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Holograms for the Generation of Vortex States with L=500ħ Fabricated by Electron Beam Lithography

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Electron Vortex beam with high quanta of OAM are interesting for their magnetic properties and to explore the transition between quantum and classical definition of Orbital Angular Momentum[1].
This justifies the technological effort to produce increasingly complicated hologram encoding for such complicated case.
While so far the technology of hologram fabrication was based on FIB [2][3] patterning on SiN with a small exception [4] we are exploring the possibility to produce the highest quanta of OAM ever built by using Electron Beam Lithography (EBL)
We demonstrate here the case of a vortex beam with nominal OAM L=500ħ. One extremely interesting problem is that the generation and characterization of such beams is indubitably challenging since the number of pixel necessary for the sampling of the vortex structure is typically very high.
For example even if the phase were directly observed on the CCD screen (e.g. by interference) most CCD mounted on modern TEM would produce a poor representation of the vortex due to the limited number of pixel. At the same time providing a large enough carrier frequency will require a very large memory representation while calculating the hologram and poses some limits in term of the FIB possibility. This is where the EBL can produce a big advantage since in principle a larger number of pixel can be controlled and potentially with a finer and more precise pitch.

For the actual realization of the hologram we created by FIB the reference circular aperture in the Au layer used to cover the standard SiN support film. The other side was used for EBL patterning. The membrane was spin coated by PMMA while different dose factors were tested. The final processing of the hologram was carried on by exposure in the chamber of Reactive Ion beam Etching.
In fig 1a it is possible to see a TEM overview of the hologram while fig 1b is a detail from which we can see that the average pitch size was about 100 nm.
While we were not able to capture a full detailed thickness map of the overall hologram, we used the nominal hologram shape to predict its diffraction. We were able to obtain a “reasonable agreement” between the simulation and the experimental intensity of the vortex and this can be considered as a proof that a beam close to L=500ħ has been generated.
In fig 1c we superimposed a simulated intensity to an experimental image at focus. While one of two vortexes was reasonably close to simulations, important deviation can be observed in the opposite diffraction order. They could be probably ascribed to the bending of the SiN membrane.
In spite of some experimental difficulties we generated one of the largest quantum angular momentum state not only in electron microscopy and we have opened the road for massive EBL application in holographic masks [5].

References:

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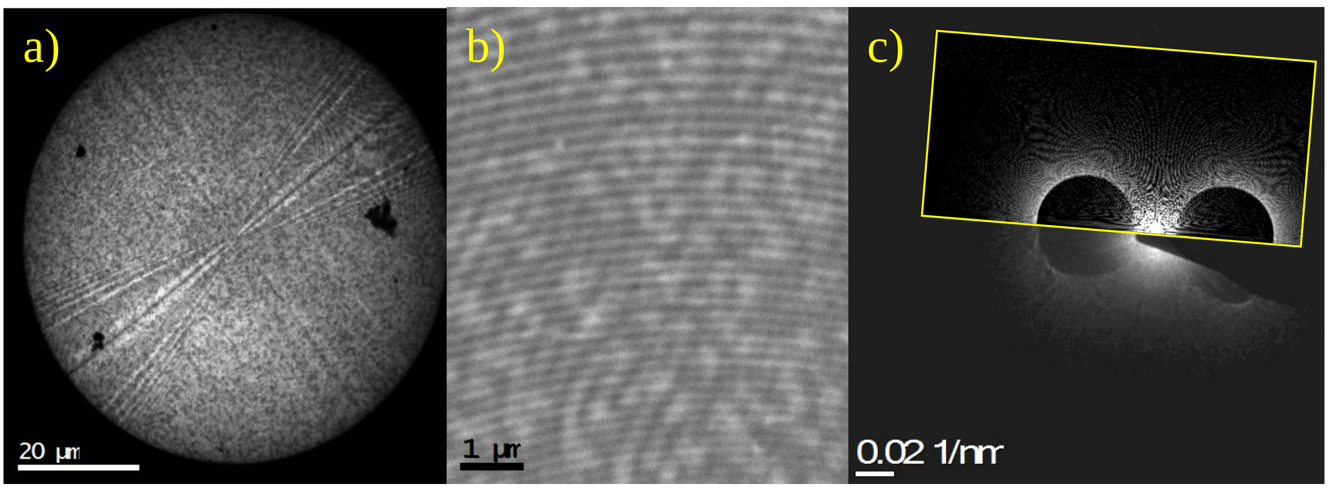

Figure 1. a) Overall image of the EBL fabricated Hologram. b) TEM image of a detail of the holographic map 3) Experimental diffraction from the hologram: In the inset we superimposed the simulation on the intensity based on the projected hologram.