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Publication date:
2015

SPATIAL MODULATION CONJUGATE TO THE TARGET PLANE: BEAMSHAPING, MICROMANIPULATION AND MICROSCOPY

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Keywords: beam shaping, optical trapping and micromanipulation, Generalized phase contrast, Fourier optics and signal processing

Creating novel laser sources enables control over the energy of emitted photons, $E = \hbar\omega$, which, in turn, enhances control over light-matter interactions that are governed by energy conservation principles. Similarly, exploiting conservation of momentum means that spatial light modulation is needed to gain better control over light's momentum (linear, $\vec{p} = \hbar\vec{k}$, spin or orbital angular momentum $S_z = \pm\hbar$ and $L_z = \pm m\hbar$), respectively). Using a spatial light modulator (SLM) as a diffractive optical element gives access to the constituent wave vectors that are then combined to form the desired beam pattern. However, placing the SLM conjugate to the target plane where the beam should be formed also offers some advantages. In this paper, we show that this latter geometry has promising applications in beamshaping [1], optical trapping and micromanipulation [2] and microscopy [3], among others.

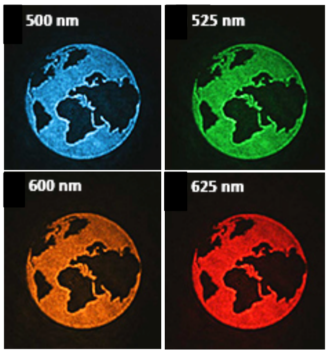

Fig. 1: GPC lightshaping a Supercontinuum source

Generalized Phase Contrast (GPC) places a phase-only spatial light modulator at the input plane of a $4f$ optical processing geometry. A static phase contrast filter (PCF) placed at the spatial frequency plane effectively synthesizes a reference wave to have a common-path interferometer that transforms input phase patterns into high-contrast intensity patterns at the output plane. This simplifies the generation of various light patterns since the needed spatial phase modulation directly mimics the desired pattern. Moreover, using the same input phase mask and PCF maintains high efficiency and image fidelity over a range of input wavelengths as demonstrated by successful GPC lightshaping of a supercontinuum source (see Fig. 1, adapted from [1]).

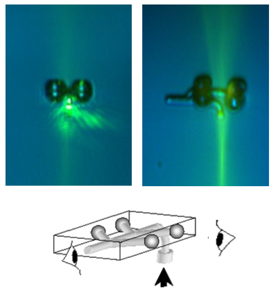

Fig. 2: Optically trapped light-guiding microstructures

Our Biophotonics WorkStation (BWS) projects matched counter-propagating patterns to create multiple dual-beam traps that can grab and mechanically control multiple targets such as, for instance, the optical handles of designed microstructures that are fabricated by two-photon photopolymerization. When the optically trapped microstructures are equipped with embedded waveguides, we get so-called wave-guided optical waveguides that can redirect and reshape light (see Fig. 2, adapted from [2]). Building upon the convenient generation of trapping patterns using an SLM conjugate to the target plane, a hybrid system that incorporates an auxiliary system that uses diffractive elements to dynamically control the coupling beam enables it to follow and maintain efficient coupling as the waveguide is manipulated in 3D.

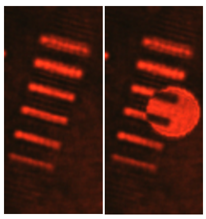

Fig. 3: Phase measurement in microscopy

Finally, placing a phase-only SLM conjugate to the object/image plane of a microscope enables one to create a "phase ruler" for phase measurements in microscopy. Controlling the SLM pattern and phase step provides direct phase measurement when the combined field is visualized in a subsequent phase imaging system by simply noting the SLM phase that cancels the object phase (e.g., see Fig. 3).

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2. M. Villangca, A. Bañas, D. Palima and J. Glückstad, "Dynamic diffraction-limited light-coupling of 3D-maneuvered wave-guided optical waveguides," Opt. Express **22**, 17880-17889 (2014)
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