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Ultra-Fast Digital Beam Scanning for Super-Resolution Microscopy

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The patented digital electro-optical scanning technology enables ultra-fast, nanometer-accurate laser beam positioning for advanced optical microscopy. Conventional mechanical beam steering is replaced with cascaded digital electro-optical deflectors, significantly increasing scanning speed, positioning precision and field of view while maintaining stable optical performance. The technology is particularly attractive for next-generation super-resolution microscopy platforms, including STED and MINFLUX systems, as well as high-performance confocal microscopes and precision photonic instrumentation.

Background

Modern laser scanning microscopy requires increasingly faster beam steering while maintaining nanometer-level positioning accuracy. Existing galvanometer-based scanners are limited by mechanical inertia, whereas analog electro-optical deflectors offer high speed but only over limited scan ranges and require complex analog control.

The presented technology introduces a digital beam steering/scanning architecture that combines multiple polarization-controlled electro-optical deflectors to achieve discrete, deterministic beam positioning with greatly expanded scan fields and excellent optical stability.

Technology

The technology employs cascaded digital electro-optical deflection stages in which the polarization state of the laser beam determines discrete angular deflection. Multiple deflection stages with progressively increasing angular increments create a hierarchical beam steering system capable of addressing a large number of scan positions.

Important technical features:

- Cascaded digital electro-optical deflectors
- Polarization-controlled beam steering
- Tilting of the beam around a fixed point within the microscope objective pupil
- Achromatic polarization optics for multi-wavelength operation
- Optional analog fine-steering stage for continuous positioning
- Efficient descanning of fluorescence emission independent of polarization

Advantages

- Ultra-fast electro-optical switching
- Excellent positioning reproducibility
- Reduced mechanical wear
- Lower vibration sensitivity
- Achromatic optical design
- Hybrid digital-analog positioning capability
- Reduced photobleaching through optimized scan trajectories
- Suitable for demanding super-resolution imaging applications
- Easily scalable by adding additional digital deflection stages.

Potential Applications

- STED microscopy
- MINFLUX microscopy
- Confocal microscopy
- Live-cell imaging
- Fluorescence imaging

Patent Information

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