Ultrasound-enabled light focusing for advanced materials processing

Martí Duocastella[1,2]

[1] Department of Applied Physics, Universitat de Barcelona, C/Martí i Franquès 1, 08028 Barcelona, Spain
[2] Institute of Nanoscience and Nanotechnology (IN2UB), Universitat de Barcelona, 08028, Barcelona, Spain
*Corresponding author email: marti.duocastella@ub.edu

The precise and timely delivery of light to specific locations on a sample is essential for laser material processing. Typically, this task is accomplished with bulky optical elements, including passive components such as lenses and mirrors, and active systems like acousto-optic deflectors and spatial light modulators. In most practical scenarios, it is not possible to place these elements inside a sample of interest. Consequently, most optical systems position all components external to the sample, imposing constraints on both the geometries that can be accommodated and the potential light trajectories. Additionally, scattering can further limit light control inside non-homogeneous media, preventing operations deep inside samples.

Here, I will show how ultrasound can address these issues and achieve rapid light focusing and guiding, even inside scattering samples[1]. Our approach is based on exploiting the acousto-optic effect. By sending 1-10 MHz pressure waves inside the sample of interest, refractive index gradients can be generated that act as embedded lenses or waveguides, helping to guide or focus light at depths not possible with standard optical elements. I will discuss the different implementations of this new technology, ranging from the use of acoustic cavities[1,2] to pulsed lasers for ultrasound generation[3] (Figure 1a) and illustrate them with applications such as fluorescence excitation and laser ablation (Figure 1b-c).

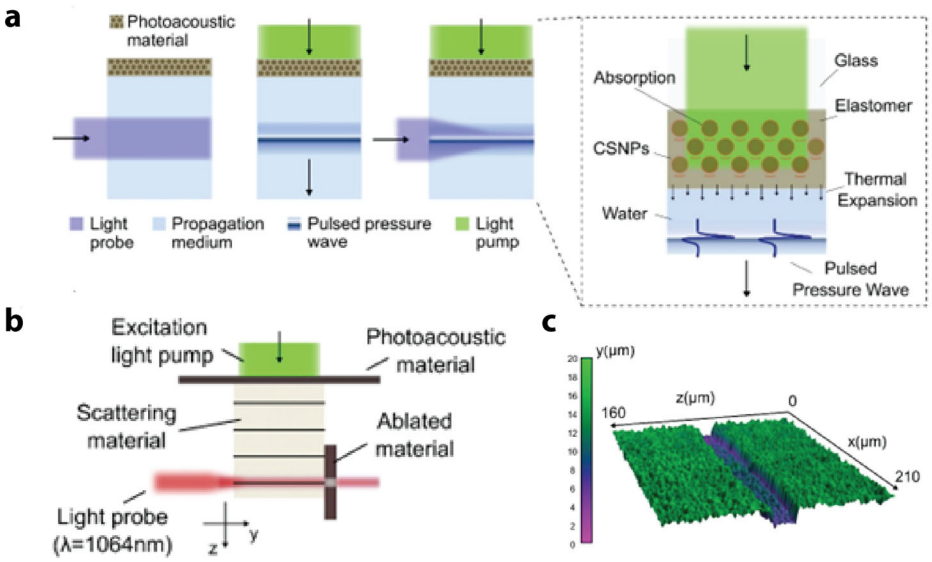

Figure 1: Light-guiding with ultrasound for materials processing. a) Scheme of the principle for light guiding using photoacoustically-generated ultrasound. b) Scheme of the lens-free setup used for ablating material inside uniform and scattering media. c) Confocal optical micrograph of a line ablated from a carbon film using ultrasound as the only focusing element.

[1] B. Mestre-Torà, M. Duocastella, "Enhanced light focusing inside scattering media with shaped ultrasound" *Sci. Reports.* 3, **2023**, *11511*, 1.
[2] B. Mestre-Torà, M. Duocastella, "Parallelized ultrasound guiding for enhanced light delivery within scattering media" *submitted*
[3] P. Ricci, M. Colom, B. Mestre-Torà, M. Duocastella, " Photoacoustics for direct light-guiding inside uniform and scattering media" *submitted*