Incredible abilities of human eyes are the results of millions of years of evolution, which has led to development of a tool that perfectly meets the needs of everyday life. However, in the recent centuries human curiosity and progress in technology have posed new important challenges that exceeded capabilities of human vision. One of the greatest demands is to visualize inner structures of micro-scale objects (Fig. 1). The team working on this project strongly believes that the solution to this challenge is digital holography. Although holography is usually associated with spectacular effects created for entertainment, the true value of this technique is demonstrated with its great measurement capability. When complemented with a high-resolution microscope imaging system, holography can provide accurate, quantitative and non-destructive examination of microobjects with spatial resolution down to fraction of micrometres. Holography gives impression of depths (parallax), however it is unable of revealing the interior of a sample and for this reason it is often called a 2½D imaging technique. The fully 3D imaging can be, however, achieved using holographic tomography. In this technique, a series of holographic measurements is performed for various angular positions of a rotating sample. Then, the captured data is numerically combined, which results in reconstruction of a three-dimensional map of refractive index that gives glimpse into internal structure of an object under study.

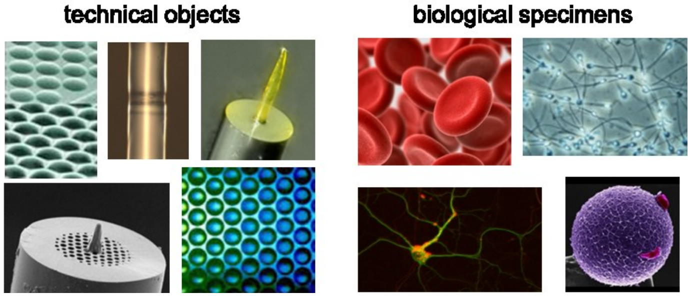

Fig. 1 Examples of microobjects

This project aims at advancing the described technique by overcoming its two main weaknesses – limited spatial resolution and 3D image deformation due to inaccuracy of the rotation system. According to authors of this proposal, both mentioned flaws can be removed with a simple modification of the conventional tomographic system, in which a rotated sample is illuminated with a single, on-axis beam of laser light. Instead, in the proposed system structured illumination is applied, i.e. an object is simultaneously illuminated with a pair of symmetrical beams that are incident on a sample at large angles. Thanks to the interference phenomenon, the two beams form a spatial pattern of alternately bright and dark fringes, hence the name of this kind of illumination. The proposed modification allows achieving the so-called superresolution effect, which enables visualization of fine details of a sample. Furthermore, the applied structured illumination can be used for reliable tracking of the object position, which in turns enables accurate numerical correction of the rotation errors. In addition, the simultaneous illumination of a sample from two directions allows speeding up the measurement by a factor of two and reduces the number of registered holograms without any loss in quality of the 3D reconstruction. The proposed novel technique provides significant improvement in accuracy and resolution of the 3D refractive index measurement and thus enables investigation of objects, which pose a great challenge to the presently known techniques of holographic tomography. Two prime examples of the research areas that may considerably benefit from the proposed technique are nondestructive biomedical investigation of intercellular structures and study of photonic crystal components, i.e. artificially created, micro- and nano-structures with impressive potential in many areas of technology.

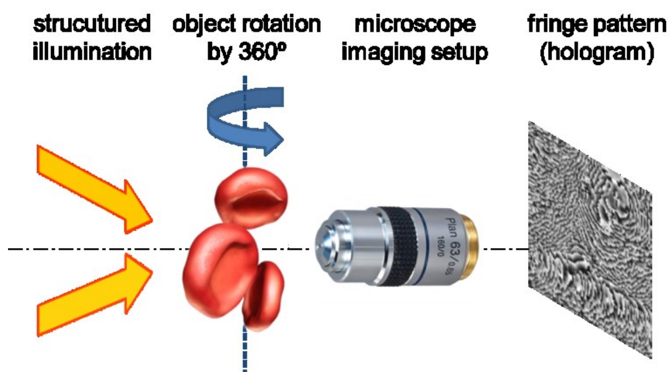

Fig. 2 Conceptual scheme of a tomographic system in the proposed configuration.

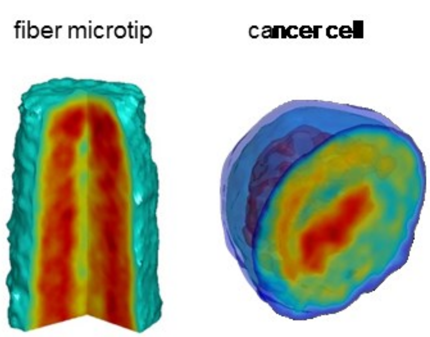

Fig. 3 Results of measurements with holographic tomography.