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Laser Beam Shaping for Material Processing

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Tailored intensity distributions are an efficient tool in micro structuring of materials with ultrashort pulsed (USP) lasers. As USP laser ablation is usually most efficient at a material-specific laser fluence, the conventional Gaussian beam does not provide optimal working conditions. Central parts of the distribution exceed the ablation threshold such that the efficiency of the process decreases. Likewise, outer areas of the beam with low fluence cause undesirable heat transfer. Holographic beam shaping allows to dynamically adapt the beam profile such that the fluence can be optimized with respect to the material's ablation threshold. This can be realized with a phase-only liquid crystal on silicon (LCoS) display as a spatial light modulator (SLM). However, the occurrence of speckle in the image plane reduces the quality of the tailored field significantly. We evaluate different approaches of speckle reduction in theory and experiment. By mathematically modelling the speckle patterns, we illustrate their statistical properties. The model includes optics-induced aberrations. The results are compared to direct laser structuring experiments. Based on them, we discuss the advantages and limitations of dynamic beam shaping for USP laser material processing with special attention on the influence of speckle noise.