Heat released by plasmonic excitation of hybrid nanoparticles: effect on proton relaxation

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Abstract

Theranostics, which combines diagnosis and treatment in medicine, utilizes innovative hybrid nanoshells (NS) with gold plasmonic properties and magnetite cores. They enable simultaneous photothermal therapy (PTT) and magnetic resonance imaging (MRI). Our research investigates the temperature effects of photothermal therapy on the proton relaxation, in MRI, and optimizes nanoshell geometry for improved results, showing promise for biomedical applications.

Heat rise mapping

The collective thermal model [1]:

\[ T_{\text{collective}}(r) = \int \frac{q(r')}{4\pi\kappa_t |r-r'|} \, dr' \]

with \( q(r) = I_0 N \sigma_{\text{abs}} e^{-(\sigma_{\text{ext}} N z)} \)

\( \sigma_{\text{abs}} \) and \( \sigma_{\text{ext}} \) obtained via COMSOL simulations

We apply the appropriate theoretical MRI model to each pixel to map \( R_2 \)

Results

MRI models

- Relaxation of the protons characterised by a relaxation rate
- Three different relaxation regimes:
  - depending on NS size, water coefficient diffusion and saturation magnetization of the magnetite core

Model selection based on the intersection between models

- Plasmonic resonance \( \rightarrow \lambda = 580 \text{ nm} \)
- Plasmonic resonance \( \rightarrow \lambda = 710 \text{ nm} \)
- Plasmonic resonance \( \rightarrow \lambda = 870 \text{ nm} \)

A small modification in the nanoshell’s geometry can result in a significant change in the relaxation rate response!

Conclusion