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Directional plasmonic nano-antennas in the visible range of the spectrum

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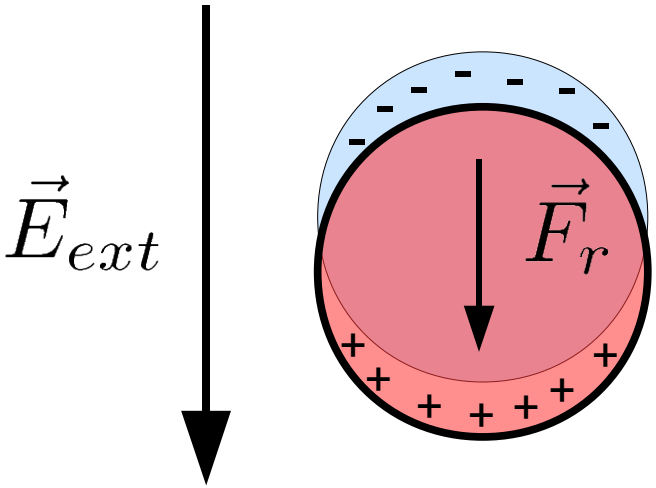
Outline

- Introduction
- Motivations: Plasmonic waveguides & RF antennas
- The model; Point-dipole approximation
- Graded linear plasmonic arrays as optical antennas
- Directionality of antennas
- Outlook

Introduction: Plasmons in metal particles



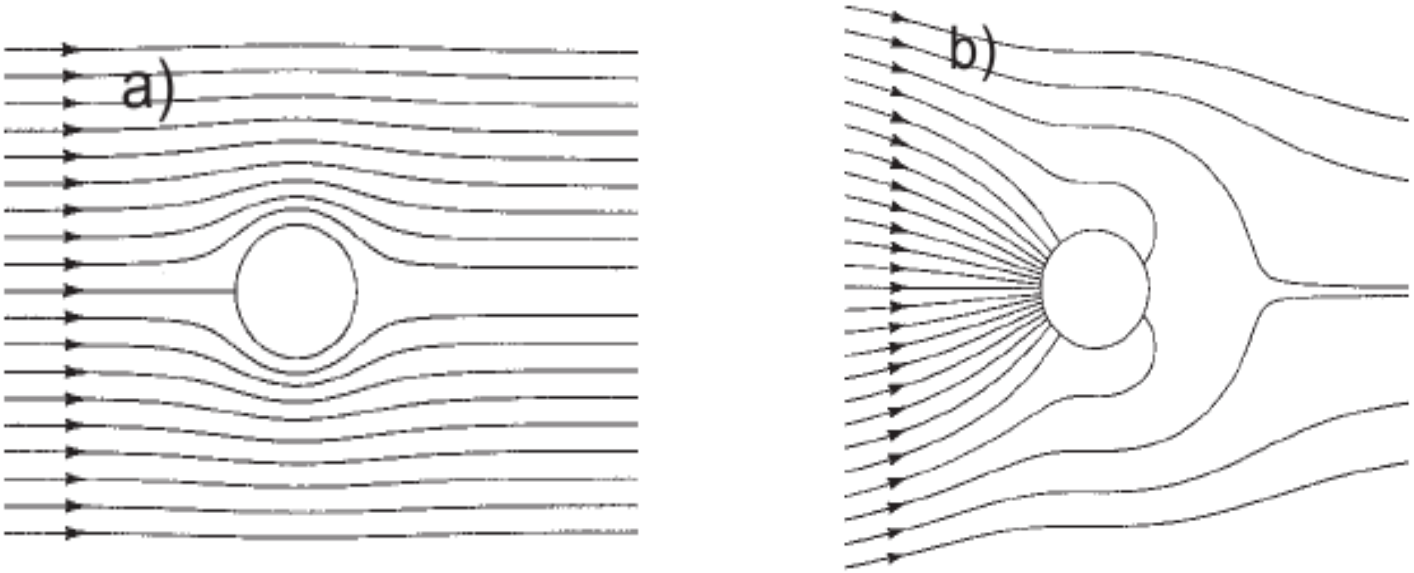
$$\vec{F}_r \quad \Rightarrow \quad \omega_p$$

Bulk metal (Drude model):

$$\omega_p = \sqrt{\frac{n\,e^2}{m}}$$

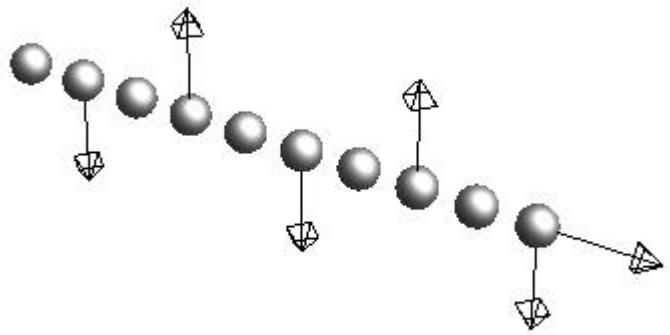
$$\varepsilon(\omega) \approx 1 - \frac{\omega_p^2}{\omega^2}$$

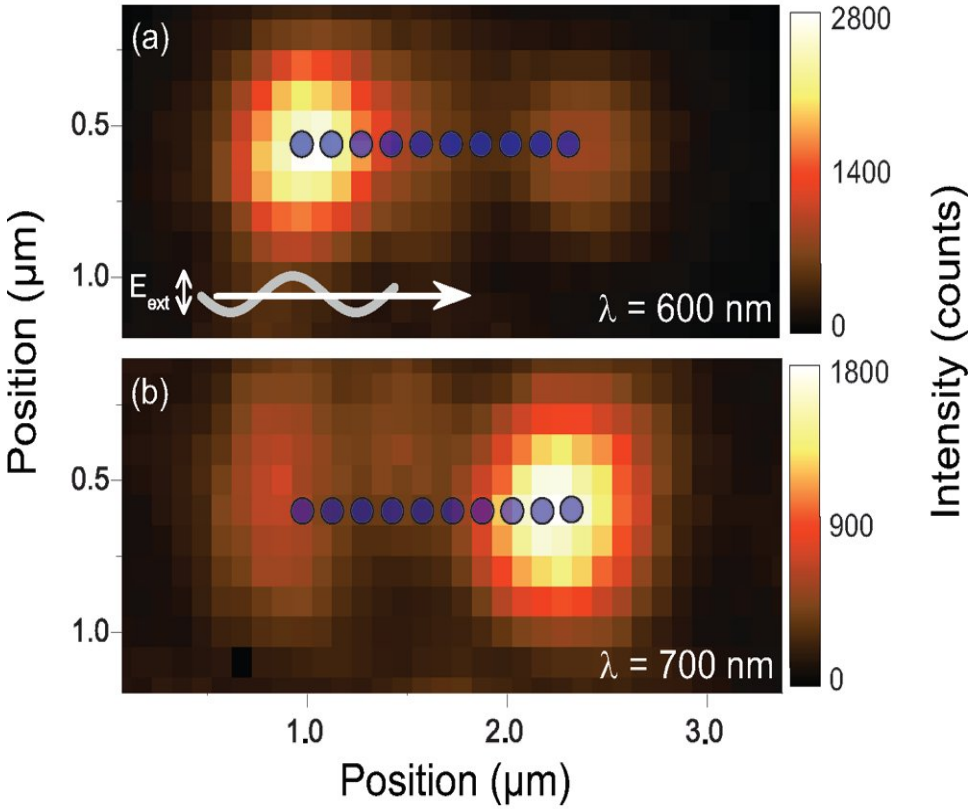
Energy flux around a metal nanoparticle



C.F.Bohren and D.R.Huffman, "Absorption and scattering of light by small particles"

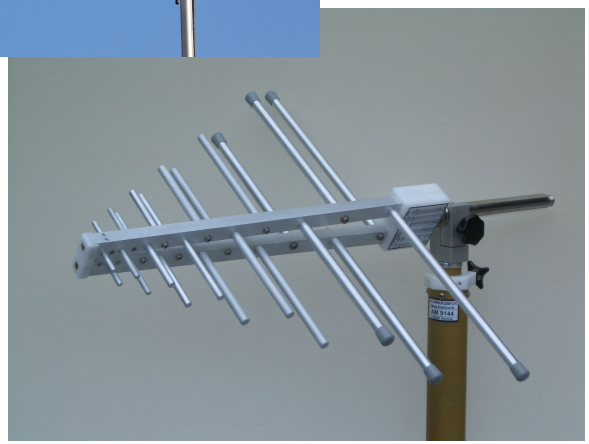
Motivation: switching of optical response

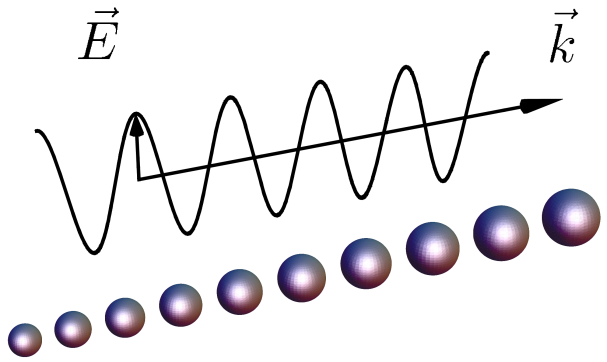




R. de Waele, A. F. Koenderink, and A. Polman, Nano Lett. **7**, 2004 (2007).

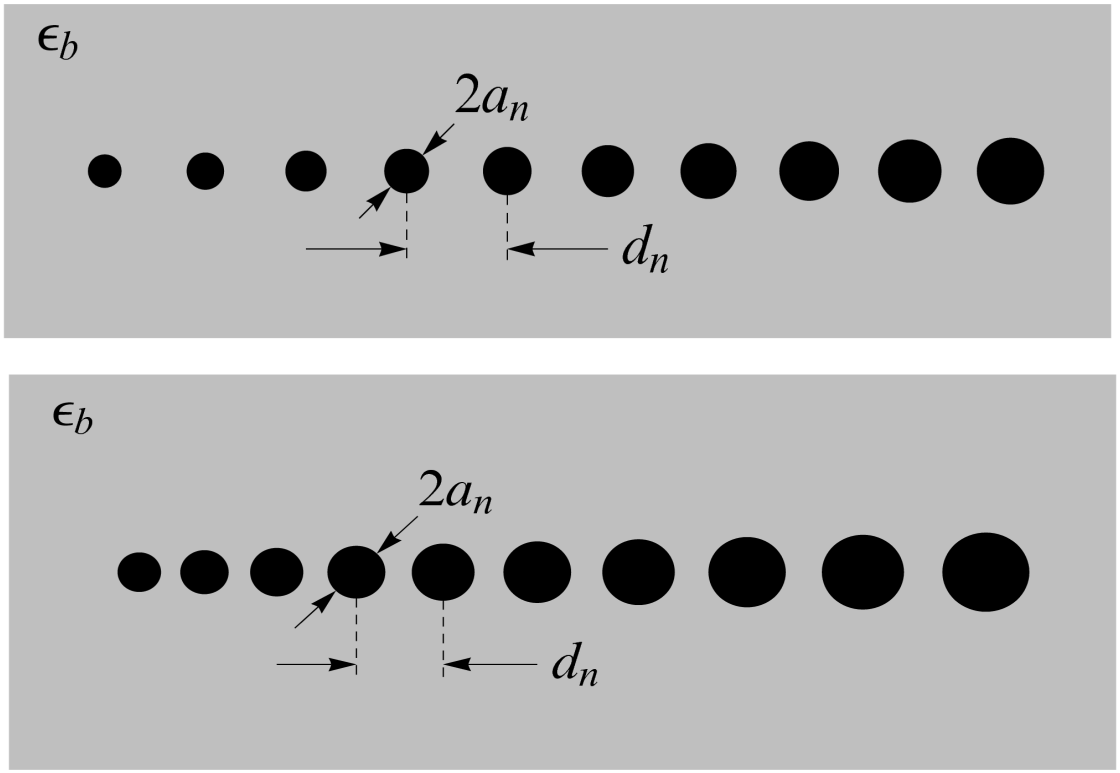
Motivation: directional broad-band RF antennas





Optical broad-band antenna?

Graded plasmonic arrays



$$\frac{a_n}{d_n} \leq \frac{1}{3}$$

Point-dipole approximation

$$p_n = \varepsilon_b \, \alpha_n \left(E_n + \sum_{m \neq n} G_{nm} p_m \right)$$

$$G_{nm} = -\frac{1}{\varepsilon_b} \left(\frac{1}{x_{nm}^3} - \frac{ik}{x_{nm}^2} - \frac{k^2}{x_{nm}} \right) e^{i \, k \, x_{nm}}$$

$$x_{nm} = |x_n - x_m| \, , \qquad G_{nn} = 0$$

Silver nano-spheres

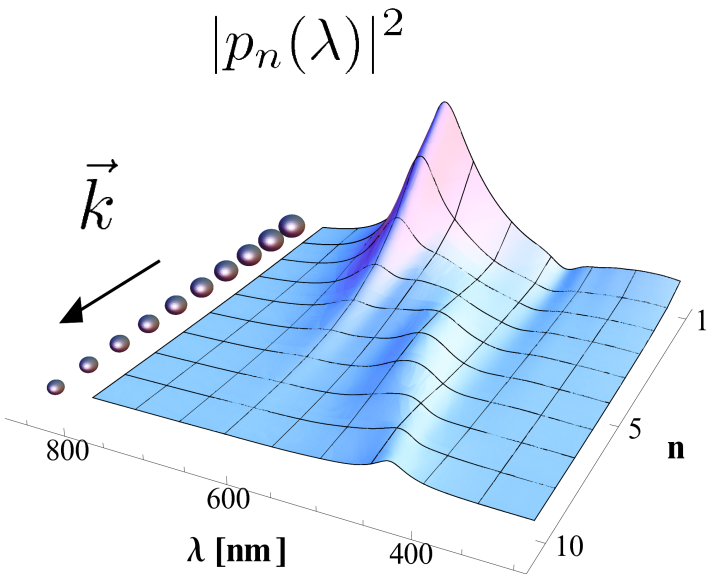
$$\alpha_n^{(0)} = a_n^3 \, \frac{\varepsilon_n - \varepsilon_b}{\varepsilon_n + 2\,\varepsilon_b} \;, \qquad \frac{1}{\alpha_n} = \frac{1}{\alpha_n^{(0)}} - \frac{k^2}{a_n} - i\,\frac{2}{3}\,k^3$$

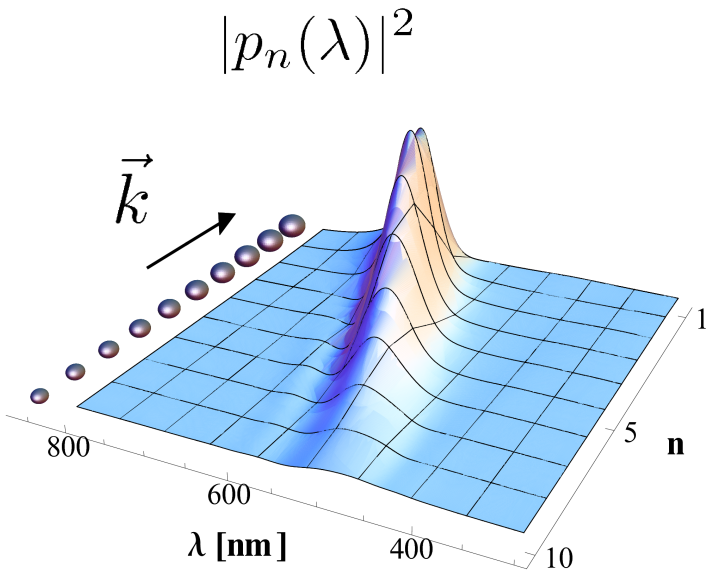
$$\varepsilon_n = \epsilon - \eta \, \frac{\omega_p^2}{\omega^2 - i\,\omega\,\gamma_n}$$

$$\omega_p = 1.72 \times 10^{16}\ rad/s \qquad \epsilon = 5.45 \;, \quad \eta = 0.73$$

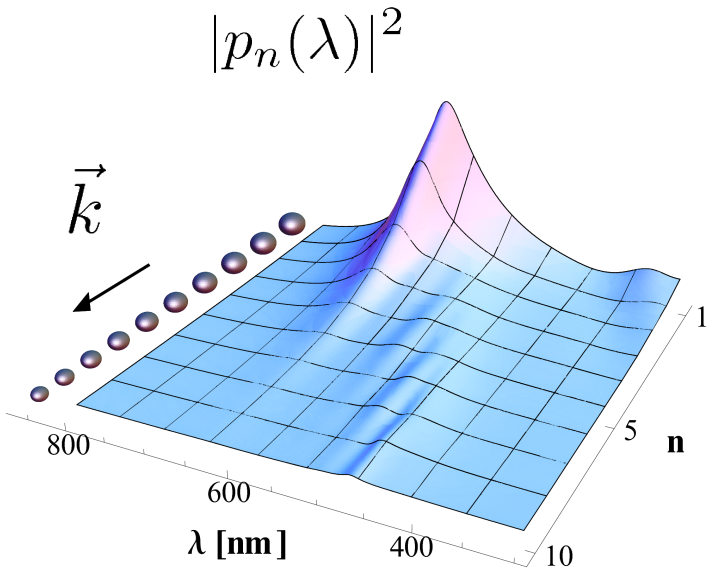
$$\gamma_n = \gamma = 8.35 \times 10^{13}\ 1/s \qquad \varepsilon_b = 1.47$$

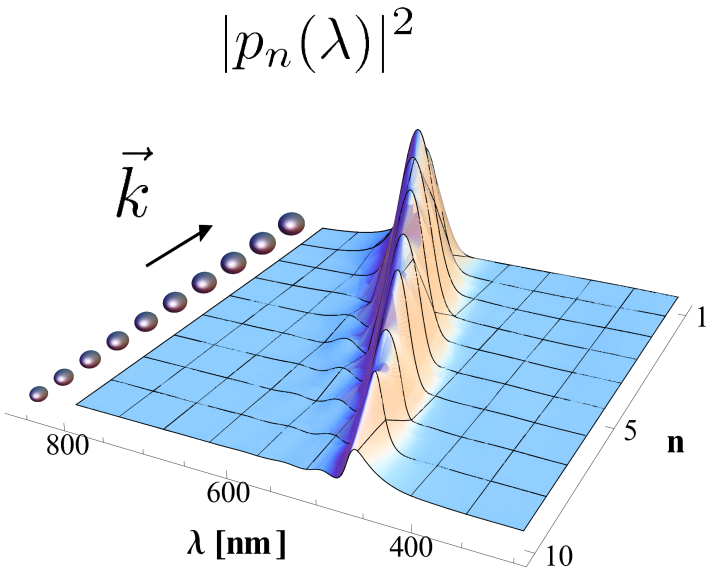
Linearly graded array: d=150 nm, a_n=25-50 nm



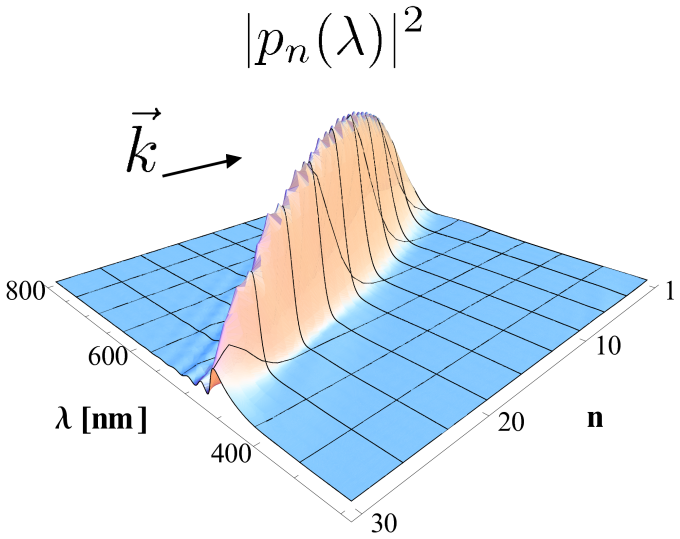


Invariantly graded array: a_n=25-50 nm, a_n/d_n=1/3

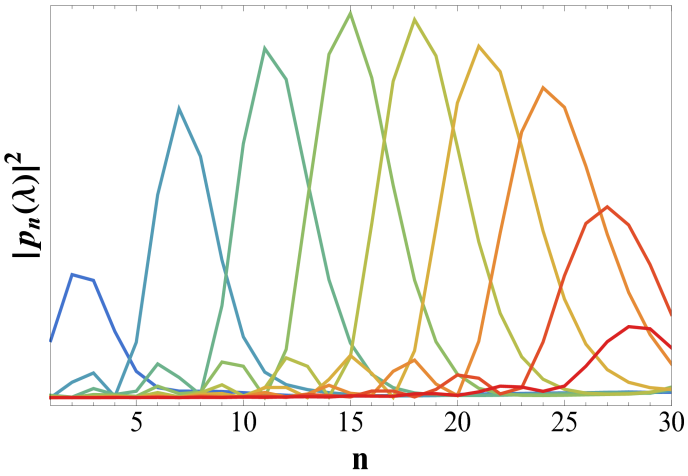




Broad-band plasmonic antenna



Cross sections: λ = 470, 500, … , 710 nm

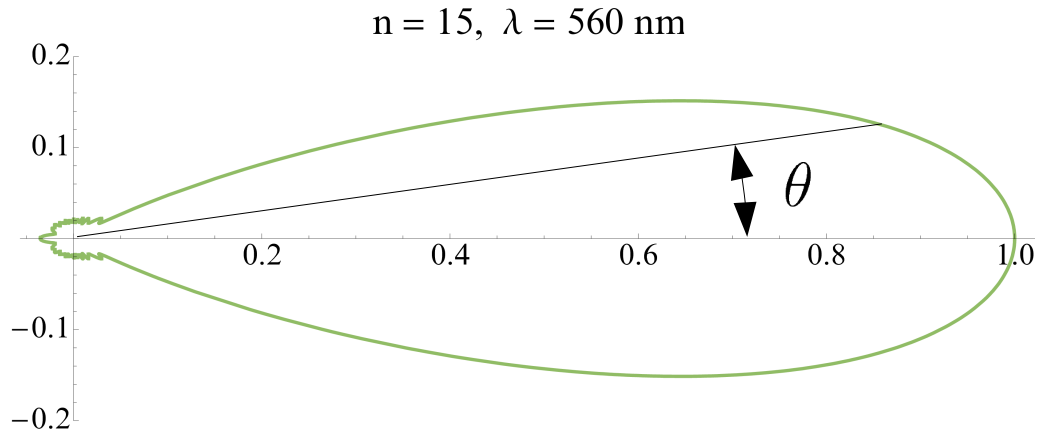


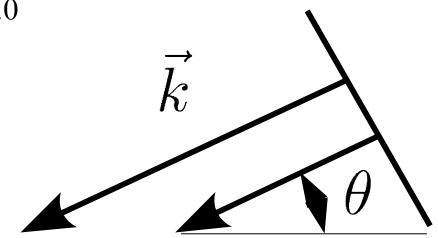
Invariantly graded array: N=30, a_n=50-25 nm, d_1=210, a_n/d_n=5/21

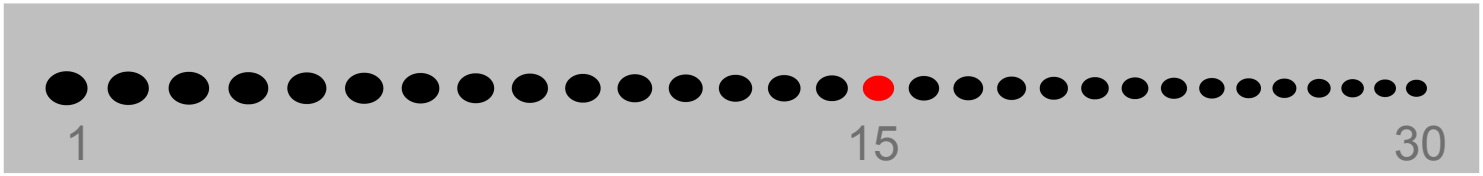
A. V. Malyshev, V. A. Malyshev, J. Knoester, Nano Lett. **8**, 2369 (2008)

Directionality: excitation polar pattern for n=15

$|p_{15}(\theta)|^2$

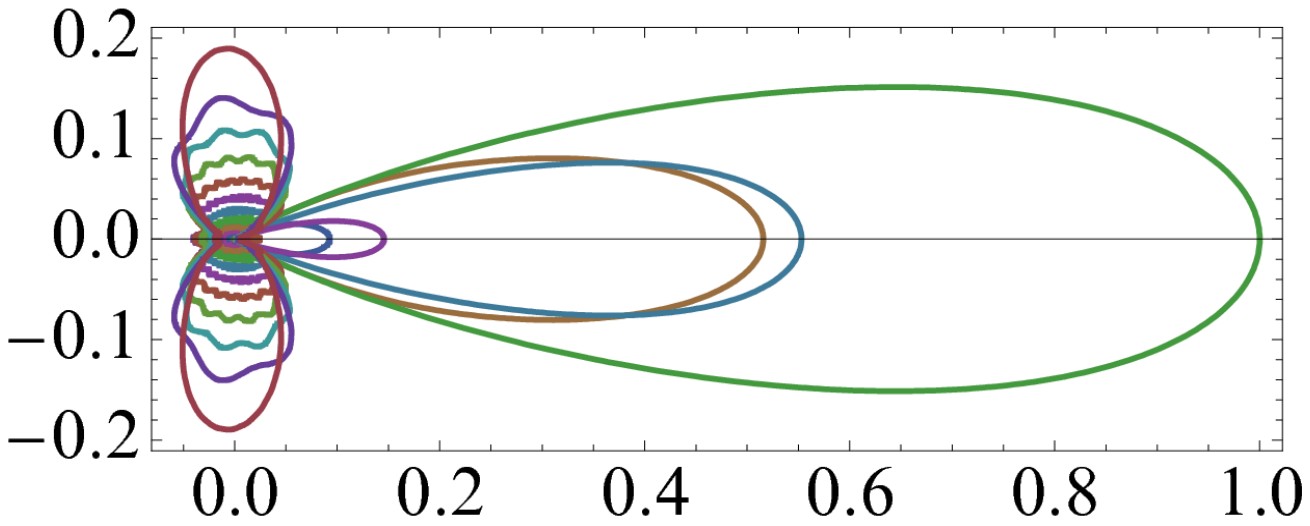






Excitation polar patterns for n=1..30

$|p_n(\theta)|^2$



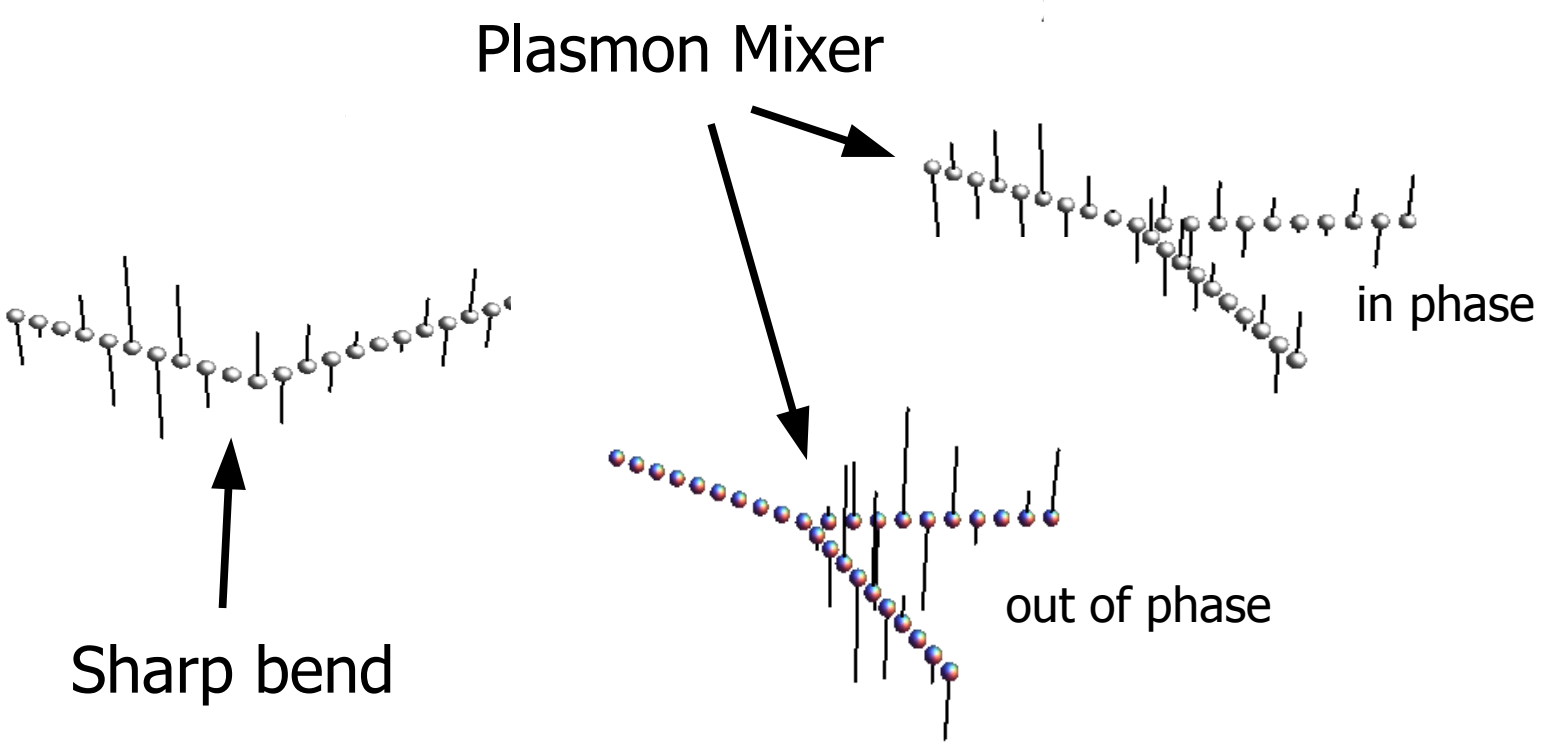
Summary

- The response signal of graded linear arrays of noble metal nanospheres can be localized at an arbitrary subset of particles by adjusting the excitation frequency

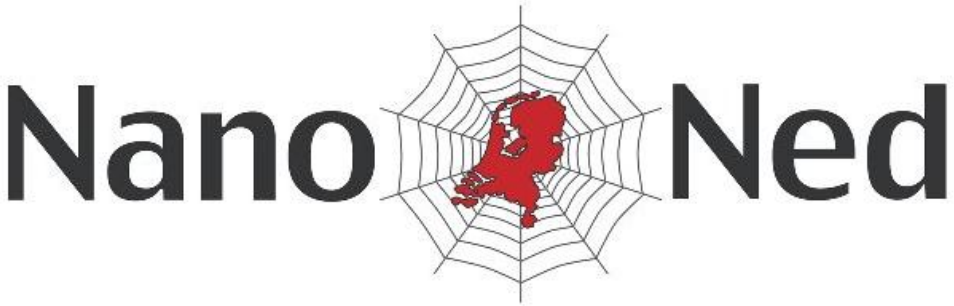
- Such systems operate as directional broad-band antennae in the visible range of the spectrum

- Possible applications: directional sensors in the visible

Outlook



Acknowledgments



Thank you for your attention