

Summary

Techniques for biomedical imaging, which aims at generating real-time images of structures of the internal and external cells, tissue or complex biological systems with the microscopic magnification, are an essential source of information in the field of biology and medicine. Optical methods (using light) have many limitations in biomedical imaging due to strong deformations of light beam introduced by biological structures. This situation is even more severe when there is a need to take an image of the living cell or tissue structure within its natural environment (in-vivo). Elements of biological structure are very uneven from the perspective of penetrating light. It is like a beam of light would travel through the bubble wrap, used for packing fragile objects. In such a turbulent tissue model each "bubble" would have various properties. Such deformation of lightwave, to a certain limit of the "crumpling", can be corrected using well-known technique called Adaptive Optics (AO). In this method, the deformed lightwave must be very accurately detected and reconstructed in a computer memory. Then, using the physical devices called "wavefront shapers" and having the prior knowledge about the lightwave deformation, it is possible to correct the original, "creased" wave. Unfortunately, in the case of biological objects the scale of distortions is too big and correction using classical adaptive optics cannot be applied.

In 2007, a group of professor Vellekoop experimentally confirmed theoretical assumptions made by Freund in 1990, that it is possible to prepare such a complicated shape of lightwave that it can be resistant for distracting effects of scattering layers. Experimental data published by the Vellekoop's group initiated a new era for Adaptive Optics. Almost 10 years of development of "diffusive optics" imaging branch has resulted in a number of techniques, which, to a certain limit, are able to recover information about the object hidden behind nontransparent layers. The common feature of these techniques is tedious and complicated lightwave "matching" process to the given structure of disturbing object. What is more, one has to use feedback system, complex mathematical algorithms or very specific location of the detection system relative to the sample. Unfortunately, most these techniques cannot be used in the double-pass microscope arrangement, so their applicability in biomedical imaging is drastically limited .

The method we propose enables to apply a large number of different shapes of lightwave illuminating the object. Each shape of the wave of illumination beam determines another possible way of propagation of light reflected back from the sample. By sending many prior-deformed lightwaves to the specimen, we cause their interaction with scattering layers of the sample which results in canceling out of beam distortions, leaving only the original, undistorted information coming from an object. Our method does not imply the prior knowledge about the properties of tissue. We do not have to know the extent to which the lightwave is deformed. Moreover, we do not use the techniques of the feedback loop and our imaging system can operate in an arrangement typical for classical microscope.

In summary, our method is likely to become an alternative imaging technique. Results of our work may help to develop novel adaptive optics instrumentation, which is as an essential component of modern biomedical imaging field.