Digitally controlling the ‘twist’ of light

Angela Dudley¹ and Andrew Forbes¹

¹ CSIR National Laser Centre, Pretoria, South Africa.

Presented at:
II International Conference on Applications of Optics and Photonics
Aveiro, Portugal
29 May 2014
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:

Orbital Angular Momentum

Classical optics
Laser optics
Quantum optics
Bio optics

Laser optics

Bio optics
Azimuthally-phased beams have helical wavefronts and consequently carry OAM

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

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)
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.

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.

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

\[ c_n = \rho_n \exp(i\phi_n) = \langle U, \Psi_n \rangle = \int\int U\Psi_n^* dxdy \]

Create these modes

Perform this integral
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

\[ U(0,0) = \iint ut^* \, dx \, dy = \langle u, t \rangle \]
Appropriate match filters can also be created to find the modal phases
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.
Assigning each match filter with its own spatial frequency allows a single snapshot measurement.
Any field in any basis can be measured

PhD and PostDoc positions are available and visitors are always welcome...

Contact: AForbes1@csir.co.za
Thank You