228
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Innovative Phase Plates for Beam Shaping

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In light optics the use of holographic beam shaping has been largely used to obtain complicated wavefronts [1] and vortex beams but recently holograms have been used in the electron vortex beam generation [2]. We show here our recent improvement in the technology of hologram fabrication by means of “phase hologram” [3] replacing the amplitude hologram so far used. Phase hologram appropriately changes the phase of the wavefront by a modulation of thickness in a Silicon nitride thin membrane.

By means of phase hologram we could produce different beam shape in both Fresnel and Fraunhofer regime. Moreover we engineered the hologram shape to obtain high efficiency on the generated wavefunction. Presently we could demonstrate an efficiency of 40% in the generation efficiency for a single beam. This is the best performance ever shown and is much higher than amplitude hologram so far used.

The particular holographic technique consists in creating a grating of Si_3N_4 and modulating the periodicity with the desired wavefront shape. In general many order of diffraction of the grating are generated while only the first order is typically interesting for application with a clear loss of intensity.

However if the groove of the grating is a ramp spanning an appropriate thickness corresponding exactly to 2π phase in the electron path (also dubbed “blazed” profile) a single diffraction with the relevant beam can be obtained.

Using this principle we generated by FIB a close to ideal hologram. The experimental thickness profile (as calculated by EELS) is shown in fig 1a. In the inset a profile in a line is extracted and compared with the “ideal” blazed pattern.

The full pattern for the generation of a Bessel beam is shown in fig 1b while the resulting series of beam in a Fresnel plane is shown in fig 1c. In particular the experimental pattern (up) is compared with the simulated one based Fresnel integral of the hologram in fig 1a [3]. The very good agreement means that the simulated phase is also correct. Therefore the figure in the inset that represents intensity and phase of the simulated beam can be considered as a realistic representation of the actual phase.

As example of generated beams we have already created Laguerre-Gauss Vortex beams [3] and Bessel beam of order 0,1,2 the last two also carrying orbital angular momentum (e.g. in fig 1) [4]. Other beam will be also presented.

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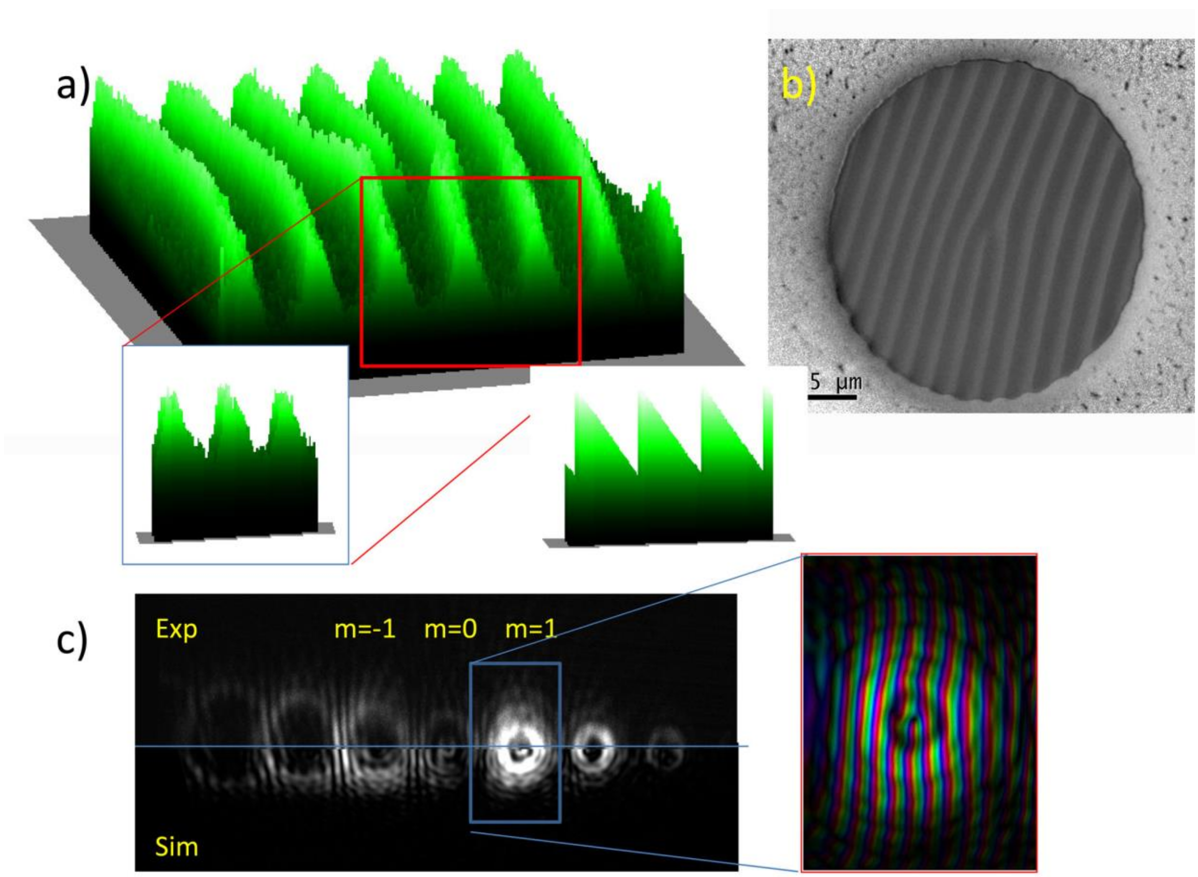

Figure 1: a) 3D rendering of the hologram thickness (calculated using EELS). The two insets show a single line profile and the comparison with an “ideal” blazed one b) planar Thickness map image of the hologram c) Diffraction pattern of the hologram: each circle corresponds to an order of the hologram diffraction. The upper part is the experiment the lower part is a propagation simulation. The inset shows the detail of the main (m=1) beam as extracted by simulation. The brightness corresponds to the intensity but the hue information corresponds to the phase. The vortex is clearly visible as black spot in the center and phase singularity.

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