#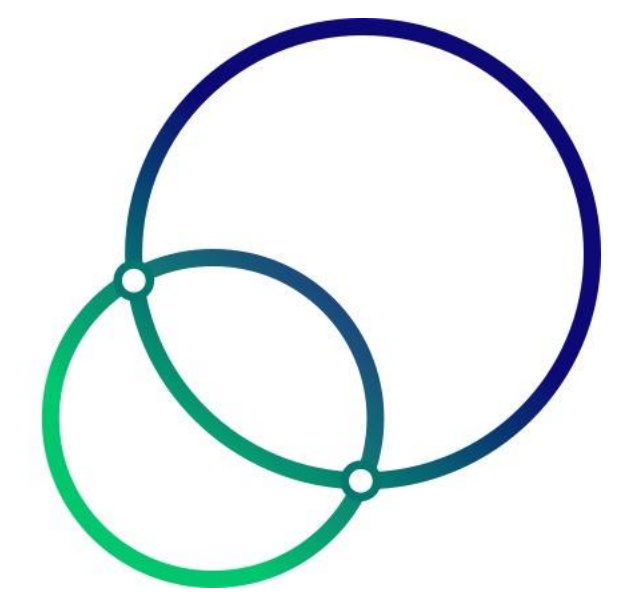 Computer generated holography for the generation of arbitrary optical fields and intensity patterns with a Spatial Light Modulator.

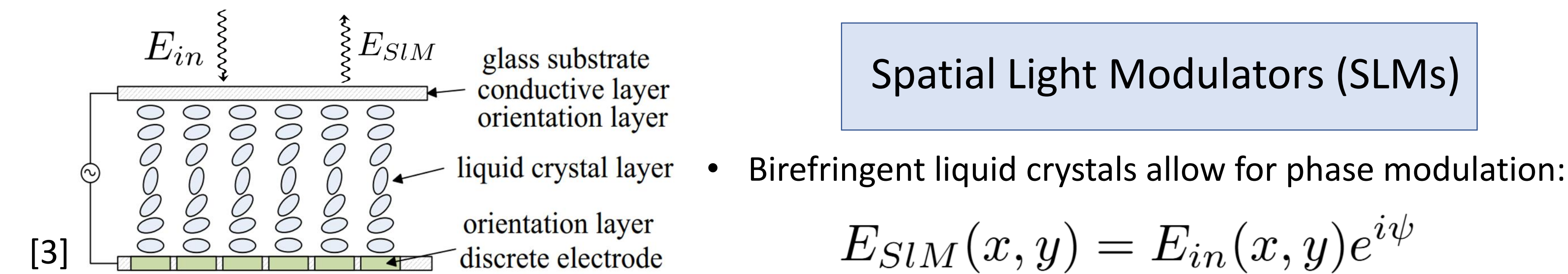**Andres Felipe Arias, Juan Carlos Rojas, Alejandra Valencia**

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Introduction

The generation of a desired optical field is of special interest in many different areas of physics, chemistry and life sciences. Arbitrary fields are generally fabricated via holography, in which a specific pattern is recorded into a diffractive element to produce a desired output field. Computer generated holography (CGH) is when the required pattern (hologram) is calculated digitally, instead of the usual method of recording the interference of an object and reference beam. Devices known as spatial light modulators (SLMs) allow for fast and precise control of the phase of an incident light beam. In this work, we present two methods to generate phase only CGHs that are sent to an SLM to recreate either a desired complex optical field with amplitude and phase information, or an intensity pattern where all phase information is lost. These methods have applications in quantum computing, microscopy, quantum tomography and optical tweezers.

Preliminaries

[3] glass substrate, conductive layer, orientation layer, liquid crystal layer, orientation layer, discrete electrode

Spatial Light Modulators (SLMs)

- Birefringent liquid crystals allow for phase modulation:

$$E_{SlM}(x,y) = E_{in}(x,y)e^{i\psi}$$

Fourier Optics

- Propagation integral:

$$E(x_1,y_1) = \frac{e^{ikz}}{i\lambda z}\iint_{-\infty}^{\infty} E(x_0,y_0)\exp\left\{i\frac{k}{2z}\left[(x_1-x_0)^2+(y_1-y_0)^2\right]\right\}dy_1dx_1$$

- A lens is a phase transform:

$$E_{lens}(x_1,y_1) \propto E(x_1,y_1)\exp\left(-i\frac{k}{2f}[x_1^2+y_1^2]\right)$$
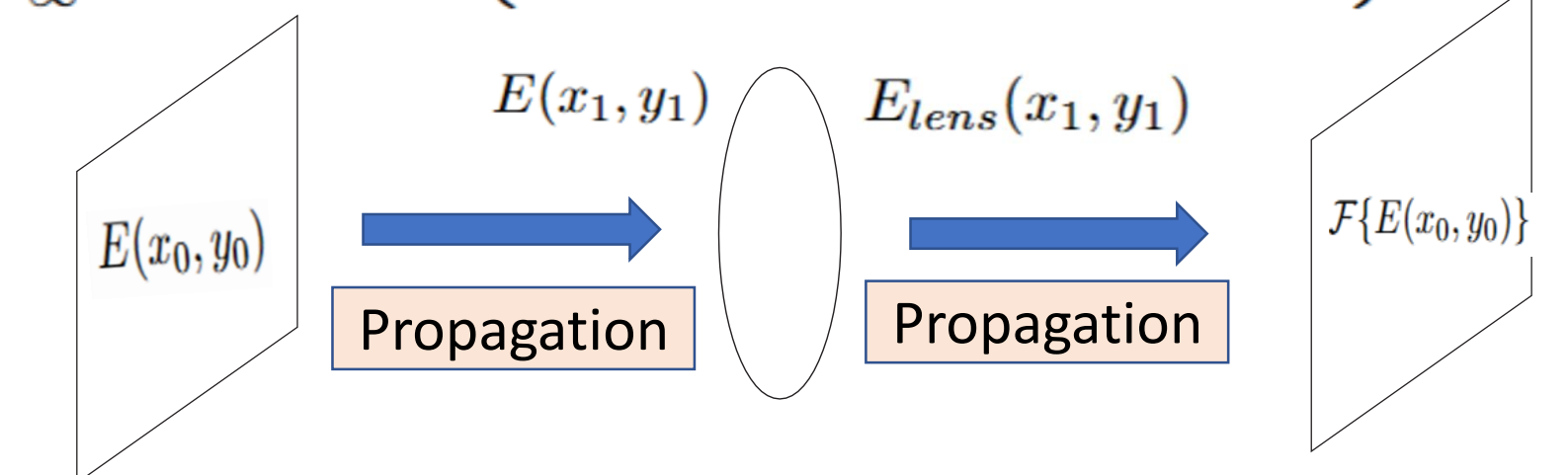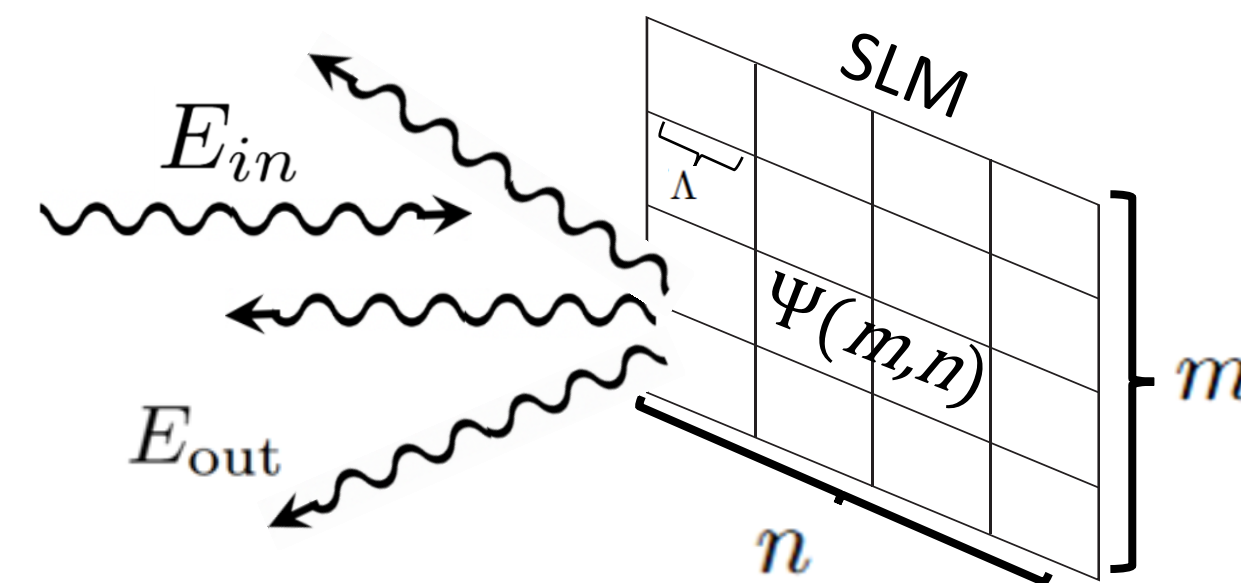
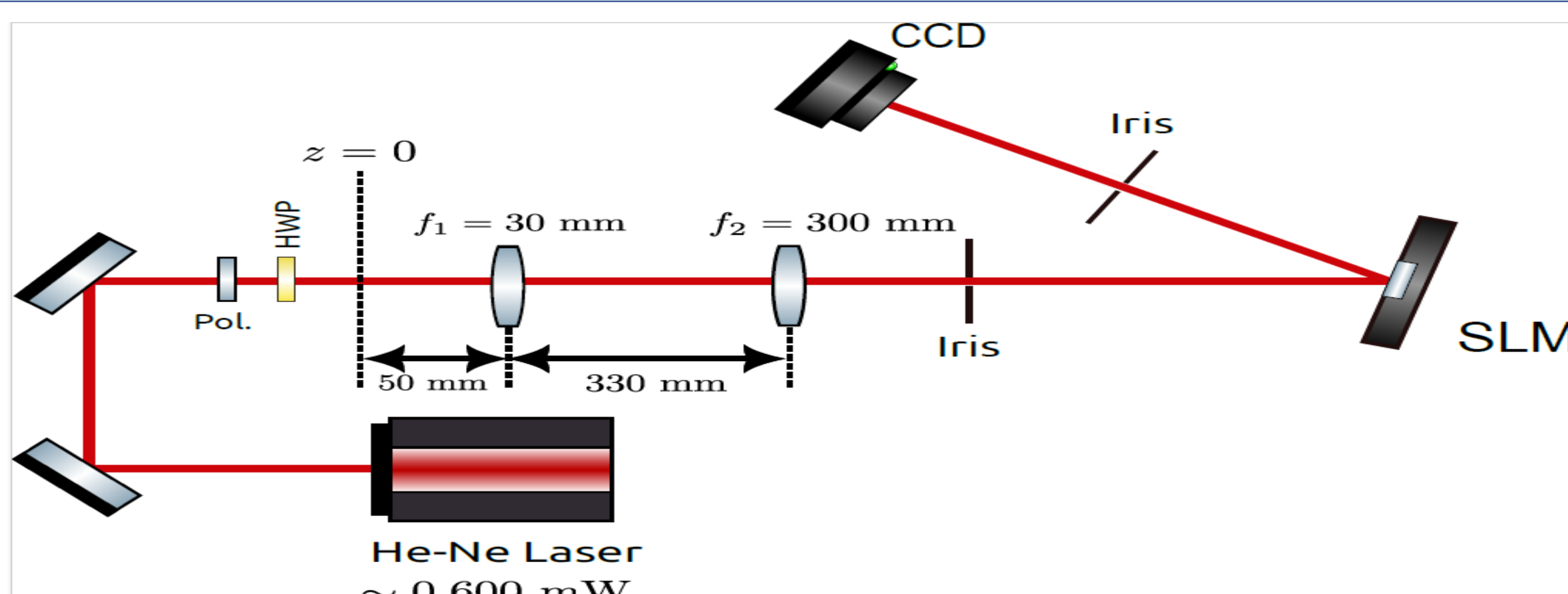## Phase holograms to recreate a complex field

Theory

- Suppose we want to recreate a field $E_{out}(r,z) = \mathcal{A}(r,z)\exp(i\Phi(r,z))$. The most general phase hologram is[2]:

$$\Psi(m,n) = \mathcal{M}(m,n)\bmod\left(\mathcal{F}(m,n)+2\pi m/\Lambda+2\pi n/\Lambda, 2\pi\right)$$

- The first order term of the Fourier series:

$$T_1(m,n) = -\frac{\sin(\pi\mathcal{M}(m,n)-\pi)}{\pi\mathcal{M}(m,n)-\pi}e^{i(\mathcal{F}(m,n)+\pi\mathcal{M}(m,n))}$$

- Making $T_1(m,n)=E_{out}(r,z)$:

$$\mathcal{M}(m,n) = \mathcal{A}(m,n)/\max(\mathcal{A}(m,n))$$
$$\mathcal{F}(m,n) = \Phi(m,n) - \pi\mathcal{M}(m,n)$$

Experimental Setup

Results

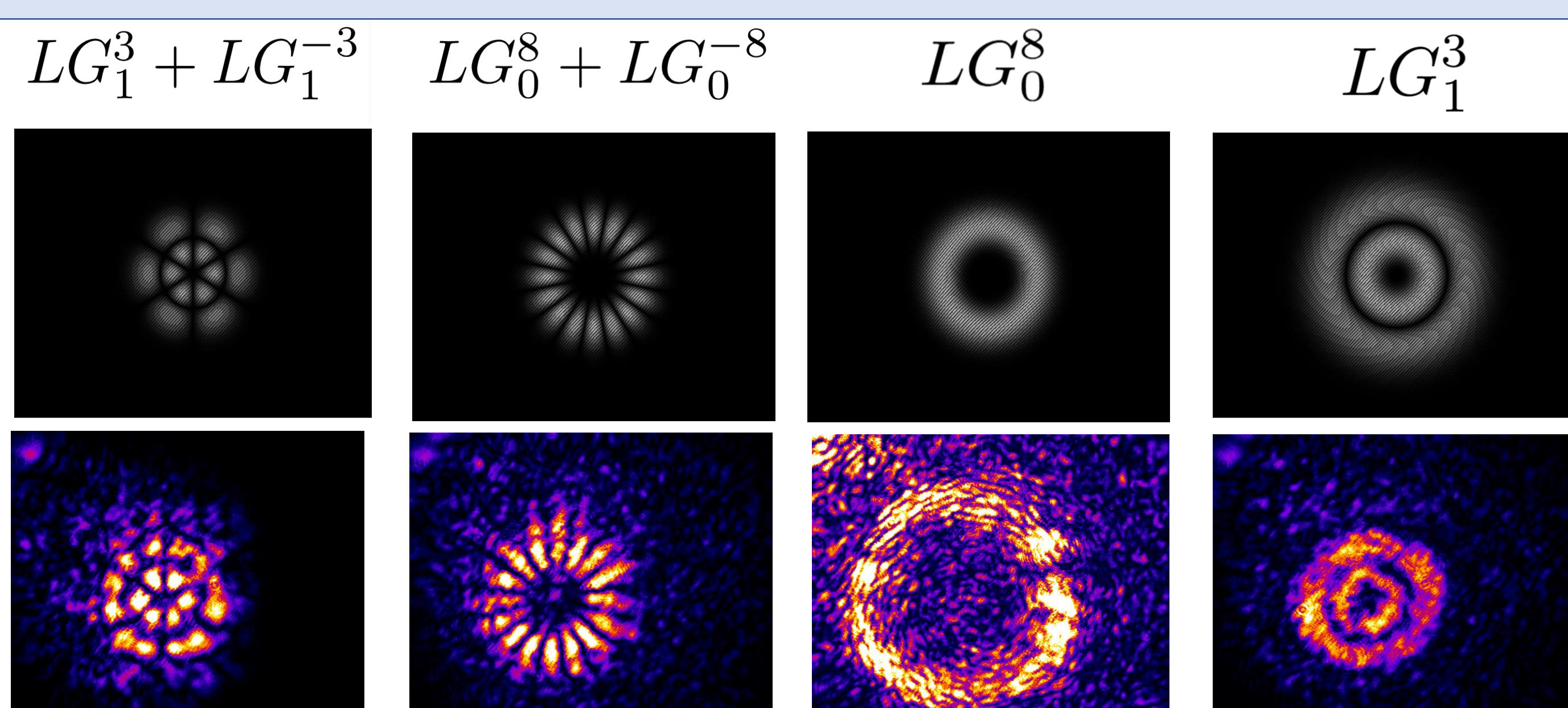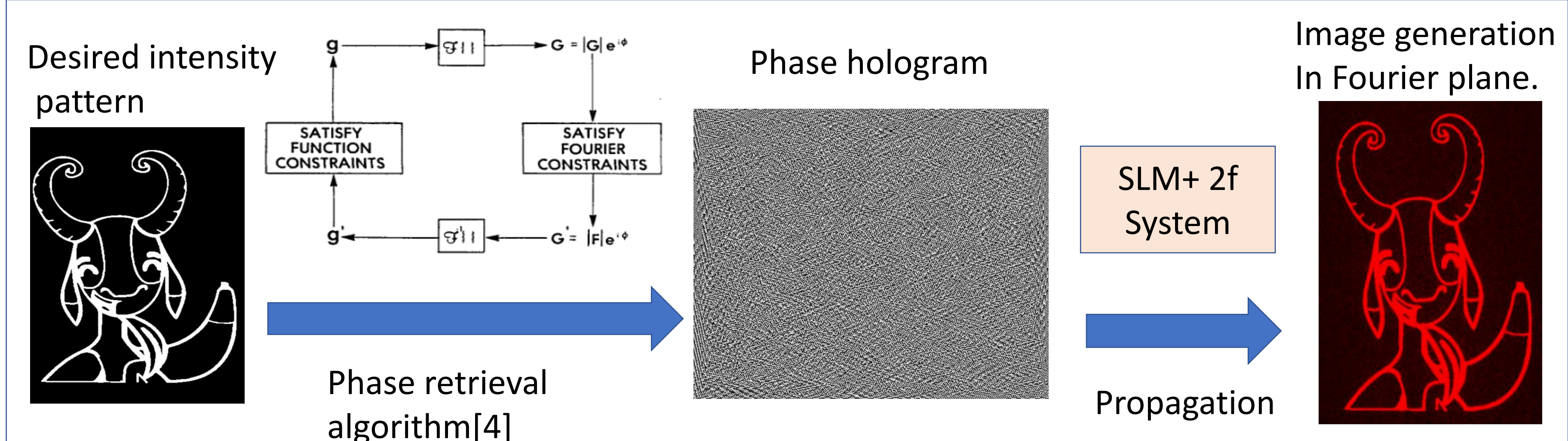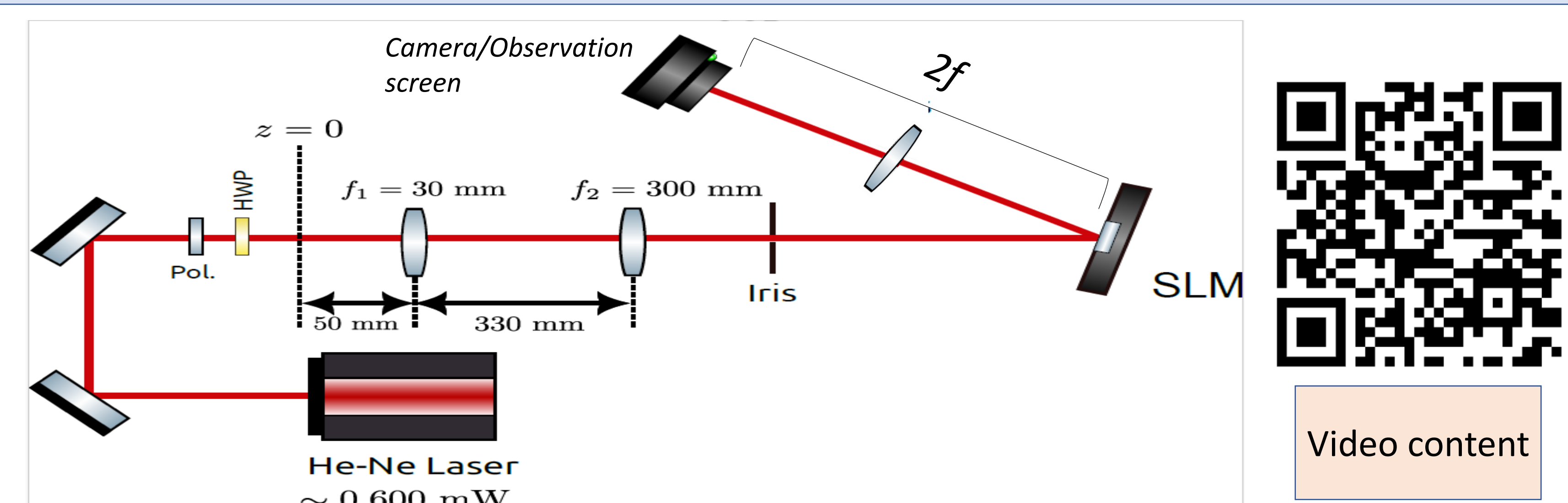$LG_1^3+LG_1^{-3}$; $LG_0^8+LG_0^{-8}$; LG_0^8 ; LG_1^3

Fig. Phase holograms (upper row) and the corresponding CCD images of the first order of diffraction for different Laguerre-Gauss (LG) modes of light, and superpositions of them.

Phase holograms to recreate an intensity pattern

Theory

Desired intensity pattern — Phase retrieval algorithm[4] — Phase hologram — SLM+ 2f System — Propagation — Image generation In Fourier plane.

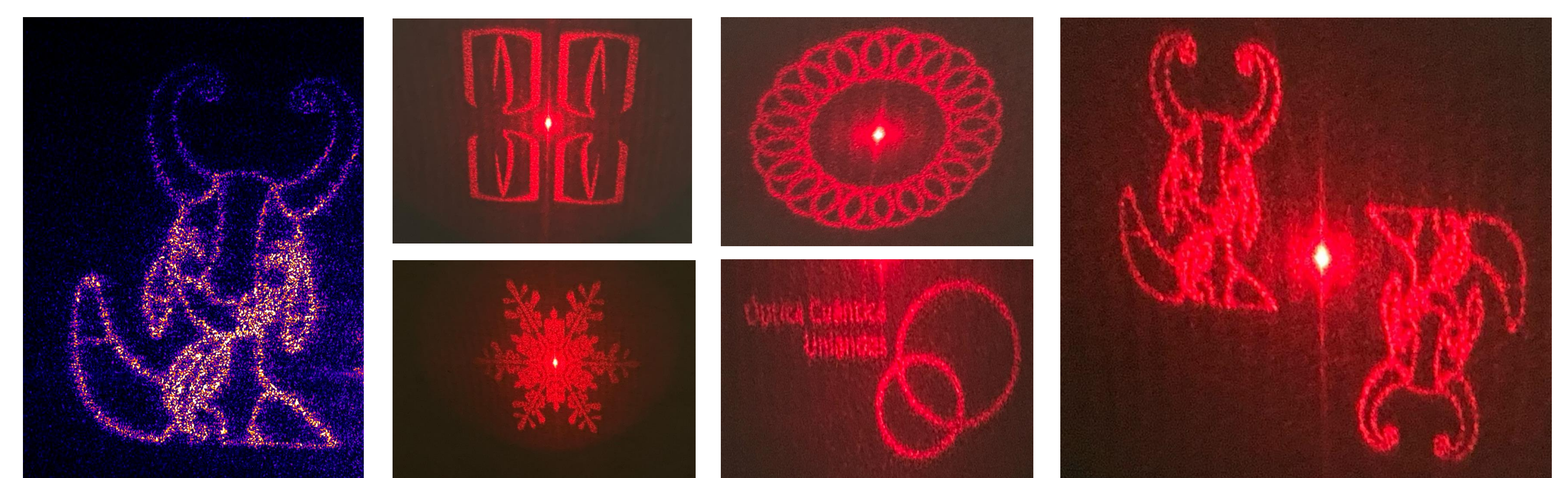### Experimental Setup

Video content

Results

Fig .CCD and Camera images of recreated intensity patterns for different figures with the method of iterative Fourier phase holograms

Conclusions

- Phase modulation using Spatial Light Modulators allows for the recreation of optical fields and intensity patterns when the corresponding phase computer generated hologram is loaded as a phase profile.
- Different methods for calculating the computer generated hologram are required depending if phase information of the desired output is accessible.
- The methods presented in this work create accurate reconstructions of the desired pattern even if low cost Spatial light modulators that do not allow for full phase modulation are used.

Bibliography

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[4] J. R. Fienup,), Phase retrieval algorithms: a comparison ,Applied Optics 21, 2758 (1982).
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[6] J. A. Davis, D. M. Cottrell, J. Campos, M. J. Yzuel, andI. Moreno, Encoding amplitude information onto phase-only filters,Applied Optics 38, 5004 (1999).