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Super-resolution optical fluctuation sensing

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Fluorescent nanosensors are powerful tool allowing measurements of temperature, magnetic field, pH, and other parameters with high accuracy at small scales. However, to ensure high special resolution, the signal from separate nanosensors should be distinguishable. To this end one should place nanosensors with very high precision, which requires precise mechanical control and does not allow to analyze environment parameters at several points of the sample simultaneously. To resolve many nanosensor particles simultaneously, one can use super-resolution approaches based on selective excitation, however they are sophisticated and require the nanosensors to remain in the inactive state most of the time, thus increasing needed exposition time and potential photo-toxicity.

Alternatively, there are methods based on specific temporal statistics of fluorescent particles, one of them is super-resolution optical fluctuation imaging (SOFI). The technique implies postprocessing of time-dependent fluorescent signal [1]. Briefly, the images fluorescent particles placed on a sample are recorded by CCD-camera, but due to point spread function of system and diffraction limit, the light from emitters is convolved and one pixel contents signal from several particles. Signal of each fluorescent source has fluctuations in time and the pixel will record the time trace composed of time tracers of individual emitters which's light reaches the pixel. Basing on the time tracers, one can calculate cumulants for each pixel and compose high resolution image using them. It is important to note that the information, used by SOFI to achieve sub-Rayleigh spatial resolution, is already present in the collected fluorescent signal and does not introduce any additional complications to the measurement.

In this work we suggest to combine sensing capabilities of nanoparticles with SOFI-based super-resolution for more accurate localization of the signal source. It is known that the emission spectrum or relaxation time of fluorescent particles may directly depend on environment parameters (for example, on charge [2]). We propose to collect light from fluorescent particles in different spectral or time windows and process data for each window separately according to SOFI algorithm. Incorporation of obtained pictures will give information about the parameter distribution on the studied sample. To demonstrate efficiency of this approach, both numerical simulations and a model experiment with laser diodes modeling fluctuating nanoemitters and intentional blurring of the image are performed. The 2nd, 3rd, and 4th order cumulant images provide improvement of the contrast and enable successful reconstruction of smaller features of the modeled temperature (or any other physical parameter) distribution relatively to the intensity-based approach.

REFERENCES

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