"Angular" Kapitza-Dirac Scattering using Optical vortices

Y.S. Rumala and A.E. Leanhardt

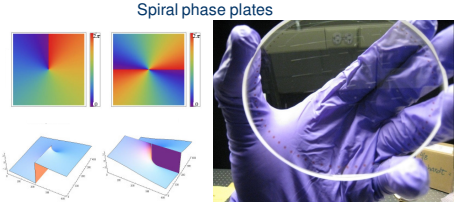
Department of Physics, University of Michigan, Ann Arbor, MI 48109, USA

70 $^1S_0$
Yb
Ytterbium
173.04
$[Xe]4f^{14}6s^2$

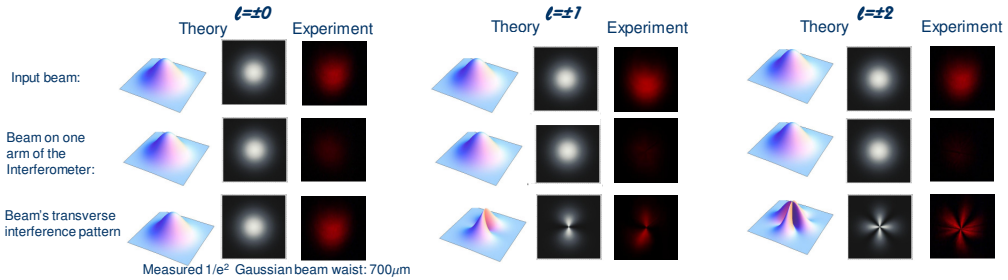
Optical Vortices

An azimuthally varying phase Exp[$i\ell\varphi$] imprinted on a TEM_{00} gaussian mode using a spiral phase plate, generates photons which posses orbital angular momentum (OAM), $\ell\hbar$. Co-propagating, counter rotating optical vortices are interfered to form an azimuthally varying standing wave

Spiral phase plates



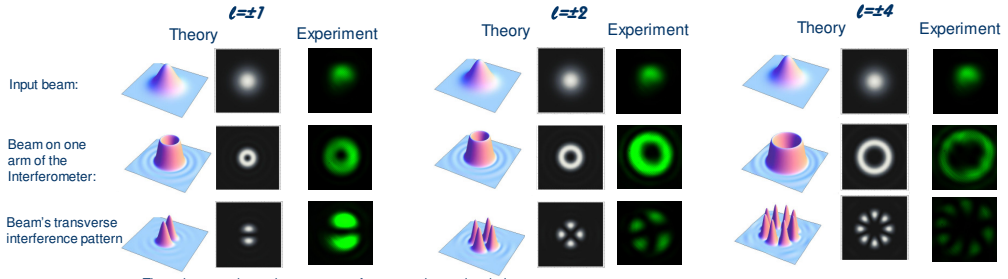
Near field intensity pattern using a 4F imaging system



Measured $1/e^2$ Gaussian beam waist: 700μm

The beams posses orbital angular momentum with no phase singularity in the middle as seen from the interference patterns.

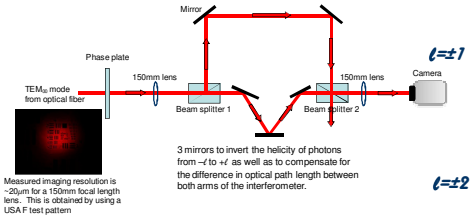
Far field intensity pattern without 4F imaging system

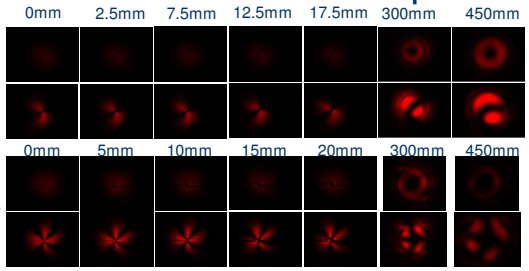


These images shows the presence of a vortex phase singularity

Propagation dynamics of an optical vortex from the near to far field in free space

Modified Mach-Zehnder interferometer





The images to the right shows the onset of a vortex core as the beam propagates through free space

2D "Angular" Kapitza-Dirac scattering

A pulsed standing wave, $I_0Cos(2\ell\varphi)$, diffracts atoms into a superposition of angular momentum eigenstates,

$$\Psi = \Psi_0 e^{-i\Theta} e^{+i\cos(2l\varphi)} = \Psi_0 e^{-i\Theta} \sum_n (+i)^n J_n(\Theta) e^{-i2nl\varphi}$$

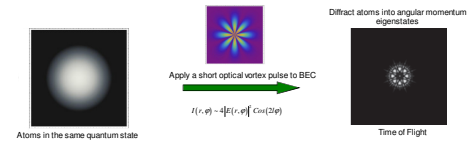
with angular momentum, $2n\ell\hbar$, n= 0, **±1, ±2...**

Copropagating, counter rotating vortices forms a matter wave interference pattern that is sensitive to the sagnac phase shift on a platform rotating at a rate Ω

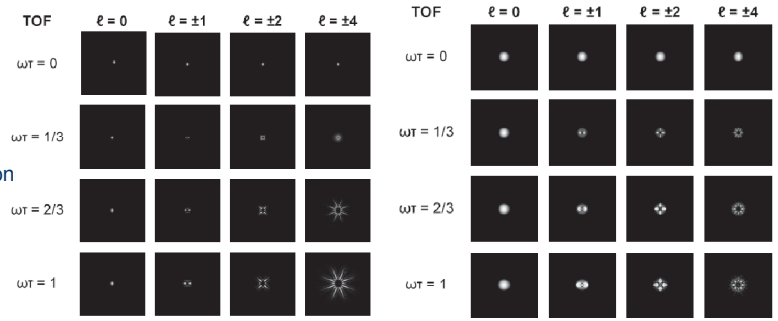
$$\Delta\phi = 2m\Omega A/\hbar = 2T L/\hbar$$

For vortices with an angular momentum per particle of L=qh, the area enclosed by the vortex wave function is A=qhT/m for an evolution time T

Basic idea



To the right are 2D simulations of the nonlinear Gross-Pitaevskii equation to derive the time evolution of a weakly interacting wave function after the optical vortex pulse.



We will also potentially study the coupling of the orbital angular momentum of light to the electronic states of atomic ytterbium during the process of making our atomic gas cold. In the future, nanofabricated structures will be used to imprint an azimuthally varying phase on the TEM_{00} gaussian mode.

Acknowledgements

- We are excited that C. Siedlecki will soon start fabricating custom phase plates for us
- Y.S. Rumala acknowledges support from the NSF Graduate Research Fellowship, Rackham Merit Fellowship, and an Applied Physics Fellowship