Digitally controlling the 'twist' of light

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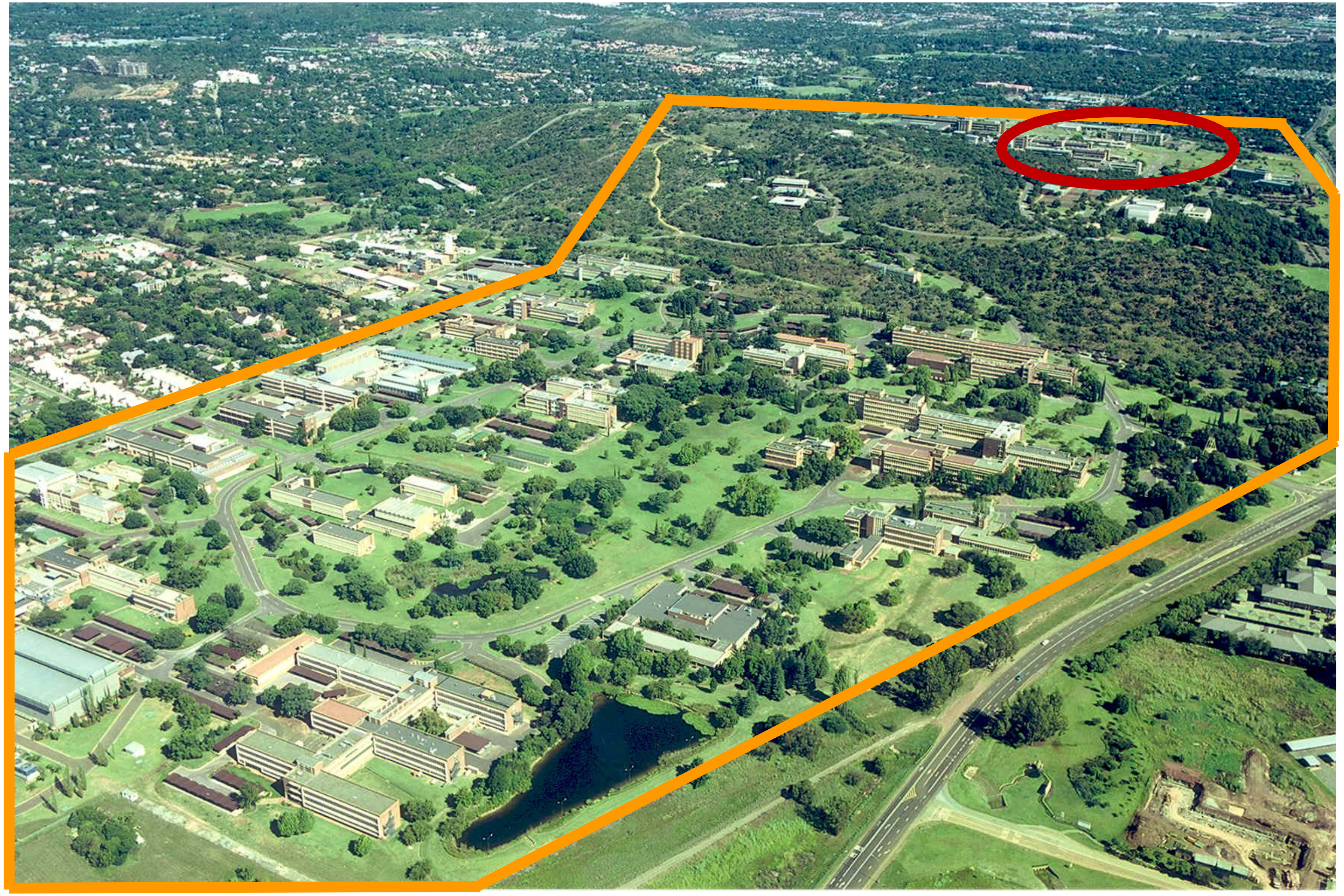
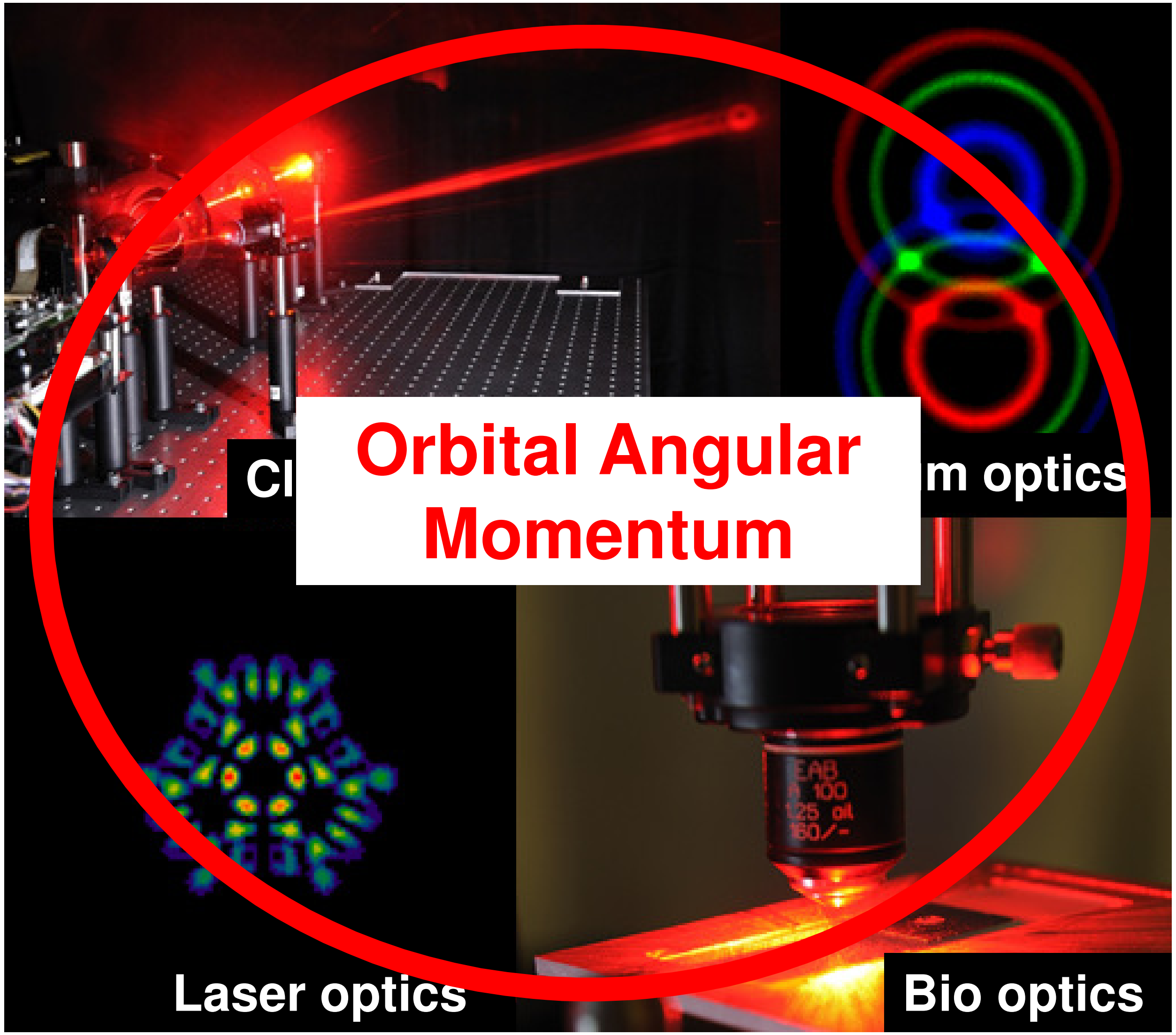
our future through science

Hopefully, not all the news you hear about South Africa is bad…

The NLC is one of many departments at the CSIR

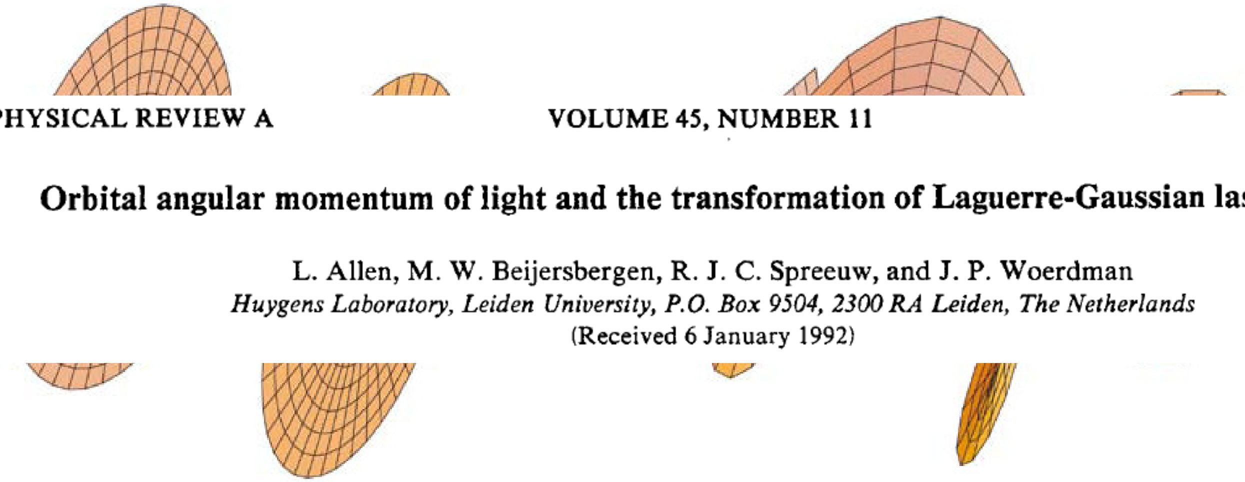


Mathematical Optics Group:



Azimuthally-phased beams have helical wavefronts and consequently carry OAM

$$u(r,\theta,z) = u_0(r,z)\exp(il\theta)$$



PHYSICAL REVIEW A VOLUME 45, NUMBER 11 1 JUNE 1992

Orbital angular momentum of light and the transformation of Laguerre-Gaussian laser modes

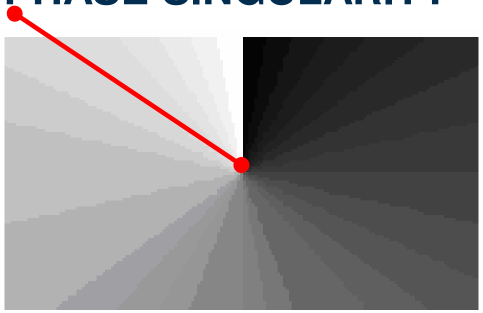
L. Allen, M. W. Beijersbergen, R. J. C. Spreeuw, and J. P. Woerdman
Huygens Laboratory, Leiden University, P.O. Box 9504, 2300 RA Leiden, The Netherlands

(Received 6 January 1992)

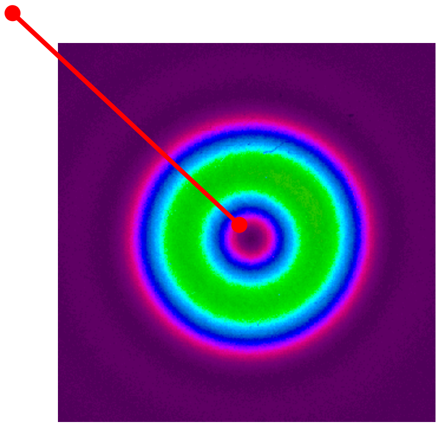
GAUSSIAN BEAM

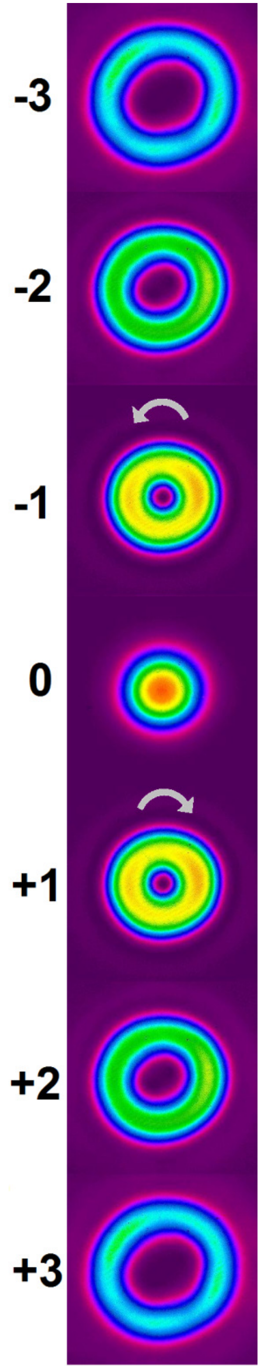
LAGUERRE-GAUSSIAN BEAM

PHASE SINGULARITY



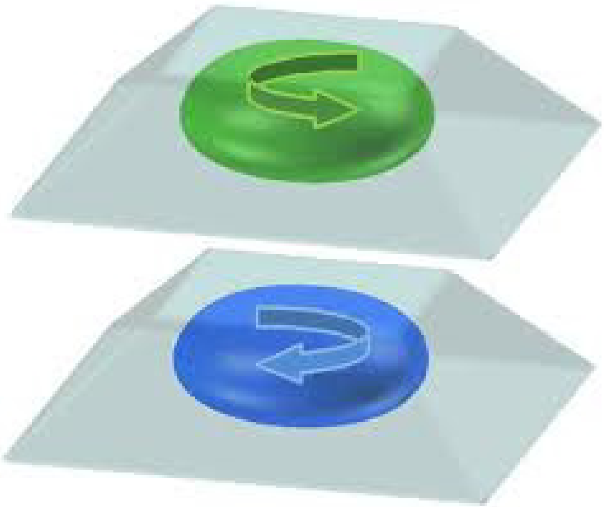
ZERO INTENSITY

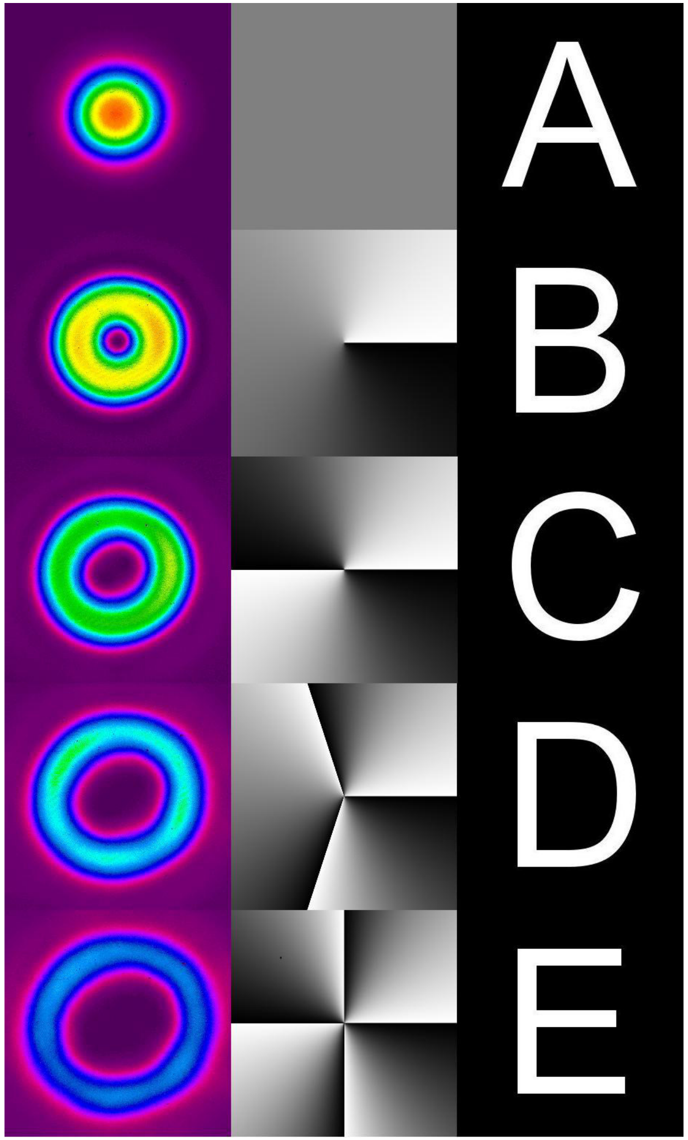




Laguerre-Gaussian beams can be used to encode a larger alphabet.

Spin Clockwise: 1 **Spin Anticlockwise:** 0

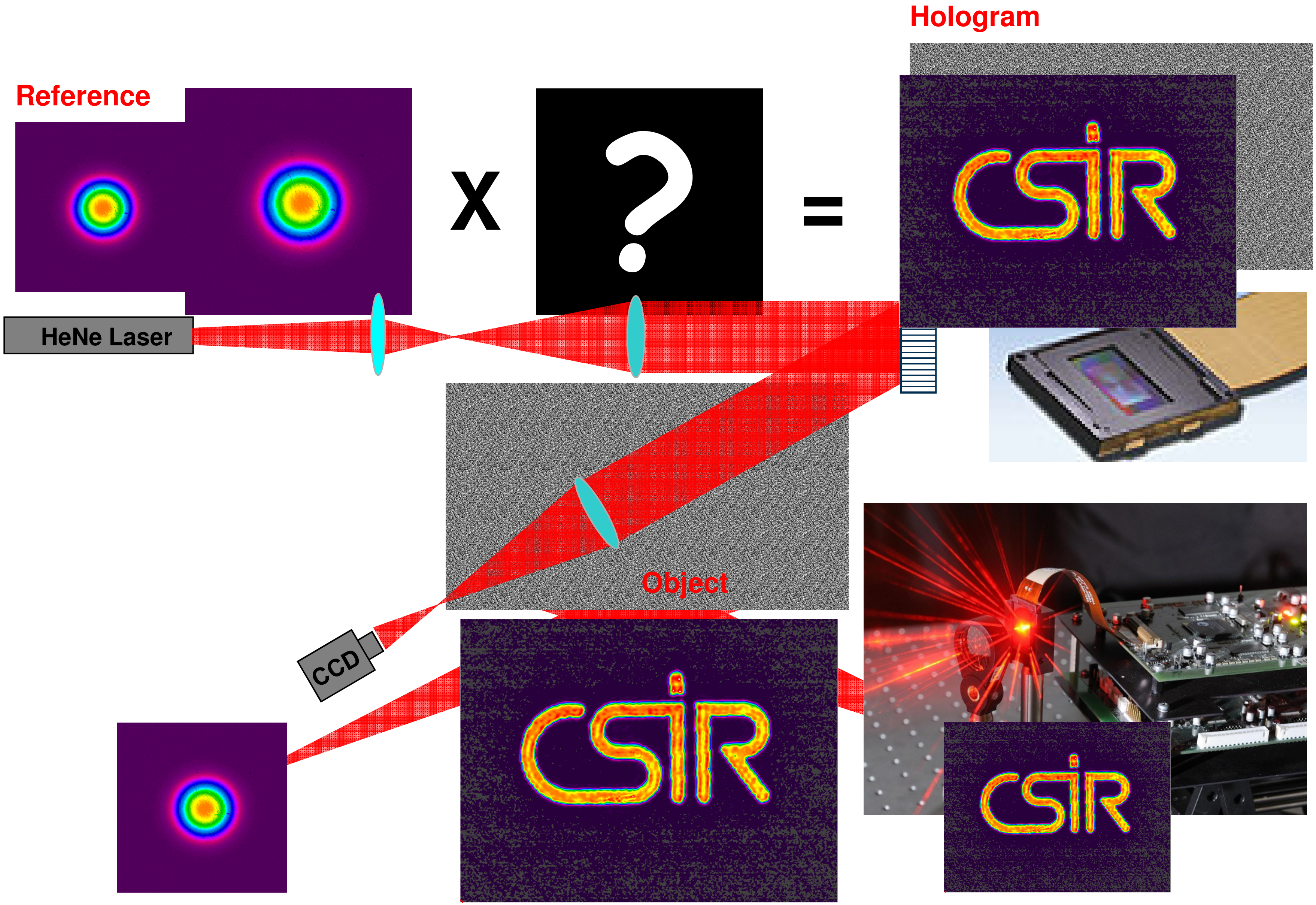




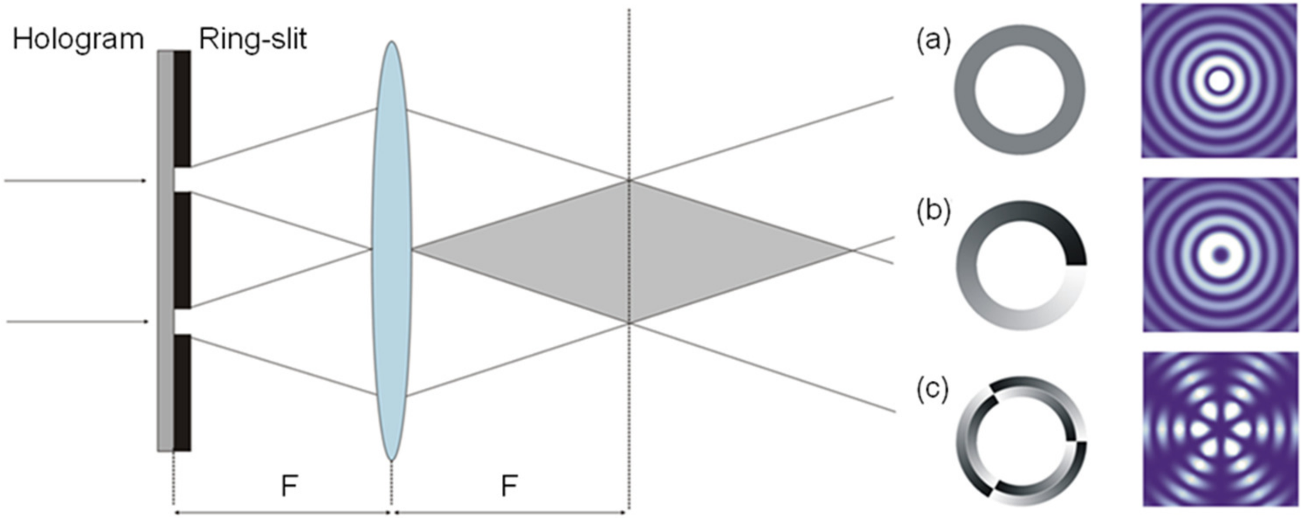
Message Received:

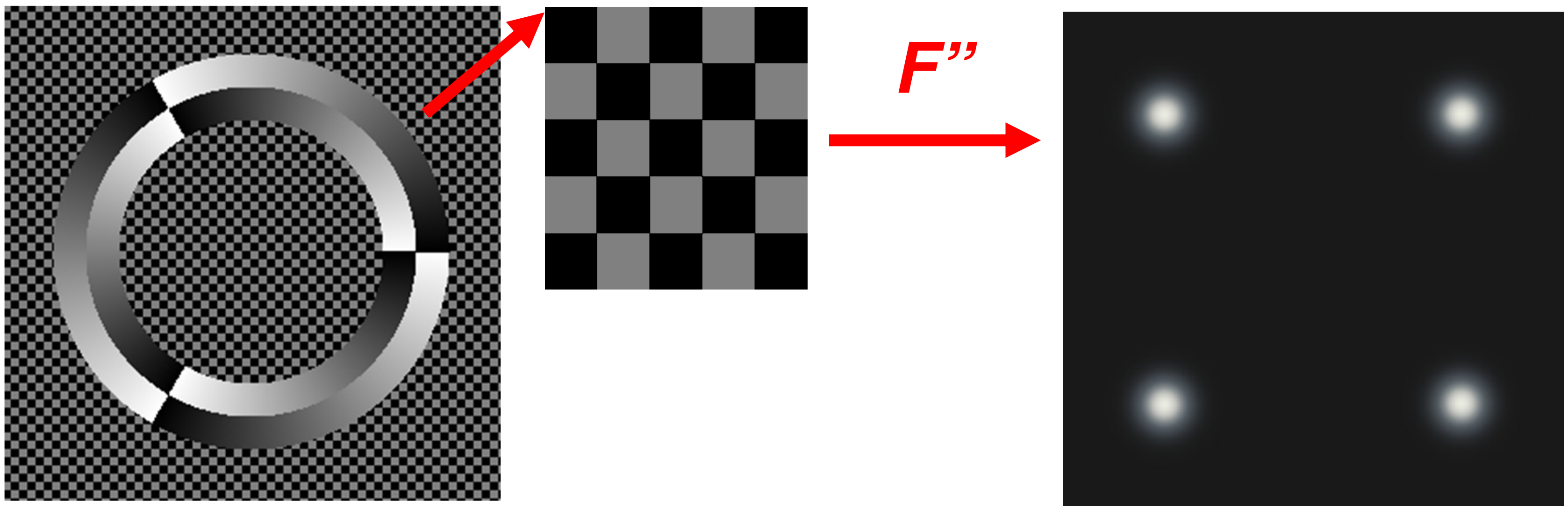
101110 = A

Laguerre-Gaussian modes are created with digital holograms.

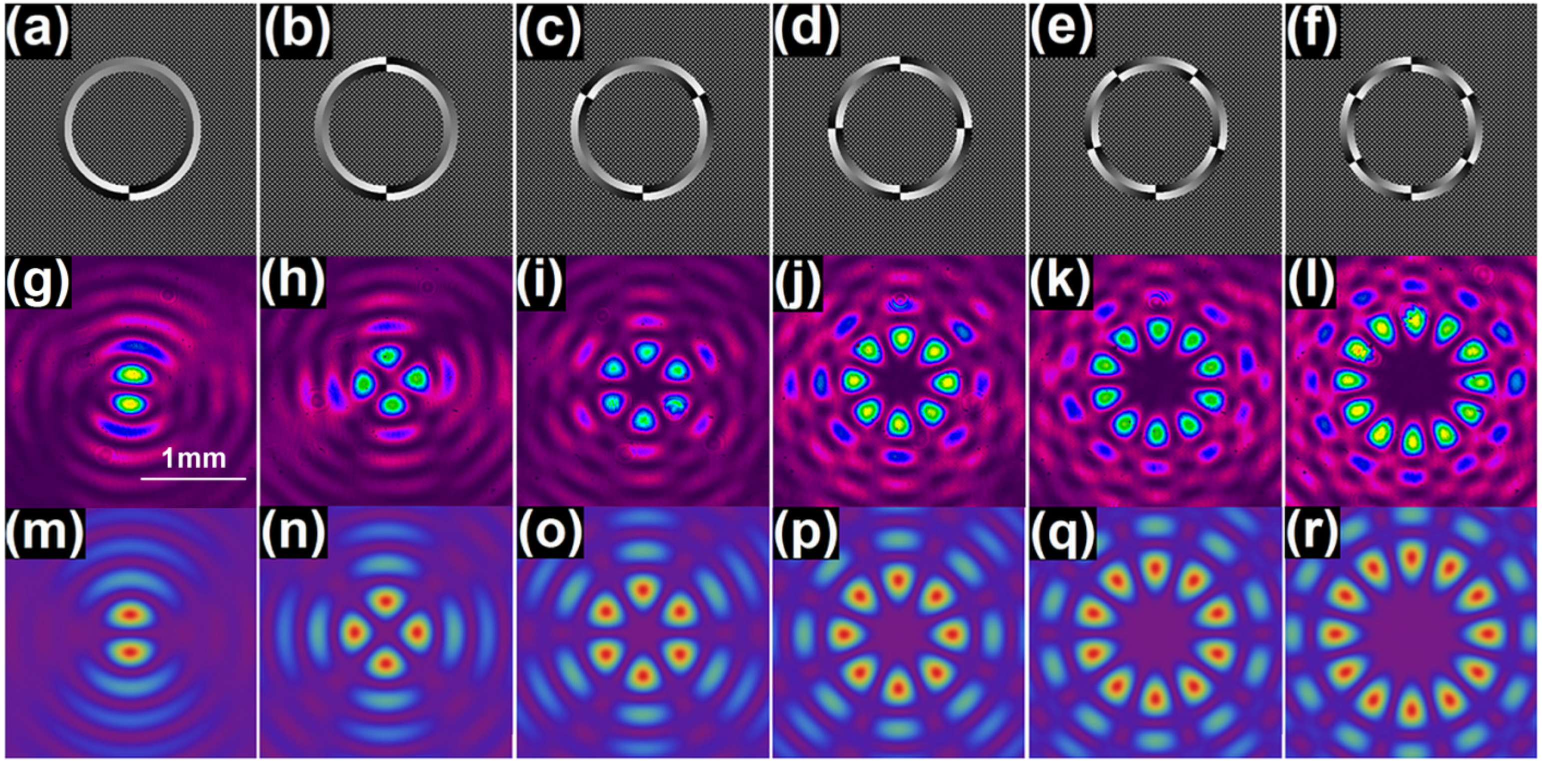


An azimuthally-varying phase (bounded by a ring-slit) placed in the spatial frequency domain produces a higher-order Bessel beam



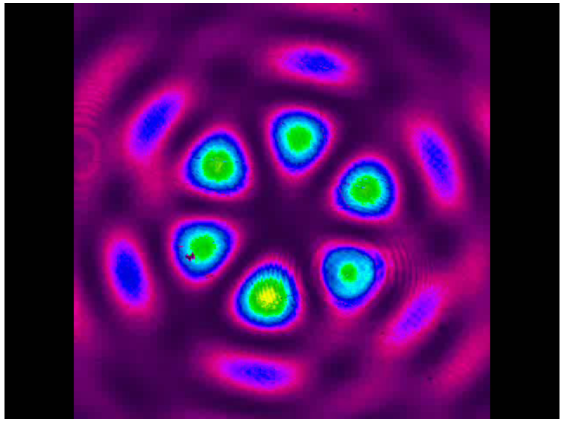


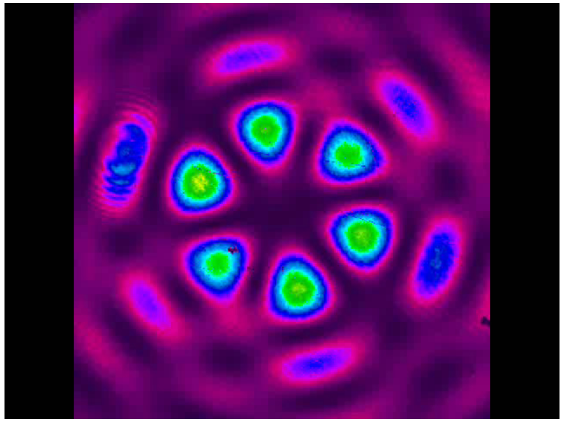
We can then create superpositions which either do or do not possess a global OAM

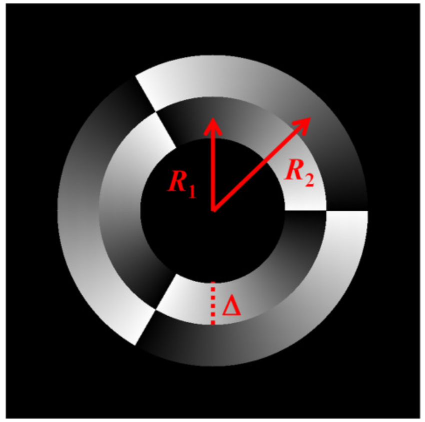


J. Mod. Opt. **59**(3), 259-267 (2012)

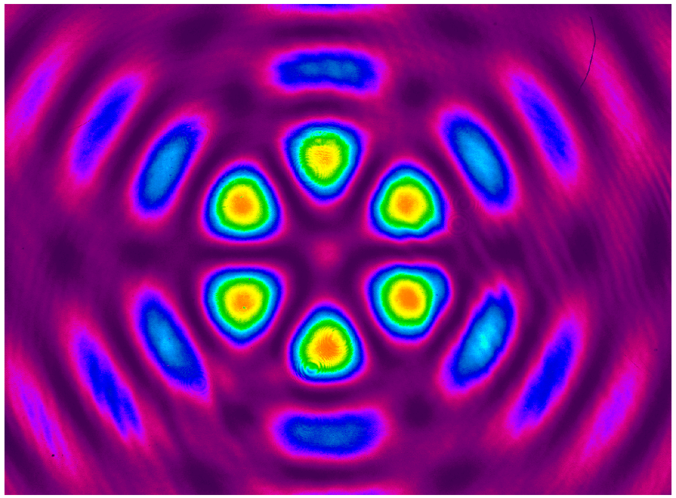
We are interested in these beams because their local OAM changes radially across the beam



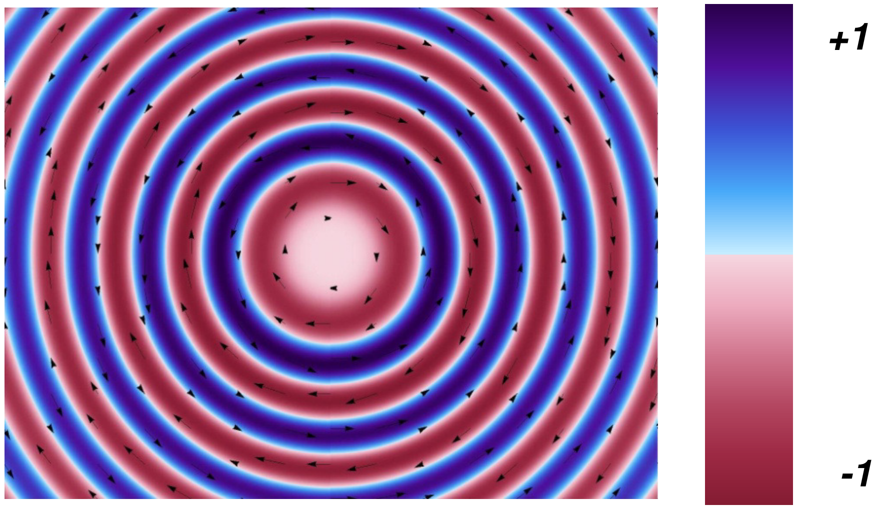




Field:

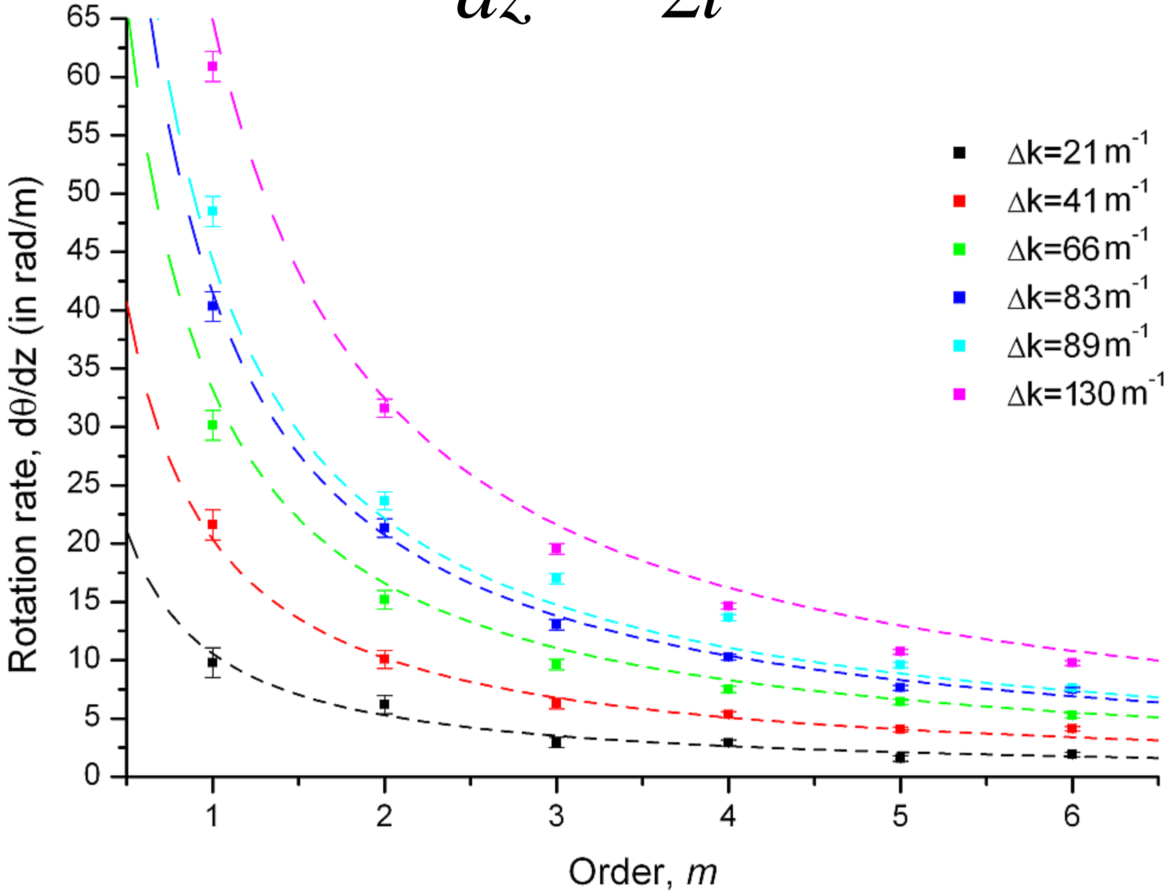


Local OAM spectrum:



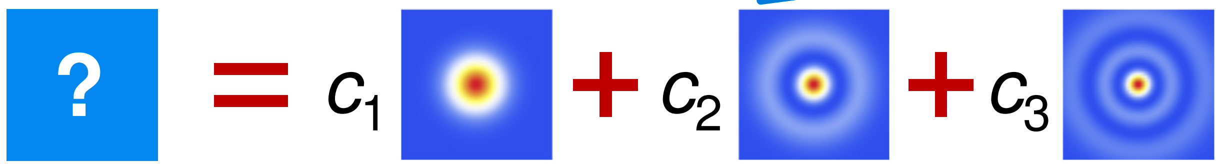
We can even control these rotation rates

$$\frac{d\theta}{dz} = \frac{\Delta k}{2l}$$



A modal decomposition is used to extract the intensity and phase of an optical field

$$U = \sum_{n=0}^{\infty} c_n \Psi_n$$

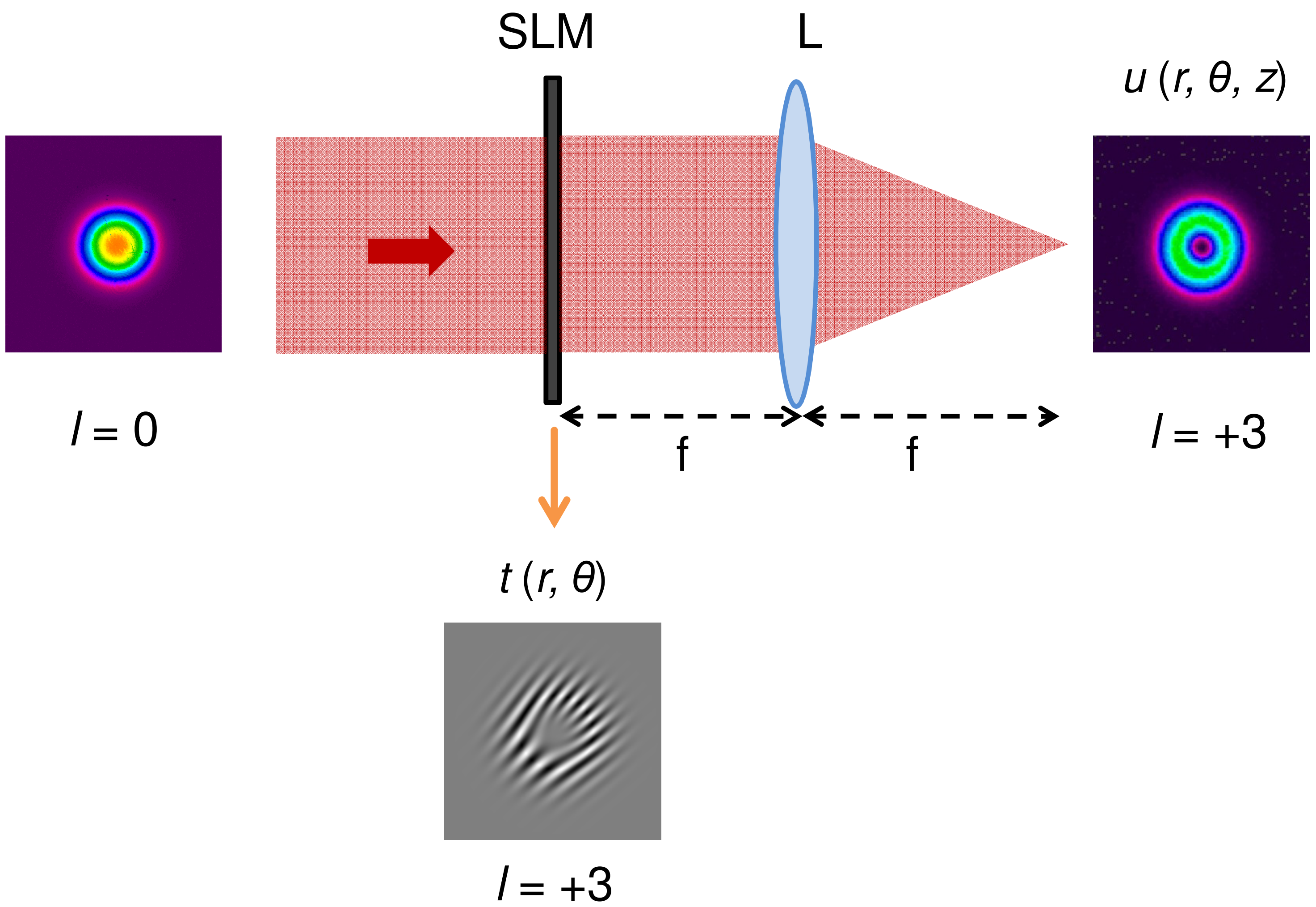


$$c_n = \rho_n \exp(i\phi_n) = \langle U, \Psi_n \rangle = \iint U \Psi_n^* dxdy$$

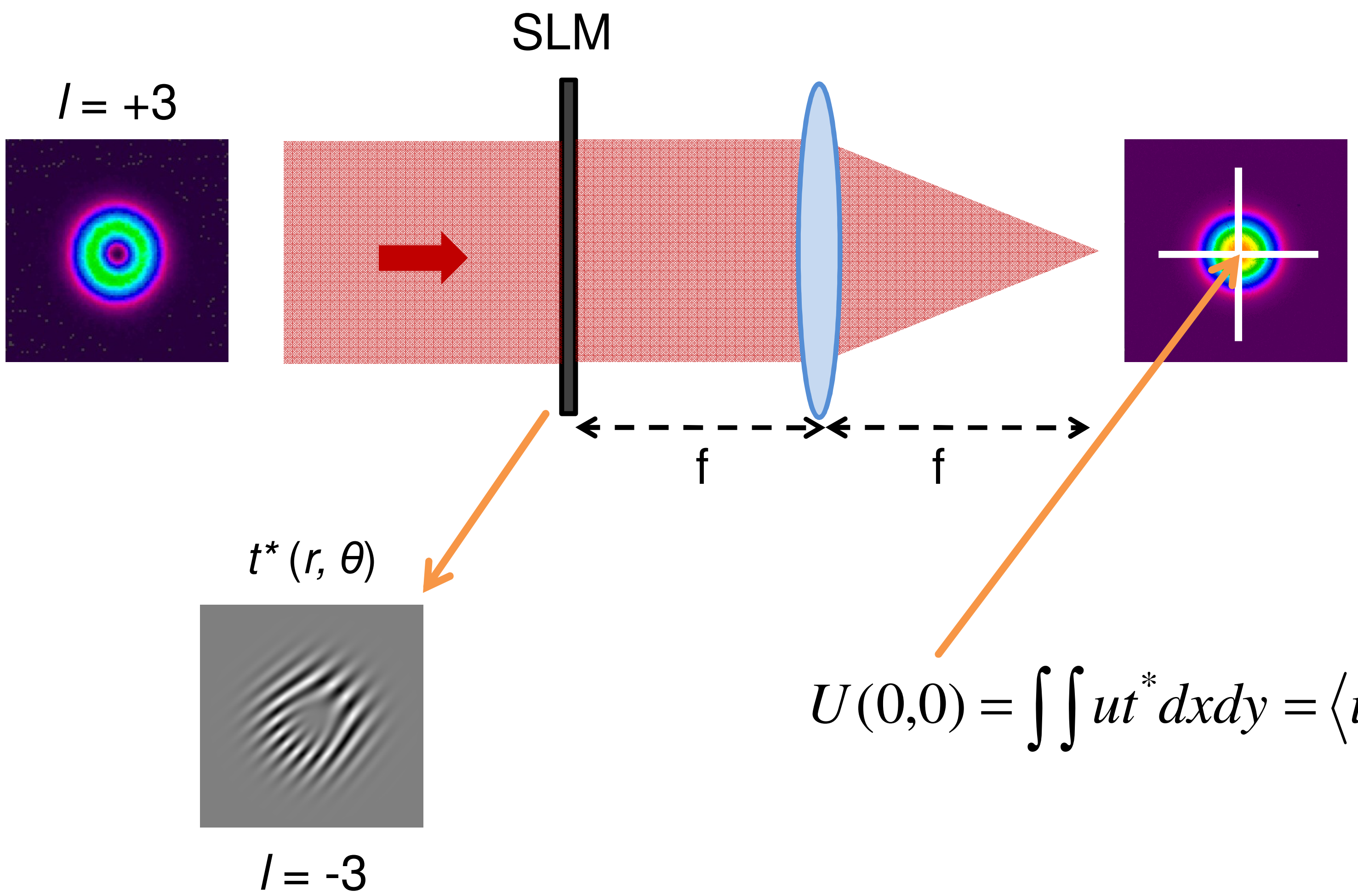
Perform this integral

Create these modes

We already know how to create any laser mode with digital holograms

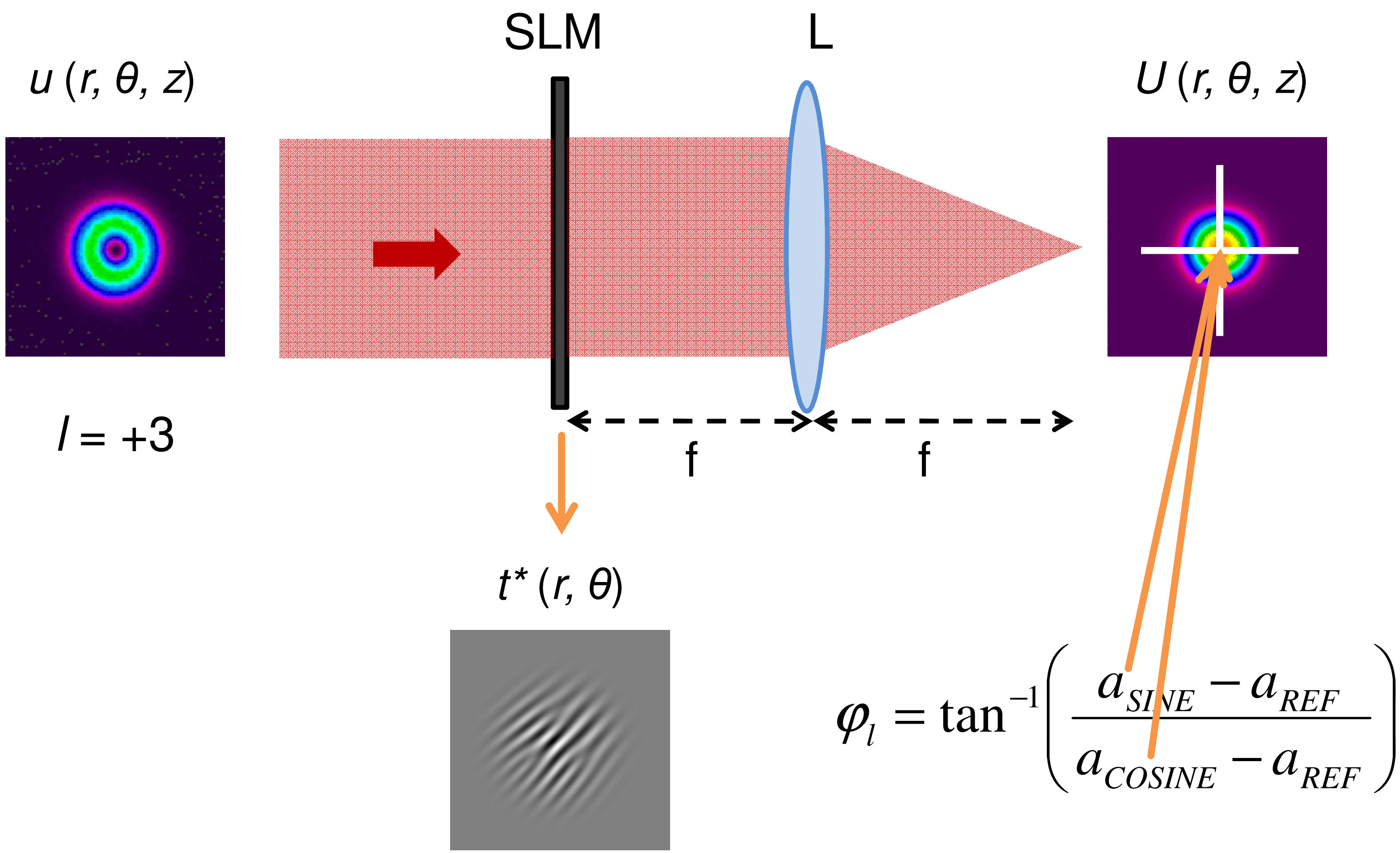


In reverse: we can pass an unknown field through a match filter to find the inner product



$$U(0,0) = \int\int ut^* dxdy = \langle u,t \rangle$$

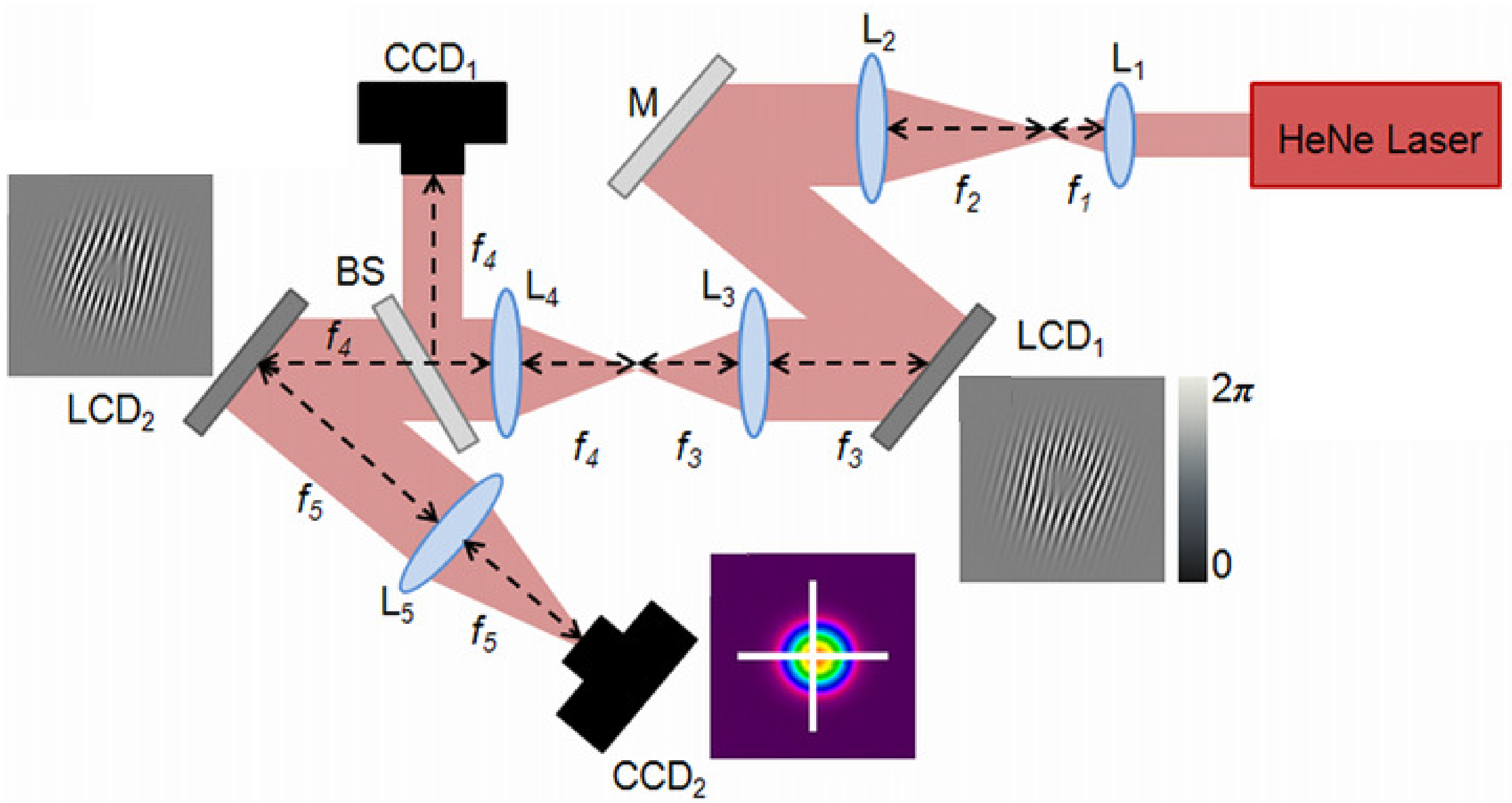
Appropriate match filters can also be created to find the modal phases



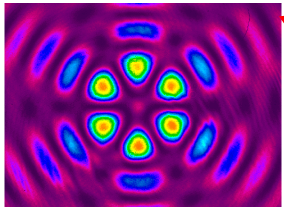
$$\varphi_l = \tan^{-1}\left(\frac{a_{SINE} - a_{REF}}{a_{COSINE} - a_{REF}}\right)$$

COSINE $\rightarrow$ $\frac{1}{\sqrt{2}}\left(t^*_{REF} + i t^*_l\right)$

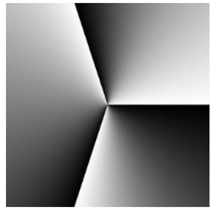
The measurement requires only a SLM and a lens

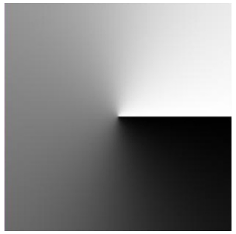
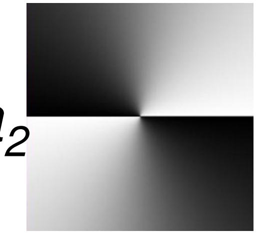
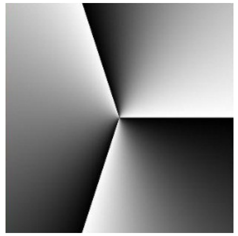


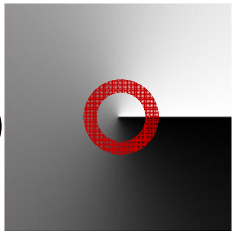
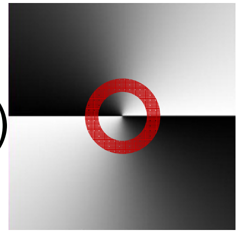
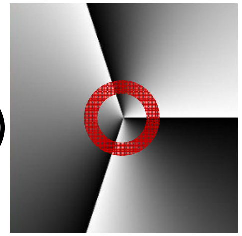
An annular ring, restricting the azimuthal match-filter, can be used to perform a scale-independent modal decomposition



$$u(r,\phi,z) = \frac{1}{\sqrt{2\pi}} \sum_{l} a_l(r,z) \exp(il\phi)$$

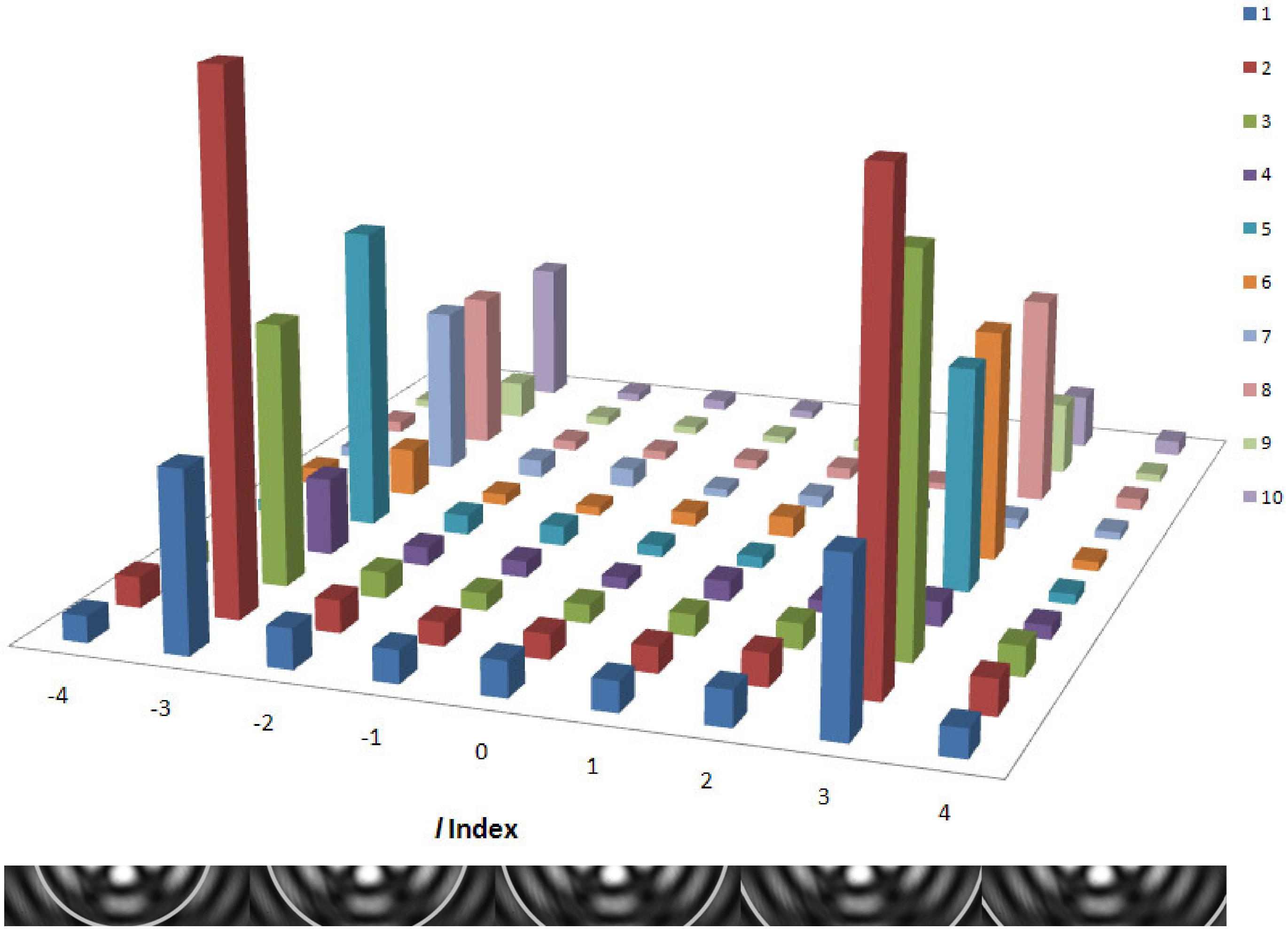


$u(\phi)$ = a_1  + a_2  + a_3 

$u(r,\phi)$ = $a_1(r)$  + $a_2(r)$  + $a_3(r)$ 

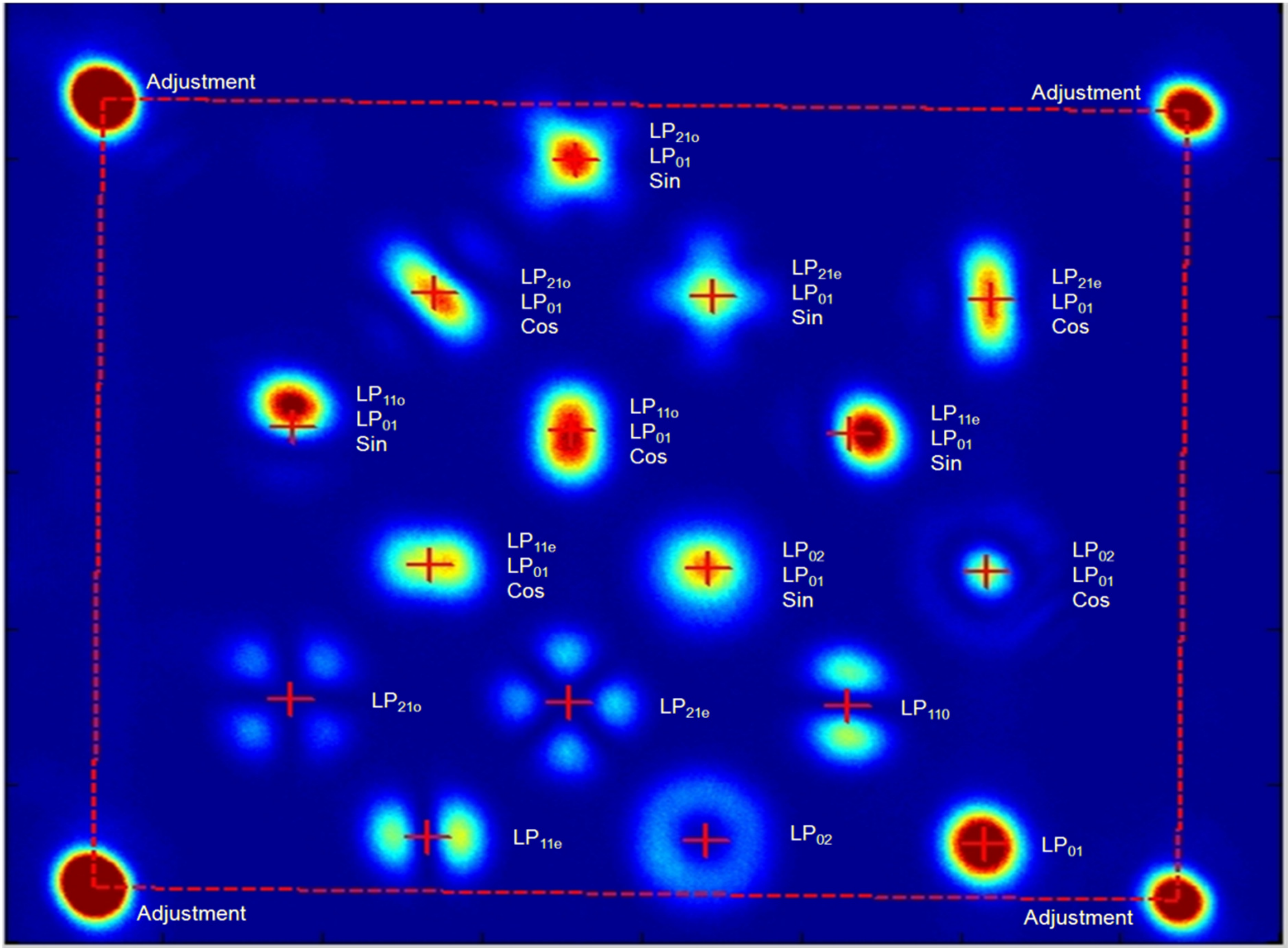
$$a_n(r,z) = \frac{1}{\sqrt{2\pi}} \int_0^{2\pi} u(r,\theta,z)\, t(r,\theta)\, d\theta$$

An annular ring, restricting the azimuthal match-filter, can be used to perform a scale-independent modal decomposition

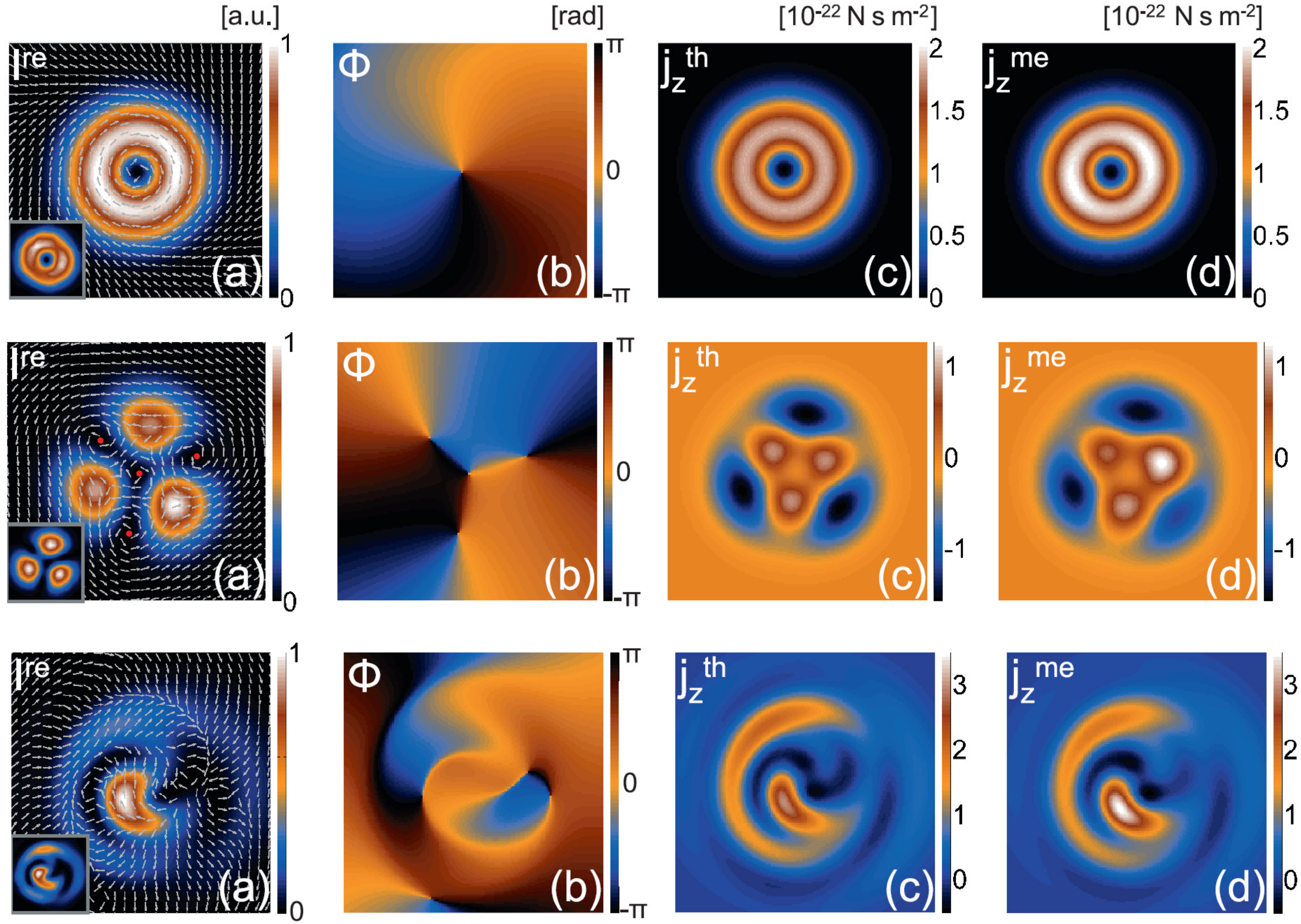


Opt. Express **19**(18), 16760 (2011).

Assigning each match filter with its own spatial frequency allows a single snapshot measurement



Any field in any basis can be measured



New J. of Phys. **15**, 073025 (2013)

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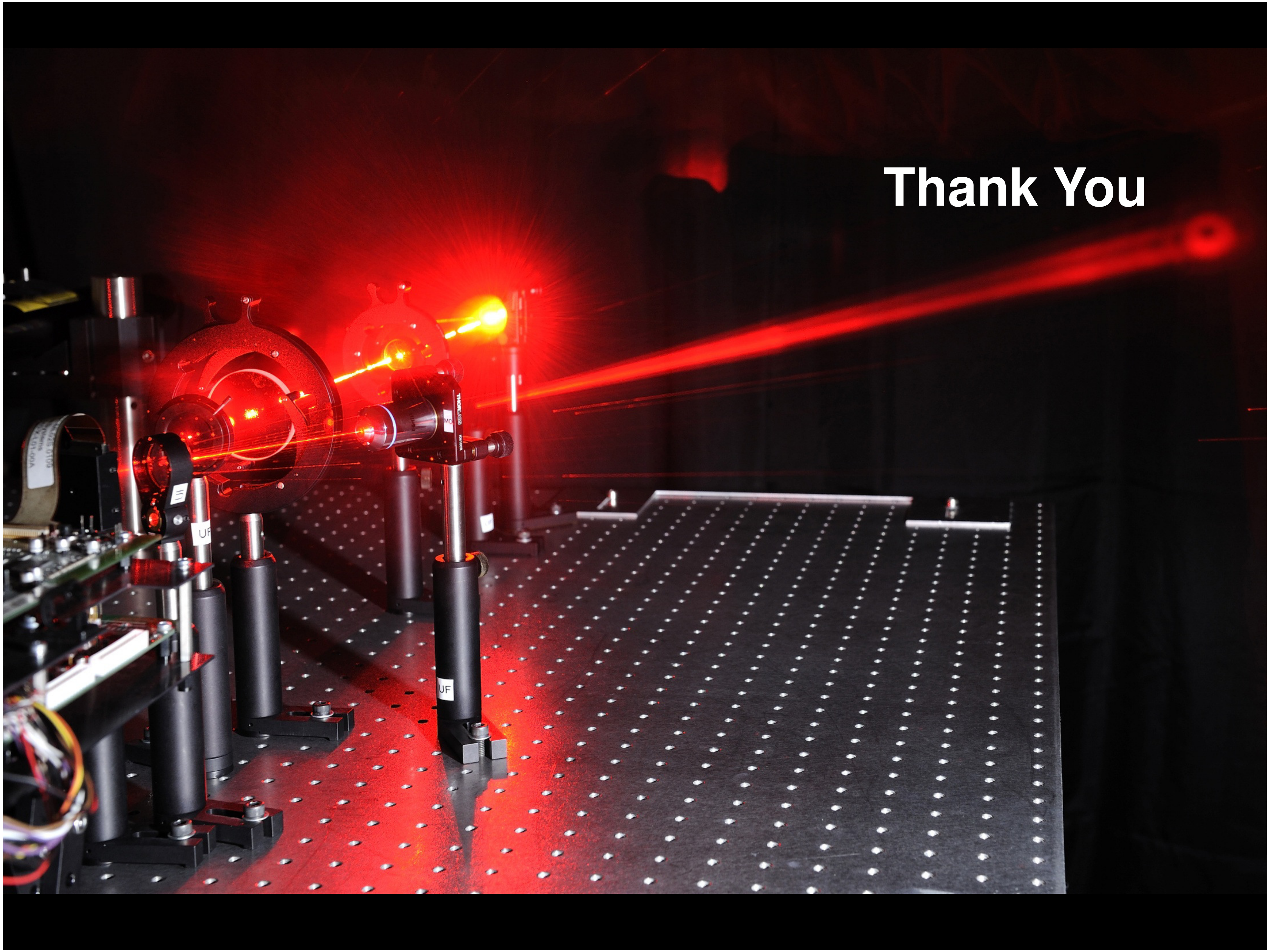
Contact: **AForbes1@csir.co.za**


Thank You