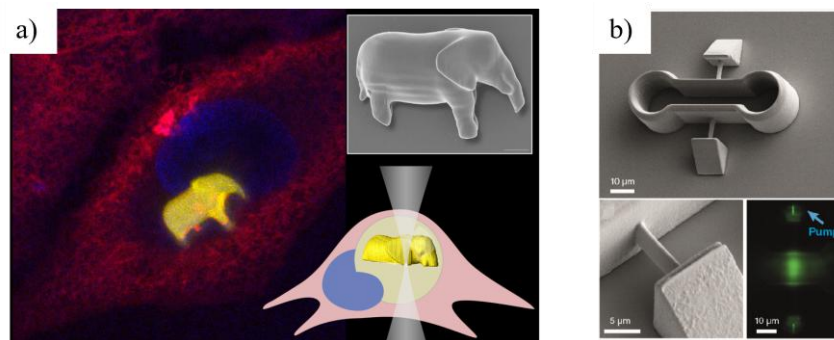


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High-resolution three-dimensional (3D) printing is transforming how photonic structures interface with living systems and soft matter. Recent advances in two-photon polymerization enable the fabrication of complex, functional microstructures inside living cells with sub-micrometer precision and long-term cytocompatibility. Intracellularly printed architectures can persist through cell division and adopt arbitrary geometries, effectively turning single cells into programmable micro-laboratories and opening pathways toward in situ optical, mechanical, and structural probes. In parallel, direct laser writing of nanostructured polymer scaffolds provides precise control over soft photonic environments, particularly through robust alignment of liquid crystals and the integration of tunable microphotonic elements. Printed nanogratings and micro-architectures enable deterministic control of optical anisotropy, light propagation, and emission, forming the basis of reconfigurable soft photonic devices.

Together, these developments establish a unified framework in which 3D printing acts as a bridge between cellular interiors and soft photonic functionality, enabling optically addressable bio-hybrid systems. This convergence of additive manufacturing, living matter, and soft photonics points toward new platforms for sensing, actuation, and adaptive photonic microenvironments driven by biological dynamics.



**Figure 1** (a) Two-photon polymerization enables the fabrication of complex three-dimensional microstructures directly inside living cells with sub-micrometer precision. Fluorescence microscopy shows an intracellularly printed free-form object (yellow) embedded within the cellular environment (red/blue), together with a schematic of focused femtosecond laser writing through the cell interior. Inset: scanning electron micrograph of an equivalent structure fabricated ex situ. (b) Soft photonic microstructures produced by direct laser writing, including suspended polymer architectures and nanostructured elements for controlled light–matter interaction. Electron and optical micrographs demonstrate complex three-dimensional geometries and localized optical excitation, illustrating reconfigurable microphotonic functionality.

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