Appendix 1: Discussions on the insignificant absorption distributions.

Please find the imaginary RI (*i*RI) distributions have lower values compared to real RI (*r*RI) distributions (Fig. S2, left). This is basically due to the transparent nature of the used polystyrene microspheres and biological samples.

However, even though the *i*RI values are far smaller than the *r*RI values, it could be detected if our optical system is sensitive enough. However, we find consistent non-zero artifacts valued around 0.01 in measured *i*RI results, which fundamentally limits the *i*RI sensitivity of current system (Fig. S2, right). Such trends are especially found on the boundaries of a sample, and even for the polystyrene microspheres have excellent transparency.

We find such artifact is originated from the complex-valued point spread function (PSF). [73] Unlike symmetric optical transfer function (OTF) gives real-valued PSF, the asymmetric OTF gives complex-valued PSF, which induces crosstalk between *r*RI and *i*RI values of scattering potential. Thus, the measured *i*RI distributions could be influenced by the *r*RI of sample and vice versa. Unfortunately, the current tomographic system utilized circular scanning has inherently asymmetric OTF, especially along the k_z-axis [see Fig 5(b)].
Such asymmetric OTF of the circular scanning may not be adequate for the precise RI measurement of absorptive samples. However, in contrary, we would like to emphasize the asymmetric OTF is generally advantageous for transparent samples such as biological cells in terms of axial (z-axis) resolution, because of the Hermitian symmetry $\mathcal{H}_0(\mathbf{k}) = \mathcal{H}_0^*(-\mathbf{k})$ for real-valued $\chi(x,y,z)$.[73] This is one reason that the circular scanning is commonly used in ODT to maximize the asymmetricity of OTF using minimum illumination angles. [65, 76]

Utilizing the asymmetric OTF might be a trade-off. However, we would like to emphasize that it is not the fundamental limitation. The scanning strategy could be changed at any time without alterations in the optical setup nor the reconstruction algorithms. Though we choose the circular scanning due to the shot-effective features for a phase-only sample in this letter, we could always use full aperture scanning to investigate the imaginary RI of the sample.