

Vector vortex light fields

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Professor Andrew Forbes  
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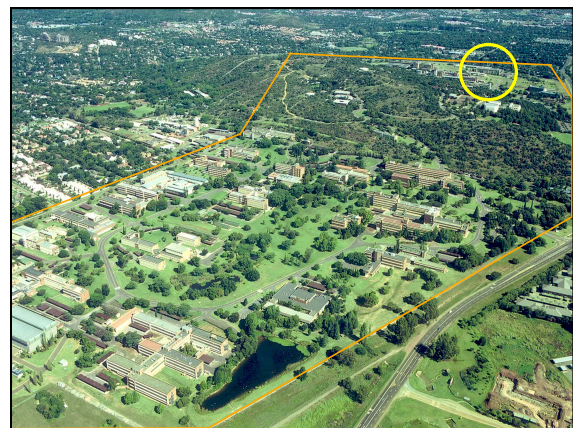

I'm not rich

Controlling light's helicity at the source

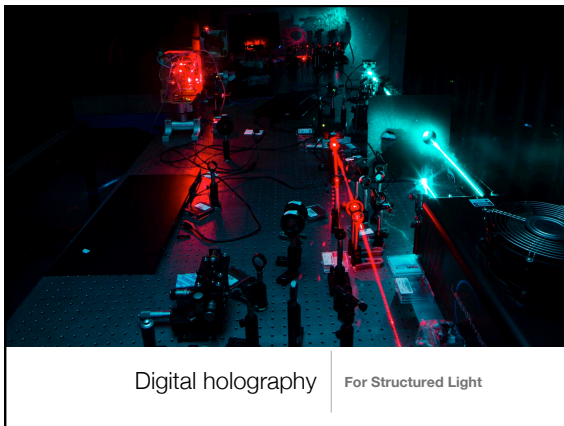
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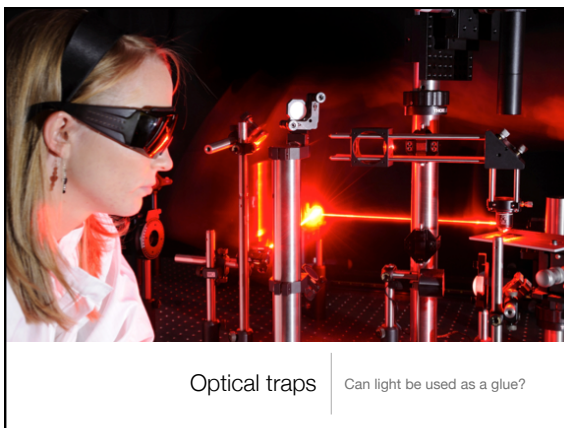
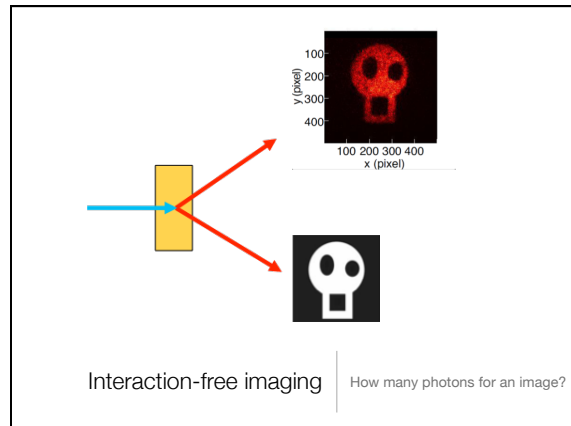
I'm not cleverer than you



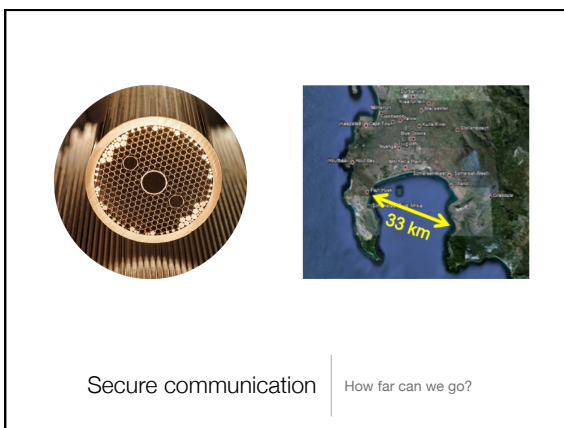
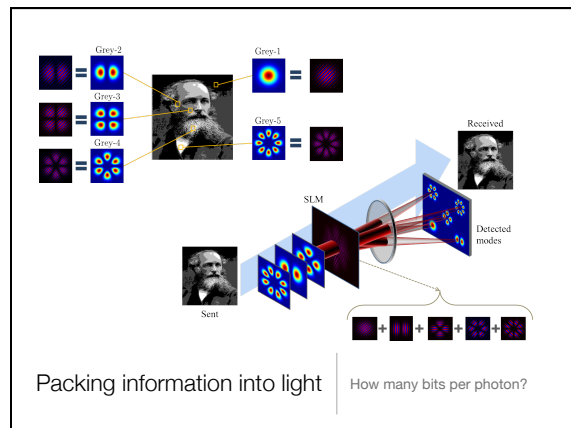
My new home: "Wits" | 4 Nobel Laureates and me ©



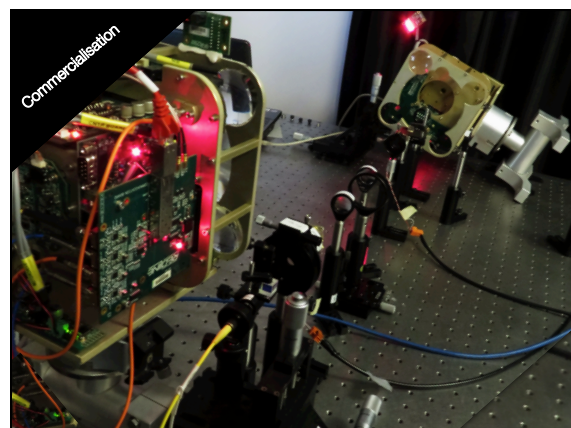
Digital holography | For Structured Light



Optical traps | Can light be used as a glue?



Secure communication | How far can we go?



Using the *transmission* of light we can tailor arbitrary optical fields

We can create a mask that introduces high loss in some region of the beam

$\text{Gaussian beam} \times \text{Smiley face mask} = \text{Smiley face beam}$

Using the *Geometric Phase* opens a new avenue to explore ...

(Anisotropic media) "extra" phase delay called **geometric phase**

$$\delta = \left( \frac{n_e + n_o}{2} \right) \frac{2\pi}{\lambda} d \pm 2\Phi$$

Geometric Phase

$\text{Gaussian beam} \times \text{Phase mask} = \text{Smiley face beam}$

Using the *Dynamic Phase* of light we can tailor arbitrary optical fields

(Isotropic media) "normal" phase delay called **dynamic phase** due to optical path length difference

$$\delta(x, y) = n(x, y) \frac{2\pi}{\lambda} d(x, y)$$

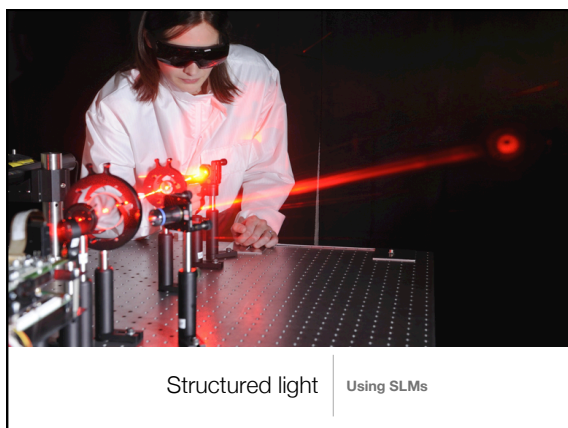
$\text{Gaussian beam} \times \text{Phase mask} = \text{Smiley face beam}$

Using the *Dynamic Phase* of light we can tailor arbitrary optical fields

(Isotropic media) "normal" phase delay called **dynamic phase** due to optical path length difference

$$\delta(x, y) = n(x, y) \frac{2\pi}{\lambda} d(x, y)$$

$\text{Gaussian beam} \times \text{Uniform mask} = \text{Smiley face beam}$



Here is how you create a "mode selective" detector ... a spatial light modulator and a single mode fibre

BG mode

Hologram

Gaussian mode

Single-mode fibre

Any mode can be created and detected

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Using complex amplitude modulation on an SLM

Adv. Opt. Photon. 8, 200 (2016)

We will consider OAM as our "pattern" or mode

Right-handed donut

$l = 0L$   
Helical wavefront

Left-handed donut

$l = 2$   
Helical wavefront

Light can be vector or scalar

Scalar beams

Vector beams

By rotating a polariser, we can change the spatial distribution

Vector vortex modes have inhomogeneous polarization distributions

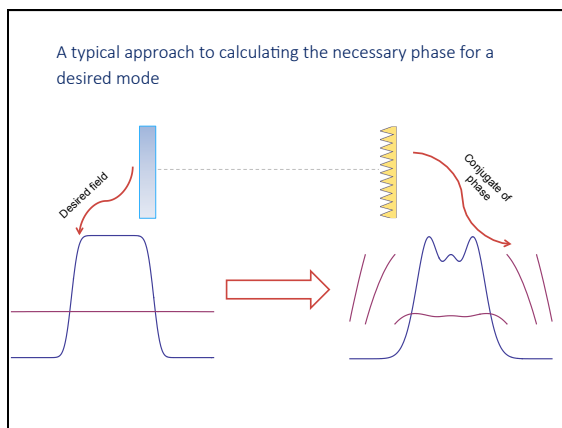
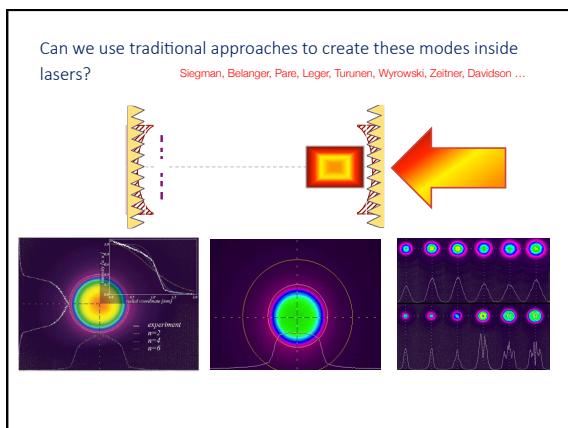
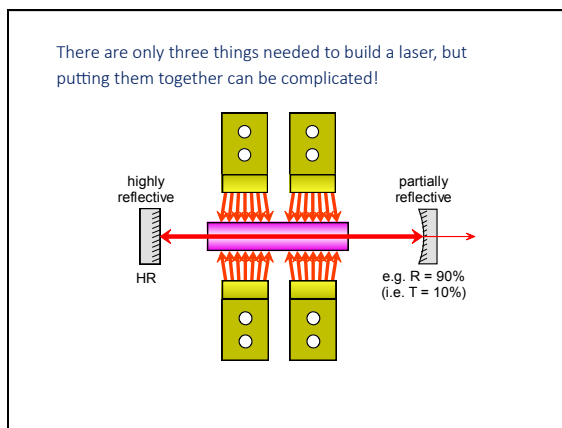
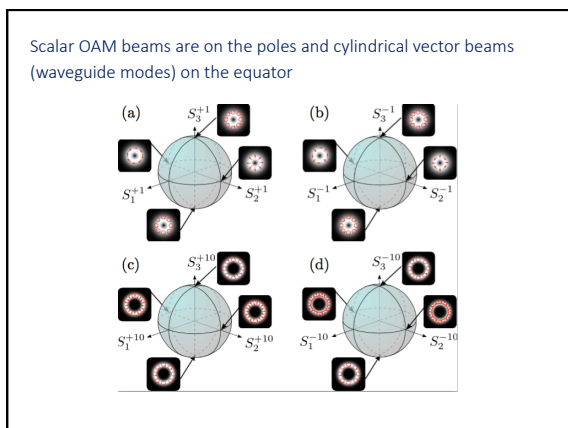
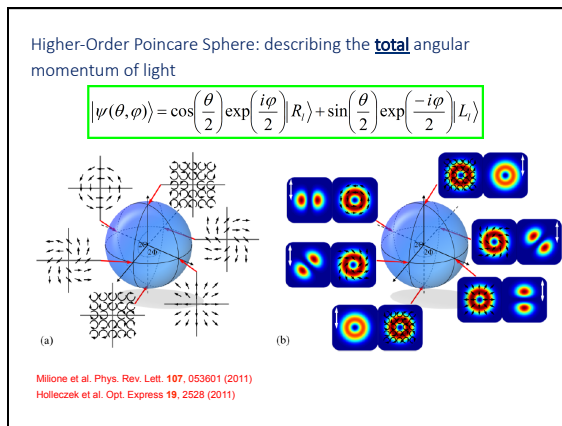
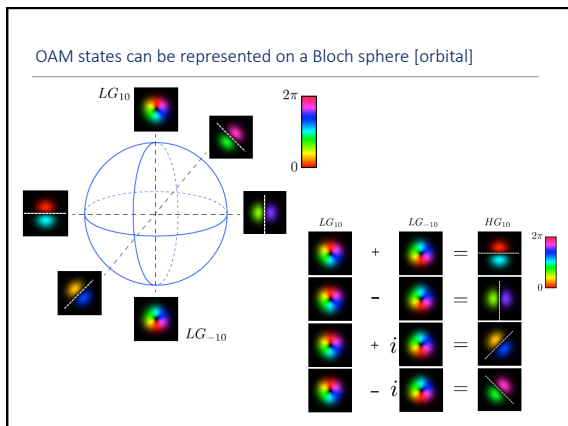
Scalar modes

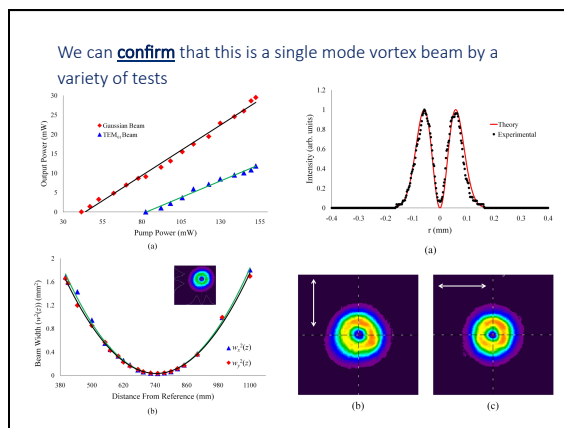
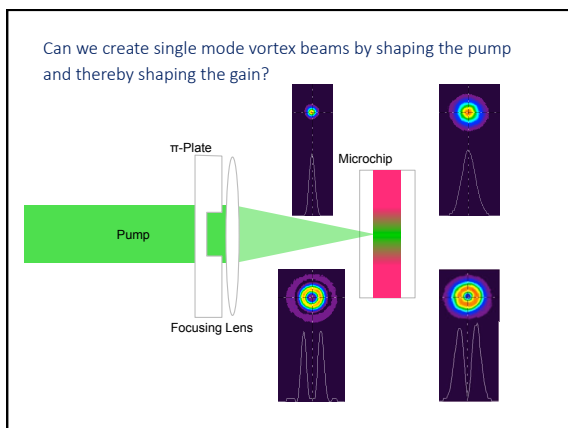
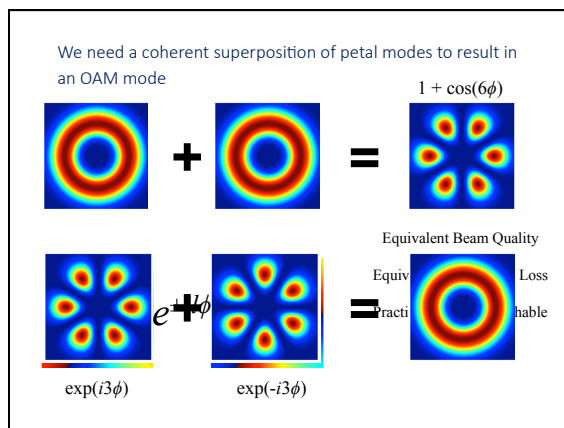
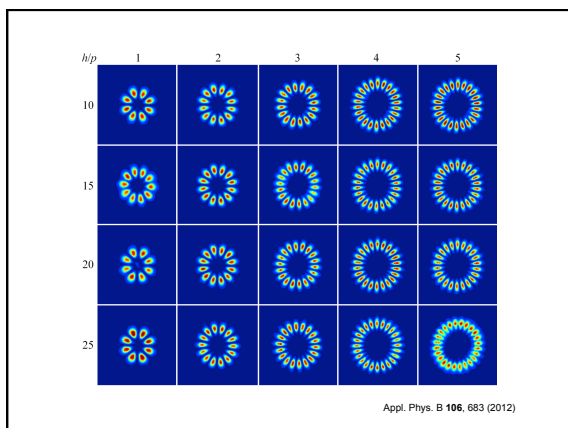
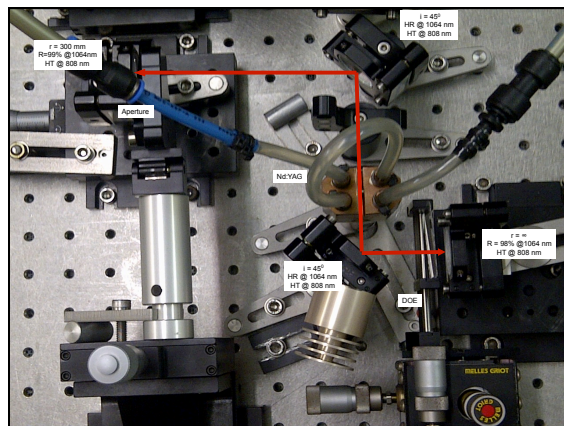
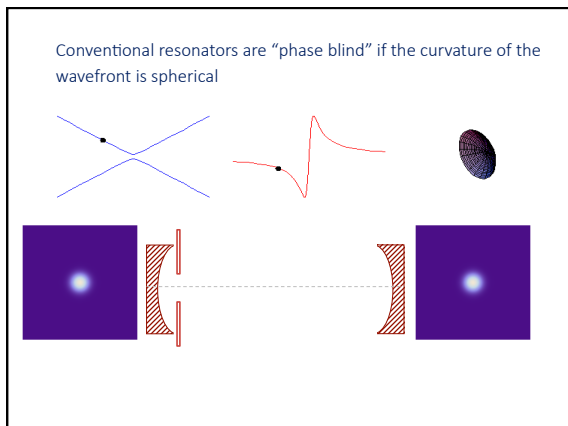
Mode

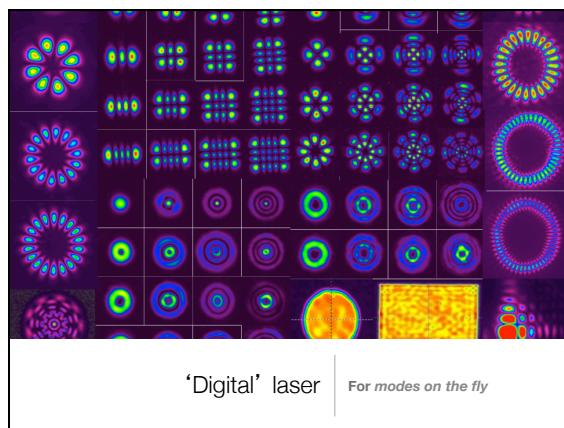
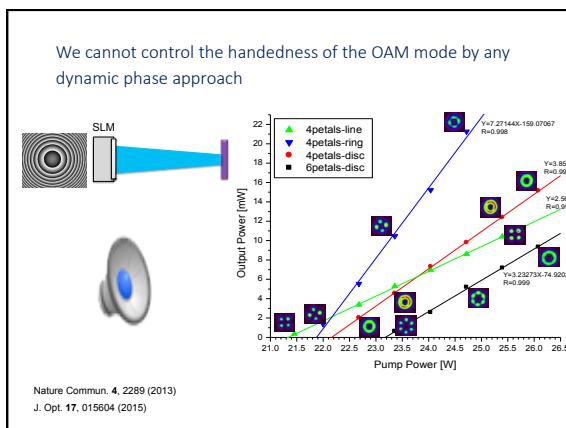
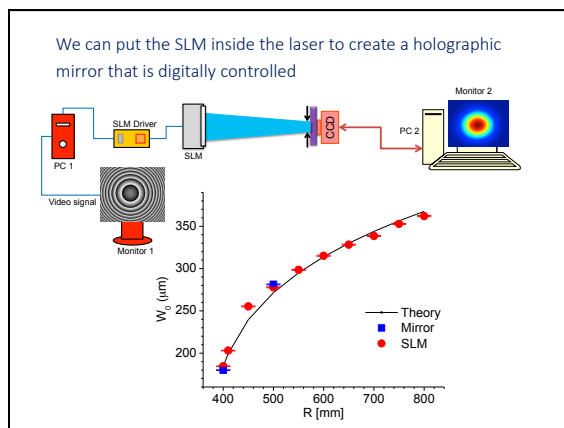
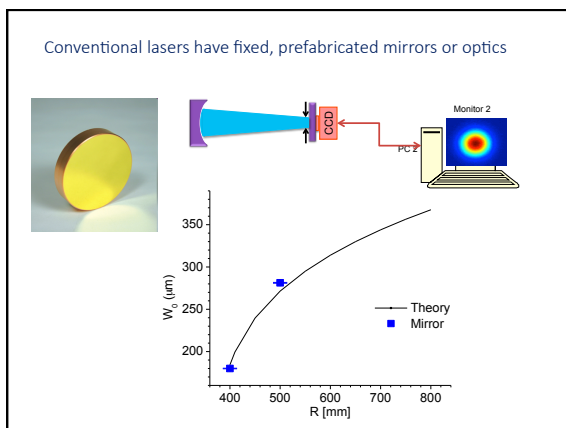
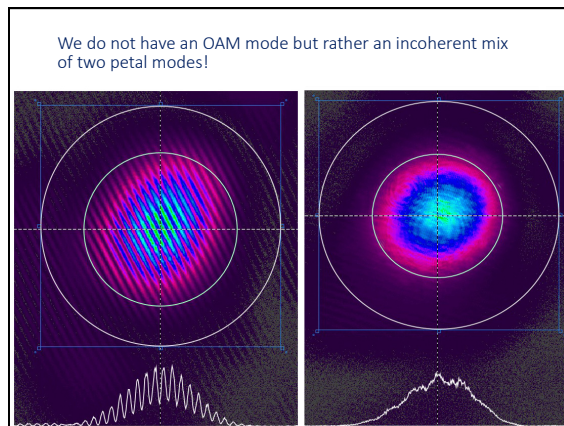
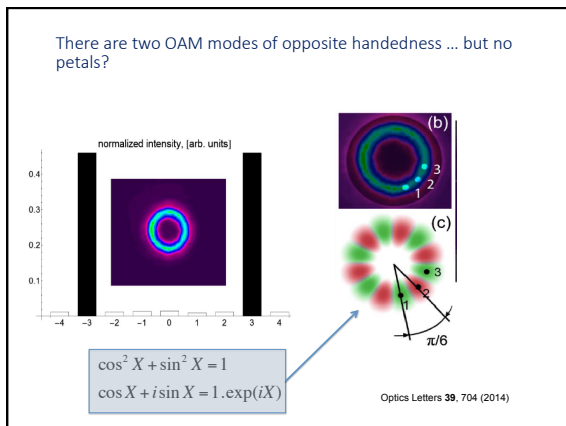
Vector modes

Mode

Polarisation states can be represented on a Poincaré sphere [spin]







Is it possible to create a coherent superposition?

Odd: 0.92967    Even: 0.92961

Do small differences in the cavity lead to mode discrimination?

Lin et al., Opt. Lett. 39, 3903 (2014)

Liang Feng/Natalia Litchinitser, Science 353, 464 (2016)

Kim et al., Opt. Lett. 40, 399 (2015)

Cai et al., Science 338, 363 (2012)

Spin angular momentum is very easy to control inside lasers

	Right Circular	$\begin{bmatrix} 0 \\ 1 \\ 1 \\ 0 \end{bmatrix}$
	Left Circular	$\begin{bmatrix} 0 \\ 1 \\ -1 \\ 0 \end{bmatrix}$
	Horizontal	$\begin{bmatrix} 1/\sqrt{2} \\ 1/\sqrt{2} \\ 0 \\ 0 \end{bmatrix}$
	Vertical	$\begin{bmatrix} 1/\sqrt{2} \\ 0 \\ -1/\sqrt{2} \\ 1/\sqrt{2} \end{bmatrix}$

Why not couple polarisation to the OAM ...

Phys. Rev. Lett. 96, 163905 (2006).

Opposite Handedness

$|l, R\rangle \rightarrow |l - 2q, L\rangle$      $|l, L\rangle \rightarrow |l + 2q, R\rangle$

We can connect the OAM to the SAM to create a "spiral" resonator that distinguishes handedness

	Right Circular	$\begin{bmatrix} 0 \\ 1 \\ 1 \\ 0 \end{bmatrix}$
	Left Circular	$\begin{bmatrix} 0 \\ 1 \\ -1 \\ 0 \end{bmatrix}$
	Horizontal	$\begin{bmatrix} 1/\sqrt{2} \\ 1/\sqrt{2} \\ 0 \\ 0 \end{bmatrix}$
	Vertical	$\begin{bmatrix} 1/\sqrt{2} \\ 0 \\ -1/\sqrt{2} \\ 1/\sqrt{2} \end{bmatrix}$

Experimental selection of pure OAM modes

- Charge  $e^{-il\phi}$

+ Charge  $e^{+il\phi}$



