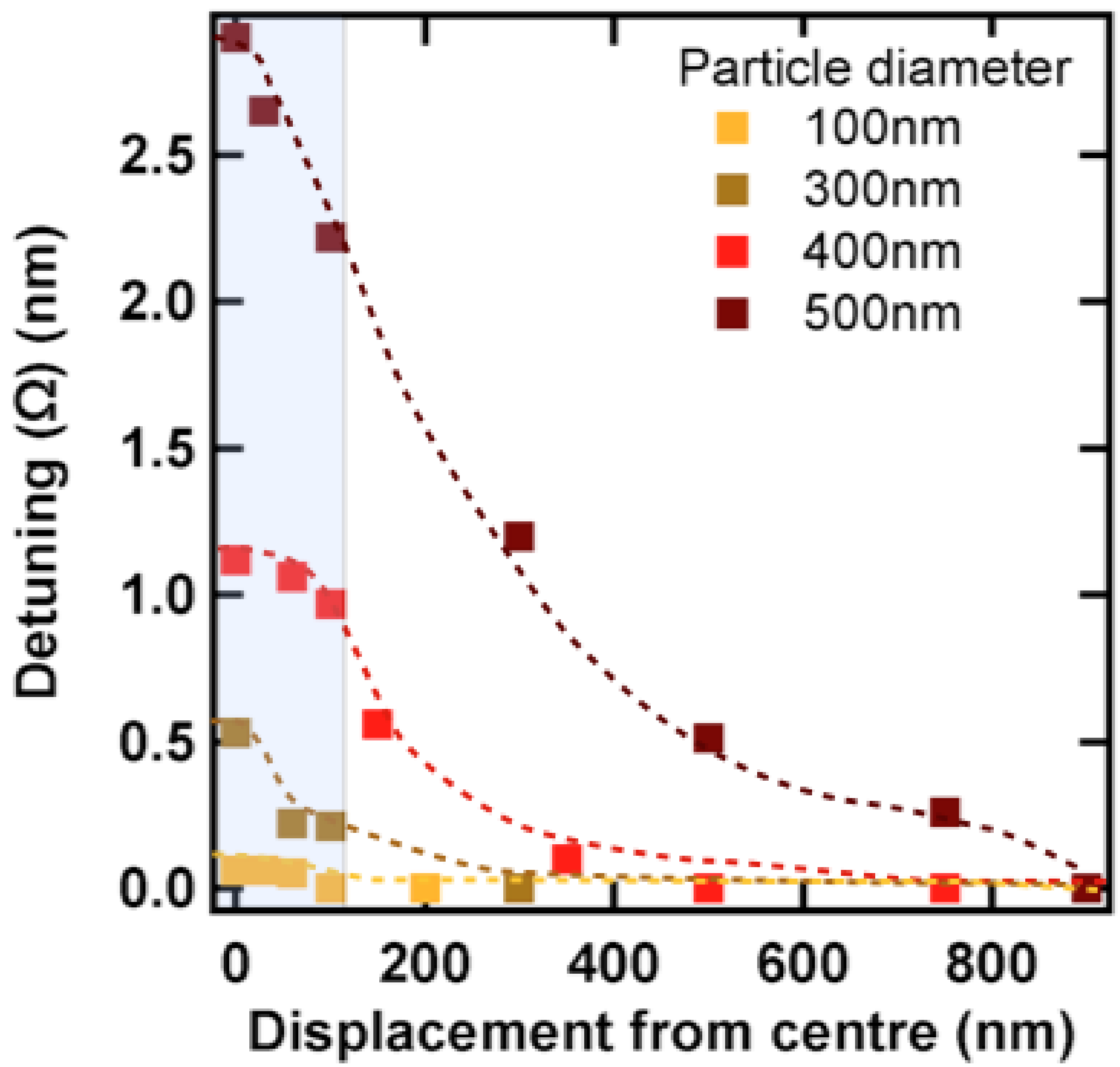


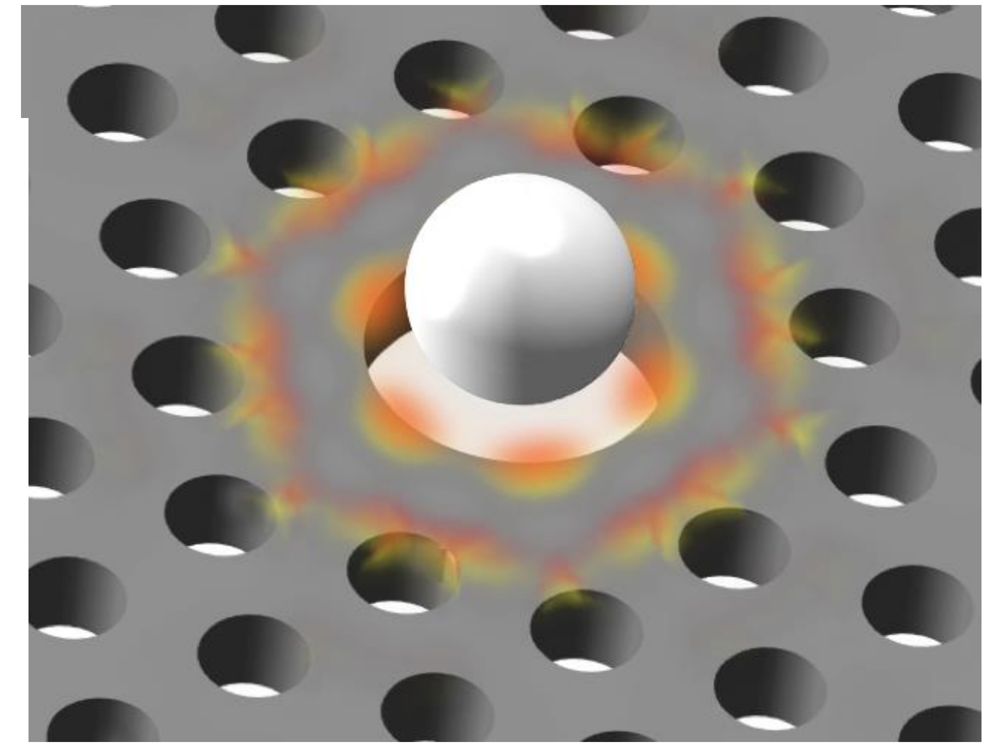
Particle is optically trapped at a red detuned wavelength inside the hollow photonic crystal cavity until the input laser is turned off.

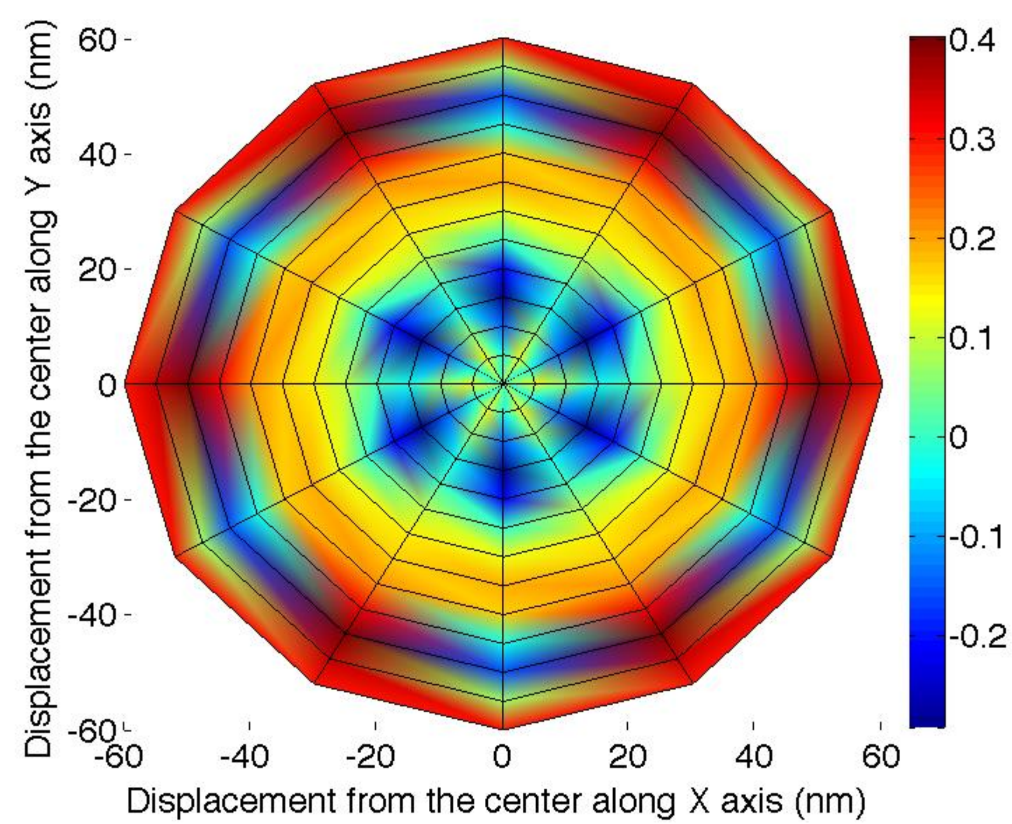
Ultra low trapping powers of 120 µW



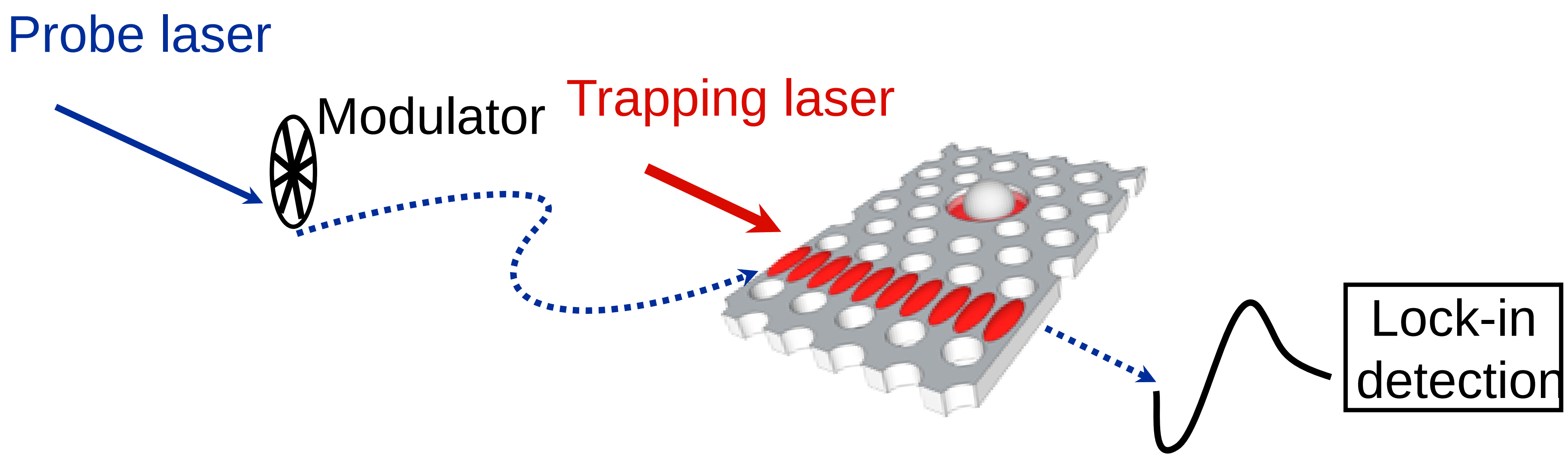
Effect of particle on field: Dynamic resonance shift: COMSOL

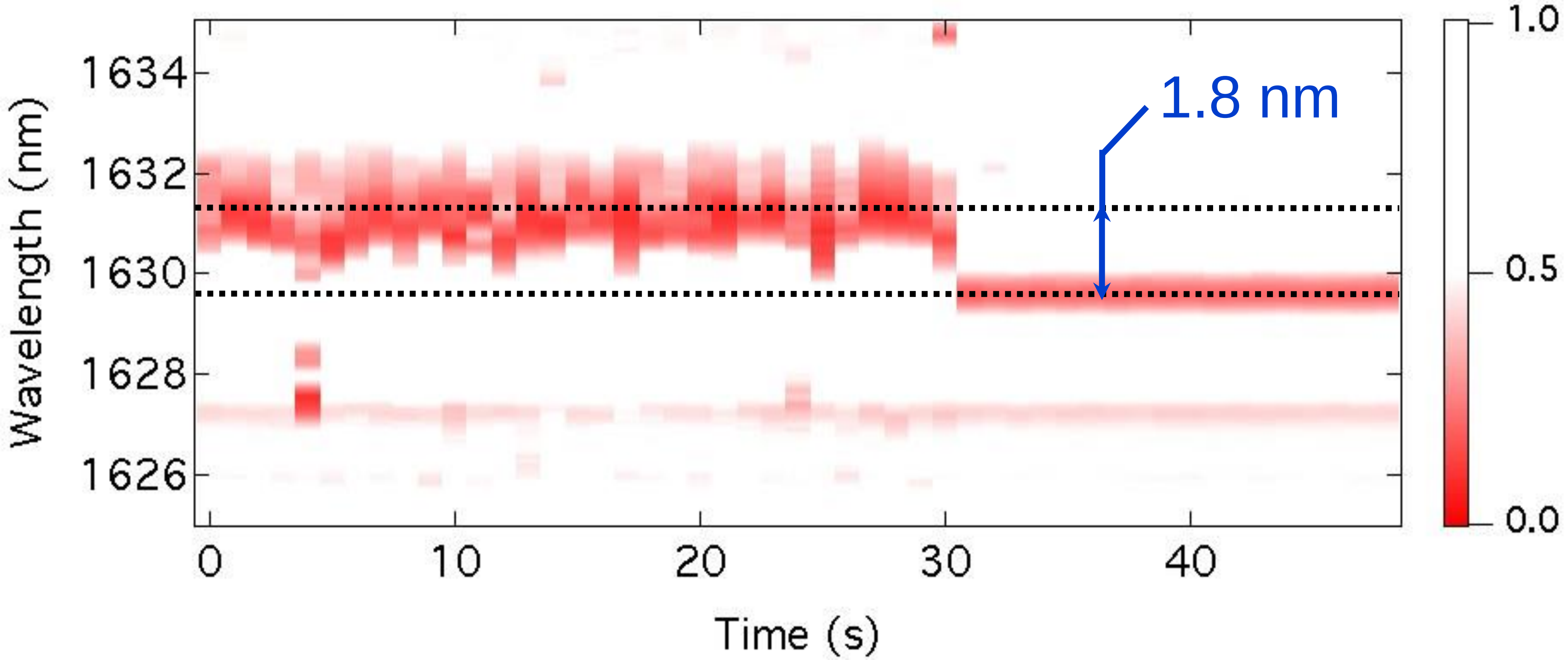




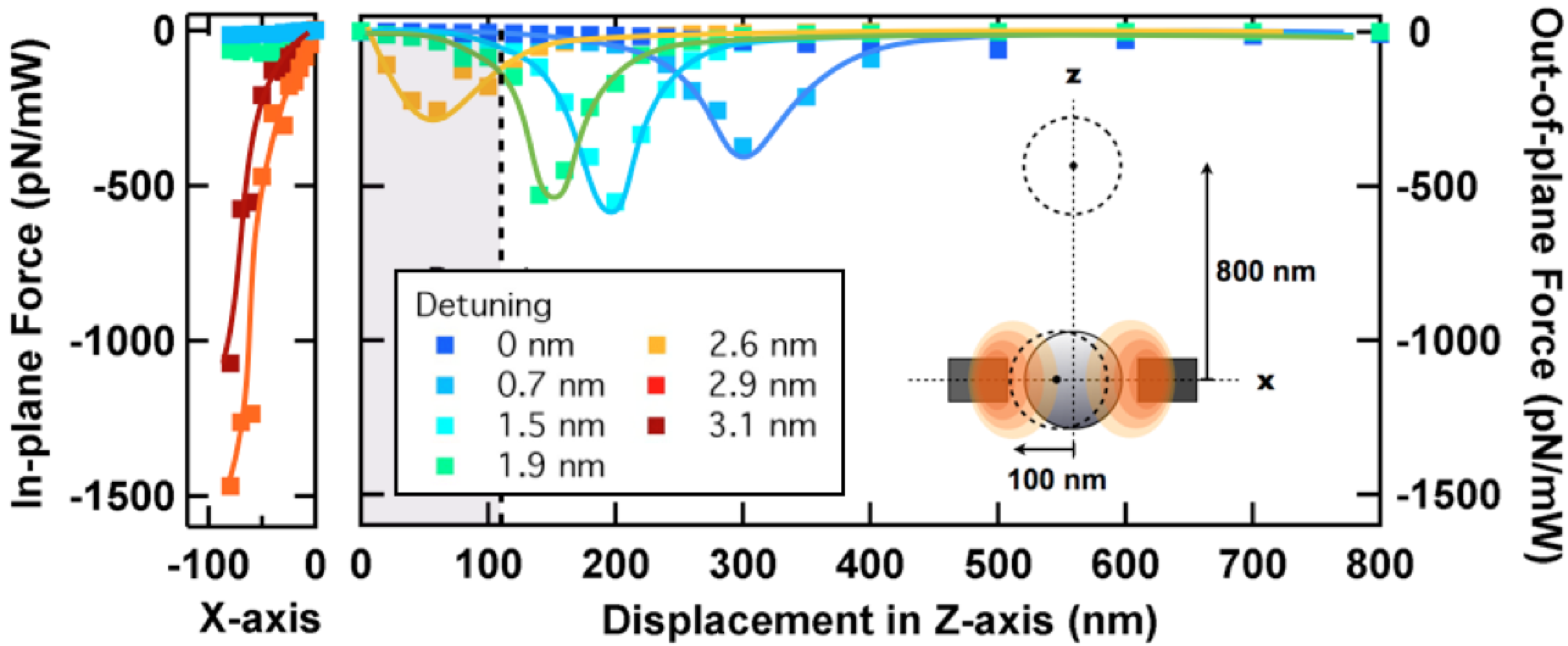


Effect of particle on field: Dynamic resonance shift: Experiment

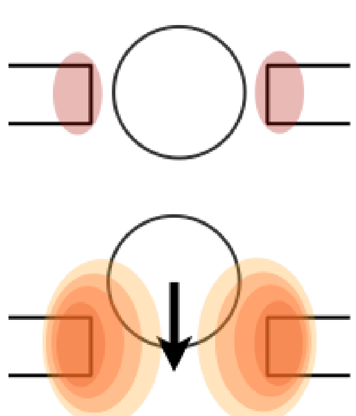


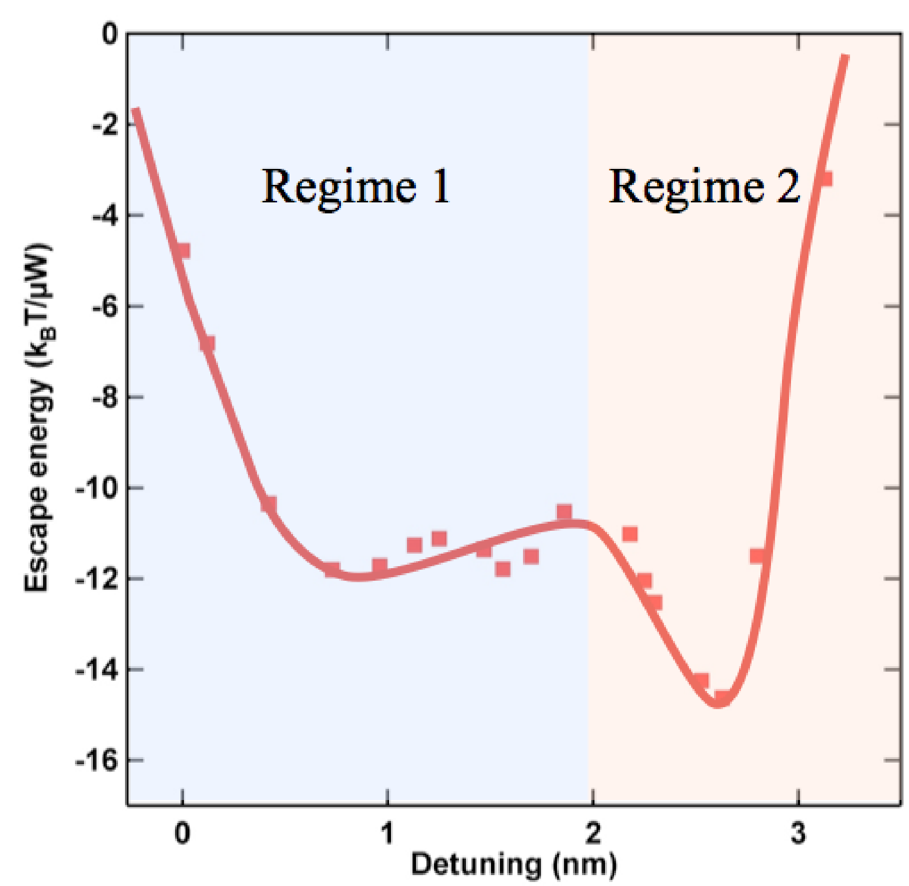


Particle – field coupling: Back-action: COMSOL

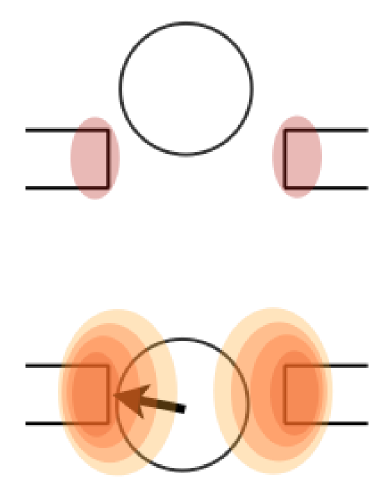


Regime 1

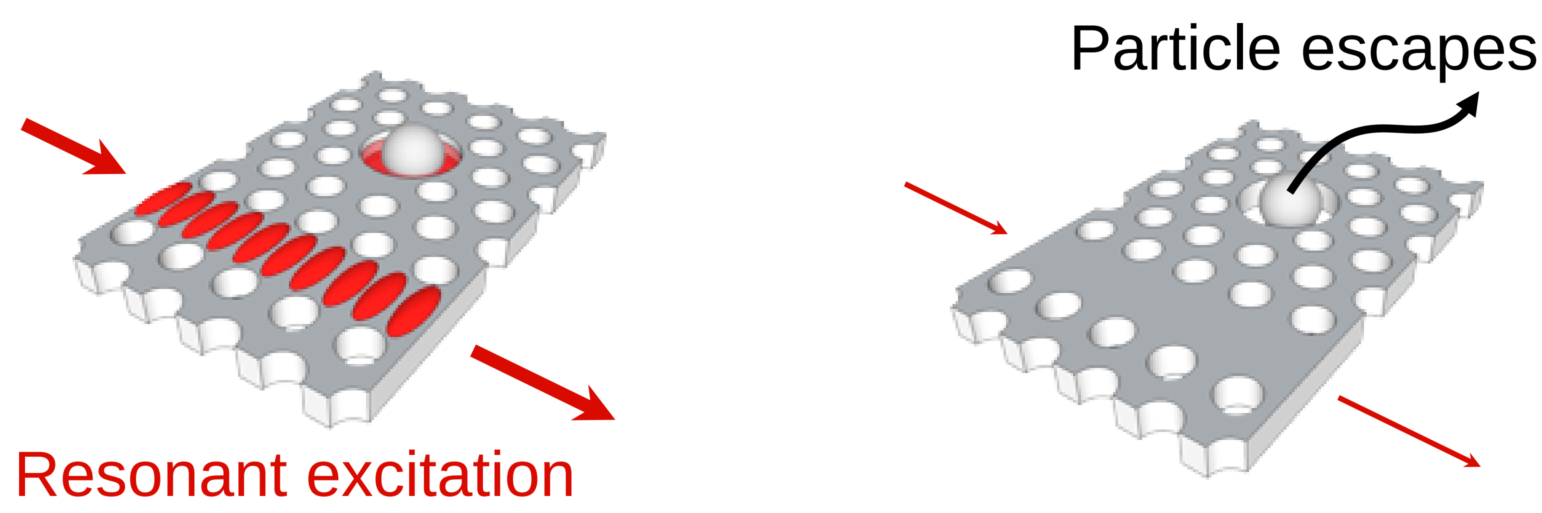


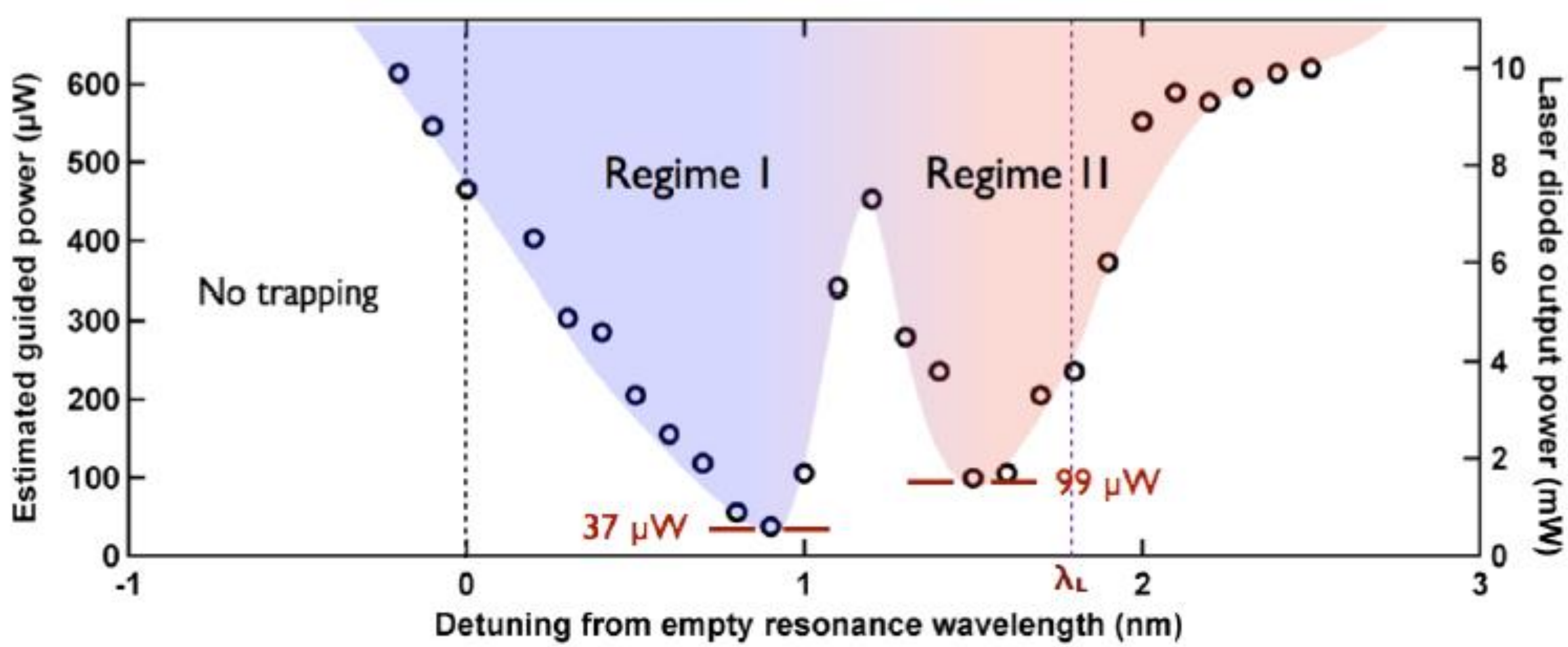


Regime 2



Particle – field coupling: Back-action: Experiment





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**

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Observation of Backaction and Self-Induced Trapping in a Planar Hollow Photonic Crystal Cavity

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