

# Effects of nonlocal response in metallic nanostructures

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## Hydrodynamic Model

Main equations:

The equations constituting the nonlocal hydrodynamic model are

$$\nabla \times \nabla \times \mathbf{E}(\mathbf{r}, \omega) = \epsilon_{\infty}(\omega) \frac{\omega^2}{c^2} \mathbf{E}(\mathbf{r}, \omega) + i\omega\mu_0 \mathbf{J}(\mathbf{r}, \omega)$$

$$\mathbf{J}(\mathbf{r}, \omega) = \sigma(\omega) \mathbf{E}(\mathbf{r}, \omega) - \frac{\beta^2}{\omega^2 + i\omega\gamma} \nabla [\nabla \cdot \mathbf{J}(\mathbf{r}, \omega)]$$

where  $\beta^2 = \frac{3}{5}v_F^2$  is the nonlocal parameter and  $v_F$  is the Fermi velocity.

Boundary conditions:

Maxwell's usual boundary conditions must be augmented with an additional boundary condition, determined from the continuity equation

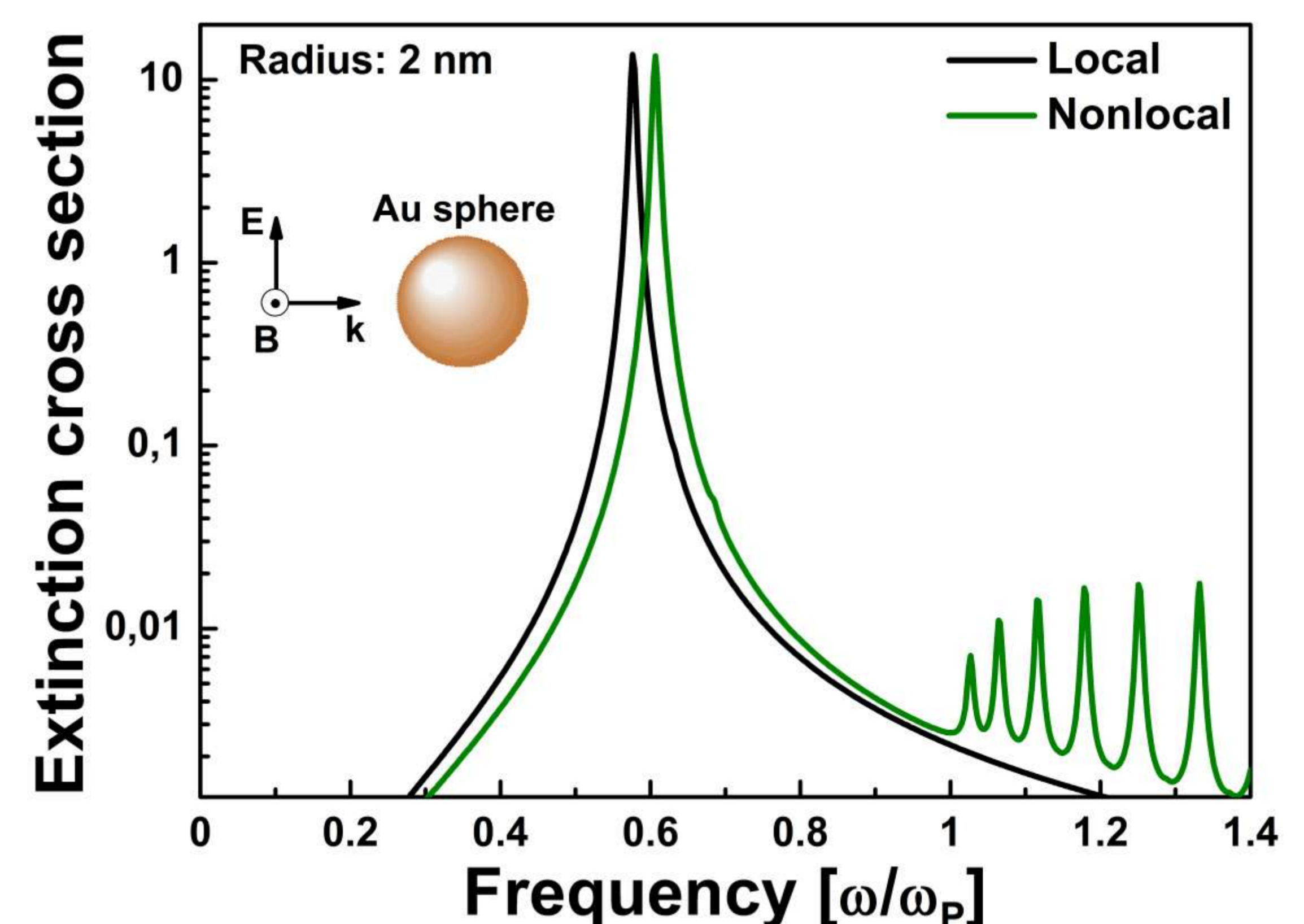
$$\mathbf{n} \cdot \mathbf{J}(\mathbf{r}, \omega) = 0$$

S. Raza et al., Phys. Rev. B 84, 121412(R) (2011)

## Isolated Nanoparticles

The two main effects of nonlocal response on single particles are

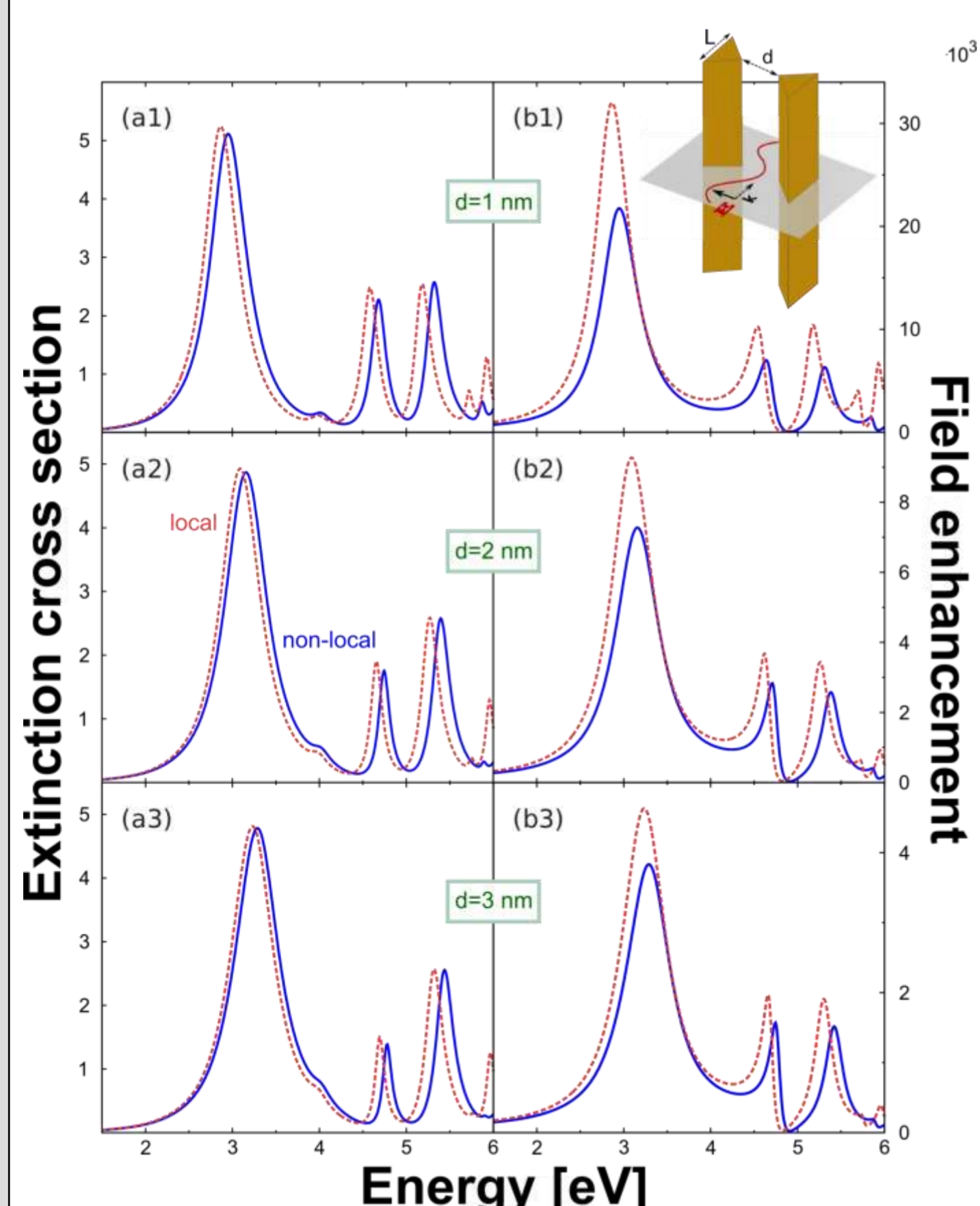
- I. The **blueshift** of the localized surface plasmon resonance
- II. The new **resonances above the plasma frequency** due to the excitation of longitudinal (pressure) waves



S. Raza et al., Phys. Rev. B 84, 121412(R) (2011)

## Field Enhancement

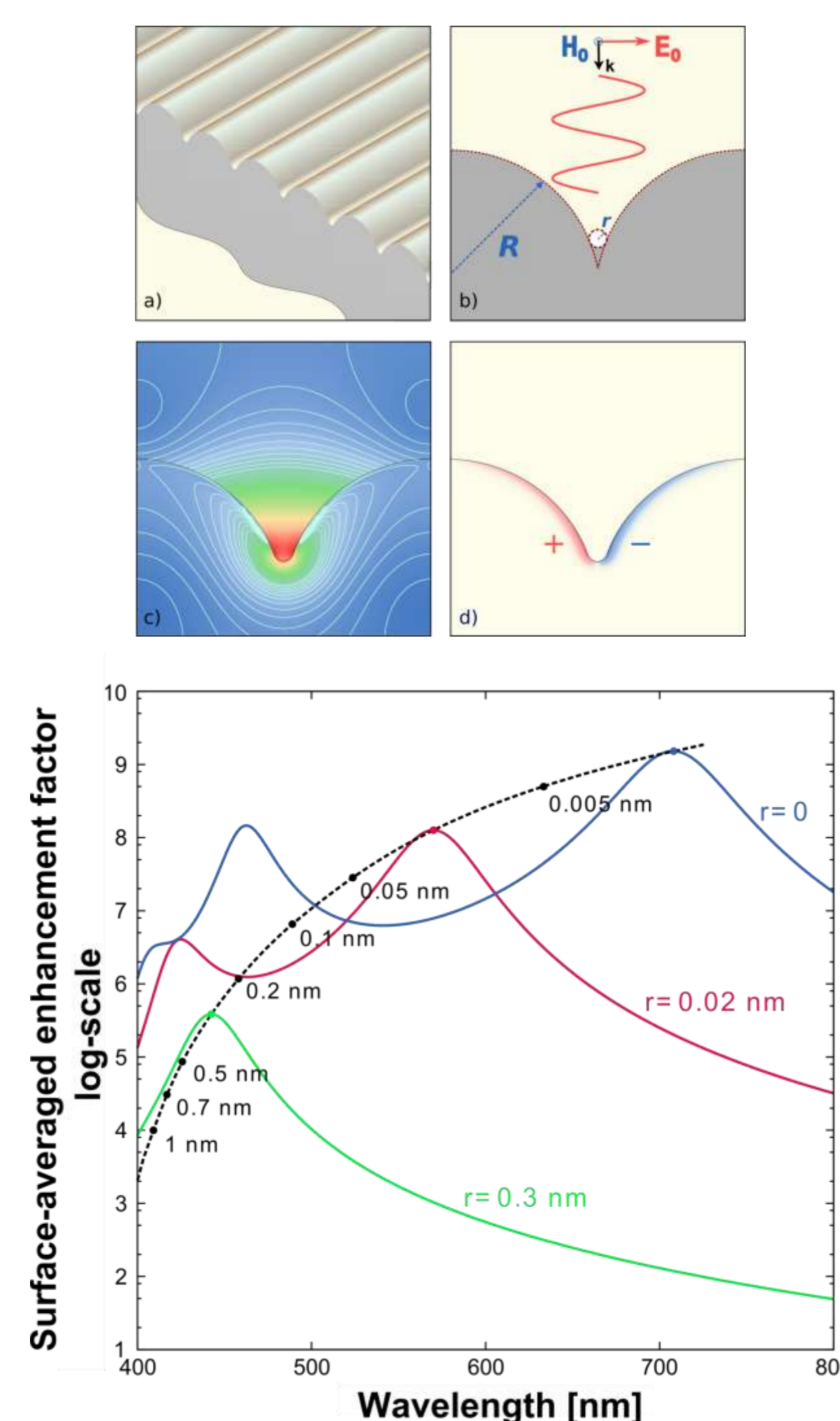
Nonlocal response **reduces field enhancement** and **keeps fields from diverging in infinitely sharp corners** (such as triangular shaped rods and kissing dimers).



G. Toscano et al., Opt. Express 20, 4146 (2012)

## SERS

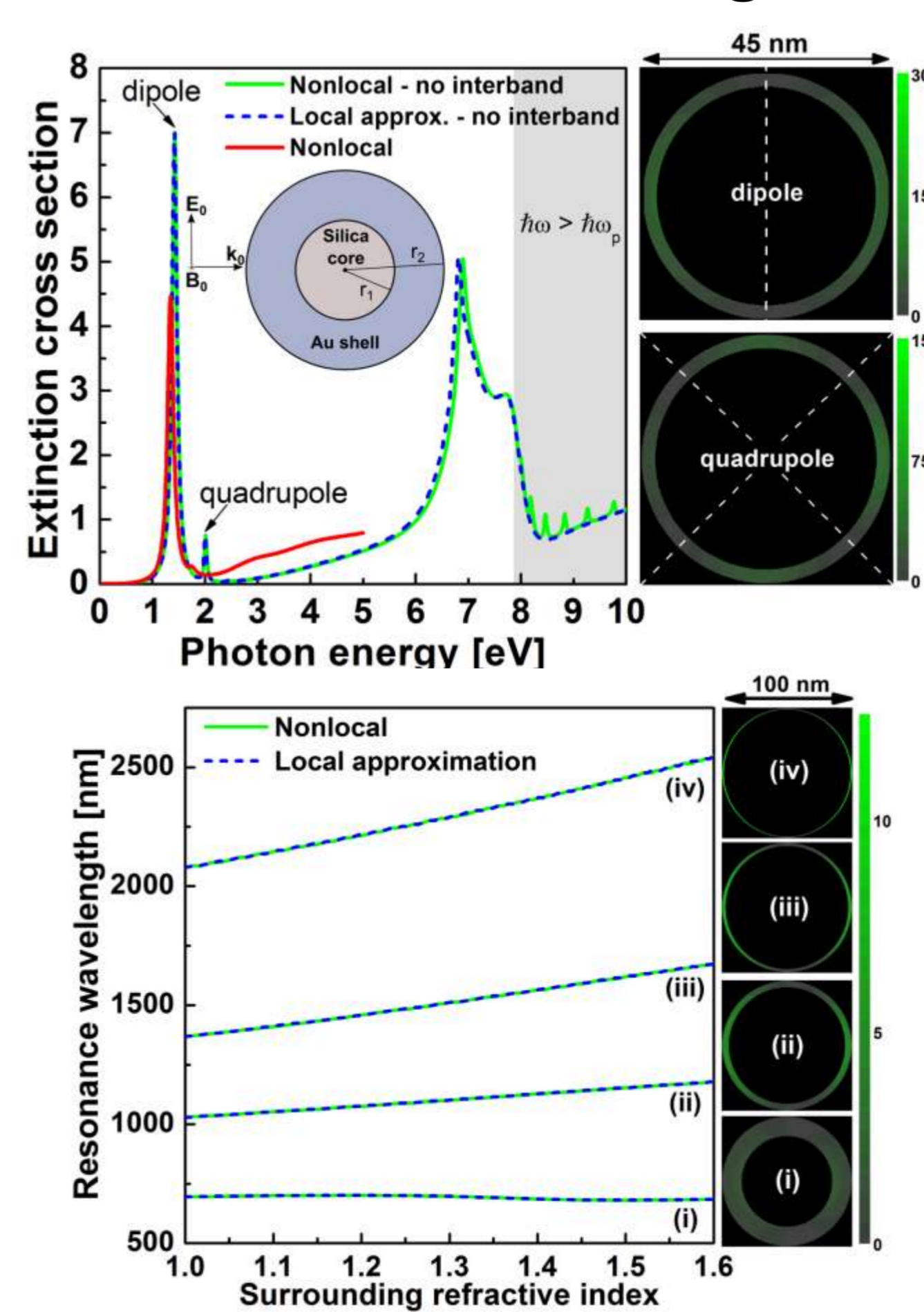
Surface enhancement factor **stays finite** due to nonlocal response.



G. Toscano et al., Opt. Lett. 37, 2538 (2012)

## Sensing

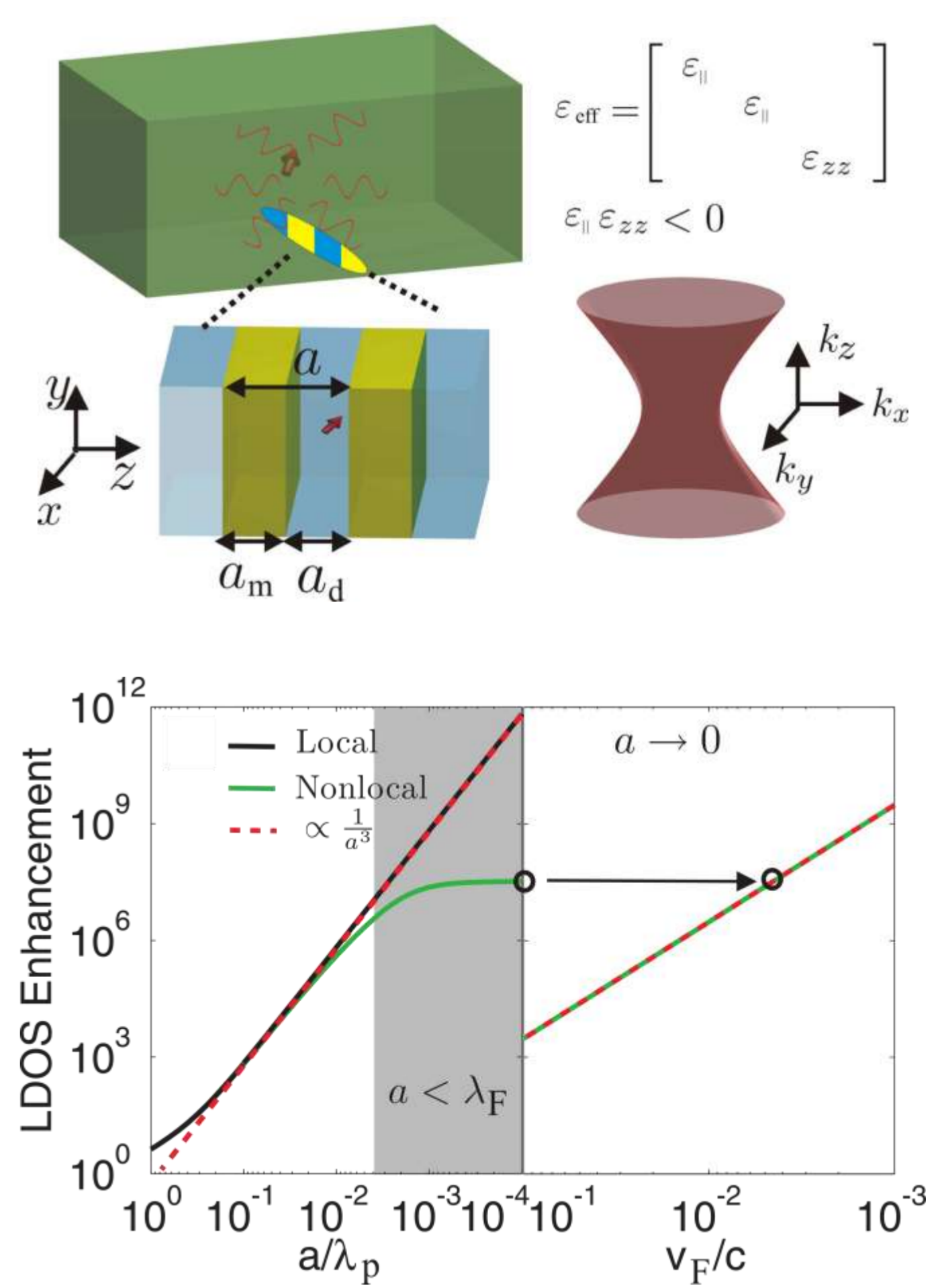
Biosensing based on localized surface plasmons is not influenced by nonlocal response due to the low excitation energy ( $< 1-2$  eV). The **nonlocal blueshift decreases for low energies**.



S. Raza et al., Plasmonics 7, (2012)

## Hyperbolic MM

Nonlocal response **regularizes the broadband super-singularity of the local density-of-states (LDOS)** in hyperbolic metamaterials.



W. Yan et al., arXiv:1204.5413, (2012)

