Wavefront correction with deformable mirror – how to put actuators

Vadim Samarkin, Alexander Alexandrov, Alexis Kudryashov, Alexei Rykosuev, Yulia Sheldakova

Adaptive Optics Lab., Moscow State Open Ubiversity, Shatura, Moscow Region, 140700 (Russia)

samarkin@nightn.ru, kud@activeoptics.ru

Introduction

One of the ways to improve the beam quality in high power lasers is the use of adaptive optical systems. Any adaptive system consists of three basic elements –wavefront corrector, wavefront sensor and control unit that implements the feedback between corrector and sensor. A choice of each element is made in terms of the real parameters of the laser beam such as peak and average power, beam aperture, wavefront distortions etc. As a wavefront corrector we use bimorph mirror (BM) [1]; this type of correctors allows to compensate for the low-order aberrations. As a wavefront sensor we use Shack-Hartmann wavefront sensor (SHWFS).

BM should have enough damage threshold for high power beam and thermally stabilized surface. The cooling of BM is very important while application it in high power CW lasers or pulse lasers with high average power. Our new water-cooled BMs consist of silicon substrate firmly glued to piezoelectric ceramic (PZT) disc. The outer surface of the disc is divided in several controlling actuators. The surface of the substrate is polished and deposited by multilayer dielectric coating which holds power density of 50 kW/cm^2 in the Nd:YAG laser. It is so-called passive cooling design when the periphery ring of BM surface has thermal contact with the cooled condenser with constant temperature (20°C) [2]. Fig.1. illustrates the design of such BM.

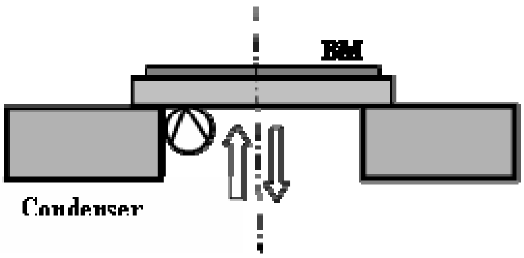


Fig.1.The design of water-cooled BM

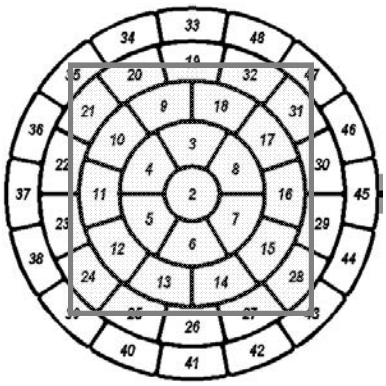


Fig.2. The grid of electrodes in the diameter 80 mm and illumination of the beam on the BM surface 48 x 43 mm

Experiment

Water-cooled silicon BM mirror with the optical diameter 80 mm was designed for correction for the CW 10 kW Nd:YAG laser beam of rectangular sizes 48 x 30 mm. This laser beam has to be reflected under the angle of 45° at the surface of BM. The image of the beam on the grid of mirror electrodes is shown on Fig.2.

Initial aberrations with P-V=1.576μ were introduced and then compensated with BM (see Fig.3a). In first experiment we used phase conjugation to calculate voltages to be applied to the electrodes of BM. All 48 electrodes were used in the algorithm of correction (Fig.3b). Voltages bar is presented under Zernike and Phase map. The voltages on the electrodes ##33-48 have maximal (or minimal) possible value of +300 V (or -250 V). Then the outer ring of electrodes was excluded from the algorithm of correction. We got better result rather then with 48 electrodes (Fig.3c). During last experiment we used hill-climbing method. Fig.3d shows the result of correction. The main disadvantage of hill-climbing method is that it takes a lot of iterations (several minutes) to get flat wavefront. Phase conjugation is very fast but it does not always lead to the best solution. We can see from the experiment that the best result was achieved when the electrodes covered with the beam were used.

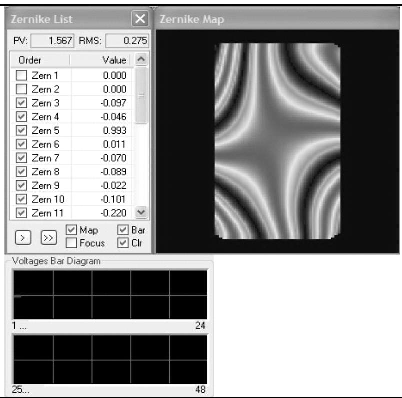
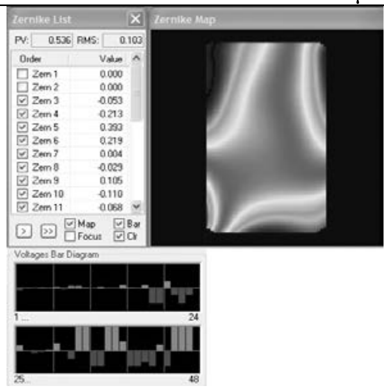
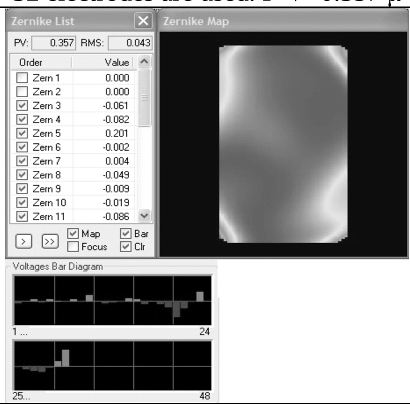
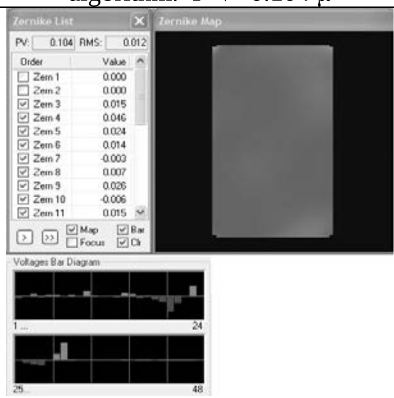
a) Initial aberrations, P-V=1.1576 μ	b) Correction with phase conjugated system with all electrodes. P-V=0.536 μ
	
c) Correction with phase conjugated system. 32 electrodes are used. P-V=0.357 μ	d) Correction with modified hill-climbing algorithm. P-V=0.104 μ
	

Fig. 3. Comparison of correction using phase conjugation and hill-climbing algorithm with different amount of electrodes

Conclusion

The proposed adaptive optical system allows to correct for low-order aberrations of high-power CW laser beam. Phase conjugation is the fastest method but it does not lead to the best result. Hill-climbing method is perfect but very slow. To get the optimal solution all the electrodes of BM should be covered by beam.

References

1. A.V.Kudryashov, V.I.Shmalhausen, "Semipassive bimorph flexible mirrors for atmospheric adaptive optics applications", Opt. Eng 35(11), 3064-3073 (1996).

2. V.Samarkin, A.Aleksandrov, V.Dubikovsky, A.Kudryashov, "Water-cooled bimorph correctors", Proc. SPIE 6018, 60180Z-60180Z-5 (2005).