Deep tissue imaging by time-reversal optical phase conjugation techniques

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We recently demonstrated that it is possible to use optical phase conjugation as a means to time reverse the scattering of light through biological tissue [1]. This newly observed phenomenon, termed turbidity suppression by optical phase conjugation (TSOPC), can potentially be adapted for numerous biophotonics applications, such as coherent deep optical imaging of tissue, enhanced light delivery for photodynamic therapy and high sensitivity absorption spectrum measurements. In this talk, we shall report on our recent findings and discuss the potential applications.

Efficient light delivery and deep optical imaging in tissues is confounded by the fact that tissues are highly scattering media. It is a general misconception that the reason we are not transparent like jellyfish is because our tissues absorb light strongly. In fact, tissue turbidity is the overriding factor that prevents us from appearing transparent. While both absorption and scattering are processes that alter photon trajectories, there is an important difference between the two - absorption is an irreversible process while scattering is time-reversible. In other words, while light scattering may appear random, it is in fact a deterministic process. This implies that if we are able to record the phase and amplitude of the scattered wave accurately, and if we able to create and send a phase conjugated version of the scattered wave back through the scattering object, it is possible to null out the effect of tissue scattering.

Our recent experiments have further demonstrated that the phenomenon is surprisingly robust. We can observe the effect in living tissues as well as through tissues that are so thick that each photon is scattered > 300 times on average [2]. In addition, the phenomenon is surprisingly robust in that some amount of reconstruction can still occur even when the fraction of the initial light field that is phase conjugated is very small (we experimentally observed the effect for a fraction as low as 0.02%). Recently, we also showed that movements within living tissues do disrupt this scattering suppression phenomenon but this decay occurs at a sufficiently slow rate (time constant of seconds) [3]. This flexibility allows us to more easily develop systems that can make use of the TSOPC phenomenon in practical terms. Furthermore, my group has recently developed an optoelectronic system that is capable of generating the OPC field [4]. This transition away from the difficult-to-use holographic film and crystal techniques allows us to more easily to produce an OPC field with sufficient power and flexibly adapt this phenomenon for practical applications.

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