Electric and magnetic effect in adiabatic polaritonic systems

ISTITUTO ITALIANO DI TECNOLOGIA

A. Alabastri, A. Toma, F. De Angelis, E. Di Fabrizio, R. Proietti Zaccaria*

*Istituto Italiano di Tecnologia, via Morego 30 Genova, Italy, *remo.proietti@iit.it*

Motivation:

We investigate the relation between two important phenomena such as lighting rod effect and adiabatic compression.
In particular, we shall explain the role of electrostatic (ES), quasi-electrostatic (QES), and quasi-dynamic (QD) excitations in the formation of optical resonances on a metallic nano-cone. The results will be compared with the resonances originating from an electromagnetic excitation (EM).
Finally, we shall demonstrate that adiabatic compression is mostly electric-generated, while the magnetic contribution is responsible for the resonance position in the spectral range.

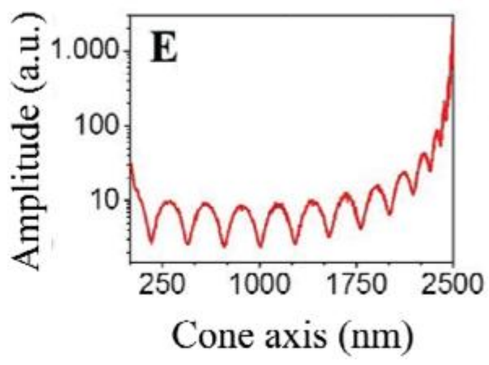
1. EM excitation: TM_0 mode

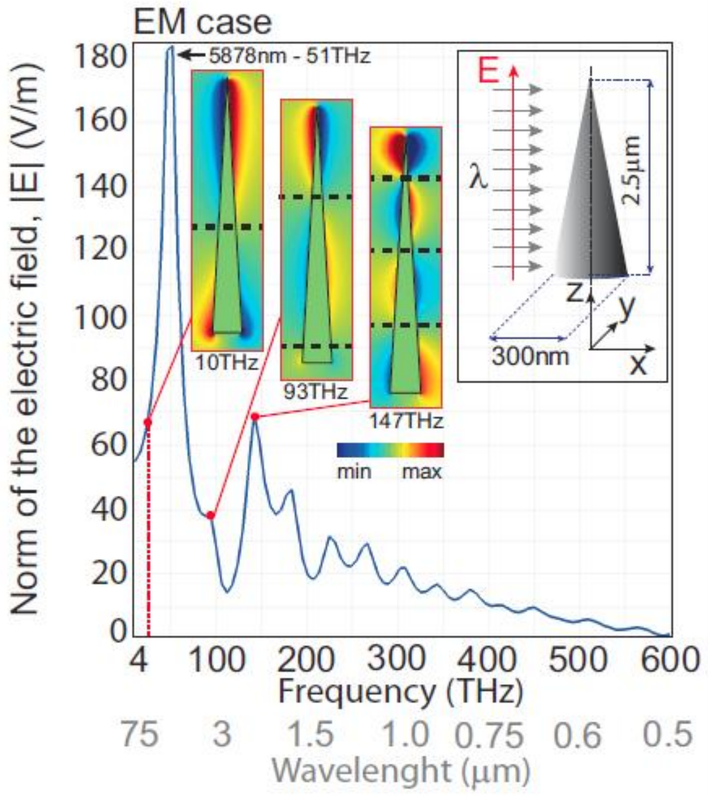
Silver cone

$$\varepsilon_r = 1 - \frac{\Omega_p^2}{\omega(\omega - i\Gamma_0)} + \sum_{j=1}^{m} \frac{f_j \omega_p^2}{(\omega_j^2 - \omega^2) + i\omega\Gamma_j}$$

$$\varepsilon_r = 1 + \sigma(\omega)/i\omega\varepsilon_0$$

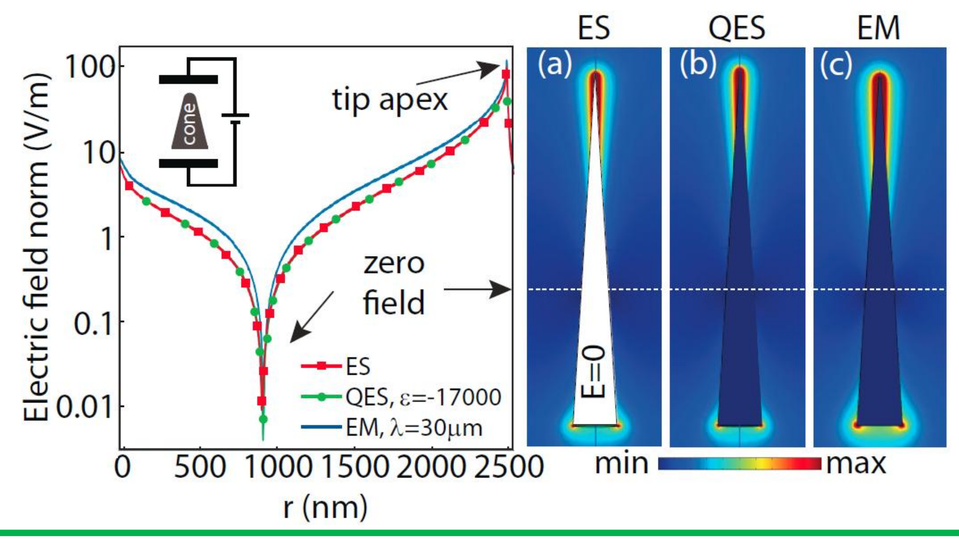
- Asymmetric nodes
- Adiabatic compression ($v_g \rightarrow 0$)





[1,2]

2. ES, QES, EM: a comparison



- ES: equipotential condition (E=1 V/m; no field oscillations→ ε not defined)
- QES: very slow oscillation, no magnetic field (E= 1 V/m; λ= 10 THz ≈ 30 μm → quasi-static approximation; ε=-17000)

- EM: very slow oscillation, full Maxwell's equations (E= 1V/m; λ= 10 THz ≈ 30 μm; ε=-17000)

ES = QES

ES = QES ≈ EM

Electrostatic equations

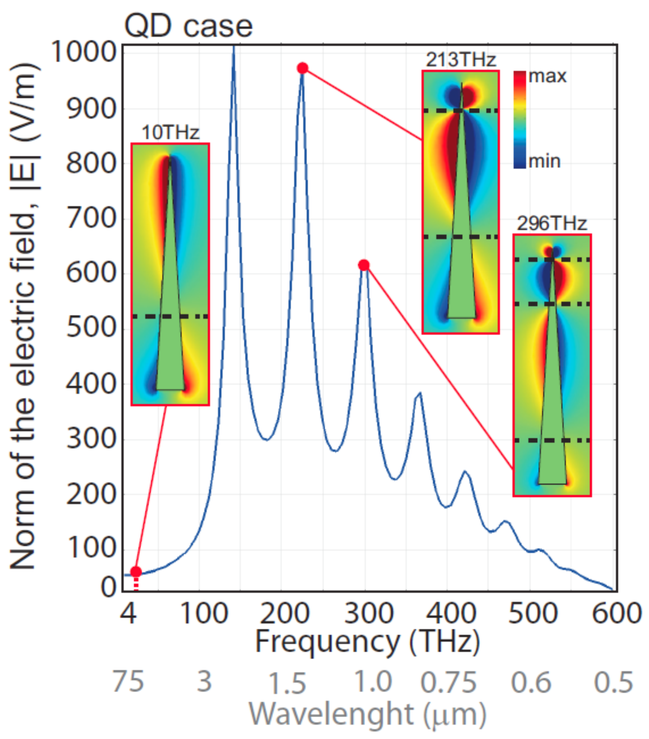
$$\vec{D} = \varepsilon_0 \varepsilon_r \vec{E}$$
$$\nabla \cdot \vec{D} = \rho$$
$$\vec{E} = -\nabla V$$

4. QD

- Fast oscillating potential
- NO magnetic contribution

$$\vec{D} = \varepsilon_0 \varepsilon_r \vec{E}$$
$$\nabla \cdot \vec{D} = \rho$$
$$\vec{E} = -\nabla V$$
$$\nabla \cdot \vec{J} + \frac{\partial \rho}{\partial t} = 0$$
$$\vec{J} = i\omega\vec{D} = \sigma(\omega)E + \varepsilon_0 \frac{\partial E}{\partial t}$$

Blue shift & higher field amplitude with respect to EM case



5. QD vs. EM

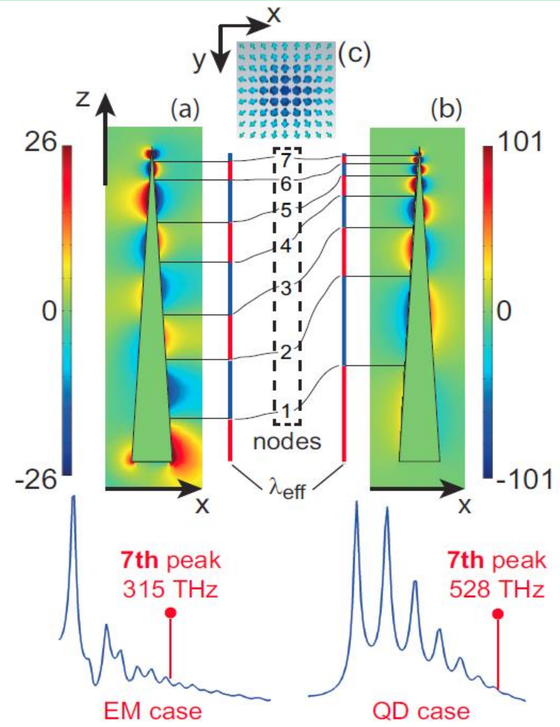
Adiabatic compression

↓

EM & QD!

↓

μ does NOT determine the adiabatic compression behaviour



6. The role of μ

- Saturation points

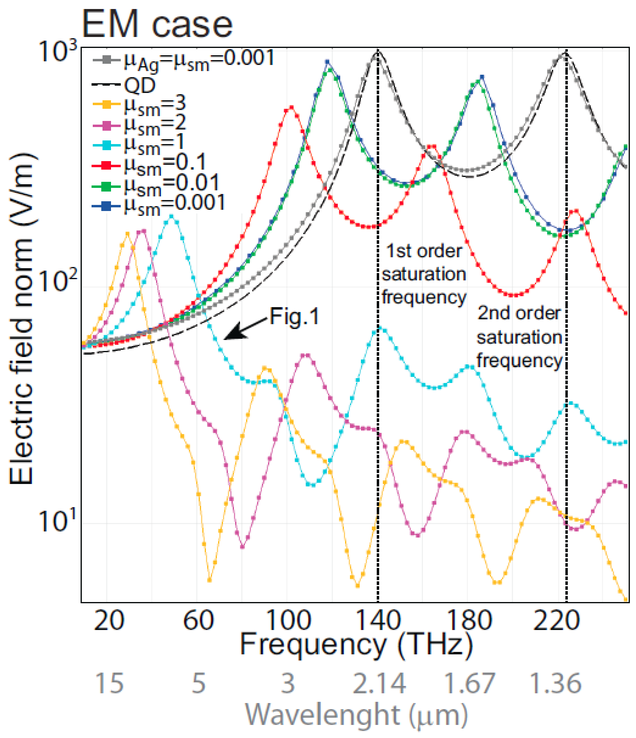
- Blue-shift & amplitude increase with decreasing μ (QD amplitude > EM amplitude)

Oscillating dipole

$$\begin{cases} \vec{E} = -\vec{\nabla}V - \frac{\partial \vec{A}}{\partial t} \\ \vec{A} = \frac{\mu}{4\pi}\frac{\dot{\vec{p}}}{r} \end{cases}$$

- Amplitude reduction with increasing ω (dipole behaviour)

[3]



Conclusion:

we have found that adiabatic compression needs only an electric contribution to be generated. In fact, the magnetic contribution plays a role mostly in determining the resonances position. This result can lead to the realization of energy concentrators which do not make use of laser systems, but instead based on purely electrical excitation (e.g., tunneling electrons).

*[1] **Superfocusing of surface polaritons in the conical structure***, A. J. Babadjanyan, N. L. Margaryan, and Kh. V. Nerkararyan, J. Appl. Phys. 87, 3785–3788 (2000).

*[2] **Fully analytical description of adiabatic compression in dissipative polaritonic structures***, R. Proietti Zaccaria, A. Alabastri, A. Toma, et al., Phys. Rev. B 86, 03540 (2012).

*[3] **Interplay between electric and magnetic field in adiabatic polaritonic systems***, A. Alabastri, A. Toma, C. Liberale, M. Chirumamilla, A. Giugni, F. De Angelis, G. Das, E. Di Fabrizio, and R. Proietti Zaccaria, Opt. Exp. 21, 7538 (2013).