

Optical imaging methods use light to visualise minute details of objects and at the same time, do not lead to their degradation as it is the case in electron microscopy or X-ray crystallography. Light-based imaging keeps evolving even despite the fact that at times it may seem that it reached its fundamental limits and cannot progress any further. For example, until not that long ago, light-based microscopy was thought to not allow to resolve a detail smaller than one particular, colour-related measure of the light. But some scientists did not take no for an answer and as a result, Nobel-prize winning superresolution microscopy was born. Of course the fundamental limitations were not broken since these limitations, being the fundamentals of physics, are unbreakable. They were bypassed instead in the most unconventional and sometimes simply ingenious ways, the core of them being that they “tied” the image generation to areas with much more room for improvement.

In our project, we will tackle a particular type of optical imaging called tomography. Tomography is a unique visualisation technique, in the sense that it is able to provide two-dimensional microscopy-like images that correspond to different depths in the object. To discern between the layers of the object, special mechanisms are introduced that exploit one of the sides of the light’s dual nature: its wave-like nature or particle-like nature. Great effort has been put into advancing the tomographic methods that take advantage of the wave-like properties of light. As a result, Optical Coherence Tomography (OCT) was developed and, within an exceptionally short time, pushed forward nearly to its very limits. Overshadowed by such a success, the tomographic methods that make use of the particle-like nature of light were in a great extent neglected although fundamentally, they are much more advantageous. Quantum OCT – the “particle-like” equivalent of the “wave-like” OCT – has shown to be superior in many aspects: it provides twice better resolution, it is immune to image-quality-degrading effects and has a better sensitivity.

The incredible features of Quantum OCT come at a price. The amount of light produced as a result of quantum phenomena is oftentimes too small to enable visualisation of biological structures and the same quantum behaviour of light that results in resolution improvement and superior image quality, leads to creation of parasitic, image-scrambling elements called artefacts and do not allow the immunity to image-quality-degrading effects to be absolute. Just as in microscopy, the barriers in Quantum OCT look impenetrable, and just as in microscopy, no will not be taken for an answer. In our research, we will investigate the image generation process in Quantum OCT and “tie” it to less restrictive areas. Firstly, artificial neural networks will be trained to learn the physical process of quantum image formation and based on the acquired knowledge, will remove artefacts and the image-quality-degrading effects in their totality. The quantum phenomenon behind the method’s resolution-doubling feature will be mimicked with an algorithm to allow further resolution improvement. Finally, Quantum OCT will be performed in more light-intensity-efficient experimental configurations which make use of novel, ultra-fast laser light sources.

Our project will considerably advance Quantum OCT because it tackles its biggest performance-curbing obstacles. Our solutions, which primarily capitalise on computational superiority of artificial intelligence, will provide a new and original set of tools that in future may be adapted in other areas of optical or non-optical imaging.