Project NOLIMIT - Publishable Summary (6/2015)

The goal of this project was to develop new tools that will allow to:

1) Control and focus light deep inside scattering media
2) Perform imaging inside and through diffusive samples with resolution and speed surpassing those possible today.

These ambitious goals have been fully achieved during the full 24 months of the project. During the first half of the project, we have developed a novel approach for imaging and light control that is based on the *photoacoustic (PA) transmission-matrix*, a new concept that we have developed and introduced to the scientific community[1-2]. The experimental realization of a PA transmission matrix measurement apparatus is based on a conventional PA tomographic setup equipped with a high resolution computer-controlled spatial light modulator (SLM). Such a setup is depicted schematically in Figure 1a. Using the PA transmission matrix allowed us to focus light at will at any absorbing target buried deep inside a complex, visually opaque sample, as is presented in Figure 1b [1-2]. In addition to being able to focus at any selected position in a large field of view, an advantage compared to optimization-based PA guided wavefront shaping[3], we have shown that the photoacoustic signal modulation, which is at the basis of the transmission matrix measurement, allows to image absorbing structures that are invisible in conventional limited-view photoacoustic-imaging systems (Figure 3c)[4]. These results carry great importance for biomedical imaging based on PA systems, which is a very active field of applied research

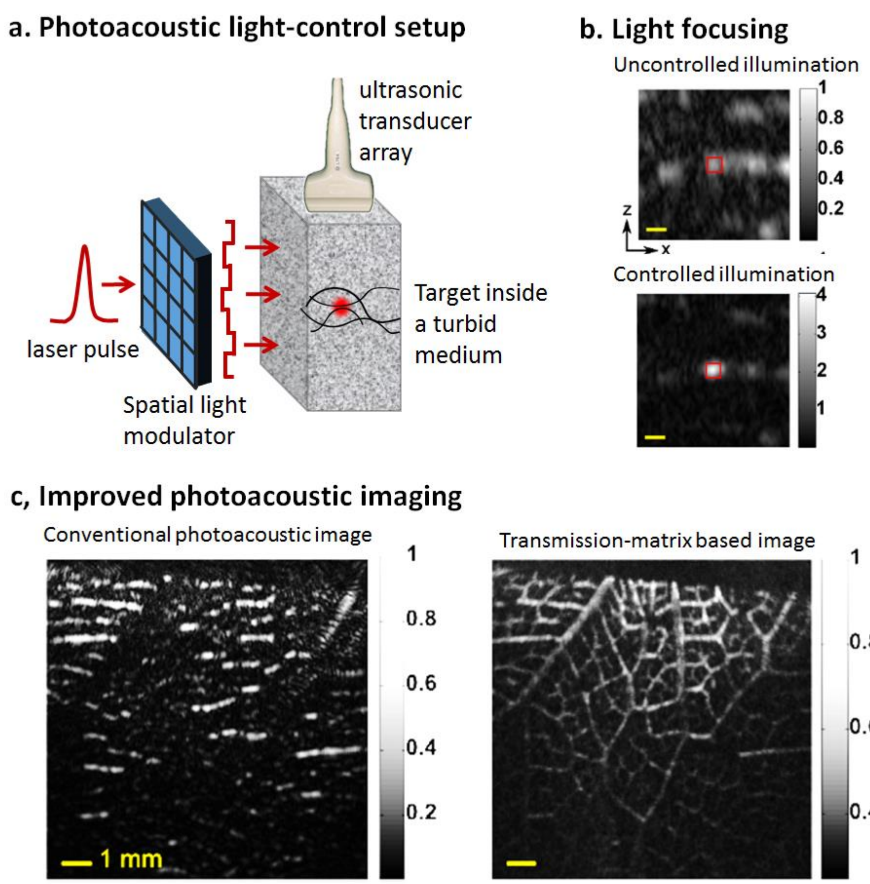

Figure 1: Photoacoustic-guided optical focusing and imaging: a, Experimental setup for the measurement of the photo-acoustic transmission matrix (PA-TM)[1-2]; b, Experimental demonstration of controlled light focusing inside a complex medium; c, experimental demonstration of improved photoacoustic imaging of a complex sample, based on the photoacoustic transmission matrix. A clear image of the vessels is obtainable only thanks to the PA-TM.

We have also gone beyond the original project objectives, by exploiting inherent correlations of scattered light for diffraction-limited optical imaging through diffusive samples, easing the original project requirement for nonlinear photoacoustic markers. This approach allows to image through visually opaque samples using only a single image from a conventional high resolution camera[5] (Figure 2), and carry great potential impact on imaging in currently inaccessible scenarios, e.g. the imaging of embryonic development through the visually opaque shell of an egg.

Another addition to the project was the invention of an endoscopic imaging technique and passive acoustic imaging approach based on new understandings on the spatio-spectral coupling in scattered light[6]. This approach allows single-shot lensless endoscopic imaging, without the need for conventional scanners or similar apparatus, and carry great potential for miniaturization of medical endoscopic imaging probes.

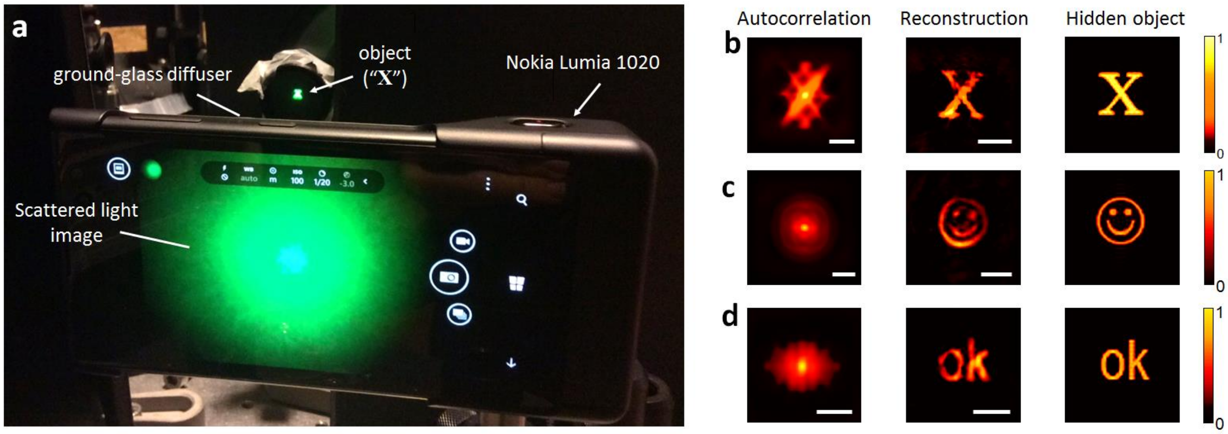

Figure 2. Seeing through a visually-opaque layer with a camera phone. a, A photograph of the experiment: a picture of the object (the letter 'X' in this image) is taken through a highly scattering ground-glass diffuser by a standard camera-phone; **b,** left column: calculated autocorrelation of the scattered light image of (a); central column: the image reconstructed from (b); right column: image of the real hidden object. **(d-e)** same as (b) but for different objects. Scale-bars, 50 camera pixels.

References

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6. S.M.Maliszewska*, O.Katz*, M.Fink, S.Gigan, *"Scanning-free imaging through a single fiber by random spatio-spectral encoding"*, ***Optics Letters*** 40 (4), 534-537 (2015).