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Development of Novel Light Propagation Algorithms in Turbid Media with Varying Optical Heterogeneity

ABSTRACT

The field of biomedical imaging has undergone a rapid growth in recent years, mostly due to the implementation of ad-hoc designed experimental setups, theoretical support methods and numerical reconstructions. Especially for biological samples, the high number of scattering events occurring during the photon propagation process limit the penetration depth and the possibility to outperform direct imaging in thicker and not transparent samples. In this thesis, we will examine theoretically and experimentally the scattering process from two opposite points of view, focusing also on the continuous stimulus offered by the will to tackle some specific challenges in the emerging optical imaging science. Firstly, we will discuss the light propagation in diffusive biological tissues considering the particular case of the presence of optically transparent regions enclosed in a highly scattering environment. We will point out how, the correct inclusion of this information, can ultimately lead to higher resolution reconstruction, especially in neuroimaging (e.g. brain tumor). On the other hand, we will examine the extreme case of the three-dimensional imaging of a totally hidden sample, in which the phase has been scrambled by a random scattering layer. By making use of appropriate numerical methods, we will prove how it is possible to outperform such hidden reconstruction in a very efficient way, opening the path toward the unexplored field of three-dimensional hidden imaging. Finally, we will present how, the properties noticed while addressing these problems, leaded us to the development of a novel alignment-free three-dimensional tomographic technique that we refer to as Phase-Retrieved Tomography. Ultimately, we used this technique for the study of the fluorescence distribution in a three-dimensional spherical tumor model, the cancer cell spheroid, one of the most important biological model for the study of such disease. Throughout the whole doctoral period, these studies have been stimulating and raising new questions and ideas, which will be analyzed and discussed as the natural continuation of the projects exposed in the present thesis.