Laser Scanning Microscope Techniques with Structured Light Beams Enabling Super-Resolution Imaging and Rapid Three-Dimensional Imaging

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The amplitude, phase, and polarization of light are the fundamental parameters that characterize light waves. In general, Gaussian beams with uniform phase and polarization distribution on the beam cross-section are mostly used in many applications using laser light beams. By contrast, when these parameters are spatially distributed on the beam cross-section, unique properties that cannot be attained by conventional light beams are manifested. Such light beams are also called structured light beams and have attracted much attention in recent years.

Radially and azimuthally polarized beams are well-known structured light beams, also referred to as cylindrical vector beams, which are characterized by axially symmetric polarization distributions. Due to the axial symmetry of polarization, vector beams exhibit distinctive behaviors when strongly focused by a high numerical aperture (NA) lens. For example, a radially polarized beam can produce a strong longitudinal electric field at the focus, which has a feature of a small focal spot compared to a conventional linearly or circularly polarized beam. This feature is particularly advantageous to enhancing the spatial resolution in laser scanning microscopy [1]. We have recently revealed that a higher-order radially polarized Laguerre-Gaussian (LG) beam can generate an extremely small focal spot, also known as superoscillation spot, by precisely controlling the incident beam size of a radially polarized LG beam on the pupil plane of an objective lens [2]. The use of the superoscillation focal spot in confocal laser scanning fluorescence microscopy enabled the significantly enhanced lateral spatial resolution approaching 100 nm even when a visible excitation beam was used.

In this talk, we will briefly review the use of structured light beams, including vector beams, in laser scanning microscopy to enhance spatial resolution. In addition, we will also introduce a new type of three-dimensional imaging technique that can be realized by controlling the spatial structure of light beams [3,4]. In this method, the depth information of samples is obtained from a single two-dimensional raster scanning of a light needle spot with an extended focal depth without the movement of the observation plane, allowing rapid three-dimensional image acquisition in laser scanning microscopy.

References:

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