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Liquid-crystal spatial light modulator for large-scale high-power infrared laser amplitude control

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High-power lasers developed for inertial confinement fusion require precise spatial beam shaping to achieve optimal performance. Amplitude modulation plays a crucial role in compensating for spatial inhomogeneities and masking beam regions to mitigate defect growth in power amplifiers. To do so, spatial light modulators (SLMs), typically localized at the front-end level, have to sustain high fluence over large area. In conventional liquid-crystal (LC) SLMs, amplitude modulation relies on the local alignment of the molecular director by an external electric field. Transparent electrodes are required, together with a photo-conductive crystal for optical addressing. This multilayer structure presents limited aperture ($\simeq$cm^2) and low damage threshold (0.1 J/cm^2). A novel SLM concept, based on the thermotropic properties of LCs, was introduced in 2020 [1]. In this approach, a metallic layer absorbs the writing beam, locally altering the temperature and, consequently, the LC birefringence. This reflective thermo-optically-addressed SLM (TOA-SLM) has shown phase control capabilities over multi-octave light spectrum [1,2]. By eliminating the need for electrodes, TOA-SLMs has many advantages over electro-optical SLMs: reduced optical losses, larger aperture, higher reflectivity and increased laser-induced damage threshold (LIDT). Here, a TOA-SLM prototype designed for amplitude modulation at 1053 nm is demonstrated. Composed of an anchored LC layer of 80-µm, confined between a Gold mirror and an AR-coated window, it features high reflectivity (90%) and large aperture (40 mm). LIDT measurements have been performed at 1064 nm in the nanosecond regime and LIDT values as high as 1.2 J/cm^2 in 1-on-1, and 0.8 J/cm^2 in S-on-1 (with S=500 at 10 Hz repetition rate) were recorded. For amplitude modulation, the TOA-SLM is paired with a quarter-wave plate, enabling it to function as a half-wave plate in reflection. A computer-controlled projector module (Vialux), integrating a high-power blue LED and a digital micromirror device (DMD), projects a patterned image onto the back of the gold mirror, locally heating the LC. Full extinction is reached for a writing beam irradiance of 0.1 W/cm^2. For a readout beam diameter of 2.5 mm, 50 grey levels are achieved, with an extinction ratio exceeding $\simeq$ 200. For a larger diameter (13 mm), the extinction ratio drops to 20. The origin of this degradation was traced back to fluctuations of the LC director (< 2°) over large surfaces probably induced by the manufacturing process of the LC cells and can be compensated by an accurate calibration of the device. These results open the way to large-aperture spatial amplitude modulation of high-fluence near-infrared beams.

References

[1] V. di Pietro et al., Opt. Lett. 45, 543 (2020).

[2] S. Barland et al. Opt Express. 31, 12597 (2023)