Extension of Spring Model to Include Fano Resonance in Scattering

James Hitchcock[1], Heidar Sobhani[2], Peter Nordlander[2]

1 – University of Tennessee - Knoxville
2 – Rice Quantum Institute, Rice University

Fano resonance in gold nano-particles has several potential applications in biosensing, nanoantennas, and optical switches, but few theoretical models approach the system from a classical viewpoint [1]. A classical model carries a few advantages, such as a more intuitive grasp of the situation, as well as allowing easier explanations in an undergraduate class. This paper represents two gold nano-objects, a gold nanodisc surrounded by a gold nanoring (with the bright mode excited due to a coupling with the external light and the dark mode destructively coupled to the bright mode) as two masses coupled together by a spring in an attempt to elucidate their interaction [2,3]. We compare the prediction of our model for scattering power when the dark mode is excited with external light to the FDTD simulation result, and demonstrate that the classical model approximates the results with little error.

1) Hao, F.; Sonnefraud, Y.; Dorpe, P. V.; Maier, S. A.; Halas, N. J.;Nordlander, P. *Nano Lett.* **2008**, *8* (11), 3983–3988

2) Mukherjee, Sh.; Sobhani, H.; Lassiter, J. B.; Bardhan, R.;Nordlander, P; Halas, N. J. *Nano Lett.* **2010**, *10*, 2694–2701

3) Alzar, C. L. G.; Martinez, M. A. G.; Nussenzveig, P. *Am. J. Phys* **2002**, *70* (1), 37–41.

Extension of Spring Model to Fano Resonance in Plasmonic Systems

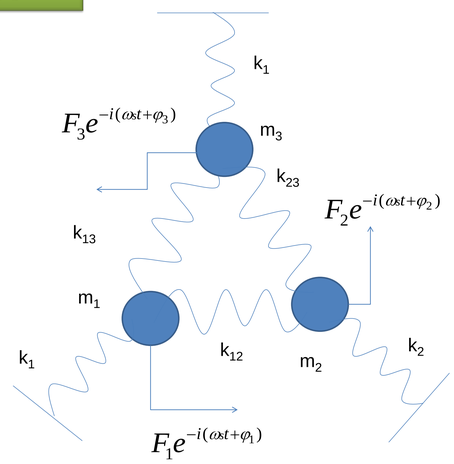
James Hitchcock[1], Heidar Sobhani[2], Peter Nordlander[2]

1 – University of Tennessee – Knoxville

2 – Rice Quantum Institute, Rice University

Ideas behind the Project

- Goal: Fano resonance in nanoscale plasmonic systems has potential applications in biosensing, nanoantennas, and optical switches.
- Problem: The in-depth theory describing fano resonance in plasmonic systems is complicated and difficult to understand.
- Solution: Utilize a classical analog of fano resonance through a joined three mass spring system.

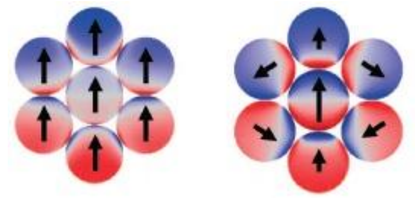


$$\beta_1\dddot{x}_1 + \ddot{x}_1 + \gamma_1\dot{x}_1 + \omega_1{}^2 x_1 - \Omega_{12}x_2 - \Omega_{13}x_3 = \frac{F_1}{m}e^{-i(\omega_s t+\varphi_1)}$$

The Modes of the Models

Subradiant Superradiant Quadrapole

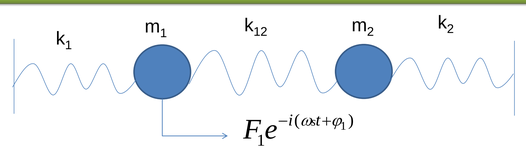
- The three primary modes of a noncocentric nanoring nanodisc system, and the surface charge distributions that generate them.
- The red is used to indicate positive charge, and the blue for negative.



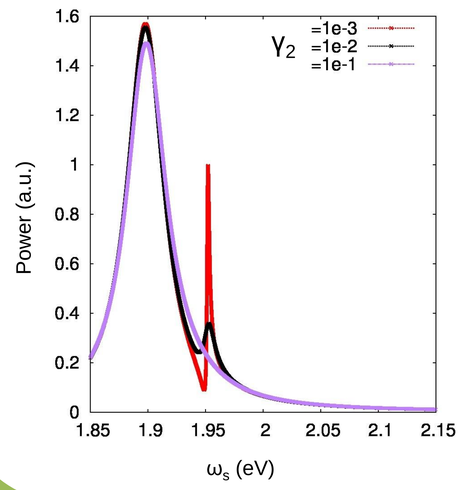
Bright Mode Dark Mode

- The two primary modes of a heptamer with their charge distributions
- The arrows indicate the direction of the charge oscillation

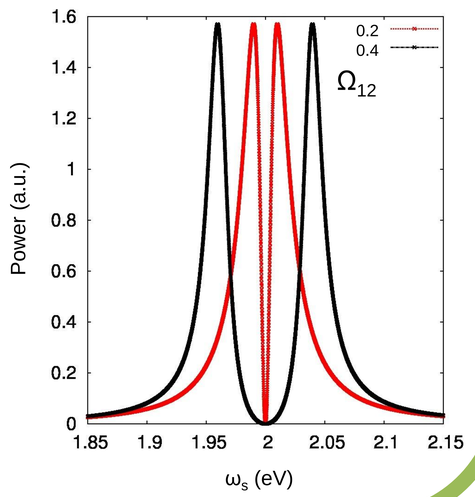
Parameter Effects on Fano Resonance



Influence of γ_2 on Fano Resonance

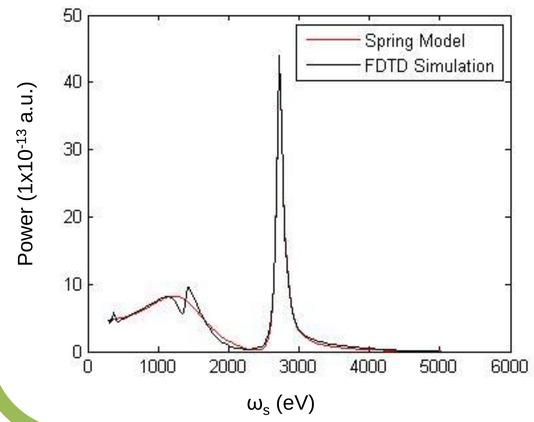


Influence of Ω_{12} on Fano Resonance

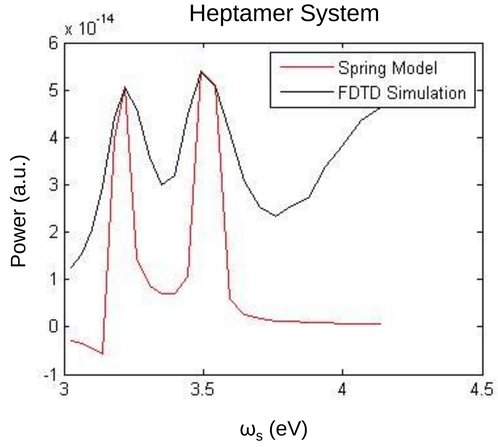


Fitting the Spring Model to Nanoscale Systems

Nanoring Nanodisc System



Heptamer System



Accounting for Higher Order Modes

- The Spring Model has great potential for being able to fit to nanoscale systems, and allowing a better intuitive grasp of Fano Resonance at the nanoscale. However, it seems that the mass spring model requires a greater number of masses to accurately fit for the higher order modes of the nanoscale systems.

This material is based upon work supported by the National Science Foundation's Partnerships for International Research & Education Program (OISE-0968405).