Plasma mirror far field characteristics of PHELIX *

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In the last ten years, plasma mirrors [1] have been often used to improve the temporal contrast of high-intensity short-pulse lasers, so that deleterious pre-ionization effects in laser-matter interaction experiments are avoided. Indeed, the use of an anti-reflection-coated mirror close to a focus in the laser beam allows one to gain up to 3 orders of magnitude in temporal contrast per reflecting surface. For petawatt-class lasers that are very complicated machines, this turns out to be one of the few solutions that one has at hand to reach the temporal contrast required by many experiments. Much work has been published on the temporal characterization of plasma mirror setups at low energy [2]; however the impact of the plasma mirror on the focal spot quality of high-energy sub-picosecond lasers has been much less studied. We propose and demonstrate an experimental setup capable of handling many 10's of Joules, allowing for the direct characterization of the focal spot of a petawatt-class laser after a plasma mirror. On the one hand we have observed that the focal spot shape of the laser is qualitatively not affected by the mirror, even at high working intensities. On the other hand, the Strehl ratio of the beam is largely reduced at high intensities because of scattering on the expanding plasma. Together with the measurement of the mirror reflectivity, we could define precisely the optimal working condition of the mirror.

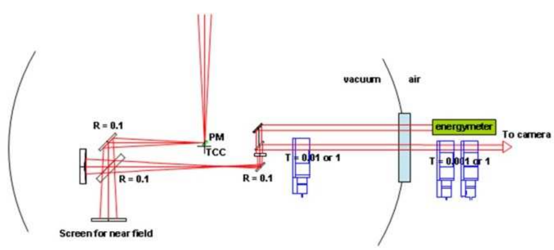

Figure 1: Experimental setup. PM: plasma mirror, TCC: Target chamber center.

The setup depicted in figure 1 has been implemented at the PHELIX laser facility [3]. An S-polarized laser beam is focused with a 90-degree off-axis f/5 parabolic mirror. During the initial alignment, a standard alignment system made of a magnifying telescope is used to image the laser spot outside the target chamber, allowing for an optimal alignment of the parabolic mirror. The 45-dregree plasma mirror is then inserted at a distance of 15 to 45 mm before the focal spot. The main problem of the setup resides in energy mitigation: for that, we rely on multiple reflections on uncoated fused silica substrates to bring the energy down to the millijoule level and density filters based on HR coated plates to get a dynamic range in energy of 7 orders of magnitude. The first part of the setup uses a 150-mm diameter spherical mirror that makes a 1:1 image of the focus while allowing for a decrease of the energy by a factor 100. The second part of the setup is a standard magnifying telescope that images the beam outside the target chamber onto a CMOS camera. During the alignment all filters are taken out of the beam and replaced by AR coated plates so that one can verify the fidelity of the imaging system. At this stage, a powermeter is used to measure the transmission of the whole setup. During high-energy shots, the reflected energy and the image of the focus are simultaneously recorded using the HR coated filters to keep the energy density on the camera constant.

After ignition at 10^{12} W/cm^2, the plasma mirror reflectivity reaches a maximum at about 90% and falls down below 80% above 2x10^{15}W/cm^2 (see figure 2). In parallel, the far field images recorded by the CMOS camera show no visible sign of alteration below the saturation level. On the plateau, the focal spot images also show very little reduction in quality. However, at higher energies, a strong scattering background can be measured around the focus, resulting in a strong reduction of the encircled energy and focal spot intensity.

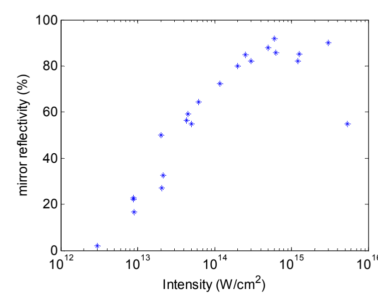

Figure 2: Measured reflectivity for different pulse intensities on the plasma mirror

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