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The Optical Properties of a Truncated Spherical Cavity Embedded in Gold

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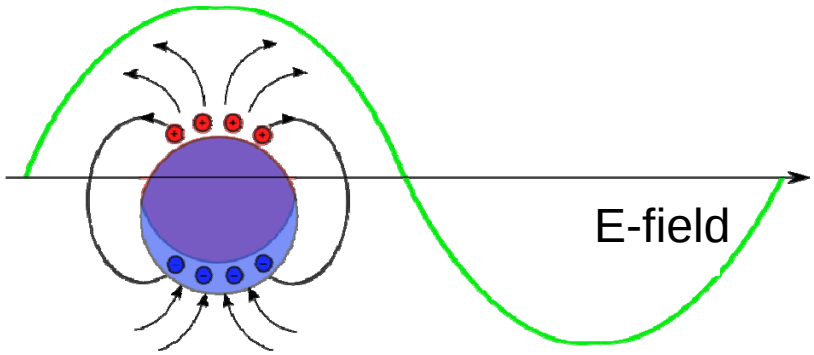
Outlook

- Introduction to Plasmonics
- The Truncated Spherical Cavity
- The COMSOL Model
- Absorption and Scattering Cross Section
- Results of Modelling
- Conclusion

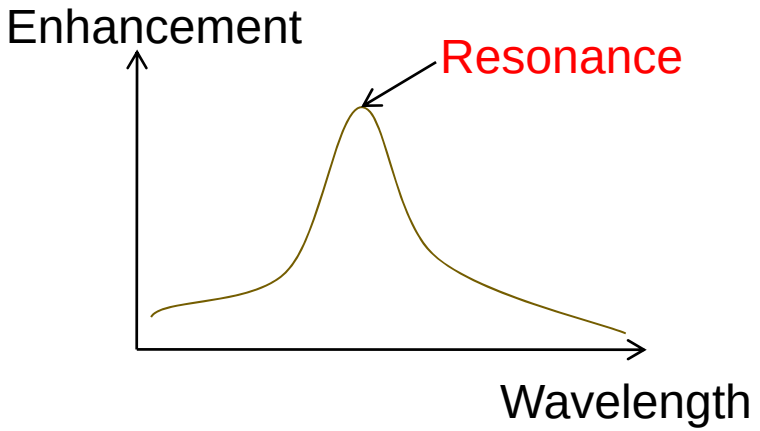
Introduction to plasmonics

- **Localized Surface Plasmon Polariton:**



  - Collective vibration of conduction electrons in a sub-wavelength structure

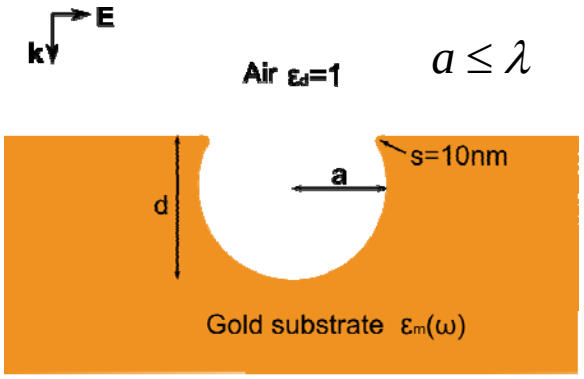
- **Enhancement of the E-field at resonance:**



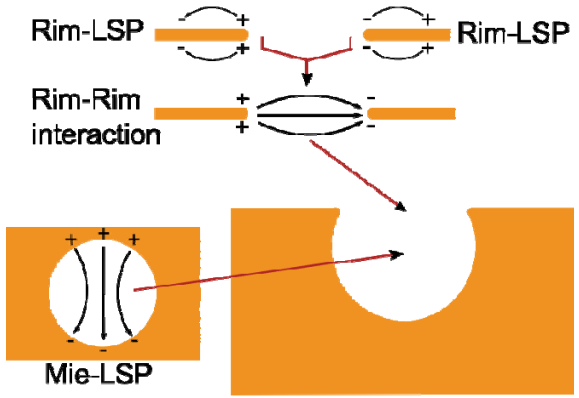
  - Possibility to control the spectral response

The Truncated Spherical Cavity

- **The Geometry:**



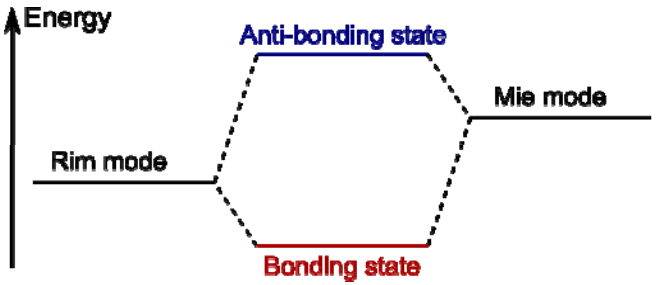
- **The Plasmonic Coupling:**



- **Governing equation:**

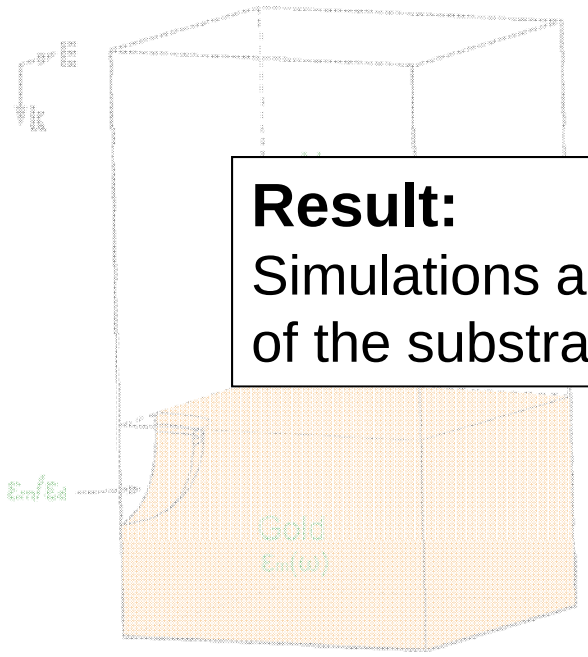
$$\nabla \times \left(\frac{1}{\mu} \nabla \times \boldsymbol{E} \right) - k_0^2 \varepsilon(\omega) \boldsymbol{E} = 0$$

- **Coupled States:**



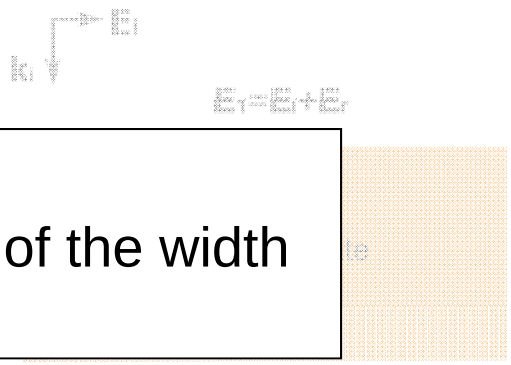
The COMSOL Model

- The 3D model:

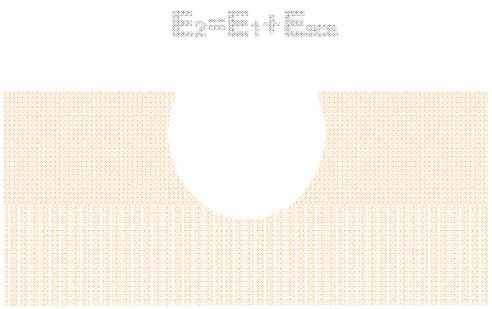


  - Only ¼ of the system is modelled

- The 2-step procedure:
  - 1. Harmonic propagation:



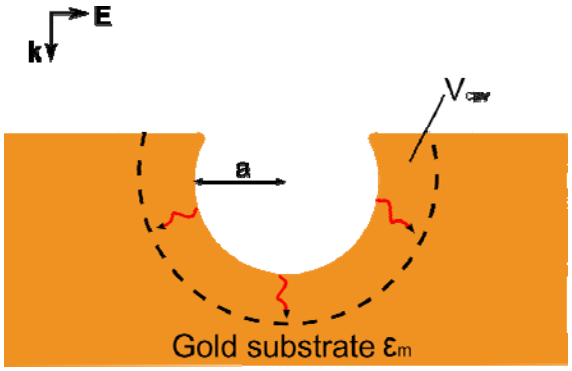
  - 2. Scattered harmonic propagation:



Result:
Simulations are independent of the width of the substrate (domain)

Absorption and Scattering

- **Absorption cross section:**



- **Quantify the dissipated energy in the gold surrounding the cavity:**

$$Q_{abs} = \frac{4}{\pi a^2}\frac{2\eta}{E_0^2}\int_{V_{cav}} U_{abs2} - U_{abs1}\, dV$$

$$U_{abs} = -\frac{1}{2}\omega \,\mathrm{Im}\left[\varepsilon_m(\omega)\right]\left|\boldsymbol{E}\right|^2$$

Results of Modelling – Excitation of LSP Modes

Mie structure

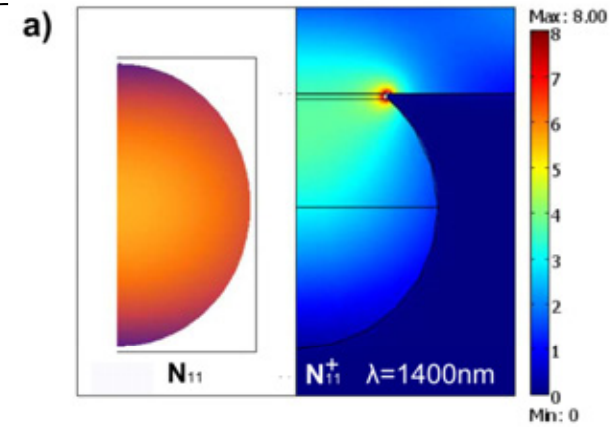
Modelled structure

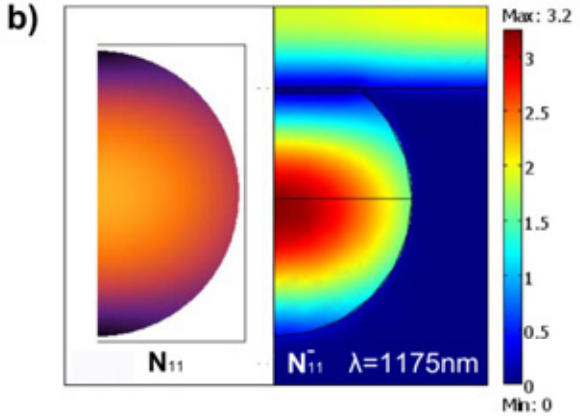
Mie-mode | Simulation

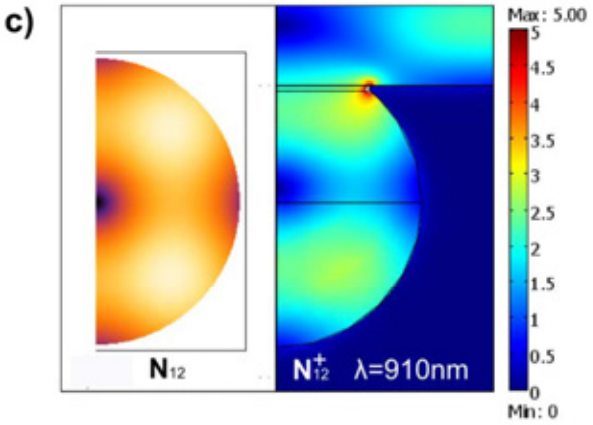
Mie-mode | Simulation

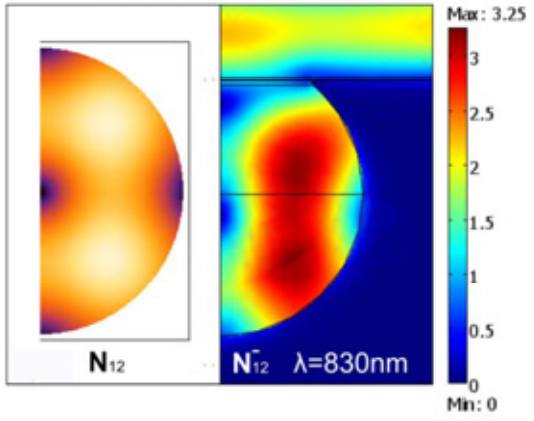
Bonding states

Anti-bonding states



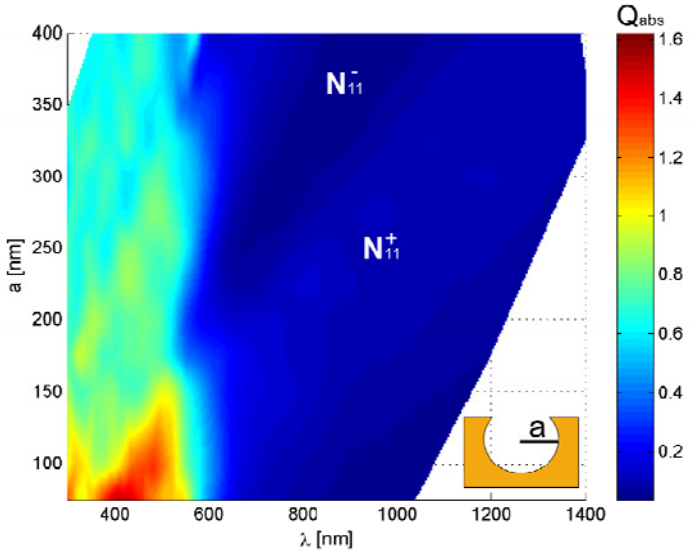






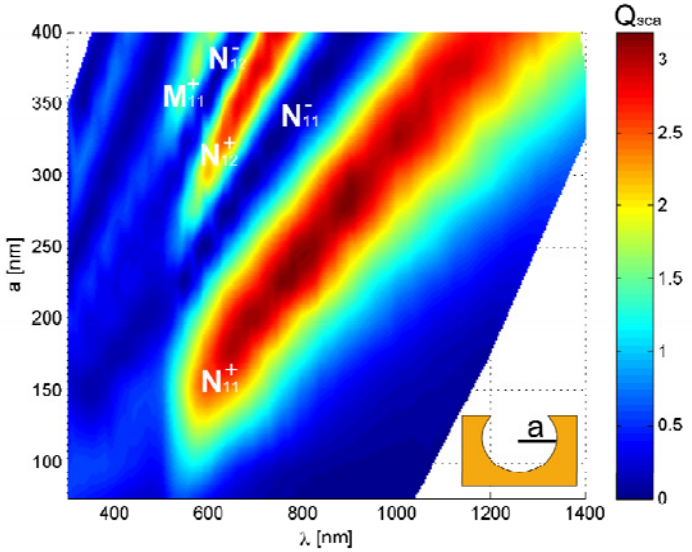
Results of Modelling – Absorption and Scattering

Absorption cross section



The absorption is related to the optical properties of gold

Scattering cross section



Excitation of bonding states increases the scattering.
Possibility to control the scattering

The optical response is dominated by the scattering

Conclusion

- **The plasmonic effects of a truncated spherical cavity is interpreted on the basis of Mie-theory.**
- **Simulations are done using a pure FEM 3D-model and a 2-step procedure making the result independent of the width of the domain.**
- **Simulation of the near-field reveals resonance of individual bonding and anti-bonding modes.**
- **The optical properties are dominated by scattering.**
- **Possible candidate as a tunable substrate for surface enhanced sensing.**