Partially structured illumination microscopy for adaptive superresolution imaging

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Structured illumination microscopy (SIM) is one of the fastest superresolution microscopy techniques. However, multiple SIM images are required in the reconstruction process, which degrades the imaging speed. In conventional SIM microscopy, structured fringe patterns are illuminated to the entire field of view, and the imaging speed is slowed down evenly across the entire image. Here, we present a new SIM method that enables custom targeted wide-field and superresolution imaging regions in a single frame. No mechanical elements are needed; a single digital micro-mirror device (DLPLCR6500EVM, Texas Instruments) was used to generate the custom illumination patterns. For areas where fast dynamic processes needed to be observed, a plane wave illumination pattern was applied, enabling single frame wide-field imaging. For areas where a high resolution was needed, structured illumination was simultaneously applied. Furthermore, the hybrid illumination pattern dynamically adapted to the target sample by utilizing parallel computing during the image acquisition to realize illumination patterns specific to the sample's location and shape. This technique achieves simultaneous observation of the subcellular structure and fast dynamic process by introducing different temporal and spatial resolutions to arbitrary regions in a single image.

For the experiments, image acquisition was performed on U87 cells cultured inside a microfluidic channel where the flow was visualized using 1-um fluorescent beads. In conventional SIM, flowing beads are located at different regions in every frame due to its movement, resulting in motion artifacts in the reconstructed SIM image. Here, we applied partially fringed patterns to the U87 cell regions in the sample, which have less movement or deformation compared with beads flows. The other regions containing moving beads were captured with a plain illumination pattern to achieve high temporal resolution. As a result, we could acquire the partially super-resolved SIM images for the U87 cell regions, as shown in Fig. 1 (a). The moving targets could be analyzed with a high temporal resolution to observe the flow, visualized as colored arrows in Fig. 1. In summary, we demonstrate imaging of fast dynamics and subwavelength scale structural changes within a single FOV, which was not possible with pre-existing superresolution methods.

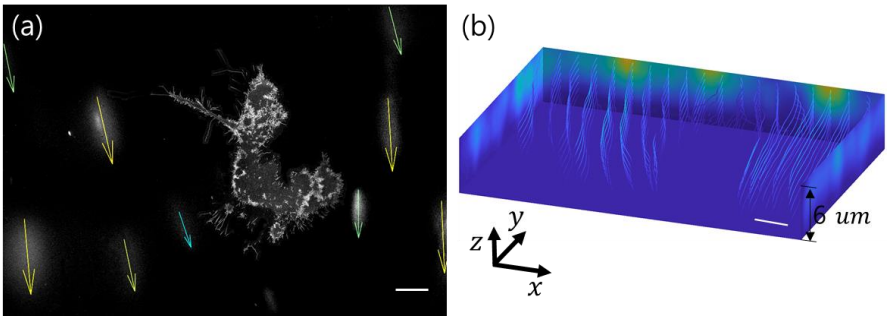

Fig. 1. (a) A reconstructed partially SIM image of the fluorescent beads and U87 cells on a microfluidic channel. Dynamics of flowing beads and U87 cells were illuminated by plain, and SIM patterns, respectively. (b) The streamline of the bead flows calculated by accumulating the direction and velocity in each frame. Scale bar; 5 μm.