HOLOGRAM AND IMAGE OPTIMIZATION USING HIGH RESOLUTION ADAPTIVE OPTICS

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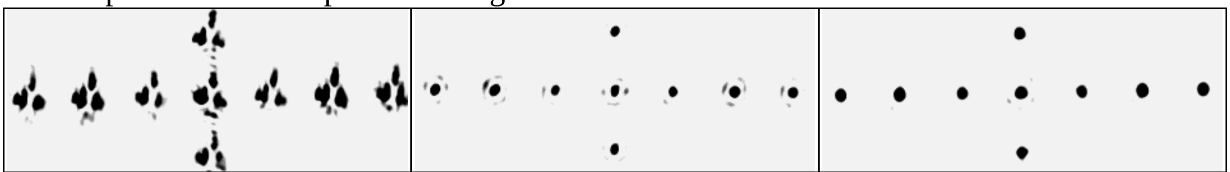
Particle and cell manipulation is possible using tightly focused laser light. Computer Generated Holograms (CGH) are calculated to create, for instance, individual spots which trap individual particles or precise shapes to locally activate molecules (encaging applications). They are then dynamically created by means of Spatial Light Modulators (SLM), which locally control the spatial phase of the laser electromagnetic field.
The trapping force is linked to the illumination intensity (flux of incident photons) and numerical aperture (or focal spot size). It is important to optimize the holograms so that aberrations induced in the experimental set-up are compensated. If not, the effective numerical aperture is lower than expected as well as the maximum intensity. This results in weaker trapping. Aberrations in the experimental set-up originate from different sources: laser, SLM, relay-image set-up, microscope objective, deep-tissue focusing.
In order to correct those aberrations, we combine a SLM (Hamamatsu LCOS-SLM X10468 series) with a wave front sensor, a Quadri-Wave Lateral Shearing Interferometer. This technology measures the wave front with a high resolution (up to 400x300 measurement points for the SID4-HR from PHASICS, used in this experiment), making it well suited to control SLM, which have more than 1000x1000 control points. The aberrations are measured and corrected in planes conjugated with the microscope pupil, which is physically located at the microscope objective exit pupil. Wave front is measured either before entering the microscope objective or after the image plane. In this case, since the microscope is a telecentric system, we need to image the pupil from infinity to the SID4 sensor.
In this paper, we propose to use the SLM both as the hologram generator and the aberration corrector. We show that the SLM potentially has a high dynamic range (over 10 waves for 10x10 spatial frequencies, and more for spherical aberration). We implement the adaptive optics loop in two configurations: the first configuration corrects the wave front that is incident on the microscope objective. This corrects laser, SLM and image relay aberrations (see Figure (1)). The second configuration corrects the aberrations at the output of the microscope. This allows correcting the microscope objectives residual aberrations and compensate for spherical aberration introduced by deep tissue focusing.
We present correction results for single spots as well as shaped beams. Contrast enhancement on complex far-field shapes is investigated.



No correction	Illumination correction	Complete system correction

Figure 1 – Cross-shaped far-field pattern recorded in the microscope image plane for three correction stages : no correction, illumination (laser+SLM+relay optics), complete system (after the image plane). Please note the residual spherical aberration (pedestal) in the middle image, that is compensated in the right-hand side image.