DeepSee project title is *"Deep learning single-shot in-line quantitative phase imaging"*. To understand the impact of this work let us break down the title into phrases.

What quantitative phase imaging mean? Seeing is believing. This short sentence encapsulates the essence of ongoing world-wide gigantic efforts focused on developing new imaging techniques. The question is whether we can see beyond what is offered to us by classical imaging. Classical light detectors (including human eye) respond purely to the intensity of incident light. As a result, a whole range of objects modulating only (or mostly) the phase of light cannot be imaged using the classical approach without sample staining. A very important group of phase modulating objects are biological cells and fragments of tissues (see exemplary object in Fig. 1). Phase map contains crucial quantitative knowledge about the object thickness and refractive index, which may provide the information about physical density, chemical composition or biological processes. In order to image the classically invisible objects one needs to invoke to the quantitative phase imaging (QPI) methods, i.e., interferometry, holographic microscopy, moiré and fringe projection technique. In all of these methods the measurement result is not given in a straightforward way but is encoded in the intensity modulation (fringe pattern) and therefore require a special phase demodulation method.

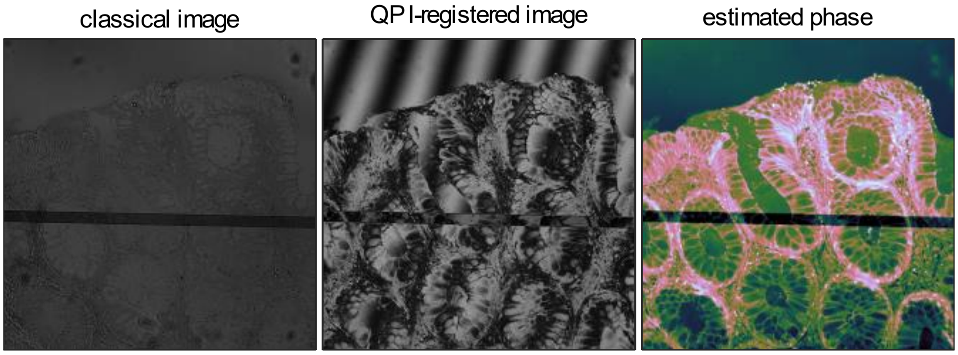

Fig. 1. Difference between classical and phase imaging.

What is the advantage of in-line setups? "In-line" means that two beams (object and reference) interfere in parallel or simply single beam is used for intensity image registration. The obvious advantage of such an approach is system compactness (see Fig. 2). Additionally, in-line setup prevent the determinant caused by the external factors (vibrations, aberrations, etc.), which lowers the cost and requirements imposed on optical components. Moreover, in-line configuration makes an optimal usage of the system capabilities, i.e., it enables simultaneously maximizing resolution and field of view. However, in the case of in-line setups we are dealing with the zero-fringe mode (infinite fringe period), which limits the range of possible phase estimation algorithms to multi-frame ones.

Why we are putting effort into single-shot analysis? Single-frame analysis is highly attractive in the case of measurements of dynamic events and in the unstable environment (e.g., living biological cells). The problem is that from the mathematical point of view, the single-shot phase demodulation is an ill-posed inverse problem, which complicates the analysis and emphasizes the need for reliable and efficient phase retrieval algorithms. Additionally, in the case of in-line interferograms the background, amplitude and phase components of the registered pattern are intertwined in the Fourier domain (see Fig. 2), which makes the phase estimation process cumbersome.

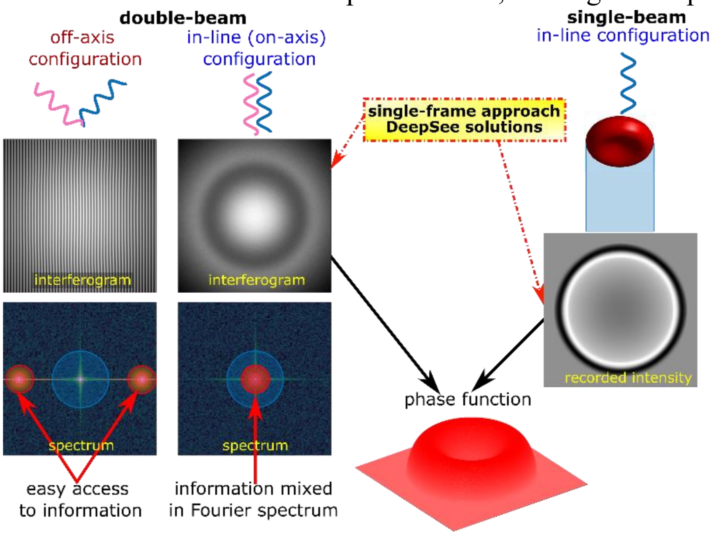

Fig. 2. DeepSee project scope.

What we can gain by using deep learning? The algorithms based on neural networks take over the task of establishing the relationship between the input data and the desired output. The sought-after relationship is found via the neural network learning process by modification and tuning of network parameters using basic mathematic operations grouped in the structure determined by the network architecture. In DeepSee outstanding computational possibilities of convolutional neural networks (CNN) and Bayesian optimization-based inference solutions will be applied for the system and sample independent single-shot in-line QPI for the first time.

The goal of DeepSee project is to push the limits of single-frame algorithms for in-line QPI. The project fits into natural, modern trend to shift the complexity of the task from hardware to software. DeepSee focuses on advancement of algorithms, however, indirectly it may also influence an advent of simplified and robust optical setups.