Integration Workflow of the Deformable Phase Plate for Enhancing Light Microscopy by Adaptive Optics

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Abstract

Adaptive optics is an evolving technology that, in terms of light microscopy, possesses as its main benefit the ability to compensate for specimen-induced aberrations due to distortions of wavefronts as they propagate through the refractive index structure of a specimen [1]. We present the concepts and challenges associated with integrating the Deformable Phase Plate (DPP) device, a refractive adaptive optics element capable of compensating high-order optical aberrations, developed by Phaseform, into various light microscopic setups [2].

The integration process typically involves hardware and software steps. Hardware integration is straightforward due to the DPP's transmissive operating principle and the housing being specially designed for easy coupling with existing standard optomechanical components, as shown in Figure Part A. Moreover, a few successful examples of DPP integration into light microscopes have been demonstrated in the following published articles: Sohmen et al. demonstrated the integration of a DPP in the illumination path of a custom two-photon microscope for sensorless adaptive optical correction of sample-induced aberrations [3]. Dorn et al. presented the integration of a DPP at the objective turret or camera port of a Zeiss AxioVert microscope [4, 5]. The DPP can be mounted into optical setups using standard cage systems, and its introduction can be at or close to the pupil plane in infinity space or directly conjugate to the aberrating layer. Additionally, the improvement of signal-to-noise and quality of acquired microscopic images was demonstrated on several modalities, including two-photon imaging in more than 150 µm deep into a mouse brain slice, shown in Figure Part B.

Software integration involves finding the optimal way to measure the present optical aberrations for correction, which plays a central role in defining the set of target wavefronts to be applied on the DPP. This estimation can be achieved either by utilizing wavefront sensor-based phase measurement techniques, such as Shack-Hartmann wavefront sensors, or by sensorless aberration estimation techniques, such as modal decomposition or iterative phase retrieval algorithms. The former method requires the addition of a wavefront sensor to the system, while the latter is computationally more complex but does not require any additional hardware.

In summary, successful integration of the DPP into microscopy setups provides researchers and engineers with a versatile adaptive optics add-on that enables high-resolution imaging of biological samples by compensating for optical aberrations. By overcoming the discussed challenges and implementing the appropriate methods for easy DPP integration, the microscopy community can advance the capabilities of light microscopy for a variety of applications.

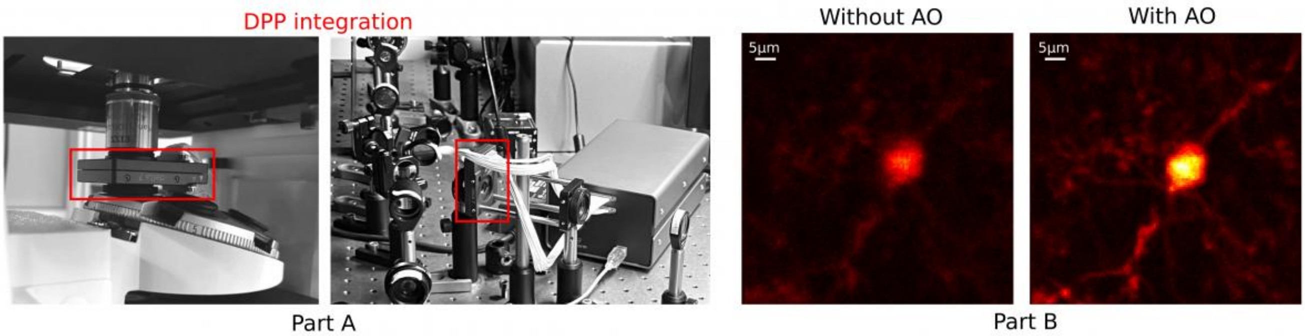

Figure represents DPP integration examples into two different microscopic systems and an example of image quality improvement.

References

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