Solid-immersion Super-oscillatory Lens for Heat Assisted Magnetic Recording Technology and Nanoscale Imaging

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Abstract: We demonstrate a solid-immersion super-oscillatory planar lens for super-resolution applications with a 102 nm full-width at half maximum focal spot in a low-loss immersion medium.

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We demonstrate for the first time a solid-immersion configuration of a super-oscillatory optical needle lens [1] that is known to create sub-diffraction limited focal spots without evanescent waves. By introducing a high-refractive-index solid-immersion medium we can further reduce the spot size. Despite the known association of super-oscillations with low energy spots [2], we demonstrate here that a properly designed super-oscillatory lens can be used to write a sub-diffraction limited spot on a registration layer such as photoresist. Our designed lens produces an optical needle measuring 102 nm laterally after travelling through 3.3 μm of low-loss medium. We will present experimental and theoretical demonstration of the system.

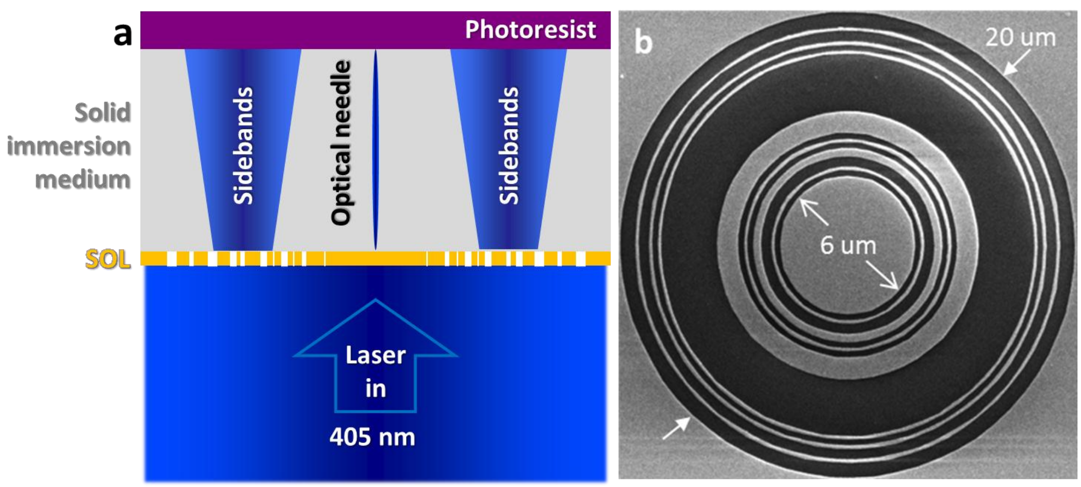

Fig.1. (a) Conceptual diagram showing a solid-immersion super-oscillatory lens writing sub-wavelength features on a registration layer (photoresist). (b) Scanning electron micrograph of a fabricated super-oscillatory lens on planar metal surface.

Figure 1(a) shows the concept of solid-immersion super-oscillatory lens. Under coherent illumination, the planar lens produces a sub-wavelength needle along the propagation direction, accompanied by concentric sidebands. On the end-face of the solid-immersion medium the optical needle tip can be used for various applications like photolithography, high-density data storage, and super-resolution solid-immersion microscopy. The super-oscillatory lens design is shown in Fig. 1(b). The scanning electron micrograph shows a binary amplitude mask made of 100 nm thin gold film with finest line width of 200 nm.

Figure 2(a) shows the calculated intensity distribution produced by the designed lens after travelling through the 3.3 μm thick solid-immersion medium. The solid-immersion medium is chosen as aluminum-doped zinc oxide (n = 2 + 0.006i at 405 nm) due to its low loss at the wavelength of choice. The full-width at half maximum (FWHM) of the central hotspot at this distance in AZO is 102 nm.

We further study the performance of the super-oscillatory hotspot after the immersion-photoresist interface. Figure 2(b) shows the intensity distribution along the propagation direction from the lens surface through the solid-immersion to the photoresist. The tail of an optical needle is visible starting 3 µm in AZO. The needle is disturbed due to the discontinuity in the refractive index profile between the two media. However it is interesting to note that 200 nm in to the photoresist thickness the optical needle is restored. The waves reflected from the interface are not shown in this figure.

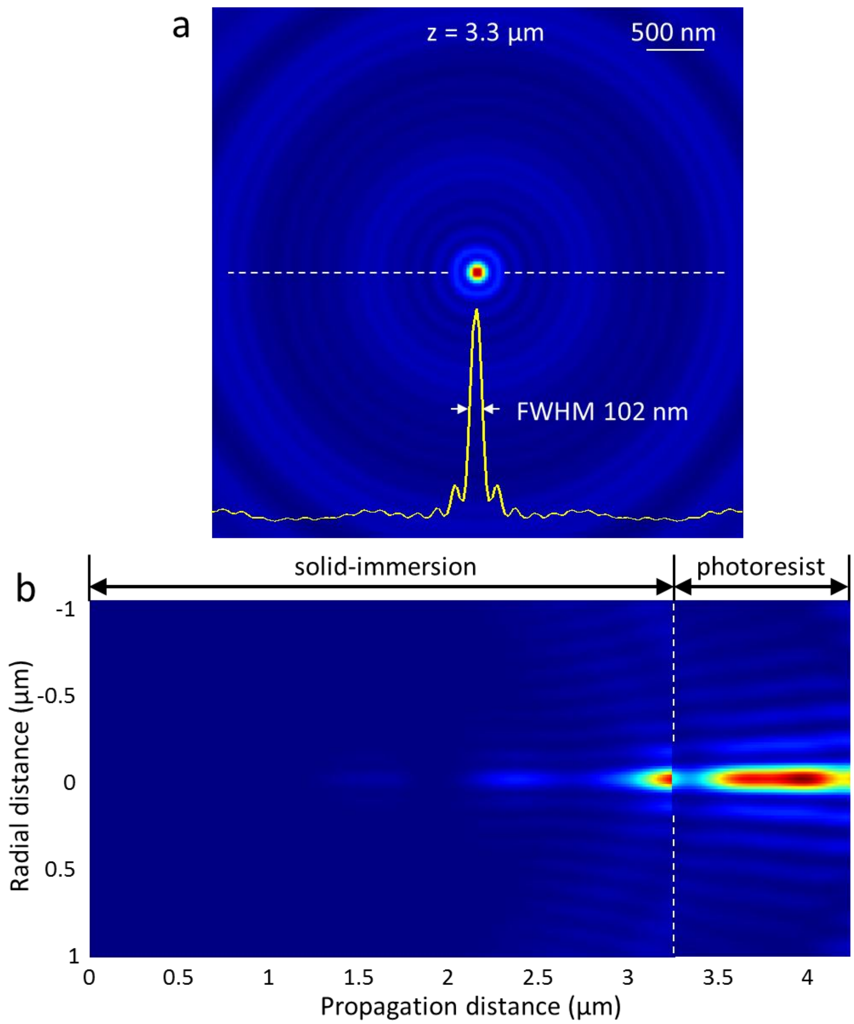

Fig.2. Performance of a solid-immersion super-oscillatory lens (a) Intensity distribution after 3.3µm of AZO. (b) Intensity distribution along the propagation direction within and beyond the solid-immersion medium.

We have shown a solid-immersion super-oscillatory lens forming a 102 nm spot in both a solid immersion medium and a registration layer. We will demonstrate experimental realization of the first solid-immersion super-oscillatory lens.

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