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Direct laser writing in maskless photolithography technology

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Direct laser writing (DLW) has become a leading technology for creating diffractive optical elements (DOE), particularly for submicron structures. As subwavelength optical devices such as photon sieves and metadevices are developed, the need for precise micro- and nanoscale structures grows. Conventional optical systems, limited by the diffraction limit, struggle to form elements smaller than the optical wavelength. Advanced technologies like electron beam lithography (EBL) and focused ion beam lithography (FIBL) offer higher precision but are costly and slow. A key development in DLW is the implementation of optical systems that exceed the diffraction limit. These systems often use nonlinear recording media with Gaussian beam distribution and special photoresists, enabling resolution enhancement. Saturated absorbers, such as chalcogenide materials, help further improve resolution by spatially reducing beam size. Recent research has explored non-Gaussian beams, like those modeled by a zeroth-order Bessel function, achieving 35-40% size reduction of recorded structures. Picosecond and femtosecond lasers also contribute to higher precision by minimizing thermal diffusion. For submicron DOE production, specialized photoresists like Heat Mode Resists (HMR) and inorganic chalcogenide semiconductors are utilized. They enable submicron exposure and yield structures as small as 130 nm, about one-third the wavelength of the laser. Optimization of DLW relies on adaptive algorithms that adjust laser parameters based on material properties, enhancing the accuracy and uniformity of created elements. These innovations are pushing the limits of DLW, making it a powerful tool for the fabrication of high-performance optical components. The authors express their deep gratitude to the National Research Foundation of Ukraine for financial support under the project No. 2023.04/0004.

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