Mirao52D electromagnetic deformable mirror: experimental assessment and first ophthalmic applications.

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PURPOSE: To characterize the performance of an electromagnetic deformable mirror and estimate its suitability for ophthalmic applications.

METHOD: We built a closed-loop adaptive-optics setup that combined a Mirao52d electromagnetic deformable mirror (Imagine Eyes, France), actuated by 52 pairs of miniature coils and magnets, with a 32x32 Hartmann-Shack sensor. This system was used to evaluate the deformable mirror for the following criteria: wavefront generation range, linearity, hysteresis, surface quality, stability.
A stroboscopic illumination was used to explore the temporal behaviour of the mirror in open loop and measure its bandwidth. A detailed study of mode coupling, up to the 5th Zernike order, was also performed.
Following these metrological tests, we integrated the mirror into two adaptive optics ophthalmic systems, to experimentally evaluate its performance on real eyes. First an adaptive-optics phoropter was built, allowing to dynamically manipulate (both correction and generation) the aberrations measured on a living eye. Then an adaptive-optics loop was integrated in a high-resolution FD-OCT retinal imaging system.

RESULTS: We obtained the following results: linearity 95%, hysteresis <2%, active flat wavefront quality 10nm RMS, maximum wavefront stroke 100µm, maximum generated Zernike aberrations (peak-to-valley wavefront): defocus +/-35 µm , astigmatism +/- 30 µm, spherical aberration +/- 8µm, bandwidth 250 Hz. Nearly no mode coupling was observed on a wavefront generation range that was found to be compatible with the statistics of aberrations measured in real eyes, including most pathological cases.
Using the adaptive-optics phoropter, we introduced aberrations of different shapes and amplitudes, up to 1µm rms, and measured their influence on visual acuity for a number of eyes.
Eventually using the adaptive-optics OCT retinal imaging system, we were able to perform adaptive-optics wavefront correction including eyes with high ametropia and high-order aberrations above normal ranges (more than 30µm peak-to-valley including sphere and cylinder, for the particular case of a suspected early- stage keratoconus). Imaging showed great improvements on the resolution of retinal structures.

CONCLUSION: The Mirao52d deformable mirror combines a relatively large stroke with a high optical quality, which make it interesting for several applications of adaptive optics. First experimental tests, on visual simulation and retinal imaging, opens the way to the development of clinical systems.