

## **Focusing through dynamic biological tissues using fast wavefront shaping**

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The propagation of light in biological tissues is rapidly dominated by multiple scattering: ballistic light is exponentially attenuated, which limits the penetration depth of conventional microscopy techniques. For coherent light, the recombination of the different scattered paths creates a complex interference (speckle). Recently, different wavefront shaping techniques [1] have been developed to coherently manipulate the speckle. It opens the possibility to focus light through complex media and ultimately to image in them, provided however that the medium can be considered as stationary.

We have studied the possibility to focus in and through biological tissues. Their intrinsic temporal dynamics creates a fast decorrelation of the speckle pattern. Therefore, focusing through biological tissues requires fast wavefront shaping devices, sensors and algorithms [2]. We have investigated the use of a MEMS-based spatial light modulator (SLM) and a fast photodetector, combined with FPGA electronics to implement a closed-loop optimization. Our optimization process is just limited by the temporal dynamics of the SLM (200 $\mu$ s) and the computation time (45 $\mu$ s), thus corresponding to a rate of 4 kHz (i.e. 245 $\mu$ s is required to optimize one mode). To our knowledge, it's the fastest closed loop optimization using phase modulators.

We have studied the focusing of scattered light through colloidal solutions of TiO<sub>2</sub> particles in glycerol, whose scattering properties are similar to biological tissues. Moreover the temporal dynamics of this sample can be tuned by changing its temperature, thus matching the different timescales of the speckle decorrelation observed with biological tissues (few milliseconds). We have shown that our set-up fulfills the required characteristics (speed, enhancement) to focus through fast decorrelating samples. We have explored also the properties of the resulting focus, and in particular its decorrelation time, as well as the possibility to scan it ("memory effect" [3]) to build an image. We are currently applying these approaches to acute rat brain slices.

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