PETER interaction model

Martin Hrtoň

arrays of antennas can support lattice resonances that might boost the integral magnetic enhancement needed for the EPR spectroscopy

BUT

it is challenging to simulate large arrays and perform parameter optimization using standard tools (e.g. Lumerical)

$\Downarrow$

we developed a theoretical model that enables us to accurately calculate and optimize large antenna arrays fabricated on top of a layered substrate, taking into account both Fabry-Perot oscillations and possible inter-antenna interaction via waveguide modes supported by the substrate

Model assumptions

our model stands on the assumption that the response of a single antenna in a limited spectral window is dominated by a single plasmonic mode (this holds rather well in the THz spectral region)

AND

that the interaction with its surroundings affects only the excitation amplitude of the plasmonic mode, i.e. the field distribution is always the same

$\Downarrow$

the intimidating problem of simulating a large antenna array shrinks to a problem of finding the excitation amplitudes of individual antennas comprising the array

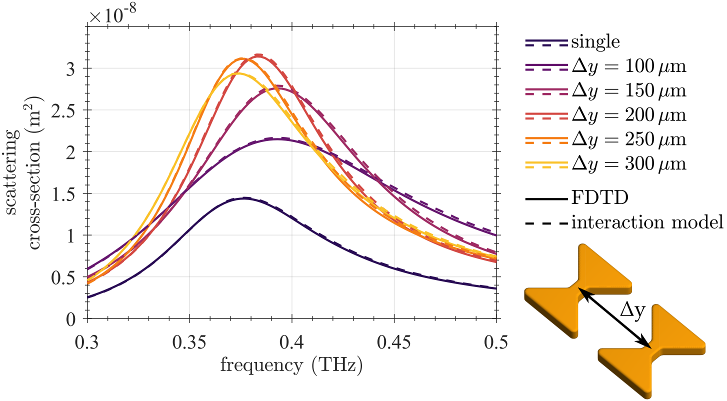
$$\vec{P}_i(\vec{r},\omega) = p_i(\omega)\,\vec{\mathcal{P}}(\vec{r},\omega) \tag{1}$$

$$p_i(\omega) = \alpha(\omega)\left[E_0(\omega) + \sum_j g_{ij}(\omega)p_j(\omega)\right] \tag{2}$$

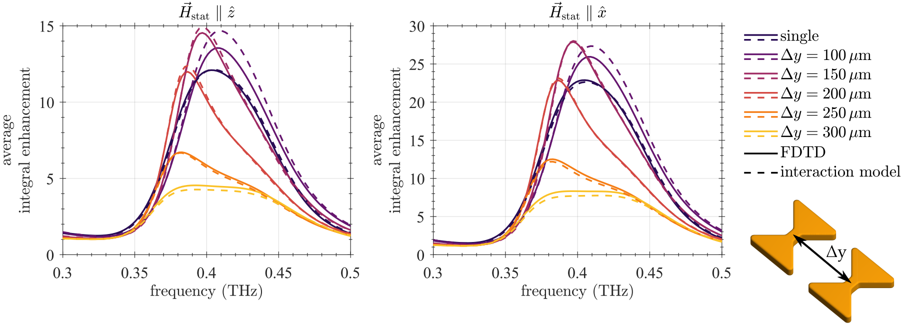
$$g_{ij}(\omega) = \frac{\int \mathrm{d}\vec{r}\ \vec{\mathcal{P}}^*(\vec{r},\omega)\cdot\int \mathrm{d}\vec{r}'\ \overleftrightarrow{G}(\vec{r}-\vec{r}'-\vec{r}_{ij},\omega)\vec{\mathcal{P}}(\vec{r}',\omega)}{\int \mathrm{d}\vec{r}\ \vec{\mathcal{P}}^*(\vec{r},\omega)\cdot\vec{\mathcal{E}}_0(\vec{r},\omega)} \tag{3}$$

$\vec{P}_i(\vec{r},\omega)$ - charge distribution of the i-th antenna
$\vec{\mathcal{P}}(\vec{r},\omega)$ - charge distribution of the plasmonic mode (extracted from FDTD)
$p_i(\omega)$ - excitation amplitude of the i-th antenna
$\alpha(\omega)$ - antenna polarizability factor
$g_{ij}(\omega)$ - interaction coefficient between i-th and j-th antenna
$\vec{\mathcal{E}}(\vec{r},\omega)$ - field distribution of the illuminating wave (extracted from FDTD)
$E_0(\omega)$ - amplitude of the illuminating wave (contains the Fabry-Perot effect)
$\overleftrightarrow{G}(\vec{r},\omega)$ - Green's tensor

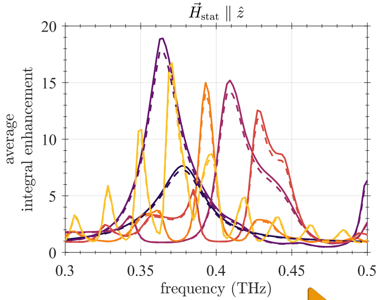
Model validation, Si substrate

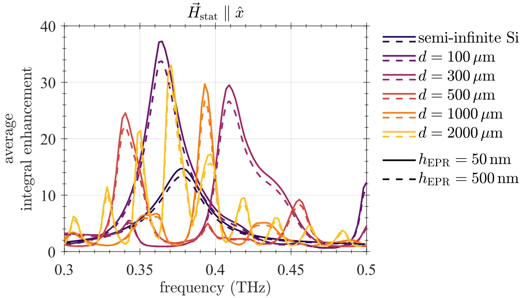


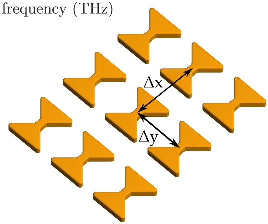
Model validation, 200 μm Si wafer

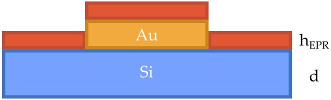


Array optimization, 3 mm × 3 mm Si wafer









Array optimization, $3\,\mathrm{mm} \times 3\,\mathrm{mm}$ SiO_2 wafer