ULTRAFAST GENERATION OF ACOUSTIC WAVES IN WATER MEDIATED BY A CARBON NANOTUBE

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Photoacoustics, the study of acoustic waves triggered by an ultrafast laser pulse, gained new interest with the use of nanoparticles as transducers, with novel applications in biological systems where they can be introduced as imaging, thermal or mechanical agents with high localization and selectivity [1, 2]. Most approaches rely on water-dispersed metallic nanoparticles excited by nanosecond pulses and involve a photothermal effect. The laser pulse triggers an impulsive temperature rise in the nanoparticle, followed by the fast temperature increase of the surrounding water, leading to its thermal expansion and the launching of a pressure wave in water. However, the physics can significantly differ when dealing with carbon nanotubes (CNT).

Here, we theoretically investigate the transient photothermal and photoacoustic response of a CNT, multi- or single-walled, immersed in water. Given the time and length scales involved, the system requires a multi-physics, multi-scale approach [3]. Our simulations follow step-by-step the photo-thermal-acoustic stages involved, thus combining the optical, heat transfer and thermo-acoustic phenomena. The macro-physics equations are solved via Finite Element Methods with insertion of relevant microscopic parameter values, such as the CNT-water interface thermal boundary resistance [4] retrieved from dedicated molecular dynamics (MD) simulations [5].

The CNT geometry and laser pulse duration characteristics are discussed for the effective generation of propagative pressure waves in water. Most interestingly, we observe the emergence of a competitive new mechanism, which involves the generation of periodic vibration or impulsive dilation in the CNT upon pulsed excitation, and the direct mechanical launching of a pressure wave in water.

References

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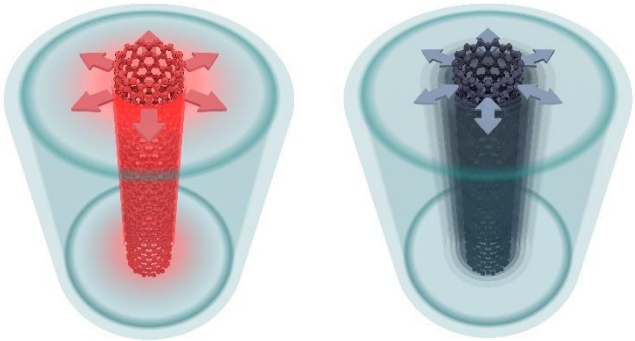

Figure 1: Schematic representation of the mechanisms for pressure wave generation in water upon nanotube pulsed light excitation. (Left) Wave triggered by photothermal dilation of surrounding water, referred to as thermophone. (Right) Wave triggered by mechanical expansion of the nanotube, referred to as mecanophone.

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