Measuring Phase with Stokes Measurements

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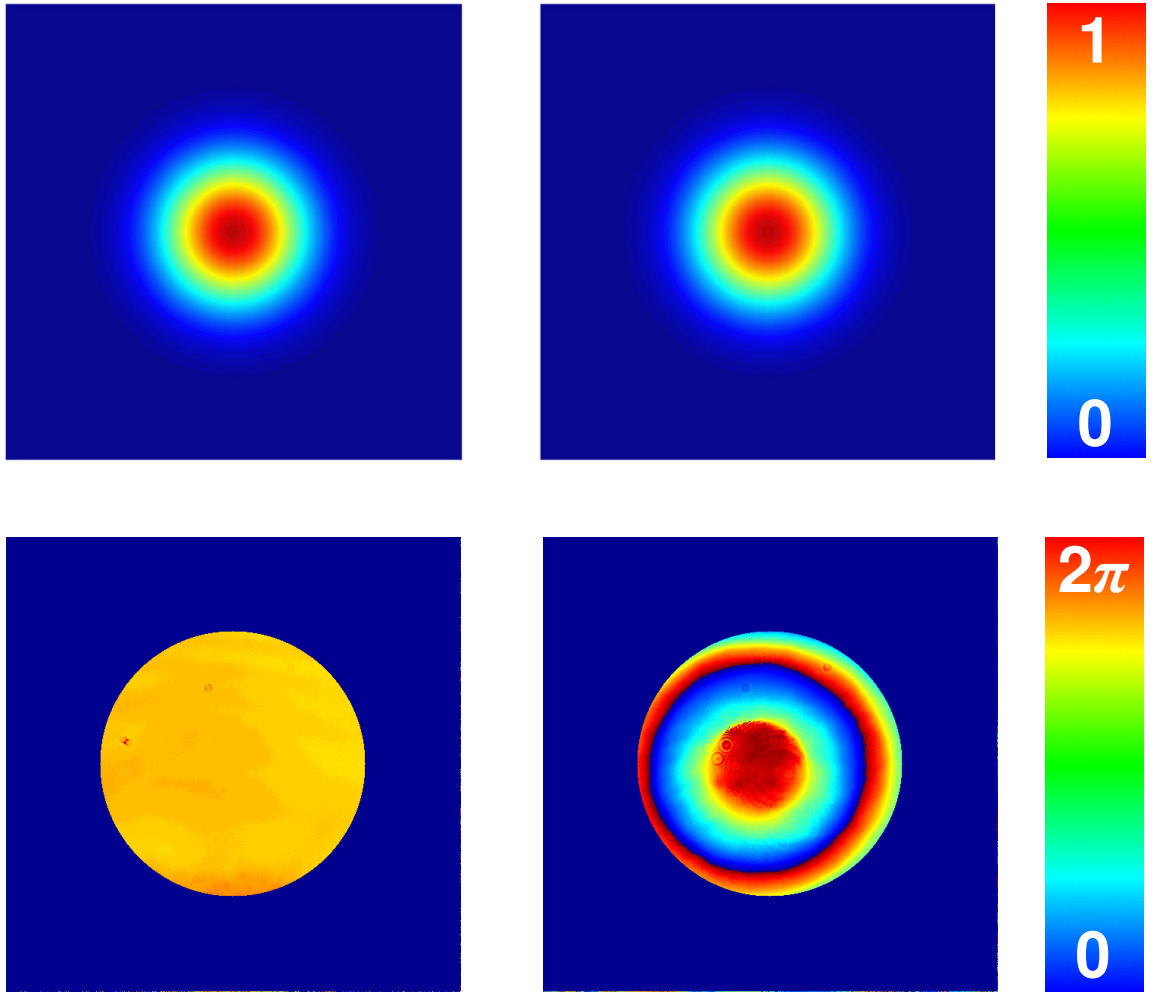
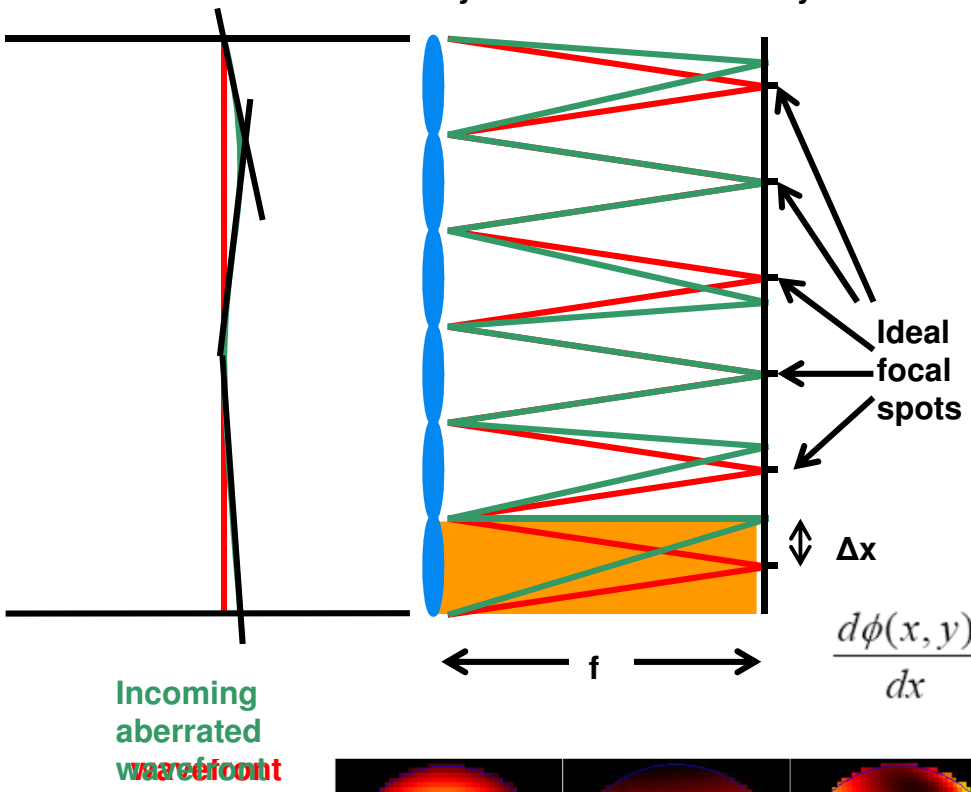
our future through science

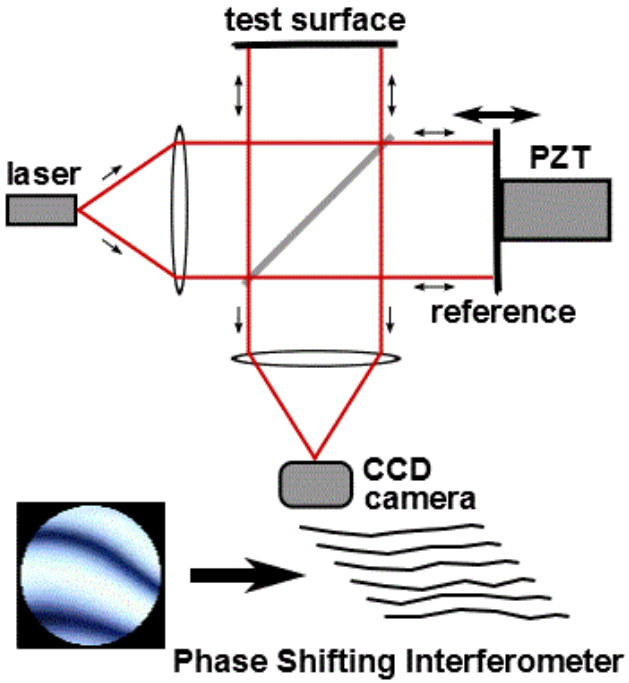
Merely measuring the intensity of a beam does not provide the full information

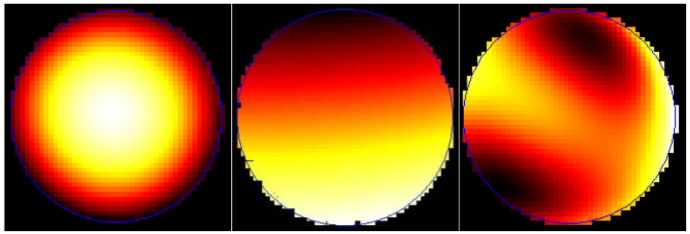


Numerous methods to extract the phase exist…
But they are often over-complicated and expensive

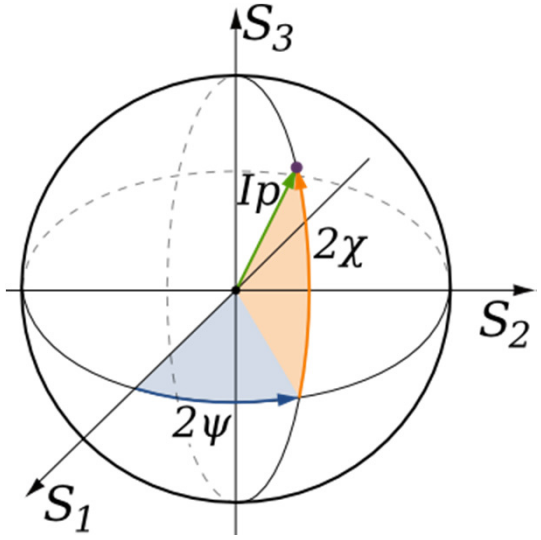


$$\frac{d\phi(x,y)}{dx} = \frac{\Delta x}{f}$$





The phase difference between the horizontal and vertical components of a field can be extracted via Stokes polarimetry



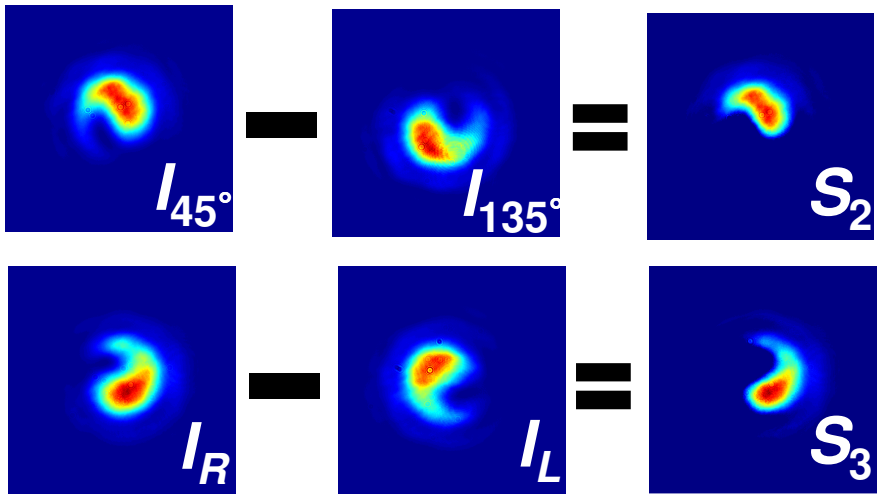
$$S_0(r,\phi) = |U_{\leftrightarrow}(r,\phi)|^2 + |U_{\updownarrow}(r,\phi)|^2 = I_{0^\circ} + I_{90^\circ}$$

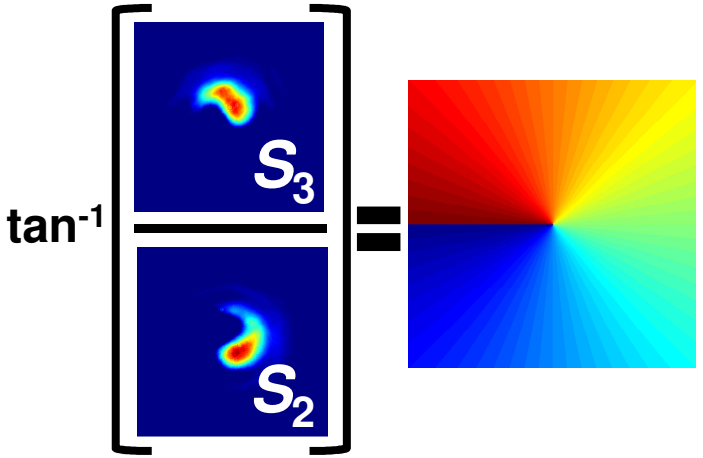
$$S_1(r,\phi) = |U_{\leftrightarrow}(r,\phi)|^2 - |U_{\updownarrow}(r,\phi)|^2 = I_{0^\circ} - I_{90^\circ}$$

$$S_2(r,\phi) = 2|U_{\leftrightarrow}(r,\phi)||U_{\updownarrow}(r,\phi)|\cos(\delta(r,\phi)) = I_{45^\circ} - I_{135^\circ}$$

$$S_3(r,\phi) = 2|U_{\leftrightarrow}(r,\phi)||U_{\updownarrow}(r,\phi)|\sin(\delta(r,\phi)) = I_R - I_L$$

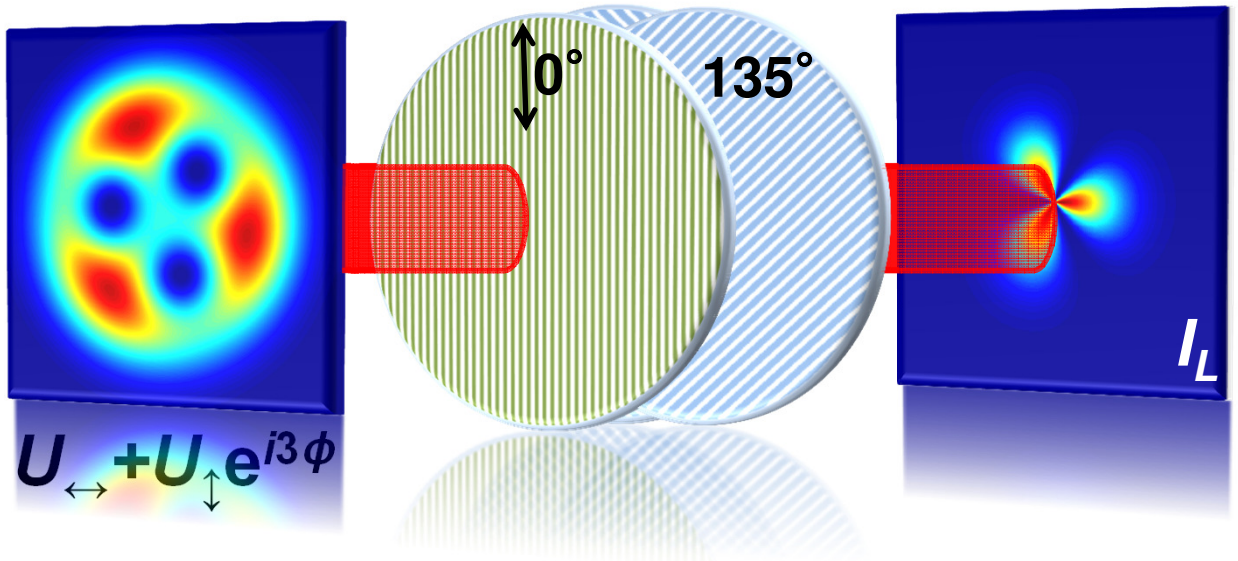
$$\delta(r,\phi) = \frac{1}{2}\arctan\left(\frac{S_3(r,\phi)}{S_2(r,\phi)}\right)$$





* $|U_{\leftrightarrow}(r,\phi)|\hat{\mathbf{x}} + |U_{\updownarrow}(r,\phi)|\hat{\mathbf{y}}\exp(i\delta(r,\phi))$: Control the phase between ↕ & ↔

Stokes polarimetry involves four separate measurements



Requirements for a digital adaptation of Stokes polarimetery:

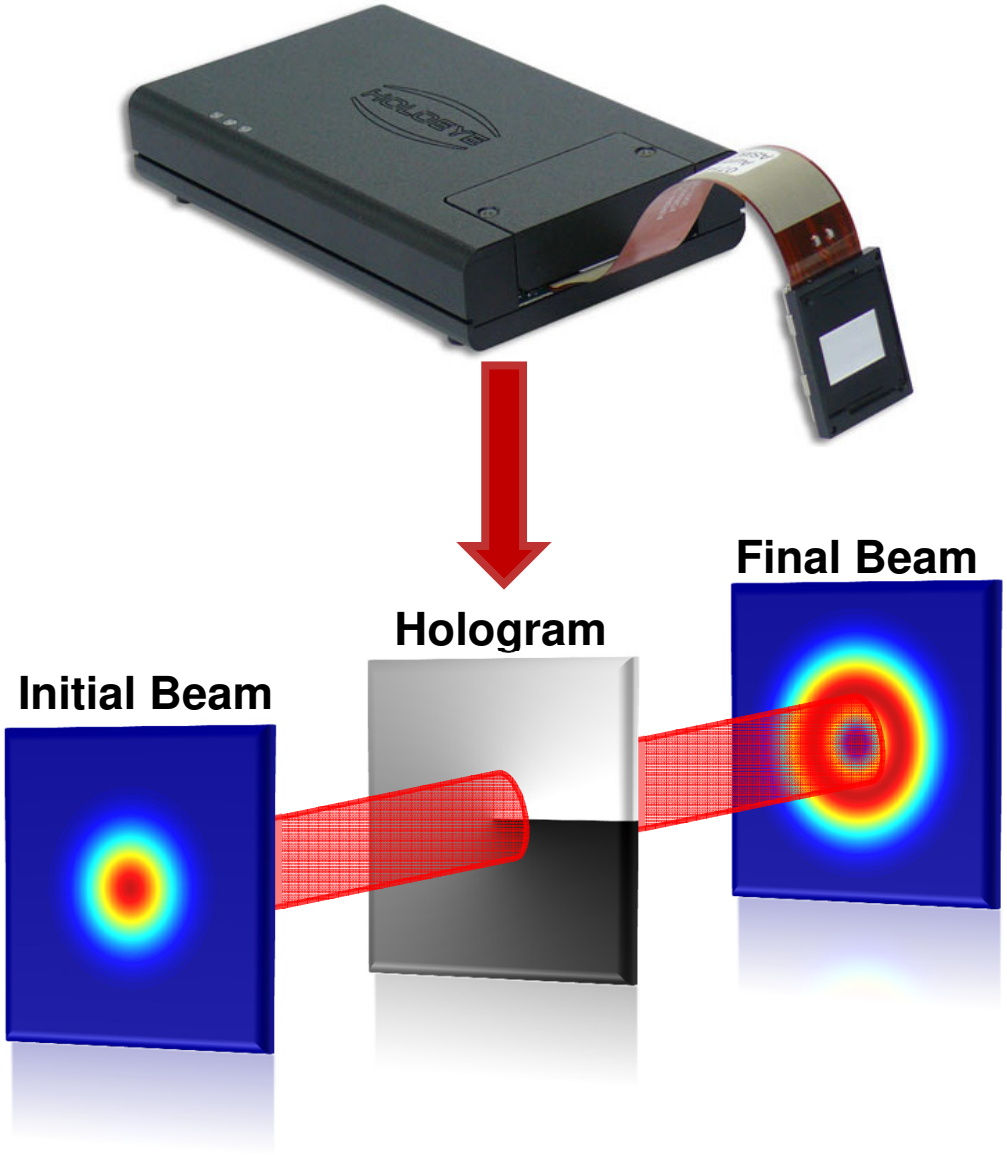
- Independently control the phase between ↕ & ↔
- Adjust the phase between ↕ & ↔ by $\pi/2$

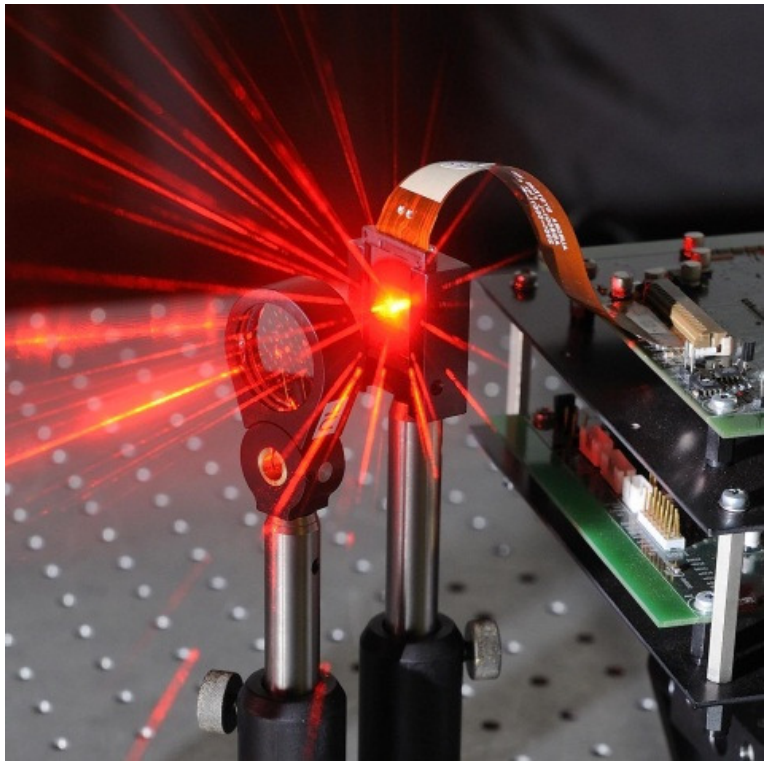
→ **LCD**

- Measure in an orthogonal basis: ↕ & ↔ OR ↻ & ↺

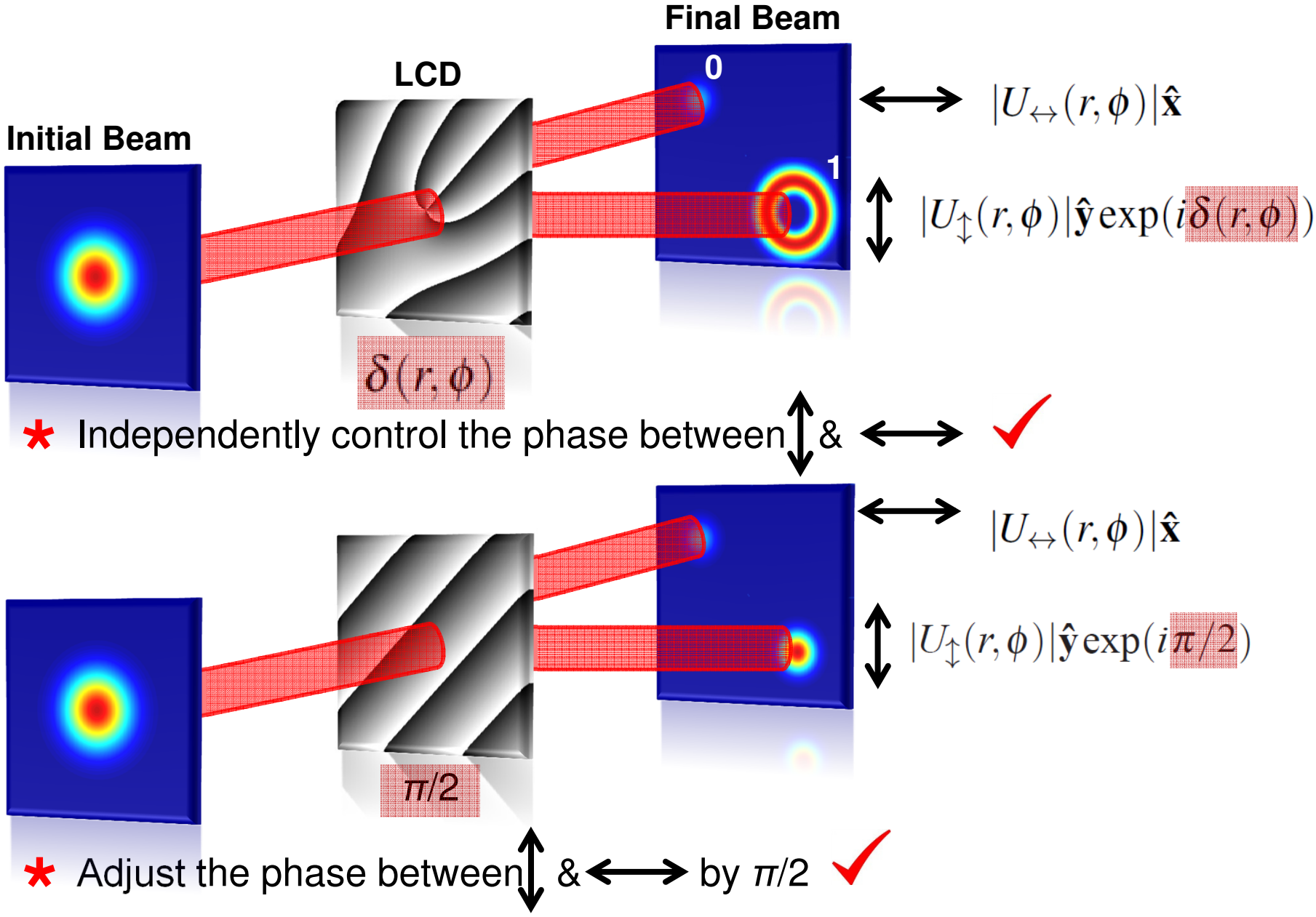
→ **PG**

Spatial light modulators allow us to alter the phase of an optical field

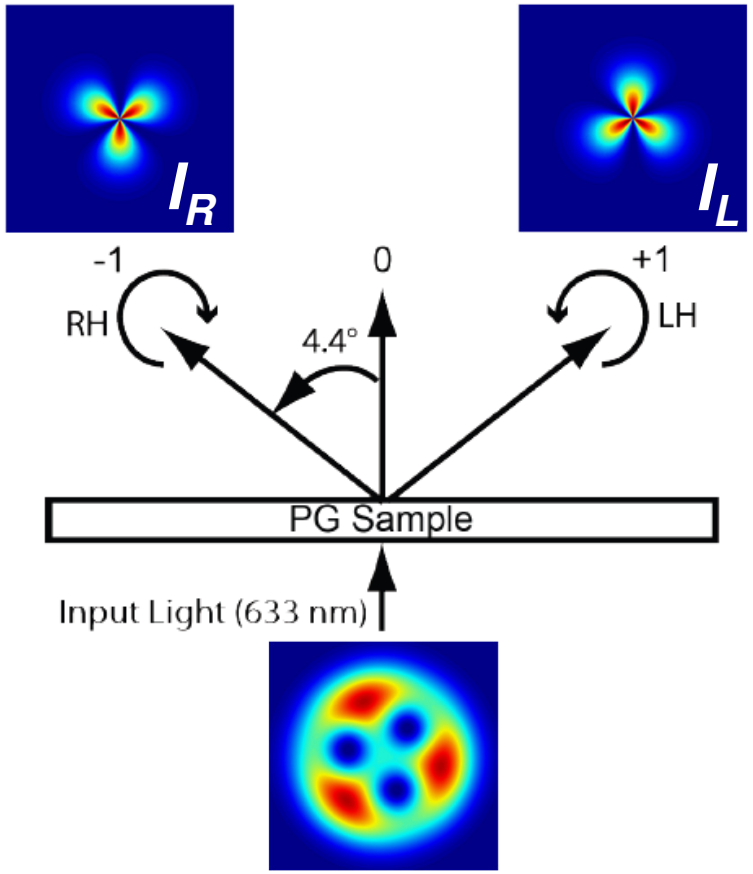




We exploit the SLM's diffraction inefficiency to independently control the phase between orthogonal polarization components

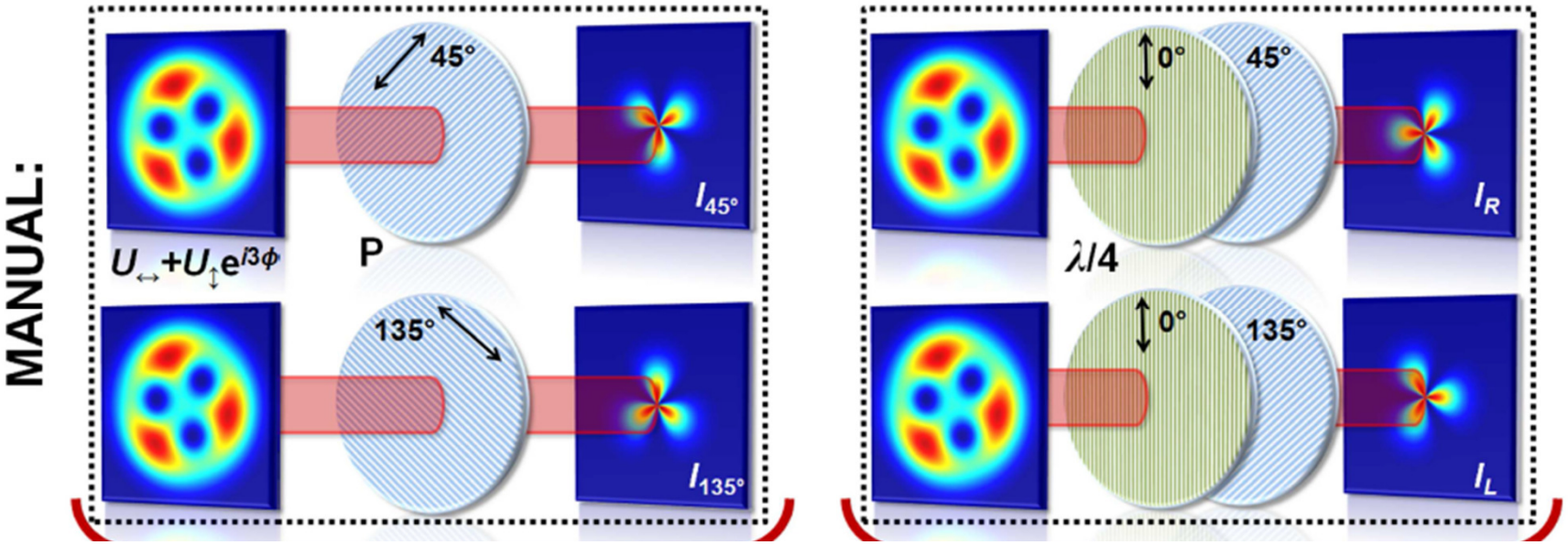


A polarization grating is a beam-splitter for left- and right-circularly polarized light… allowing two Stokes parameters to be measured simultaneously

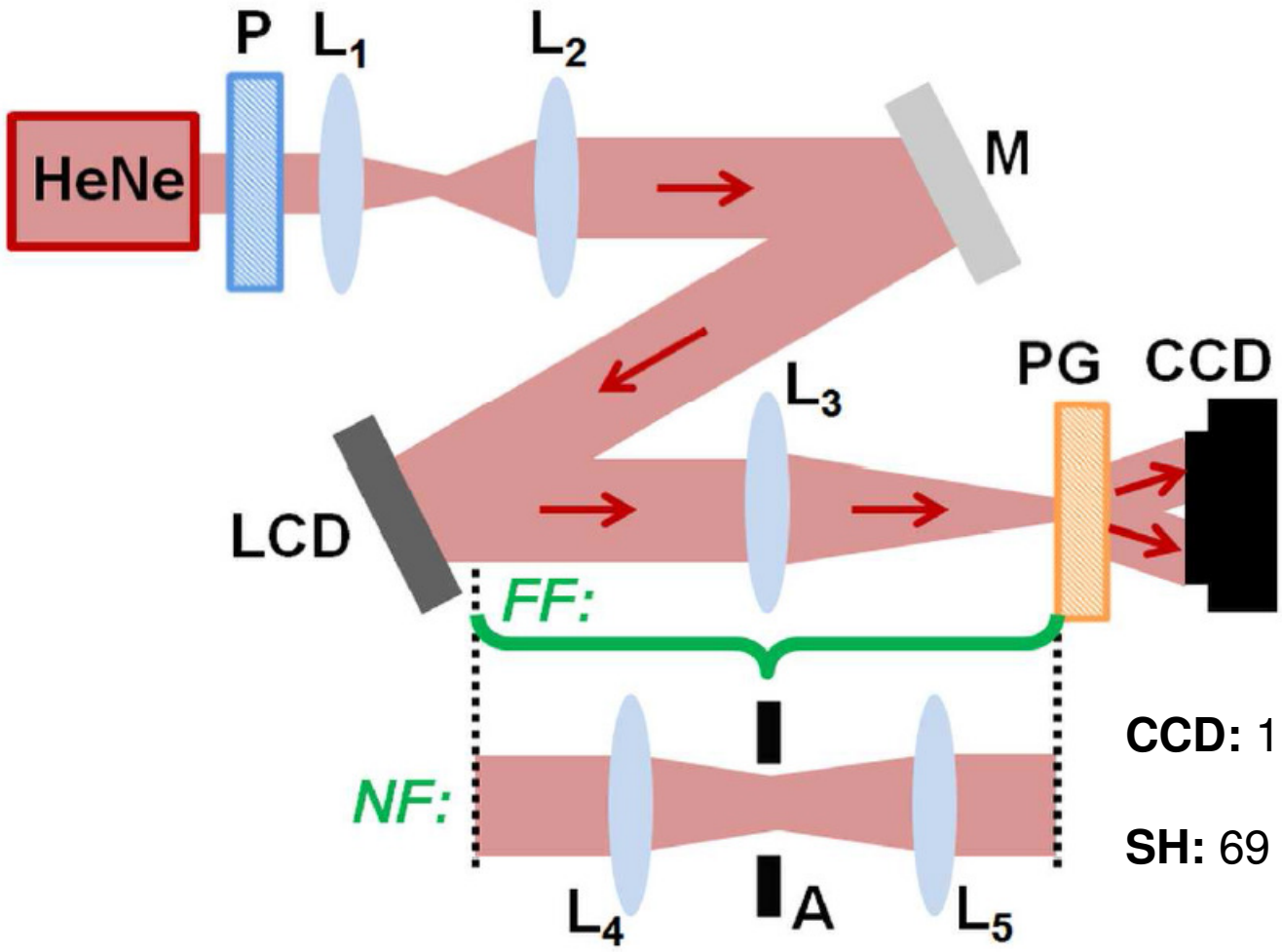


* Measure in an orthogonal basis: ↕ & ↔ OR ↻ & ↺ ✓

Combining these techniques, we can develop an all-digital approach for extracting phase



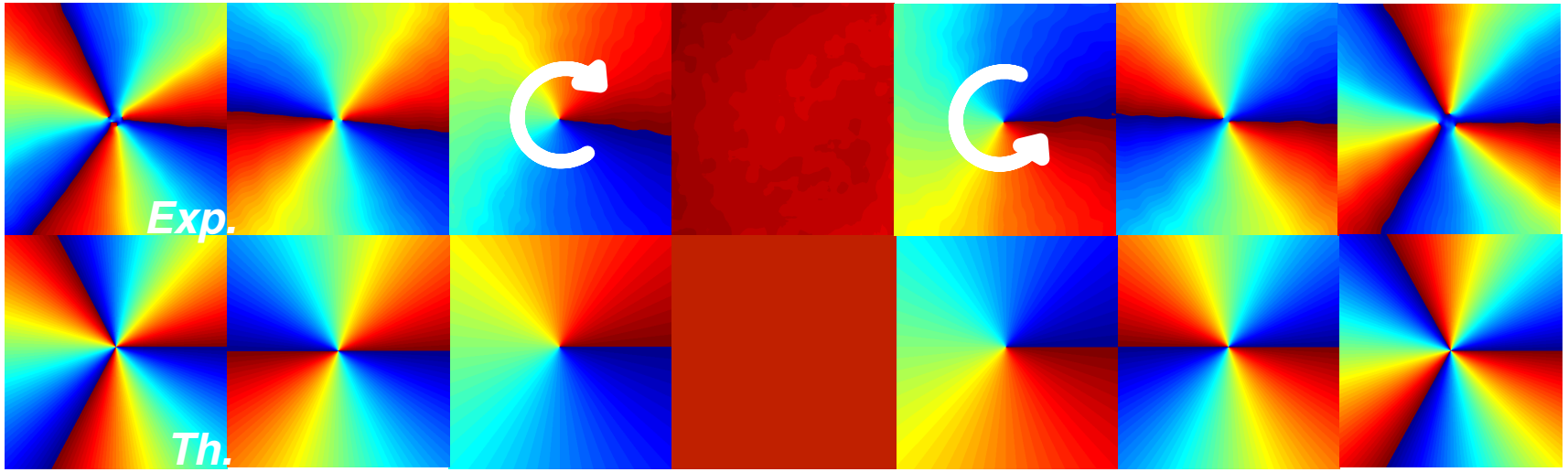
Our approach consists of only 3 components: LCD, PG and CCD

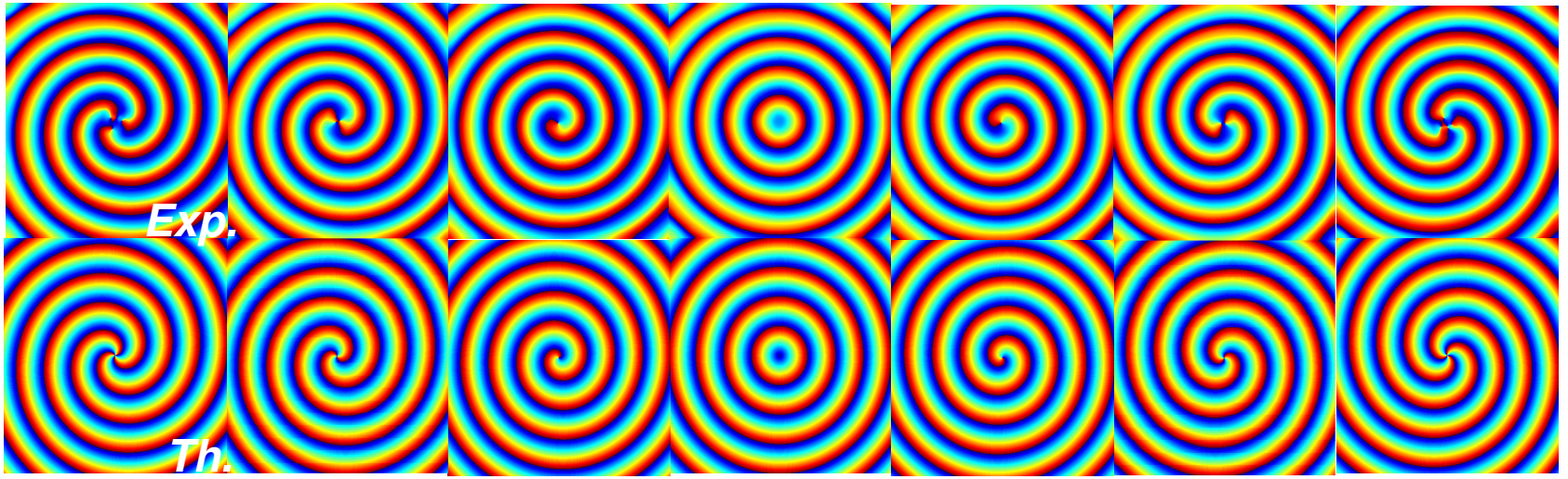


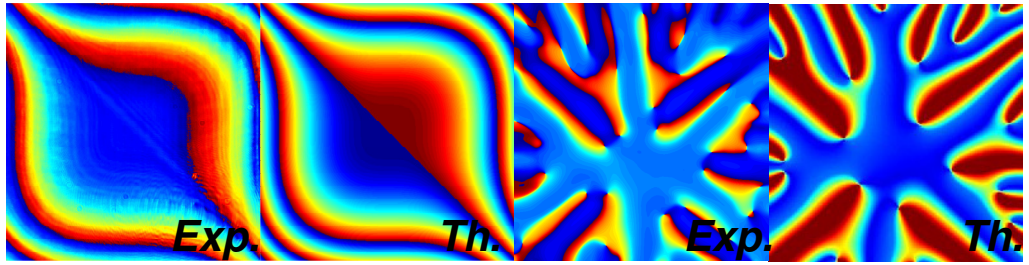
CCD: 1600 x 1200 pixels

SH: 69 x 69 lenslets

The modes that can be measured are endless…

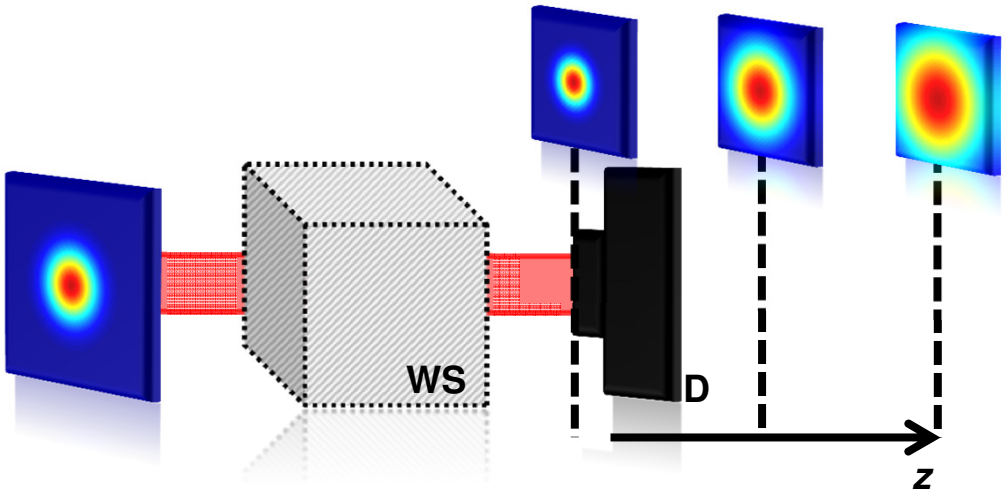




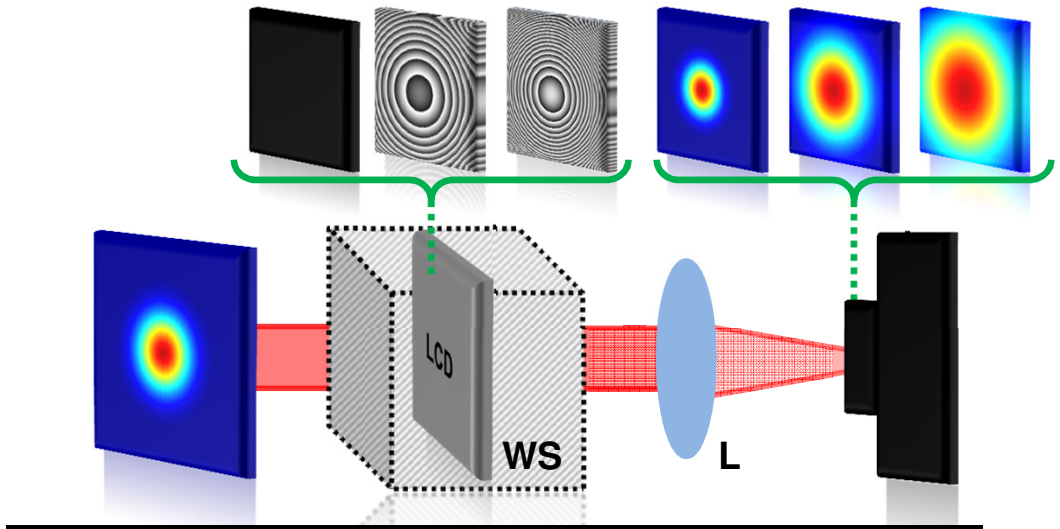


Opt. Express ***22****(11), 14031-14040 (2014)*

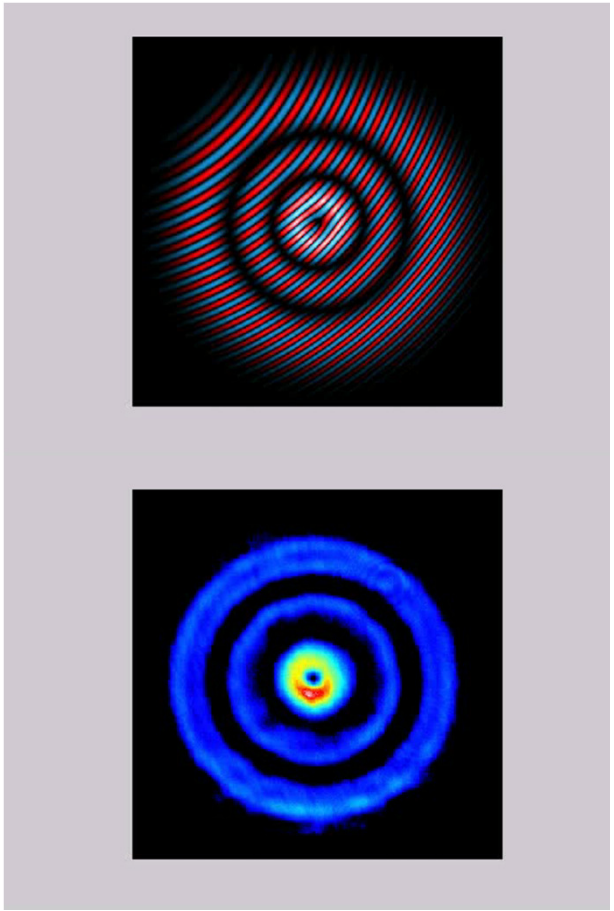
The SLM can also mimic free-space propagation



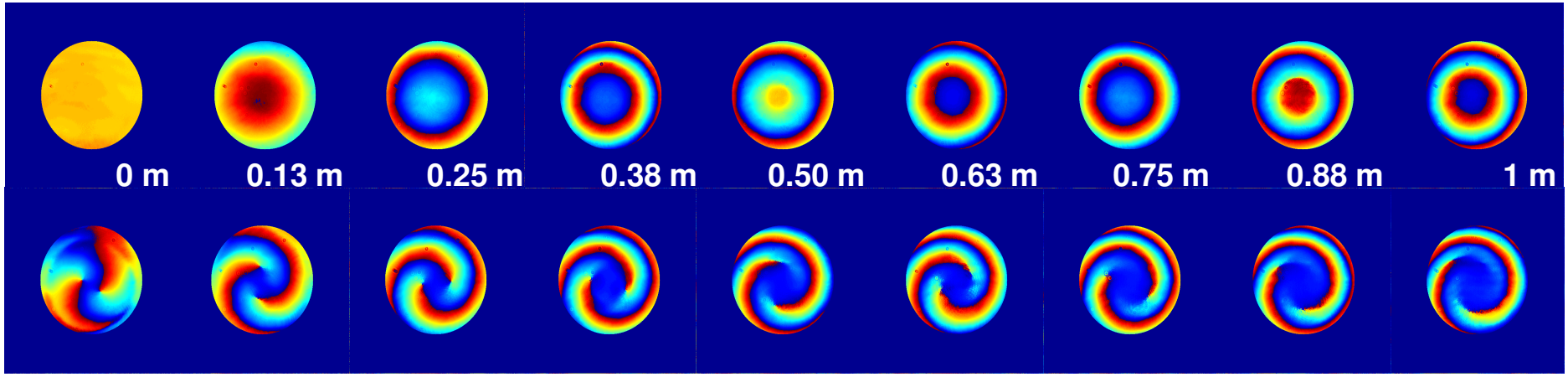
$$U(\mathbf{r}, z) = \mathcal{F}^{-1}[\mathcal{F}[U(\mathbf{r}, 0)] \exp(ik_z z)]$$

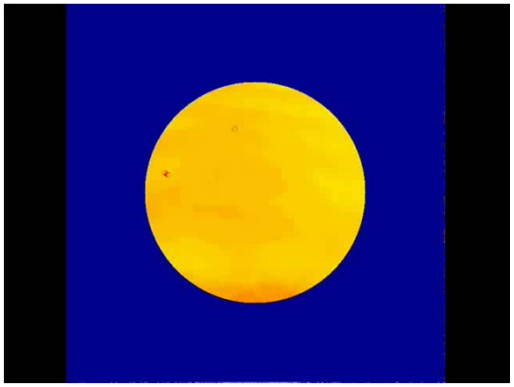


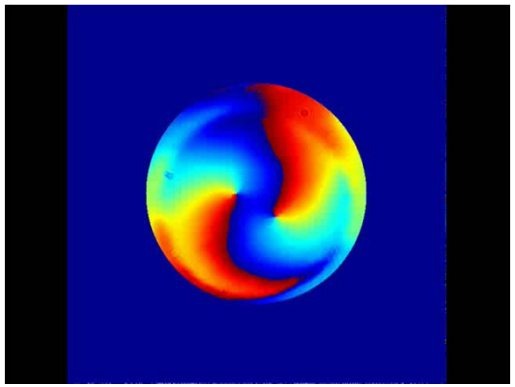
Opt. Lett. ***37****(22), 4687–4689 (2012)*



This allows us to extract the phase of propagating beams in real-time







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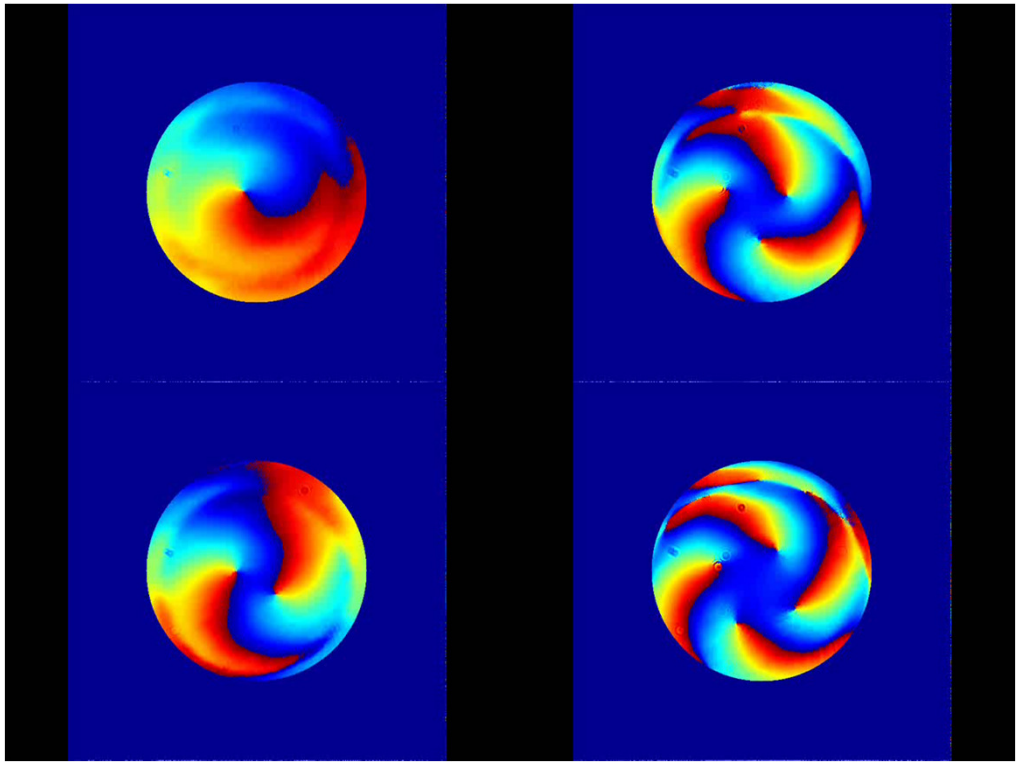
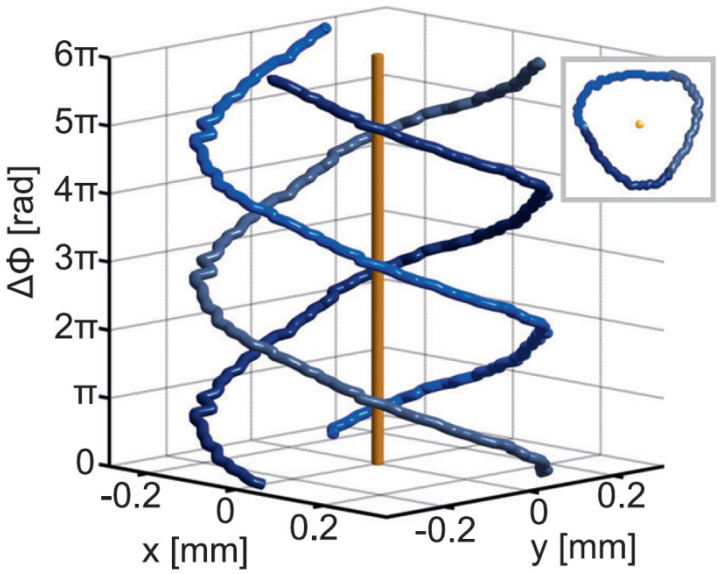
This could lead to understanding the dynamics of phase singularities






Thank You