Optical wavelength dependence of photoacoustic signal of gold nanofluid

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The photoacoustic (PA) effect is based on the generation of acoustic waves upon absorption of light [1]. In a nutshell, the mechanism is based on the conversion of the absorbed light into heat, yielding a temperature rise inside the sample. This results in acoustic waves generated by the thermal expansion of the heated medium (a sketch of the effect is reported in Fig. 1a).

This work addresses the PA signal generated by Au nano-spheres (NS) immersed in water, the latter system mimicking a biological tissue with immersed exogenous contrast agents. Previous works demonstrated that adding exogenous agents in a biological tissue can enhance PA contrast [2]. In particular, noble metal nanoparticles have been used as exogenous agents to enhance the PA contrast in imaging applications. Metal nanoparticles optical absorption is strongly enhanced at wavelength matching the localised surface plasmon resonance (SPR), possibly resulting in the generation of high amplitude pressure waves upon illumination with moderate light fluences. This fact yields a wide detectable PA signal, a key feature for PA imaging.

The results presented in this work are based on the solution of a numerical opto-thermo-acoustic model considering the absorption of a light pulse – across the visible and near-infrared (NIR) range – in a gold NS and in a surrounding water shell [3], see Fig 1b). The excitation wavelength dependence of the PA signal is discussed. The PA signal is triggered by thermal expansion of the water surrounding the NS, caused by the photothermal temperature increase in the liquid. The latter is due to the light absorption in the NP, for wavelengths around the NS SPR, while for longer, NIR wavelengths, photothermal heating of water is driving the signal.

The water thermal expansion coefficient $\alpha_{\text{wat}}$ is temperature dependent. If the temperature increase is high, the photoacoustic signal amplitude increases more than linearly with increasing laser fluence.

In Fig. 1 c) the photoacoustic signal detected in water at a distance 10 $\mu$m from the NS center is plotted as a function of time. The full orange and dotted black curves were obtained neglecting (accounting for) the thermal dependence of the water absorption coefficient.

In this work, we discuss how NS radius and the thermal boundary conductance affect the photoacoustic effect. Furthermore, we show that, contrary to uniform materials, linear proportionality between the spectrum of the photoacoustic signal amplitude and the one of the optical absorption coefficient of the effective medium is not satisfied, especially for larger values of the nanosphere radius.

References
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