Wide field lensless superresolution microscopy using random phase mask

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The simplest and novel phase retrieval technique has been implemented in multi-angle illumination scheme to enhance the resolution of lensless microscopy. The random phase mask (0, 2π) preceded the sample to encode the information at the sensor plane [1]. The recorded image consists of sample information as well as the phase mask. The image which has been captured earlier during calibration of the system without insertion of a sample is subtracted from this recorded image. The resultant image is back propagated to the sample plane through Fresnel propagation. The image is successfully retrieved to sample plane with low resolution and aliasing effects. To enhance the resolution of system, multi-angles illumination technique is adopted [2]. During imaging process; two types of images with sample and without sample are recorded with multiple angles illumination along x and y direction. The two types of images are subtracted corresponding to their illumination angles and combined at sample plane having resolution of 3µm. The technique is useful for robust imaging due to fast phase retrieval algorithm. The method is straightforward analytical reconstruction instead of using complicated iterative algorithm. For the first time, the phase mask has been used to improve resolution in lensless microscopy.

The sample information $O(x', y')$ are retrieved after multi angles illumination through Eq. (1), in which $I_{m,n}$ and $I_{r,m,n}$ show the images of sample and without sample from multi-angles of illumination along x and y direction while '$P_{sr\to s}$' and $U_{r,m,n}$ show the Fresnel propagation from sensor to sample plane and field of phase mask at the sensor plane correspondingly . The noise term is speckles which are evenly distributed throughout the sample with minor impact.

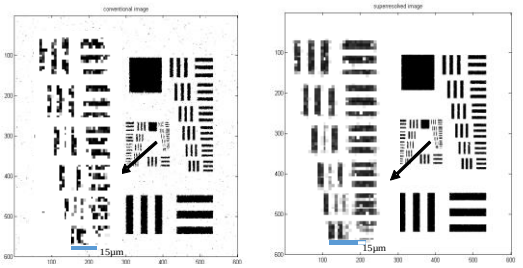

Figure: Comparison of conventional (normal angle) and superresolved image (multi-angles) with phase mask retrieval method.

$$O(x', y') = \sum_{m,n} \frac{P_{sr\to s}\left(\left(I_{m,n} - I_{r,m,n}\right).\exp\left(i.\varphi\left(U_{r,m,n}\right)\right)\right)}{P_{sr\to s}\left(\exp\left(i.\varphi\left(U_{r,m,n}\right)\right)\right)} + noise \quad (1)$$

The significant resolution and signal to noise ratio improvement of right side image reveal the validity of the multi angles illumination compared to left side conventional image, which is obtained under normal angle of illumination with the phase mask.

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