Details about equations in manuscript

1. Transitions of two equations in Eq. (4)

The transition of two equations is based on auxiliary angle method:

 (S1)

where . More details about Eq. (S1) can be found in <http://www.mathcentre.ac.uk/resources/uploaded/mc-ty-rcostheta-alpha-2009-1.pdf>. Substituting and to Eq. (S1), then we can obtain the Eq. (4) in the manuscript.

2. Transitions from Eq. (6) to Eq. (7)

Substituting Eq. (6) to Eq. (4), we have

 (S2)

Move to the left side and square both sides of the equation, Eq. (S2) becomes:

 (S3)

Eq. (S3) means that is modulated by the spatially varying term , whose mean value is , which can be explained as follows:

The term “” is a periodic function of variable and the period is (*n* = 1, 2, 3…), where is a fixed value for a certain position **r** and doesn’t change as the pattern shift (*i.e.* the change of the phase ). As a result, the mean of the term “” equals 1, where φ is uniformly distributed over a range of , *i.e.* (is the initial phase, a constant, ).

Now we can solve by averaging both sides of the Eq. (S3):

 (S4)

By rewriting Eq. (S4), we obtain

 (S5)

where is the number of frames, is the frame linked to phase (is the initial phase, a constant, ), and . From Eq. (S5), the actual reconstructed result is equivalent to . It has the same resolution, and can be obtained without measuring the actual values of the modulation depth . However, in reality, considering the effects of the noise, the contrast of the final reconstructed image will decrease if the modulation depth is not perfect.

Details about parameters in simulation

The two-dimensional ’star-like’ sample whose fluorescence density is given by

 (S6)

where are the polar coordinates of in the sample plane. In all the simulations, the PSF is chosen as

 (S7)

where is the first-order Bessel function of the first kind, and is the free-space wavenumber with . The images were simulated without noise. The image pixel size taken in all the simulations is 15 nm, about .

In our simulation, we assumed that the speckle pattern was generated by a phase-only reflective spatial light modulator (SLM) [1], which was illuminated by a collimated linearly polarized laser beam. The SLM was placed at the front focal plane of the objective lens (NA = 1.49) in an epifluorescence microscope. On the premise of this, the speckle pattern was recorded at the Fourier plane of the SLM by imaging the back focal plane of the objective lens. Then we applied to the SLM a random uncorrelated phase matrix, where phases were uniformly distributed over a range of , a Rayleigh speckle pattern was observed at the Fourier plane.

Reference

1. Y. Bromberg, and H. Cao, "Generating Non-Rayleigh Speckles with Tailored Intensity Statistics," Physical Review Letters 112 (2014).