Deliverable Report

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Deliverable Title: Novel holograms

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Name, title and organisation of the scientific representative of deliverable's lead beneficiary (task leader):

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Deliverable table

Deliverable no.	D1.1
Deliverable name	Novel holograms
WP no.	1
Lead beneficiary no.	4 (UGLAS)
Nature	P
Dissemination level	PU
Delivery date from Annex I	Month 12
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D1.1) Novel holograms: Novel hologram patterns developed to control the OAM and radial mode of the diffracted beams in order to obtain coherent superpositions of OAM modes having a unique Gouy phase, so as to be stable in the subsequent propagation. The achieved performances of these holographic methods for OAM multiplexing will be evaluated and reported. The prototype quality and the extent to which its perfomances reach our target goals will be assessed and validated by the steering committee. The device will be also illustrated in a short report and/or in scientific publications. *[Excerpt from GA-Annex I DoW]*

We have developed a technique allowing multiplexing for modes defined by both their OAM and radial modes (as in Laguerre-Gauss modes). The system is based on our previously developed communication system,[1] incorporating also the required phase profile of radial modes. It is important to note that, in contrast to the separation of OAM modes, detection of radial modes requires that the beam waist of the incoming light is matched to that of the holograms. The generation of holograms that allow multiplexing of an arbitrary number of modes specified by their indices ℓ and p (corresponding to the azimuthal and radial index, respectively) is performed in a LabView routine. **This LabView program prototype is the core of the present deliverable.** It will be made freely available online on the Phorbitech webpage. The Labview program has been also demonstrated to the Steering Committee in the 1st year meeting (held at ICFO, Barcelona, September 16-17), which could hence assess its good performances and approve it for delivering.

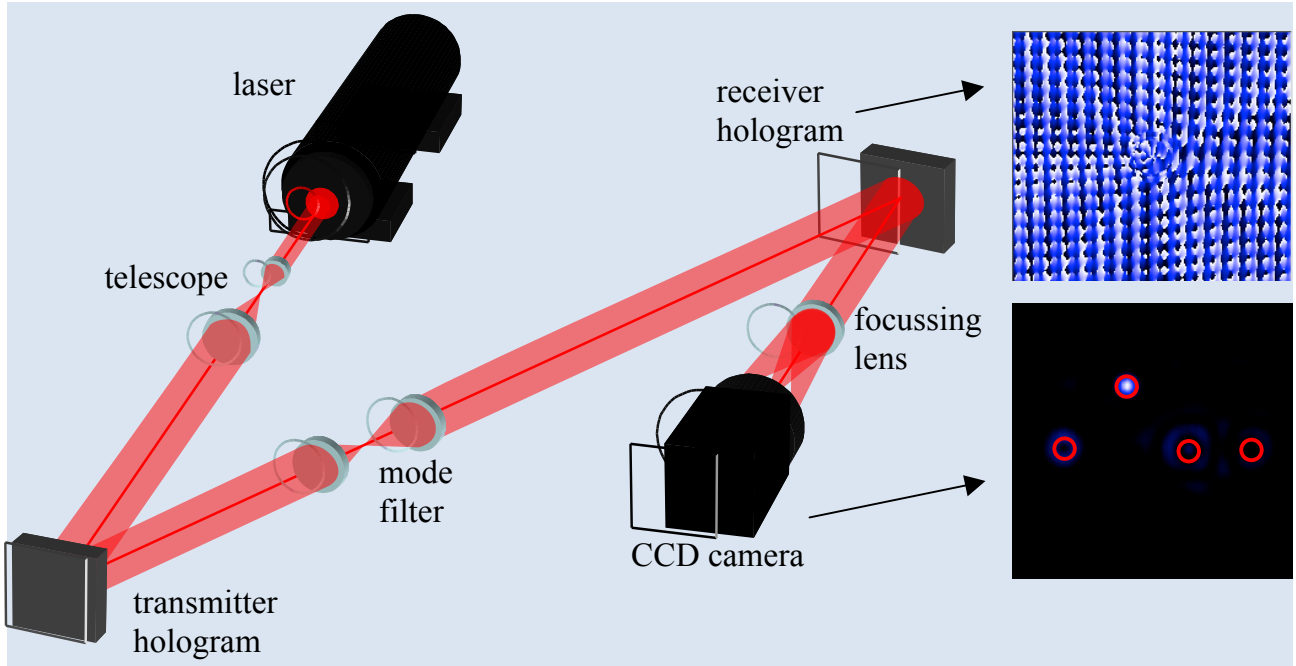

Figure 1: left: proposed set-up for a communicator transmitting and decoding modes characterised by both radial and azimuthal indices. Right: Hologram pattern suitable to decode 4 different modes by generating on-axis intensity at pre-defined positions in the detection plane, depending on the mode indices.

The labview program can be used to drive directly a spatial light modulator (SLM) on which the hologram patterns are visualized, so as to act on the light beam.

[1] Graham Gibson, Johannes Courtial, Miles J. Padgett, Mikhail Vasnetsov, Valeriy Pas'ko, Stephen M. Barnett and Sonja Franke-Arnold, *Free-space information transfer using light beams carrying orbital angular momentum*, Opt. Express **12**, 5448 (2004)

The efficiency of systems like this can, however, never exceed the inverse of the number of channels, and they are therefore useful only for the communication of modes in classical light beams but not for quantum applications. A multiplexing system like this could be used to communicate using a full set of LG modes, shown in Figure 1. In an experiment, a collimated light beam would be directed at the hologram, and the diffracted light beams would be measured on a CCD camera or a correctly spaced array of spot-like detectors. Used in detection, the mode indices can be inferred from the on-axis light intensity at the specified positions, as shown below.

We have performed a proof-of-principle experiment, showing the generation of beam with mode indices $\ell = 1, 2, \mathbf{3}$ and $p = 0, 1, \mathbf{2}$, see Figure 2.

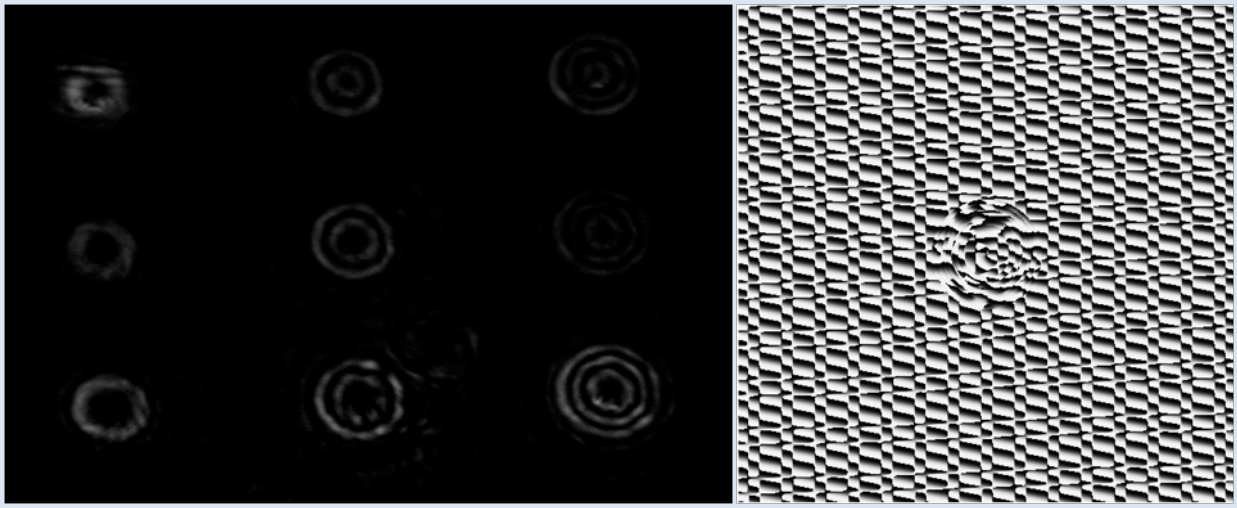

Figure 2: Different LG modes in the far field generated simultaneously from a Gaussian input beam by the hologram displayed on the left.

Finally, some specific software-designed holographic patterns for generating prescribed superpositions of OAM modes have been also developed by UNAP in the form of holographic phase optical elements, which can then be used in a optical setup without the need of a SLM, using a photographic technique. The obtained devices are convenient because they are small and portable. However they are not dynamically reconfigurable, of course, and also have a limited efficiency as compared with SLMs (in our case typically 10-15%). Following is a photo of one such device (before and after chemical bleaching).