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Adaptive optics for multi-photon microscopy using direct and sensorless measurement

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Abstract content
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Adaptive optics is widely used in astronomy to obtain diffraction-limited images through the turbulent atmosphere of the Earth. Over the last years, adaptive optics has gained the attention of a wider audience including microscopy. In this field, deep imaging in turbid media such as tissue is challenging due to scattering and optical aberrations. Adaptive optics can compensate the tissue aberrations.

We use a coherence-gated wavefront sensing (CGWFS) scheme for multi-photon scanning microscopes using the pulsed, near-infrared light reflected back from the sample. Coherence gating isolates the light from a layer of interest and rejects ghost reflections in the optical system, solving an intrinsic problem for direct wavefront sensing methods.

By interfering the back-reflected light with a tilted reference beam, we create a fringe pattern with a known spatial carrier frequency in an image of the back-aperture plane of the microscope objective. The sample-induced wavefront aberrations distort this fringe pattern and thereby imprint themselves at the carrier frequency, which allows us to separate the aberrations in the Fourier domain from low-frequency noise. A Fourier analysis of the modulated fringe pattern retrieves the wavefront aberrations, and the pulsed laser rejects spurious signals through coherence gating. This wavefront sensing method can directly measure the wavefront which is subsequently corrected using a deformable mirror.

Our method has a reproducibility of $\lambda/86$ peak-to-valley for defocus. We verified our method with a deformable mirror (DM) to measure the wavefront sensing accuracy. We present wavefront measurements of biological samples, and compare our method to sensorless methods, where the feedback loop uses an image quality metric instead. Finally, we will present first results of AO corrected measurements.

Primary author: Mr VAN WERKHOVEN, Tim (Leiden Observatory, Leiden University)

Co-authors: KELLER, Christoph (Leiden Observatory, Leiden University); GERRITSEN, Hans (Molecular Biophysics, Utrecht University); TRUONG, Hoa (Molecular Biophysics, Utrecht University); Mr ANTONELLO, Jacopo (Delft University of Technology, Delft Center for Systems and Control); VERHAEGEN, Michel (Delft University of Technology, Delft Center for Systems and Control)

Presenter: Mr VAN WERKHOVEN, Tim (Leiden Observatory, Leiden University)

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