Monitoring of thermal lenses

with a high-resolution wavefront sensor

Laser-
Laboratorium
Göttingen e.V.

As generally known, radiation-induced thermal lenses in optical components can cause considerable problems in a variety of different laser applications. E.g., ´lens heating´ due to absorbed UV laser radiation can diminish the achievable spatial resolution of the lithographic process in semiconductor wafer steppers. Photo-thermal influences also govern the development and operation of high-power solid-state lasers: High stability of both laser output characteristics and the employed optical elements inevitably requires appropriate provision for the thermal lens induced in the laser rod.

At the Laser Lab Göttingen a measurement system for quantitative registration of this thermal effect was developed. It is based upon a strongly improved Hartmann-Shack wavefront sensor with extreme sensitivity, which can now record relative wavefront changes in the range of λ/10000. This corresponds to deformations of less than 0.1 nm for a sampled area of a few square centimeters. In spite of its high sensitivity, the system is still very compact and flexible, especially as compared to interferometric devices. Sampling of the wavefront is performed in real-time using a 12-bit CCD camera interfaced to a PC via USB port.

Figure 1 shows the results of a photo-thermal measurement carried out on a fused silica plate, which is irradiated by an ArF excimer laser (wavelength 193 nm) at moderate intensities. Within a few seconds after turning on the laser, caused by the temperature-dependent refractive index as well as thermal expansion of the plate, the formerly plane wavefront of a well collimated test laser (633nm) is distorted to form a rotationally symmetric pit. This is equivalent to a convex lens, the focal length of which can be computed from a Zernike analysis. In the displayed example the defocus is about 1 km (!), corresponding to an over-all (peak-valley) wavefront deflection of ~ 2 nm.

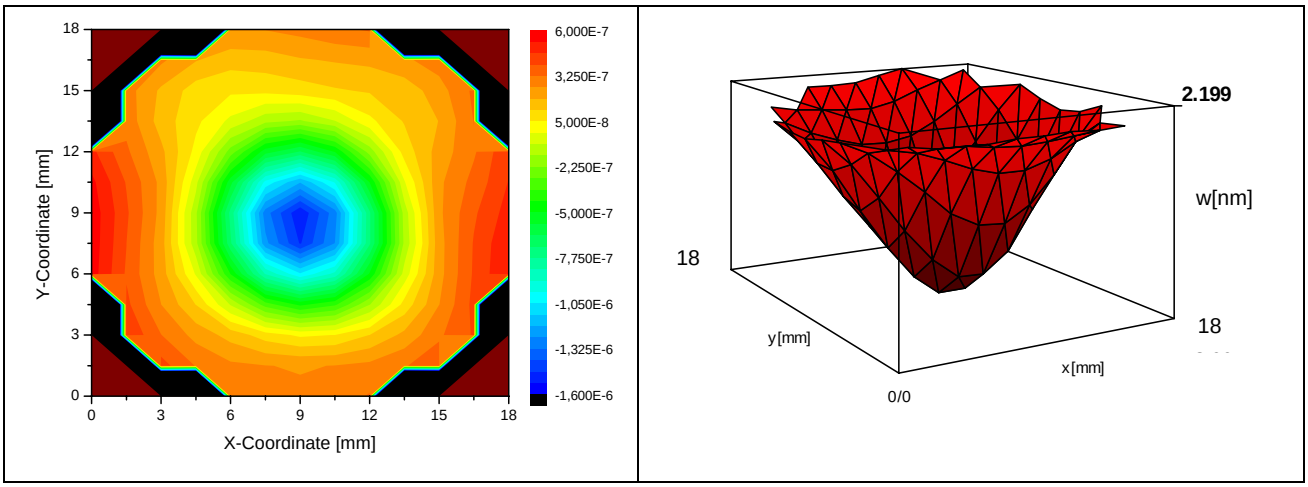

Fig. 1: *Transient thermal lens formed in ArF excimer laser irradiated quartz plate; the wavefront deformation of about 2nm (peak-to-valley) is registered after a few seconds, corresponding to a defocus of ~1km. Left: two-dimensional representsation; right: real-time display of control software ´MrBeam´.*

The new measurement device allows registration and precise characterization of induced wavefront changes by real-time Zernike analysis, affording to implement measures for static or dynamic compensation (e.g. by adaptive optics). On the other hand, the photo-thermal technique can be employed for a rapid assessment of the optical quality, since the extent of wavefront deformation is directly proportional to the thermal absorption losses. That opens a new field of application for the Hartmann-Shack sensor, which is employed also for on-line characterization of laser radiation (beam profile, propagation, M^2).

Contact: *Dr. Klaus Mann, kmann@llg.gwdg.de*