Appendix 2: Red blood cell as a phase-dominant sample.

As shown in Appendix 1, the Hermitian symmetry $\tilde{\chi}^{*}(\mathbf{k}) = \tilde{\chi}(-\mathbf{k})$ holds only for phase-only samples. However, there is no such perfect phase-only sample. Even the polystyrene bead should have non-zero absorptive properties in used wavelength. Therefore, the practical 'phase-only sample' should mean the 'phase-dominant sample' having negligible imaginary part of scattering potential compared to its real part, namely $\mathrm{Re}\left[\chi(\mathbf{r}')\right]$? $\mathrm{Im}\left[\chi(\mathbf{r}')\right]$, where the $\mathbf{r}'$ denotes spatial coordinates inside of sample boundaries.

Now, let us calculate the expected real and imaginary scattering potential values of red blood cells (RBCs). We assume the RBC is full of oxidized hemoglobin (HbO_2) with mean corpuscular hemoglobin concentration (MCHC) of human RBC c_{MCHC} = 4.8-5.7 mM (31-37 g/dL with the molecular weight of hemoglobin 64,458 g/mol).

According to the Ref. [77], expected *r*RI of the RBC is $\mathrm{Re}\left[n_{588\ \mathrm{nm}}\right]$ = 1.3816–1.3904 in the used wavelength (588 nm), while the RI of surrounding medium (phosphate buffered saline) is $m_{588\ \mathrm{nm}}$ = 1.336. For the expected *i*RI of the RBC, we used the known molar extinction coefficient of HbO_2 in used wavelength ($\varepsilon_{\mathrm{HbO_2},588\ \mathrm{nm}}$). [78] Used conversion equation is

$$\mathrm{Im}\left[n_{588\ \mathrm{nm}}\right] = \log 10 \frac{(588\ \mathrm{nm})}{4\pi} c_{\mathrm{MCHC}} \varepsilon_{\mathrm{HbO_2},588\ \mathrm{nm}}, \quad \text{(S1)}$$

and the result is $\mathrm{Im}\left[n_{588\ \mathrm{nm}}\right]$ = 0.0010–0.0012.

From the definition of the unitless scattering potential, $\chi_{\lambda}(\mathbf{r}) = \left[n_{\lambda}(\mathbf{r})/m_{\lambda}\right]^{2} - 1$, we get $\chi_{588\ \mathrm{nm}}(\mathbf{r}')$= (0.0694 + 0.0015*i*)–(0.0831 + 0.0019*i*), whose real part is about 45 times larger than the imaginary part. Therefore, we could regard a human RBC as a phase-dominant sample in used wavelength, and expect the sufficient Hermitian symmetry on $\tilde{\chi}(\mathbf{k})$. If one uses blue light source around 400 nm, the imaginary part of scattering potential increases up to about 1/3 of the real part, which is no longer negligible (Fig. S3).