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Achieving super-resolution through nonlinear structured illumination

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Conventional imaging systems are limited in their optical resolution by diffraction. Thus, super-resolution techniques are required to overcome this limit. Many super-resolution techniques, such as structured illumination (SIM) [1,2], have been developed. However, these techniques often take advantage of linear optical processes and only a few techniques applicable to nonlinear optical processes exist [3, 4]. Here, we propose a scheme similar traditional SIM compatible with coherent nonlinear processes such as second- and third-harmonic generation and predict a resolution improvement of up to ˜4 fold.

In traditional SIM the resolution is doubled by capturing and utilizing spatial frequencies that would otherwise not be received by the imaging system [1]. This may be further enhanced if the saturable absorption of the fluorescent molecules can be utilized to collect even higher harmonics of the spatial frequencies [5]. Since coherent imaging systems are linear with respect to the electric field, the concepts of structured illumination may be generalized to nonlinear widefield microscopy modalities where field amplitudes instead of field intensities are measured [6]. We show that this is possible through the use of second-harmonic and third-harmonic widefield microscopy and show a resolution improvement of three- and four-fold, respectively. Our results suggest that a spatial resolution smaller than 100 nm may be achievable.

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