On how to turn quantum dynamical phase transitions into plasmonic applications.

Raúl A. Bustos Marún,[1,2] Axel D. Dente,[1] Eduardo A. Coronado,[2] and Horacio M. Pastawski. [1]

[1]IFEG, Facultad de Matemática Astronomía y Física, Universidad Nacional de Córdoba, Córdoba, Argentina
[2]INFIQC, Facultad de Ciencias Químicas, Universidad Nacional de Córdoba, Córdoba, Argentina

rbustos@famaf.unc.edu.ar

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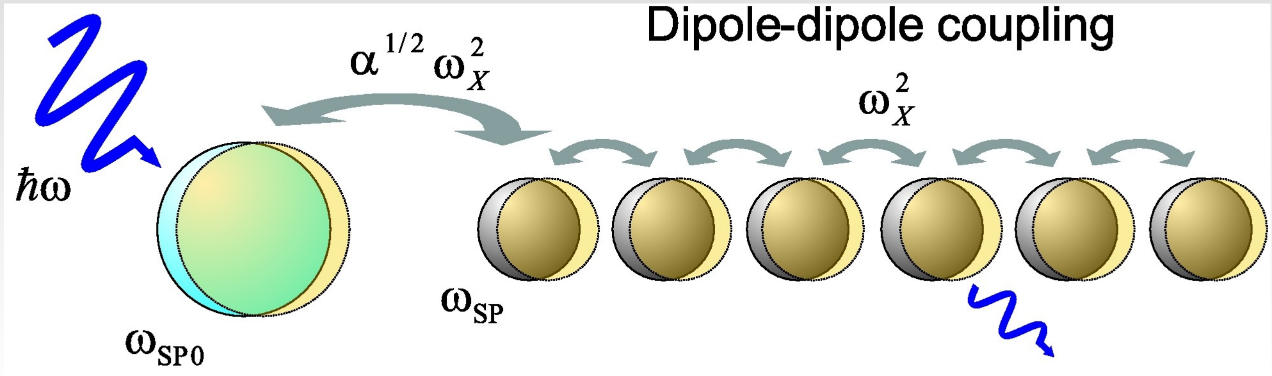
- **Injection of excitations into waveguides.**
  (Localized-delocalized transition and role of virtual states)

- **Using dynamical phase transition in plasmonics.**
  (Nano-rulers, dielectric constant sensors, and deformation sensors)

- **Plasmonic synchronization.**
  (New possibilities at the nanoscale)

Injection of excitations into waveguides.

The system



Coupled dipole approximation

$$[\omega_{SPi}^2-\omega^2-i\,\eta_i\omega]\vec{P}_i=V_i\,\omega_{Pi}^2\epsilon_0\left[\vec{E}_i^{(ext)}+\sum_{j\neq i}^{N}\vec{E}_{j,i}(\vec{P}_j,\vec{d}_{j,i}\vec{k})\right]$$

Near field approximation

$$\vec{E}_{j,i}(\vec{P}_j,\vec{d}_{j,i}\vec{k})_{kd\to 0}\approx\frac{\vec{P}_j-3\hat{d}_{j,i}(\vec{P}_j\cdot\hat{d}_{j,i})}{4\pi\,\epsilon_0 n^2 d_{j,i}^3}=\frac{\gamma^{T/L}}{4\pi\,\epsilon_0 n^2 d_{j,i}^3}\vec{P}_j$$

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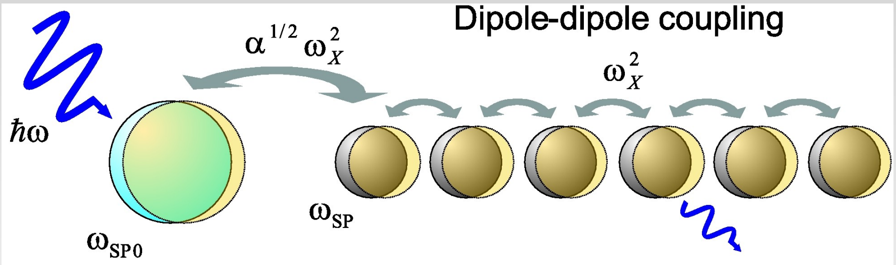
Response function



$$\boxed{|P_m|^2 = |\chi_{m,0}|^2 |E_0^{(ext)}|^2}$$

$$\boxed{\chi_{m,0}(\omega) = \chi_{0,0}(\omega)\,\alpha^{1/2} e^{-m(\kappa + ik)}}$$

$$\vec{P} = \left[\omega^2 \boldsymbol{I} - \boldsymbol{M}\right]^{-1} \boldsymbol{R}\,\vec{E} = \boldsymbol{\chi}\,\vec{E}$$

$$\chi_{0,0}(\omega) = \frac{V_0\,\omega_{P0}^2\,\epsilon_0}{[\omega^2 - \tilde{\omega}_{SP0}^2] - \alpha\,\Pi(\omega)}$$

$$\boldsymbol{M} = \begin{bmatrix} \omega_{SP0}^2 - i\eta\omega & \omega_{x0-1}^2 & 0 & 0 \\ \omega_{x1-0}^2 & \omega_{SP}^2 - i\eta\omega & \omega_x^2 & 0 \\ 0 & \omega_x^2 & \omega_{SP}^2 - i\eta\omega & \omega_x^2 \\ 0 & 0 & \omega_x^2 & \ddots \end{bmatrix}$$

$$\alpha^{1/2} = \frac{\omega_{x1-0}^2}{\omega_x^2}$$

$$\kappa + ik = \ln(\omega_x^2 / \Pi)$$

$$\omega_{xi-j}^2 = \frac{\gamma^{T,L}\,\omega_{Pi}^2}{3n^2}\left(\frac{r_i}{d_{i,j}}\right)^3$$

$$\Pi = \frac{(\omega^2 - \tilde{\omega}_{SP}^2)}{2} - sgn(\omega^2 - \omega_{SP}^2)\sqrt{\left(\frac{\omega^2 - \tilde{\omega}_{SP}^2}{2}\right)^2 - \omega_x^4}$$

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Poles of the response function

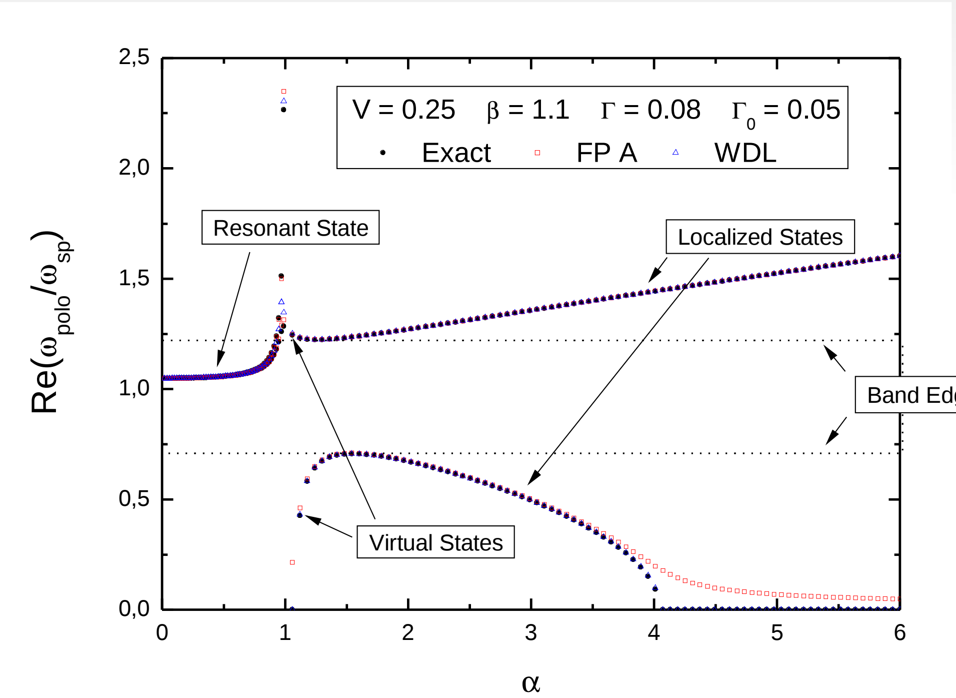
$$M=\begin{bmatrix} \omega_{SP0}^2-i\eta\omega & \omega_{x0-1}^2 & 0 & 0 \\ \omega_{x1-0}^2 & \omega_{SP}^2-i\eta\omega & \omega_x^2 & 0 \\ 0 & \omega_x^2 & \omega_{SP}^2-i\eta\omega & \omega_x^2 \\ 0 & 0 & \omega_x^2 & \ddots \end{bmatrix}$$

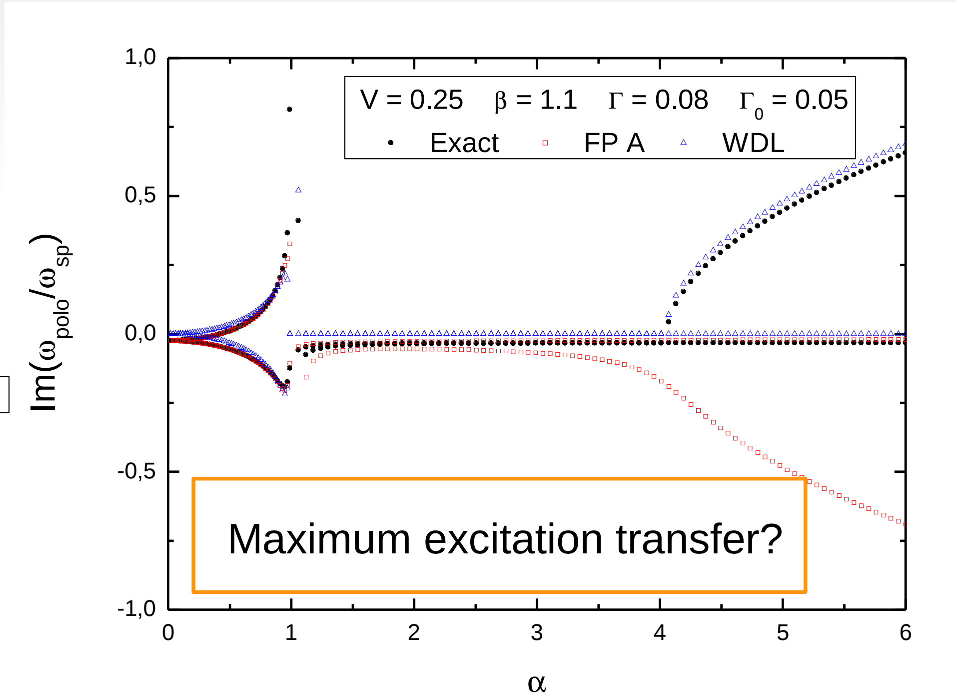
$$\boxed{\chi_{0,0}(\omega)=\frac{V_0\,\omega_{P0}^2\epsilon_0}{[\omega^2-\tilde{\omega}_{SP0}^2]-\alpha\,\Pi(\omega)}}$$

$$\Pi=\frac{(\omega^2-\tilde{\omega}_{SP}^2)}{2}-sgn(\omega^2-\omega_{SP}^2)\sqrt{\left(\frac{\omega^2-\tilde{\omega}_{SP}^2}{2}\right)^2-\omega_x^4}$$

$$\alpha=\frac{\omega_{x0-1}^2}{\omega_X^2}\quad \beta=\frac{\tilde{\omega}_{SP0}^2}{\tilde{\omega}_{SP}^2}\quad V=\frac{\omega_x^2}{\tilde{\omega}_{SP}^2}$$

$$\boxed{\tilde{\omega}_{pole}^2=\frac{[\beta-\alpha(\beta+1)/2]}{(1-\alpha)}\pm\frac{\alpha}{2(1-\alpha)}\sqrt{(1-\beta)^2-4V^2(1-\alpha)}}$$





Real and imaginary part of the poles of the response function as function of the relative coupling between nanoparticle “0” and the chain (α).

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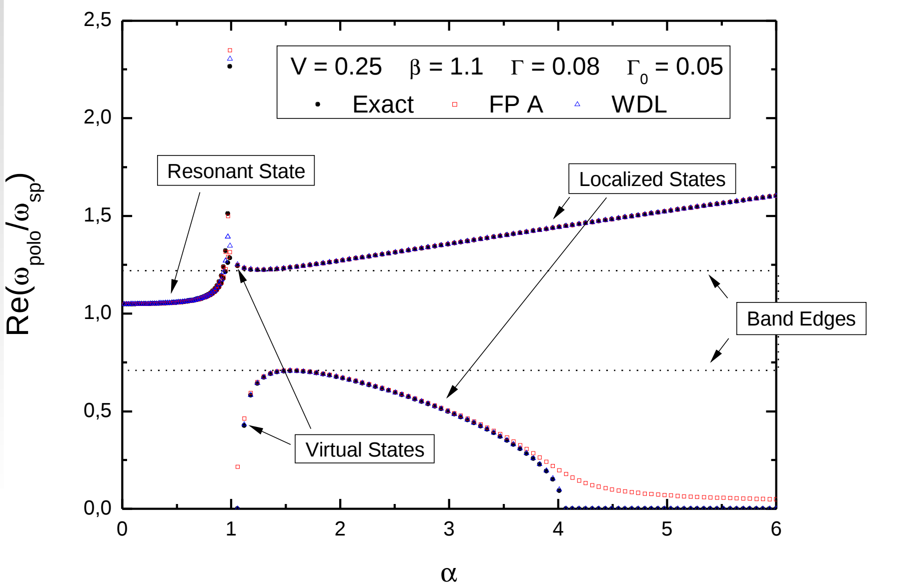
What is a virtual state?



They appear as solutions of the pole equation

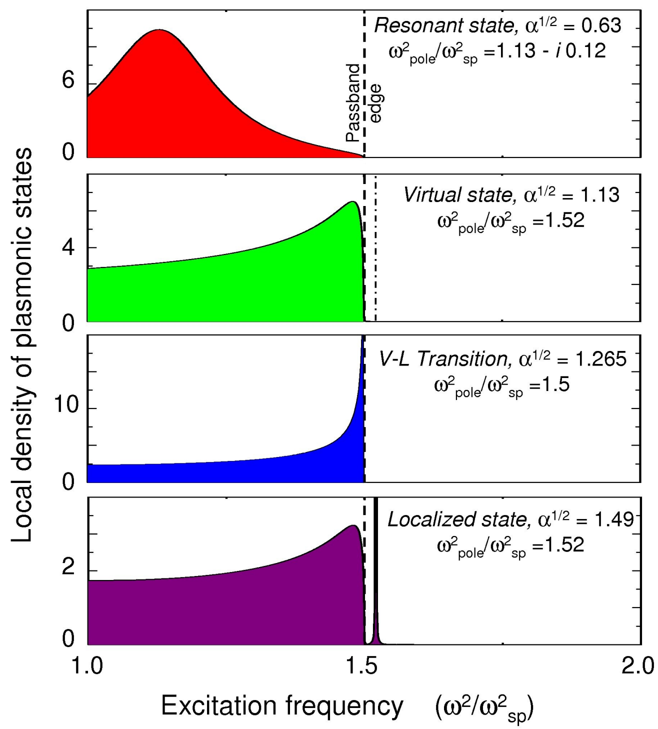
$$\tilde{\omega}^2_{pole} = \frac{[\beta - \alpha(\beta+1)/2]}{(1-\alpha)} \pm \frac{\alpha}{2(1-\alpha)}\sqrt{(1-\beta)^2 - 4V^2(1-\alpha)}$$

Pole of a non-physical response function

$$\chi'_{0,0}(\omega) = \frac{V_0 \omega^2_{P0} \epsilon_0}{[\omega^2 - \tilde{\omega}^2_{SP0}] - \alpha \boldsymbol{\Pi}'}$$

Non-physical sef-energy

$$\boldsymbol{\Pi}'(\omega) = \Delta(\omega) + i\Gamma(\omega)$$



Why care?

$$\Im(\chi_{0,0}) \approx \frac{-V_0 \omega^2_{P0} \epsilon_0 \alpha \Gamma}{[\omega^2 - \tilde{\omega}^2_{SP0} - \alpha\Delta]^2 + \alpha^2\Gamma^2} \qquad \Im(\chi'_{0,0}) \approx \frac{V_0 \omega^2_{P0} \epsilon_0 \alpha \Gamma}{[\omega^2 - \tilde{\omega}^2_{SP0} - \alpha\Delta]^2 + \alpha^2\Gamma^2}$$

Within the passband, the poles of the LDOS are the same!!!

They describe the localized-delocalized transition.

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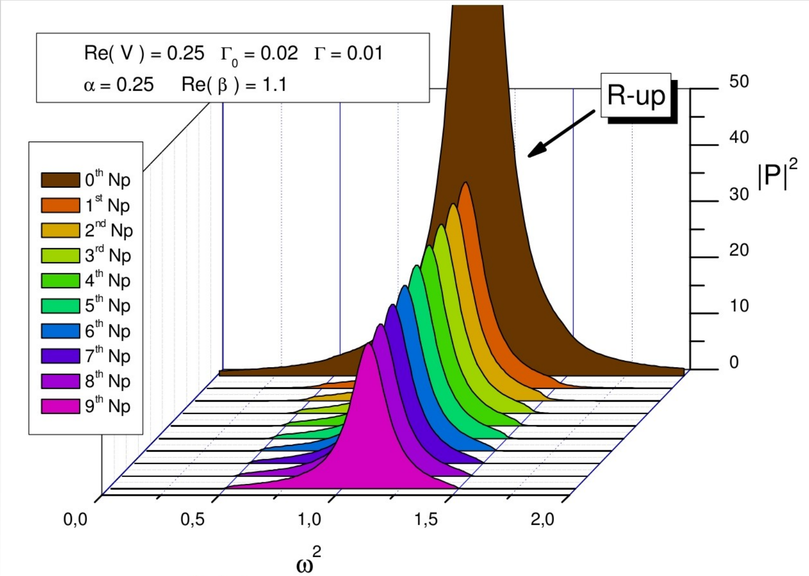
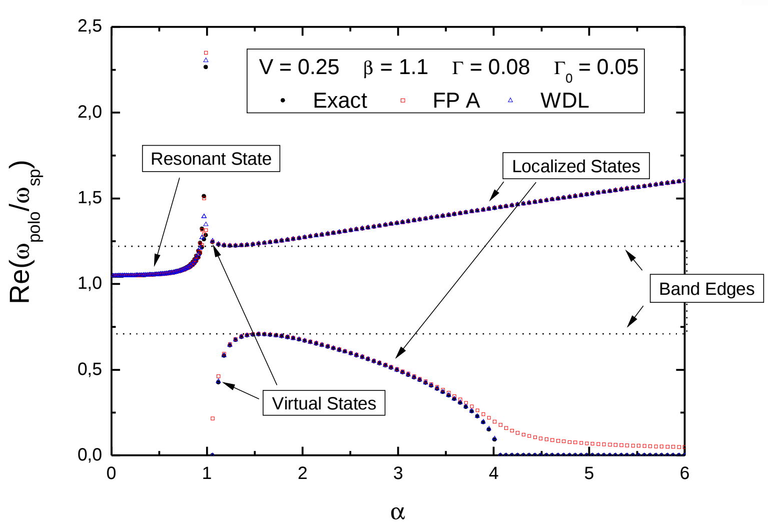
Propagation of the excitation

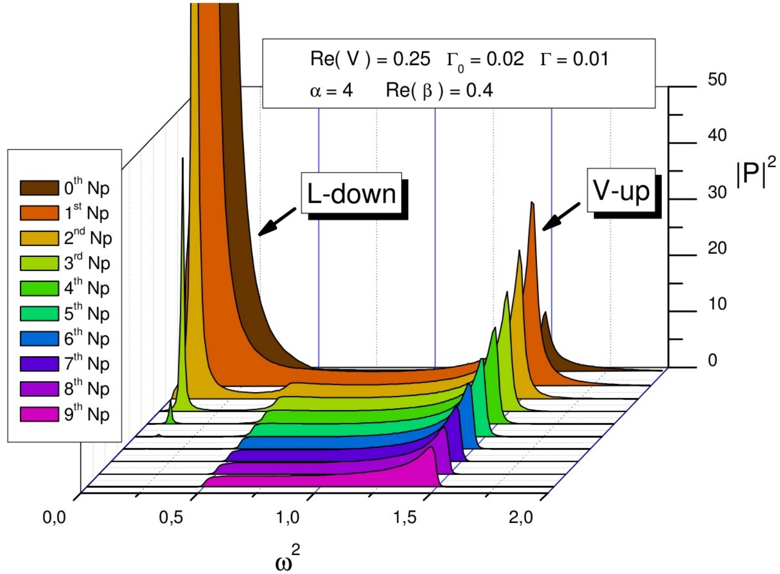
$$|P_m|^2 = |\chi_{m,0}|^2 |E_0^{(ext)}|^2$$

$$\chi_{m,0}(\omega) = \chi_{0,0}(\omega)\alpha^{1/2} e^{-m(\kappa+ik)}$$

$$\kappa + ik = \ln(\omega_x^2/\Pi)$$







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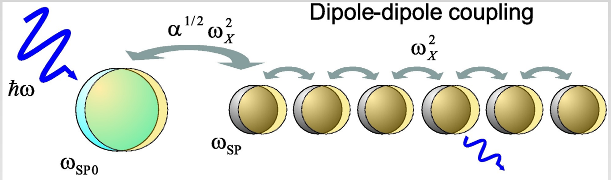
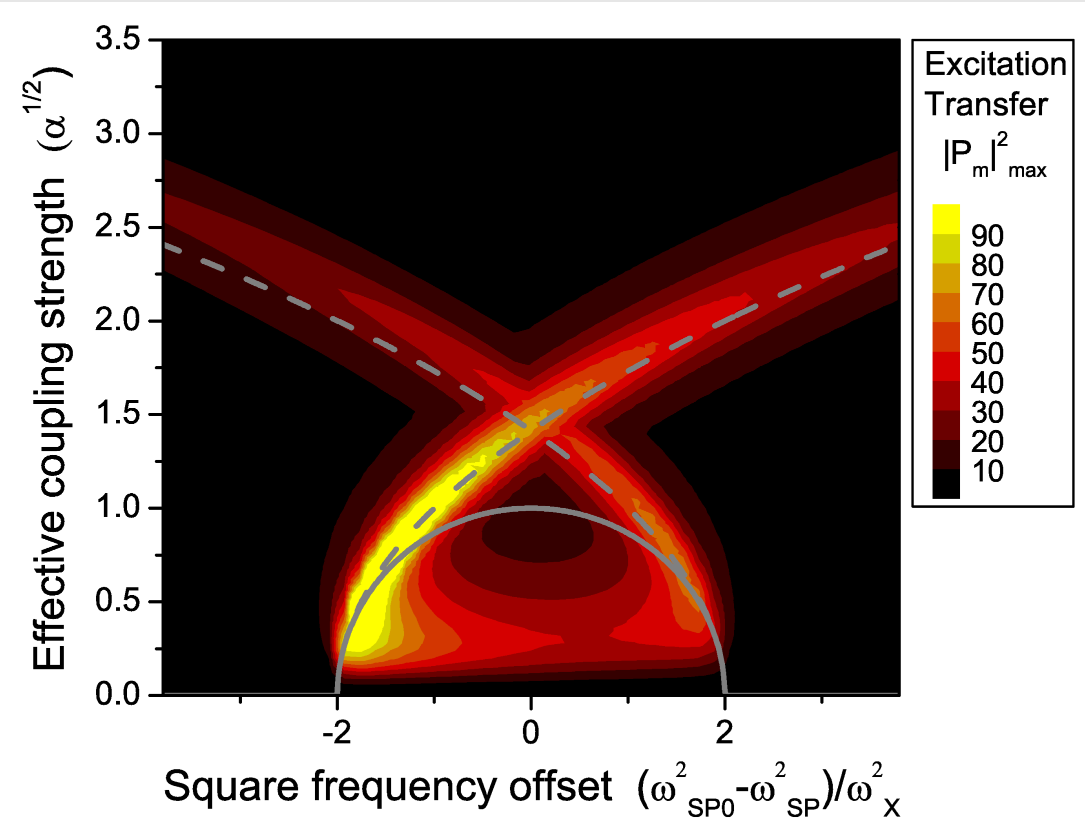
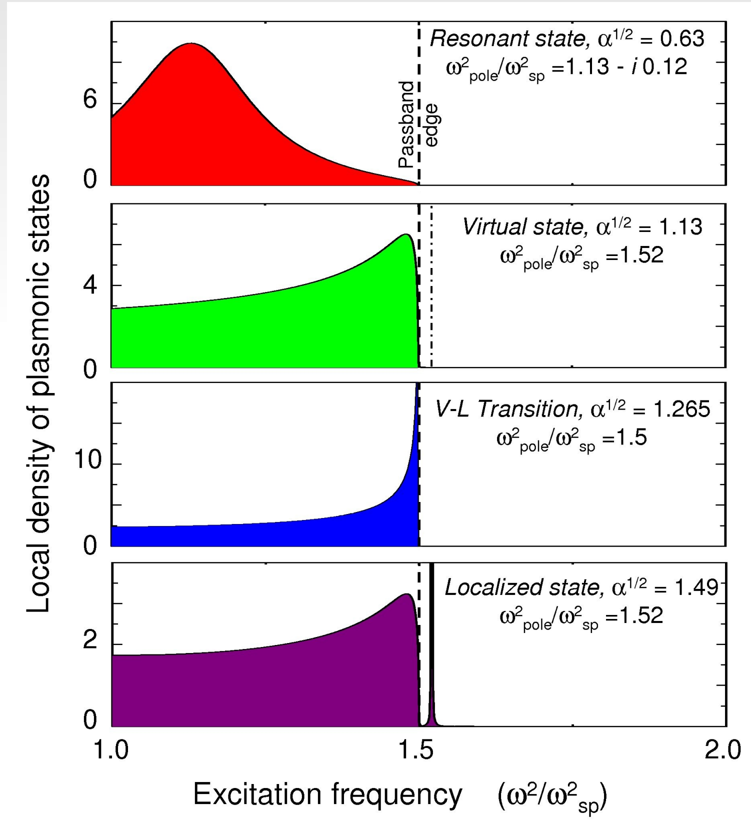
Phase diagram



At the virtual-localized transition there is an accumulation of states at the passband edge.





Dynamical phase transitions control excitation transfer!!!

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Using DPTs in a concrete plasmonic example.

Nps modeled as Dipoles

=> small Nps => size and shape corrections to damping

Dipolar interaction

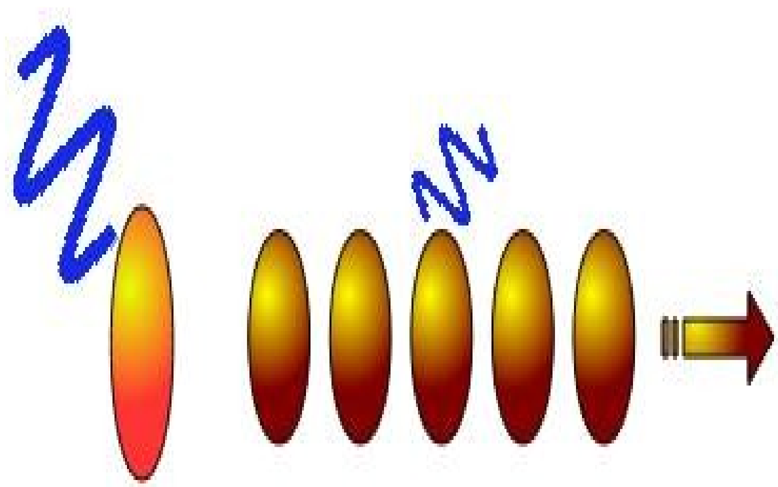
=> distance/radius not too small

...but...

Near field approximation

=> Small separation

Are stronger damping compensated by stronger coupling?
Are "needed parameters" within actual limits?

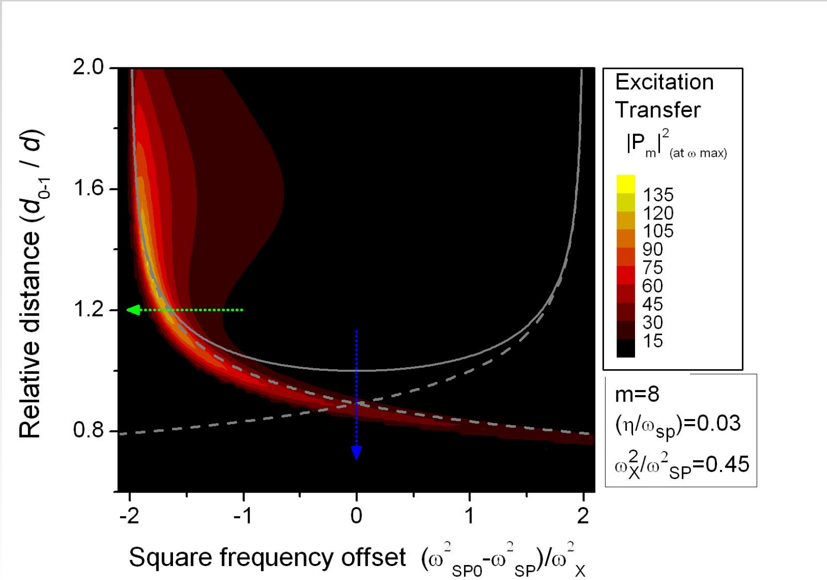


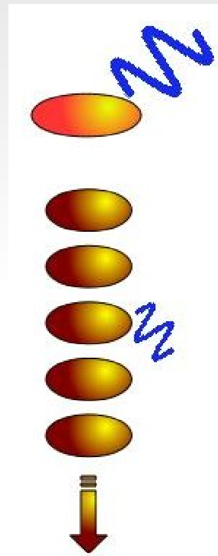
YES!!
Ag Spheroidal NPs
Dimensions: a=3nm, b=c=10.5nm
Separation d=9nm

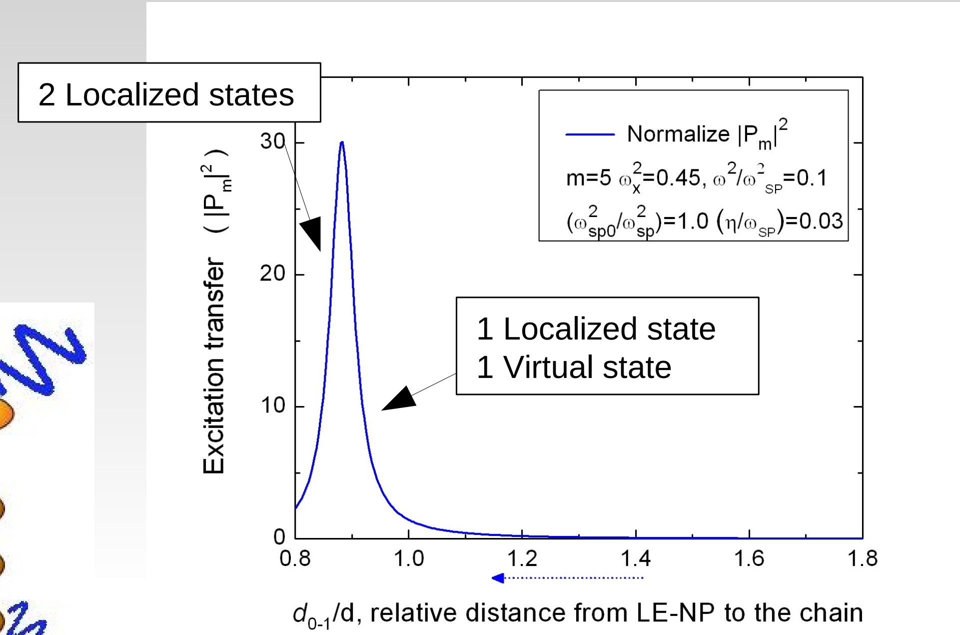
$$\frac{\omega_X^2}{\omega_{SP}^2}=0.45$$

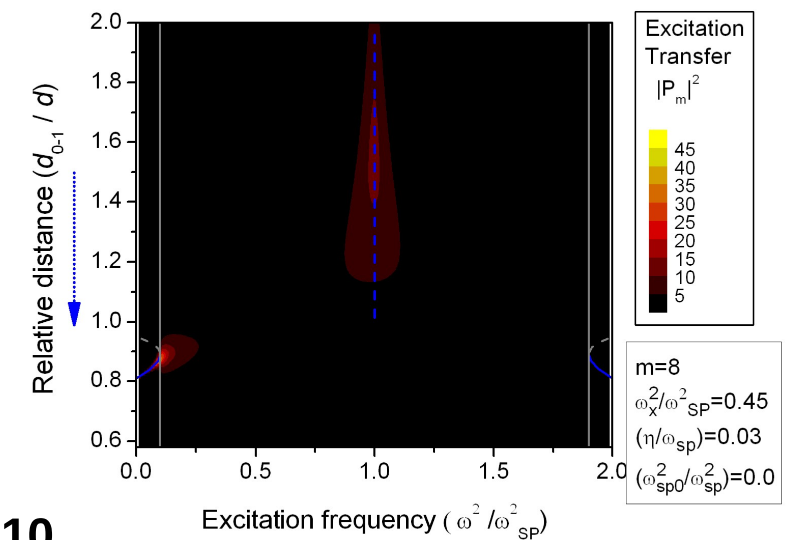
$$\frac{\eta}{\omega_{SP}}=0.03$$

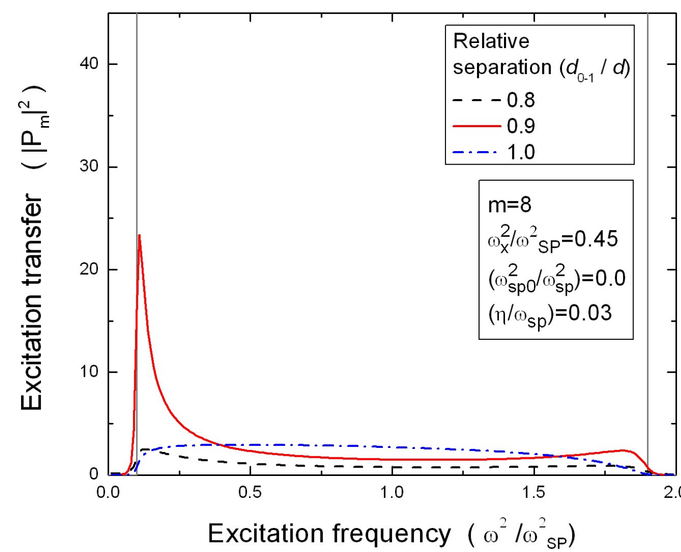
Using DPT for a Nano-ruler



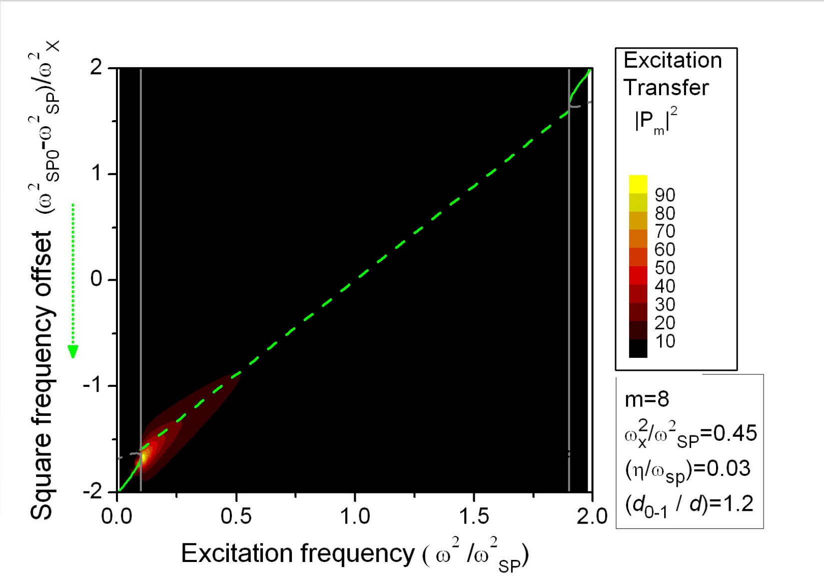


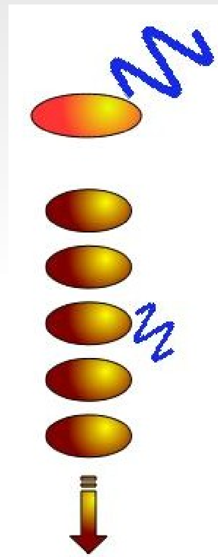


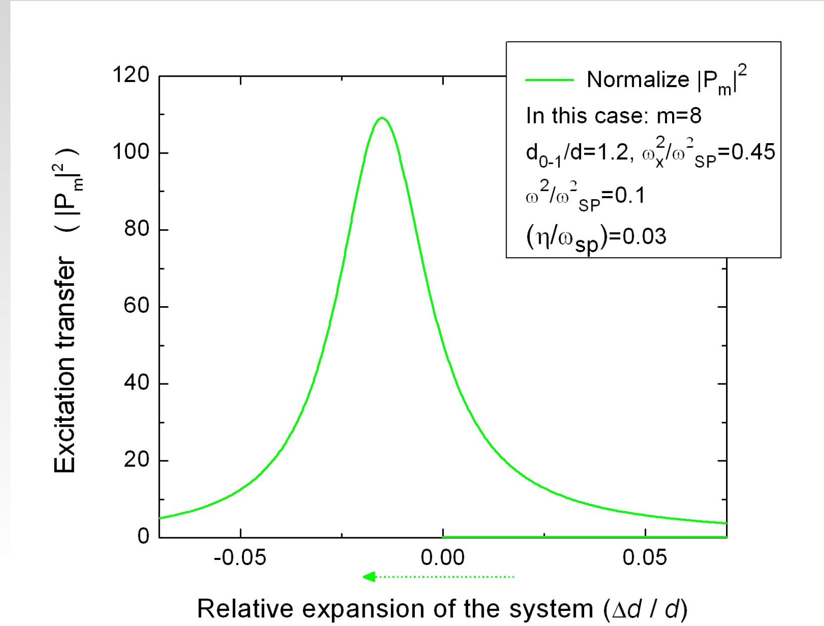


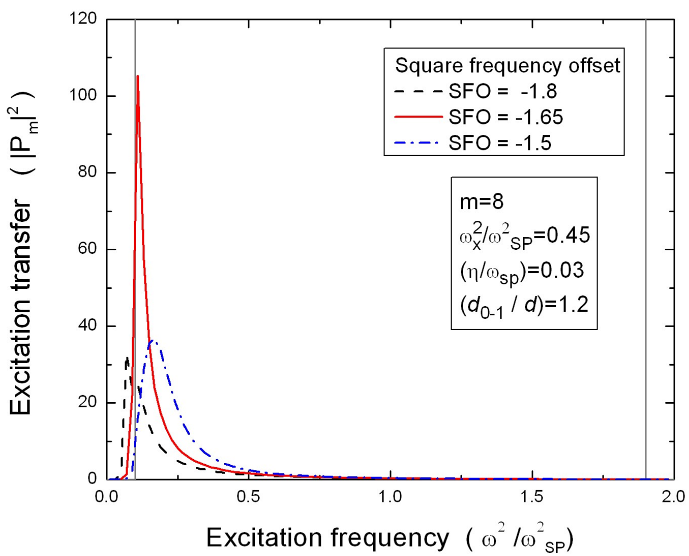


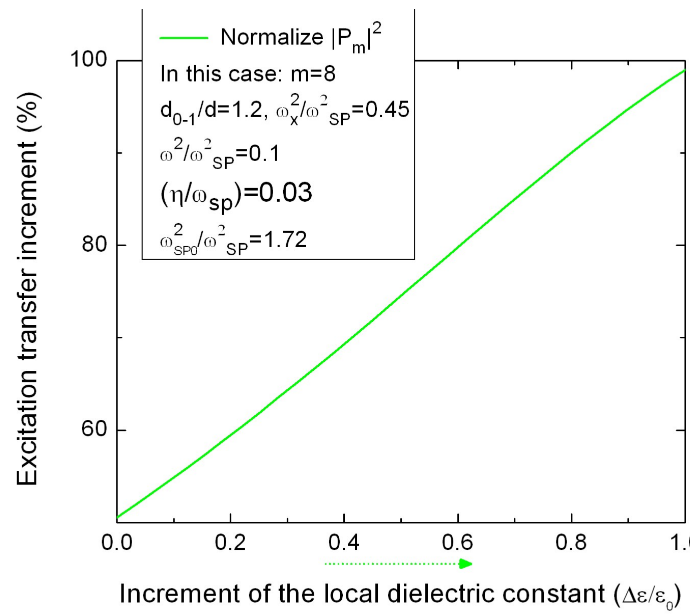
Using DPT to measure local dielectric constant and material expansion.











Conclusions:

Injection of excitations into waveguides.

• **C**ontrary to common wisdom, the largest excitation transfer **does not** occur when the poles of the response function present the **biggest imaginary part** (resonant state) but when a virtual state is transformed into a localized state.
• **E**xcitation transfer is controlled by dynamical phase transitions.
• **G**enerality of the model => conclusions applicable to great number of physical situations.

Using dynamical phase transition in plasmonic.

• **W**e show that even under realistic conditions, DPTs still provide new tools for plasmonics.
• **T**hree examples were analyzed nano-rulers, dielectric constant sensors, and deformation sensors.

Plasmonic synchronization.

• **P**reliminary results shows that it is possible to build synchronized plasmonic circuits. Possible applications.... Initialization of plasmonic circuits?....

Thanks you very much.

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