

# Nonlinear Beam Shaping in an Anisotropic Magneto-optical Trap



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## Introduction

### Motivation: Single Photon Nonlinear Optics

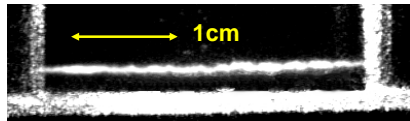
- Large optical intensities are typically required to see nonlinear optical (NLO) effects because the nonlinear response of most materials is small
- Current methods to realize low light level NLO include
  - Local field enhancements
  - Confined light for larger interaction lengths
  - Sensitive optical instabilities

### Goals:

To determine whether:

- 1) cold atoms can be used to guide and confine light
- 2) spatial optical patterns can be generated at ultra-low light levels in cold atoms

## Anisotropic MOT<sup>1,2</sup>

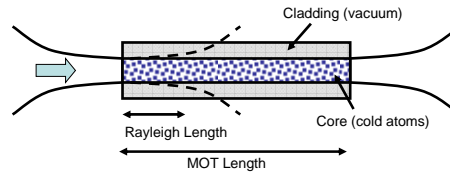


- Length: 3 cm
  - Radius: 0.3 mm
  - Optical Depth ~55 ( $e^{-OD}$ )
  - Density  $7 \times 10^{10}$  atoms/cm<sup>3</sup>
  - Temperature ~30  $\mu$ K
  - <sup>87</sup>Rb trapped on  $F=2 \rightarrow F'=3$
- Aspect Ratio 100:1

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## Light Guiding

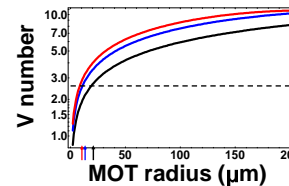
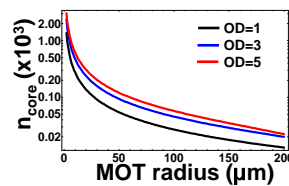
Guiding light with a cold atom fiber allows for higher intensities over longer distances



For single mode operation, the fiber V-number < 2.4

$$V = \frac{2\pi}{\lambda} a \sqrt{n_{core}^2 - n_{cladding}^2}$$

$\lambda$ : wavelength  
 $a$ : core radius  
 $n$ : index of refraction



Single mode guiding in the MOT is possible at fixed OD for transient trap compression to a radius of ~10  $\mu$ m

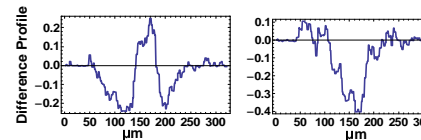
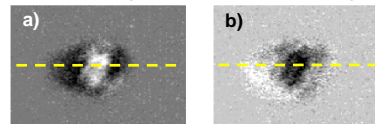
## Linear Lensing: A Path Toward Waveguiding

The Gaussian density profile of the atoms acts as a lens to produce focusing/defocusing for small  $s$  in the near field

$$s = \frac{I/I_{sat}}{1 + 4(\Delta/\gamma)^2}$$

$I_{sat}$ : saturation intensity  
 $\Delta$ : detuning from resonance.  
 $\gamma$ : natural width

Difference Results ( $s=10^{-4}$ ,  $\Delta=\pm 1.5\gamma$ )

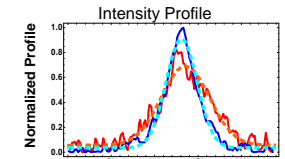
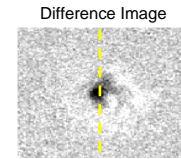


## Nonlinear Beam Shaping

- Self-focusing is a standard metric in NLO
- The intensity threshold for pattern formation tends to be less than the intensity needed for self-focusing

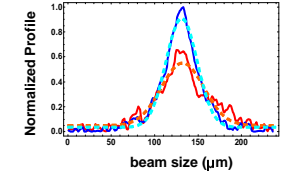
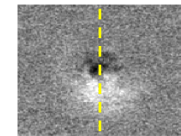
### Nonlinear Defocusing in the Near Field

$s = .02$   
 $\Delta = -\gamma$   
 $M = 1.3$



$M \equiv r/r_0$

$s = .8$   
 $\Delta = -\gamma$   
 $M = 1.5$



Pattern formation via cold atoms is possible<sup>3</sup>

## Future Work

- Realize single mode cold atom waveguide
- Model self-focusing in long, absorbing medium
- Study optical pattern formation

### Citations

- 1) J. Greenberg, M. Oria, A.M.C. Dawes, D.J. Gauthier, Opt. Express **15**, 17699 (2007)
- 2) M. Vengalatorre, W. Rooijakkers, M. Prentiss, PRA **66**, 053403 (2002)
- 3) W. Guerin, F. Michaud, R. Kaiser, arXiv:0804.0109v1 [physics.atom-ph] 1 Apr 2008

### Funding

US Army Research Office (grant # W911NF-05-1-0228),  
DARPA (grant # Contract PO #412785-G-2)