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Exploring novel structures for manipulating relativistic laser-plasma interaction.[1]

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The prospect of realizing compact particle accelerators and x-ray sources based on high power lasers has gained numerous attention. Utilization of all the proposed schemes in the field requires the laser-matter-interaction process to be repeatable or moreover, controllable. This has been very challenging at ultra-high light intensities due to the pre-pulse issue and the limitation on target manufacturing. With recent development on pulse cleaning technique, such as XPW and the use of plasma mirror, we now propose a novel approach that leverages recent advancements in 3D nano-printing of materials and high contrast lasers to manipulate the laser-matter interactions on the micro-scales. The current 3D direct laser-writing (DLW) technique can produce repeatable structures with at a resolution as high as 100 nm. Based on 3D PIC simulations, we explored two typical structures, the micro-cylinder and micro-tube targets. The former serves to enhance and control laser-electron acceleration and the latter is dedicated to manipulate relativistic light intensity. First principle-of-proof experiments were carried out in the SCARLET laser facility and confirmed some of our predictions on enhancing direct laser acceleration of electrons and ion acceleration. We believe that the use of the micro-structured elements provides another degree of freedom in LPI and these new results will open new paths towards micro-engineering interaction process that will benefit high field science, laser-based proton therapy, near-QED physics, and relativistic nonlinear optics.

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