Micro-Optic Spatial Mode Conversion for Terawatt Class Amplifiers

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Abstract: Microoptic technology is used in a terawatt multipass Ti:sapphire amplifier to convert high multimode, 532nm radiation from an unstable resonator Nd:YAG laser into TEM00, M2=1.04+-0.06 amplified output without sacrificing the amplified/pump energy conversion efficiency.

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Developments in micro-optic fabrication allow the construction of lenslet arrays with well-controlled spatial energy filtering characteristics using refraction and diffraction. The motivation for using lenslet arrays include improvements to the focus, peak intensity, reliability, and damage characteristics of high power laser systems. Experimental high intensity science requires laser pulses with very high contrast ratios, both in time and space to prevent the measurements from being dominated by lower intensity processes since high intensity experiments are spatially averaged. We demonstrate lenslet arrays can improve the spatial contrast for terawatt amplifiers by orders of magnitude.

The micro-optical structure surfaces were fabricated using photolithography with wet etching capable of reaching feature modulation depths of several microns. The micro-lens structures consist of randomly arranged lenslets on a fused silica substrate. The positive and negative lenslets in the array are designed to give gaussian intensity distribution as a function of angle.

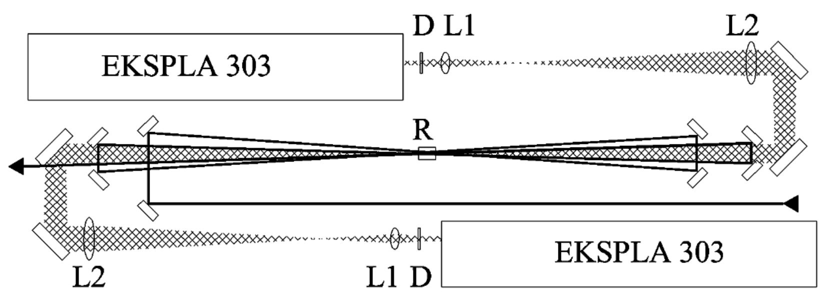

Figure 1: Scale drawing of the linear chirped pulse ti:sapphire amplifier. The micro-optic (D), Ti:saphhire rod (R), 100mm (L1) and 200mm (L2) focal length optics, and two doubled Nd:YAG pump lasers (EKSPLA 303).are labeled.

The lenslet arrays were incorporated into a 4-pass bow-tie, Ti:sapphire laser amplifier. The system is injected by 5mJ and pumped by two 400mJ, 532nm doubled Nd:YAG lasers. When operated as a chirped pulse amplifier, the system produces 4-terawatt peak powers. The general setup is shown in Fig.1. Using the lenslet array eliminates the need for vacuum relays and pinhole spatial filtering. The output mode from the original laser system (using traditional vacuum relay imaging from the Nd:YAG) is shown in Fig.2(a) in the near-field as grayscale color map and in the far-field as a lineout of the focus. In Fig.2(b) the output is show when using the lenslet arrays to reshape the 532nm pump. The pump energy to amplified output conversion efficiency for the amplifier was 34% and 31% using conventional vacuum relayed Nd:YAG pump laser light and lenslet array reshaped light, respectively. An M^2 focal region analysis of the amplified beam using the lenslet array gives a value of M^2=1.04+-0.06. Furthermore, within a radius of four times the exp(-2) beam radius, the difference between the integrated energy for an ideal gaussian and the experimental amplified output is less than 2%. Compared to amplification without the lenslet array, the low intensity spatial energy "wings" on the pulse were reduced by nearly two orders of magnitude between 2 < r < 3 in Fig. 2.

In conclusion, the application of modern microoptic design and fabrication was demonstrated as a "loss-less" spatial filtering technique that brings true TEM_{00} mode performance to terawatt class ultrafast amplifiers.

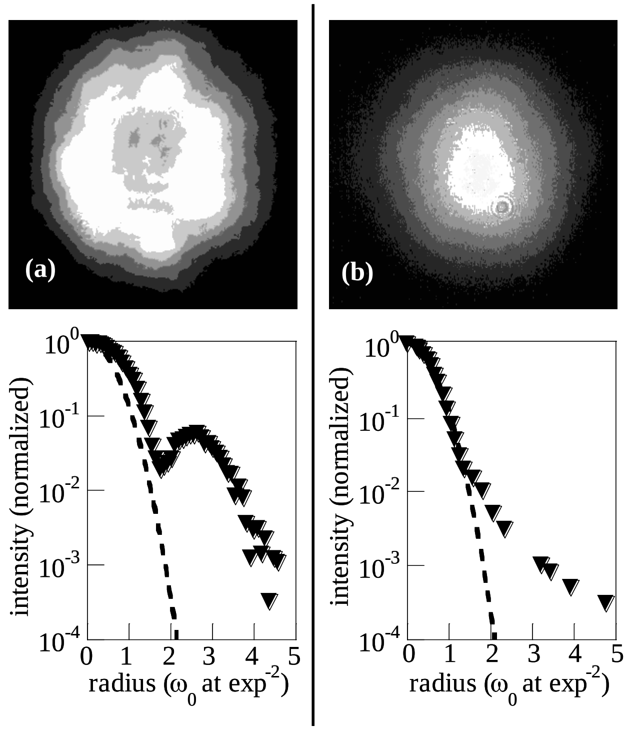

Figure 2: The profiles of the amplified beam before (a) and after (b) the use of the micro optics to reshape the pump mode are shown using an eight color gray scale and across a dynamic range of four orders of magnitude. The profile of the focus is shown with a gaussian whose near field profile has the same FWHM energy content.