Type of presentation: Poster

IT-1-P-2510 Toward electron polarizators

Grillo V.[1,2], Karimi E.[3], Balboni R.[4], Gazzadi G. C.[1], Frabboni S.[1,5], Mafakheri E.[1,5], Tang W. X.[6,7], Boyd R. W.[3,8]

[1]CNR-Istituto Nanoscienze, Centro S3, Via G Campi 213/a, I-41125 Modena, Italy, [2]CNR-IMEM, Parco delle Scienze 37a, I-43100 Parma, Italy. , [3]Department of Physics, University of Ottawa, 150 Louis Pasteur, Ottawa, Ontario K1N 6N5, Canada, [4]CNR-IMM Bologna, Via P. Gobetti 101, 40129 Bologna, Italy, [5]Dipartimento FIM, Universitá di Modena e Reggio Emilia, Via G. Campi 213/a, 41125 Modena, Italy, [6]College of Materials Science and Engineering, Chongqing, 400044, China, [7]School of Physics, Monash University, Clayton, VIC, 3800, Australia, [8]Institute of Optics, University of Rochester, Rochester, New York 14627, USA

Email of the presenting author: vincenzo.grillo@cnr.it

We describe the experimental and theoretical improvements toward the realization of an efficient electron spin polarizator. The initial proposed polarizator [1] was based on the spin-orbit conversion of a vortex beam [2] to a beam with a defined polarization. The conversion occurred within a compensated quadrupolar Wien Filter (WF).

The theoretical improvements are supported by simulations of the beam-field interaction through a new multislice for propagation including spin [3]. The experimental steps are based on the introduction of phase holograms to produce e-beams close to ideal Bessel beams [4]. To improve the flexibility and feasibility of the polarizer we have considered different possible alternative design: e.g. when the pitch fork hologram is positioned below the WF it is possible to obtain simultaneously the 2 polarized beams and switch between them [3]. Alternative design permit also to remove the electric fields. We have also studied the higher order corrections of the WF by magnetic multipoles of higher order and calculated the possible effects of the fringing fields: the efficiency in the selection of the polarized states increases with the order of the vortex and consequently of the multipoles in the WF.

Fig 1 is an example of simulation of the wavefunction after a WF for a beam at 15 KeV (e.g. for SPLEEM and low voltage TEM applications) for 2 initial spin state. The brightness is proportional to the wave intensity, the phases encoded in the color. Due to the spin orbit coupling different spin are transformed, inside the WF, in different phase factors and orbital momentum. Only the center of the state $|\ell=0,\uparrow>$ has stationary phase and therefore contributes to the intensity at the center of a pupil in far field diffraction.

For this simulation we corrected the asymmetric aberrations by multipolar elements but still obtained a strong phase oscillation beyond a radius dependent of the size of the field that must be further corrected to obtain maximal efficiency.

Fig 2 a,b is an example of phase hologram described in its thickness map and overall pattern. This pattern reaches an efficiency of 40%. In fig 2c an example of Bessel beam with $\ell=2$ is shown. These beams, in the diffraction plane (see fig d), transform to narrow rings. This strongly reduce the demand of lateral stability of the fields and the problems of phase oscillations described in fig. 1

[1] E. Karimi et al. Phys Rev. Lett 108, 044801 (2012)
[2] J. Verbeeck et al Nature 467, 301 (2010).
[3] E. Karimi et al Ultramicroscopy 138, 22 (2014)
[4] V. Grillo et al. Phys. Rev. X 4, 011013 (2014)

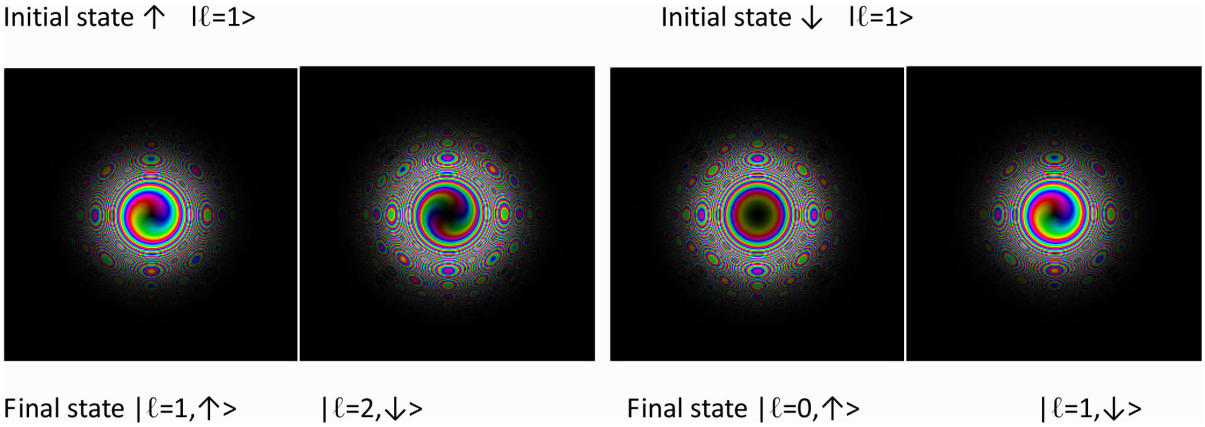

Fig. 1: Wavefunction after a Wien filter for a beam at 15KeV. The initial beam had ℓ=1 and 2 spin states were considered. The final spin state are also separately plotted. The external phase oscillation are due to residual aberrations.

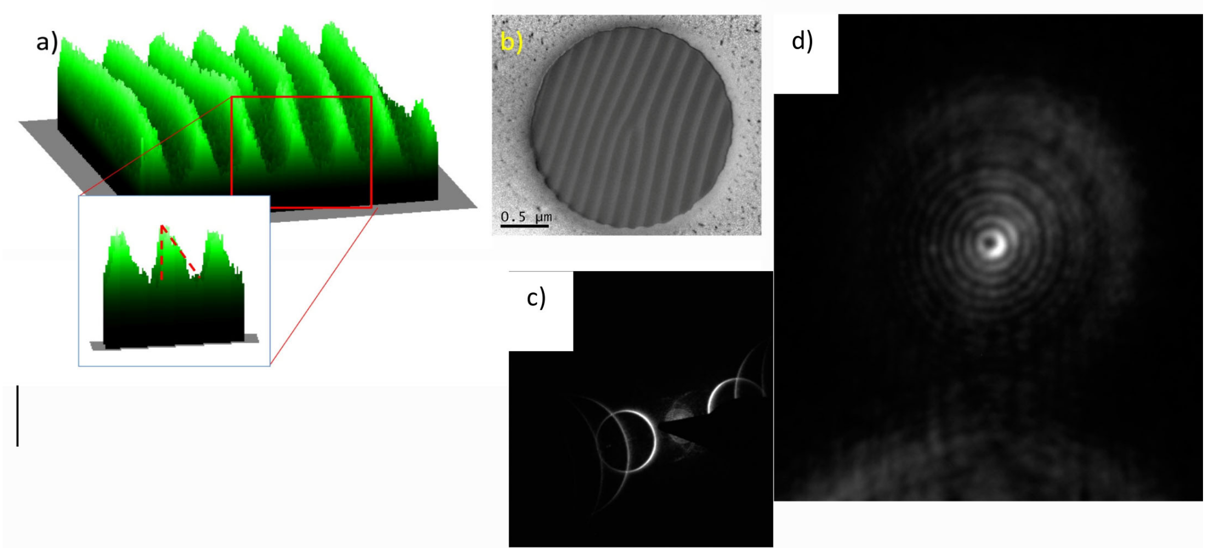

Fig. 2: Example of phase hologram: the thickness profile in Si3N4 a) and the full pattern b)are shown. Example of Bessel beam with ℓ=2 in the Fresnel c) and Fraunhofer d) regime