Aberration correction with pupil segmentation and an adaptive lens

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A relatively recent approach to correct for aberrations in microscopy is to use an adaptive optics system (AO)[1], but most common used AO systems involves deformable mirrors or spatial light modulators, in conjunction with a wavefront sensor (WFS) implying a noticeable increase in the optical system complexity and a loss in gathered light signal due to the beam splitter needed for the WFS to work.

Our work shows how it is possible to recover diffraction limited performances in different type of microscopes (fluorescent microscope and light sheet microscope) using a deformable lens in conjunction to the pupil segmentation technique without the need of a wavefront sensor and even non constant aberrations in the whole field of view. This very compact setup solves all the problems related to the complexity and the loss of light common to most AO systems. Moreover, the fact that the WFS and the scientific camera are in the exact same plane, all non-common path errors are avoided.

The correction module, composed by an adaptive lens and a rotating wheel, was placed in the microscope pupil or in its image plane. The Adaptive Lens [2] has 18 actuators and the wheel has 4 radial holes capable of sectioning the pupil into 18 sub-apertures[3].

The correction process takes 18 images, one image for every sub-aperture, and then compute the displacement of each image from a reference image chosen between the 18 images. From the displacement, we can compute the gradients, thus the Zernike's coefficient.

We tested the system on different samples and microscopes.

Initially we tested the system on a fluorescent microscope on a calibrated USAF target is used (Group 7, Elements 1-2). To induce aberration two 0.17mm coverslip are placed between the objective front element and the USAF target.

In a second experiment, we used the system on a light sheet microscope. The tests were carried out on fluorescent nanobeads (Fig. 1) and chemically cleared, fluorescently labeled mouse brain tissues.

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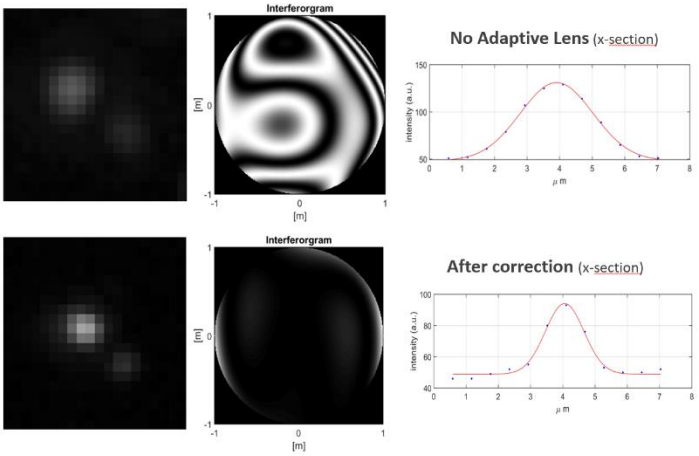

Figure 1: images of fluorescent beads without (top) and with wavefront correction (bottom).

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