Characterization of the deformable mirror Mirao 52e

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The deformable mirror (DM) Mirao 52e (Imagine Eyes, France) is widely used in adaptive optical systems, especially in ophthalmology and visual sciences. At the IAO such a DM is used in an "adaptive optics visual simulator" (AOVS) (P41, [1,2]). Hence, it was necessary to investigate its spatial and temporal behavior. The setup to measure its properties is illustrated in Fig. 1. The collimated beam of a laser-diode illuminates the DM completely and is imaged by a telescope onto the Shack-Hartmann-sensor HASO32. The laser-diode can either be triggered by the controller of the mirror (dynamic characterization) or can be used continuously (spatial characterization). For the measurements, the provided standard software and C++-libaries were used only.

Mirao 52e

- 15 mm effective pupil
- 52 electromagnetic actuators
- 50 µm wavefront stroke
- continuous membrane
- 95% linearity
- lack of hysteresis (<2%)
- TRIG-OUT for TTL synchronization

Measurement - Setup

Fig. 1

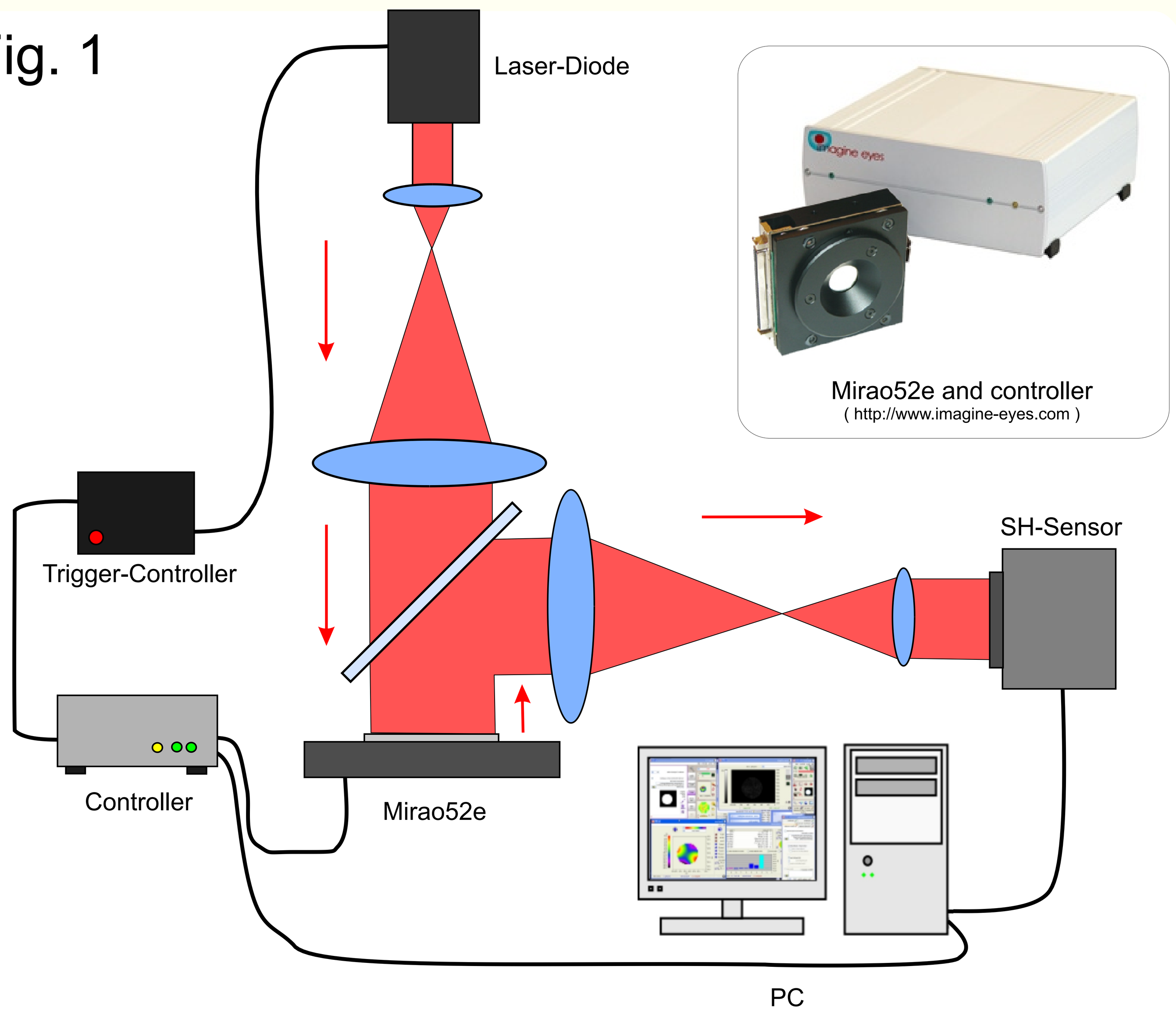
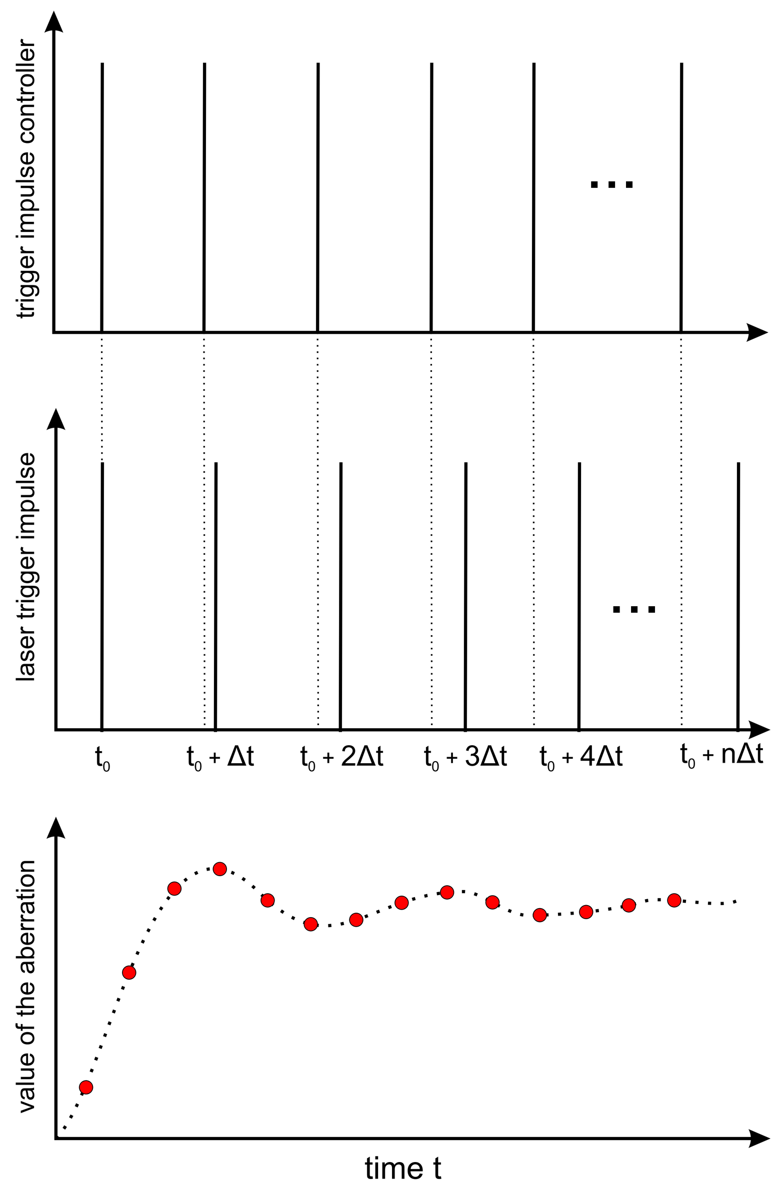


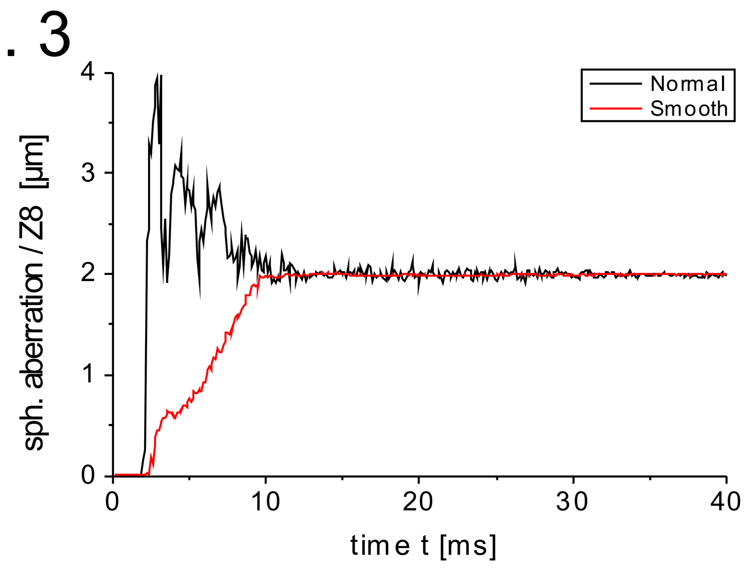
Fig. 2



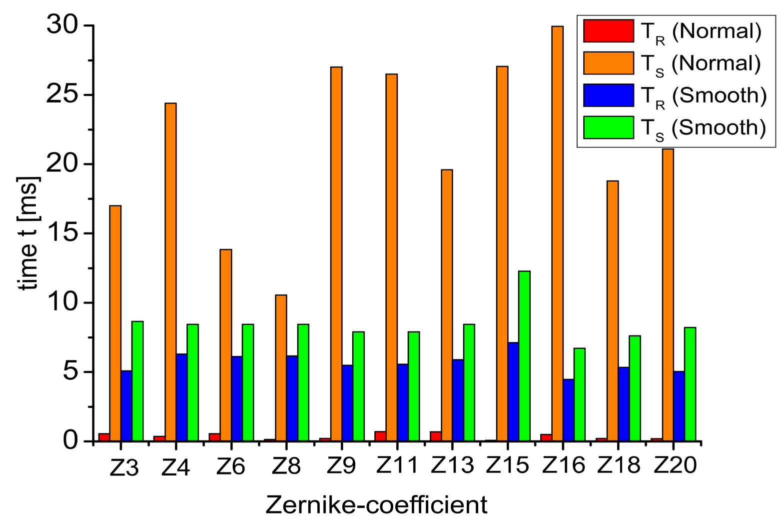
A stroboscopic technique was used to measure the transient response of the DM Mirao52e. Repeatedly, the investigated aberration was generated and the laser diode was switched on for 20 µs, controlled by the trigger-function of the mirrors controller. With every passage, the diode was switched Δt = 100 µs later. This process is illustrated in Fig. 2 schematically.

In Fig. 3.a) the measurement of the building of the spherical aberration by the DM is presented in normal (NM) and smooth mode (SM). Operating in the SM, the necessary voltage is not applied at once but is linearly increased over a period of 6 ms. The comparison between the NM and the SM is illustrated in Fig 3.b) for the first 20 Zernike polynomials. In SM the rise-time (T_R) is significantly higher as in NM but the settling-time (T_S), defining the time until the aberration is constant (fluctuation < 5%) is fairly below the T_S of the NM. The measured T_S had a value of about 10 ms, therefore the DM can oberate at a frequency of about 100 Hz.

Fig. 3

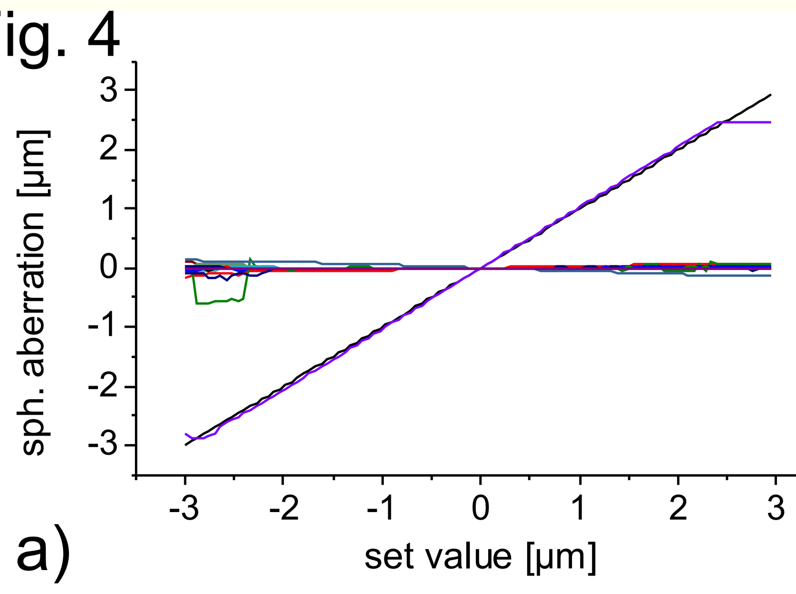


a) Comparison of the generation of a spherical aberration between the normal (black) and the smooth mode (red).

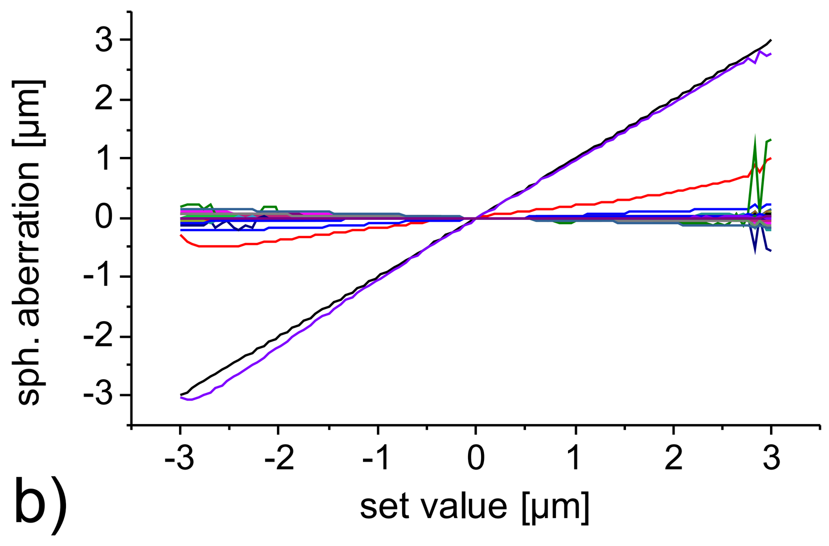


b) Comparison of the rise-time (T_R) and the settling-time (T_S) in the normal and the smooth mode.

Fig. 4



a)



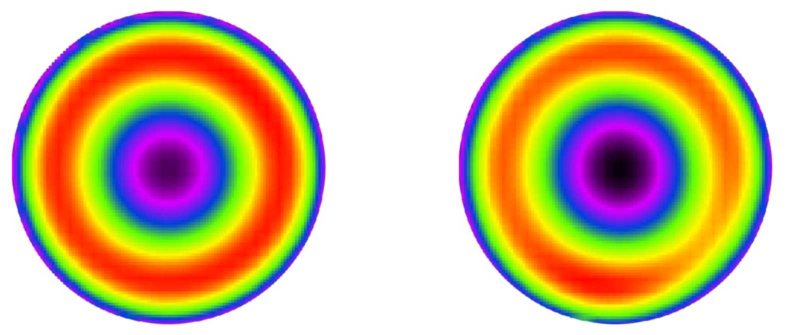
b)

Comparison of the closed-loop (a) and the open-loop (b) mode using the example of the sph. aberration (purple). The ideal behavior is plotted black. The other graphs represent the remaining 19 zernike polynomials.

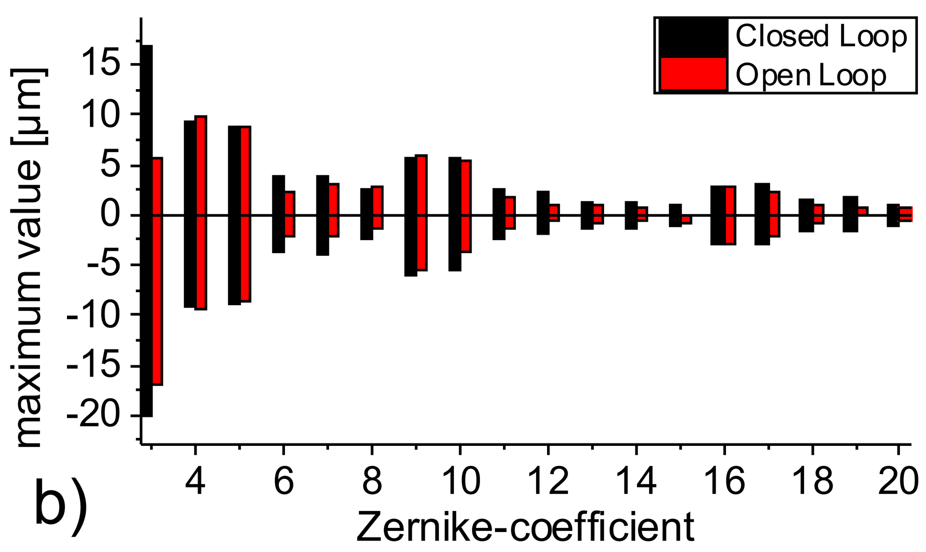
During the spatial characterization of the DM, the closed-loop (CL) and the open-loop (OL) were investigated. The CL is a feed back system between the mirror and the SHS. In contrast, the OL provides the generation of a wavefront in one step, based on a command matrix. As an example Fig.4 demonstrates the spherical aberration. It is one of the aberrations which can be generated more accurately in the CL (a) than in the OL. Additionally, there is more mode coupling in the OL.

The maximum values of the first 20 Zernike polynomials of the DM are illustrated in Fig. 5.b) for the CL and the OL. As visible higher aberrations as well as the defocus (Z3) could be generated with higher values in CL mode. The OL is especially important in ophthalmologic studies. Fortunately, almost all aberrations can be generated in OL with values up to 1 µm covering the area of interest.

Fig. 5



a) Spherical aberration (-2 µm RMS) generated using the closed-loop mode (left) and using the open-loop (right). The deformation of the wavefront caused by the generation of other aberations using the open-loop is visable.



b) Generation of the highest available values of the 20 first Zernike coefficients in closed-loop (black) and in open-loop mode (red).

[1] H. Jungnickel, H. Babovsky, A. Kiessling, M. Gebhardt, H.J.Grein, R. Kowarschik.,"Effects on Vision With Glare After Correction of Monochromatic Wavefront Aberrations," Journal of Refractive Surgery 27, 602-612 (2011)
[2] H. Babovsky, H. Jungnickel, A. Kiessling, R. Kowarschik.,"Wellenfrontkorrektion menschlicher Augen", DGaO-Proceedings 2010

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