Journal Club

Single Atom in a Superoscillatory Optical Trap

Xintao Feng

CONTENTS

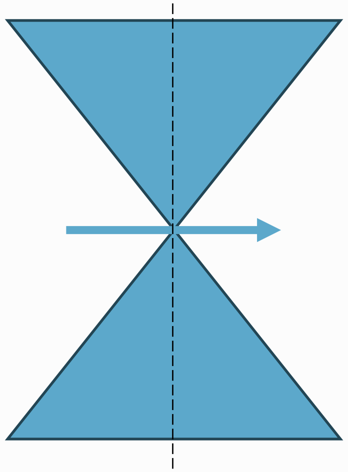
Introduction

CONCEPTS AND PARAMETERS

Introduction

CONCEPTS AND PARAMETERS

Transverse Size



The size of the trap in the plane perpendicular to the direction of the laser beam

- Confine and manipulate small particles
- More precise control
- More stable and less thermal fluctuation
- Reduce the effects of scattering and aberrations

Trapping frequency (f) : Optical power (P) and transverse cross-section (σ)

$$f \sim \frac{\sqrt{P}}{\sigma}$$

Introduction

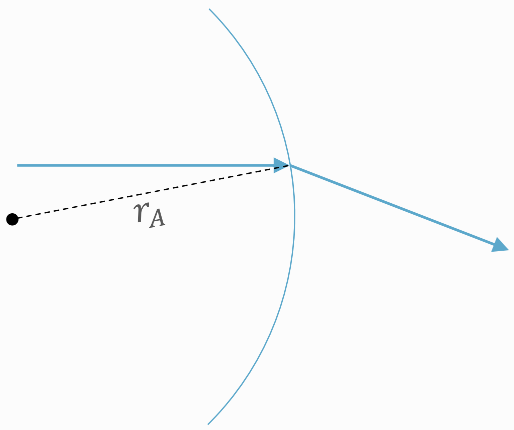
CONCEPTS AND PARAMETERS

Abbe's limit

The radius of curvature of the surface at the point where the refracted ray intersects the axis of the lens.

Defining the Abbe radius of optical hotspot:

$$r_A = \frac{\lambda}{2n\sin\theta} = \frac{\lambda}{2\mathrm{NA}}$$



Introduction

CONCEPTS AND PARAMETERS

Superoscillation

Phenomenon: A function oscillates faster than its Fourier transform

Time / Space domain → Frequency domain

Superresolution imaging and optical metrology

Laser → Abbe limit

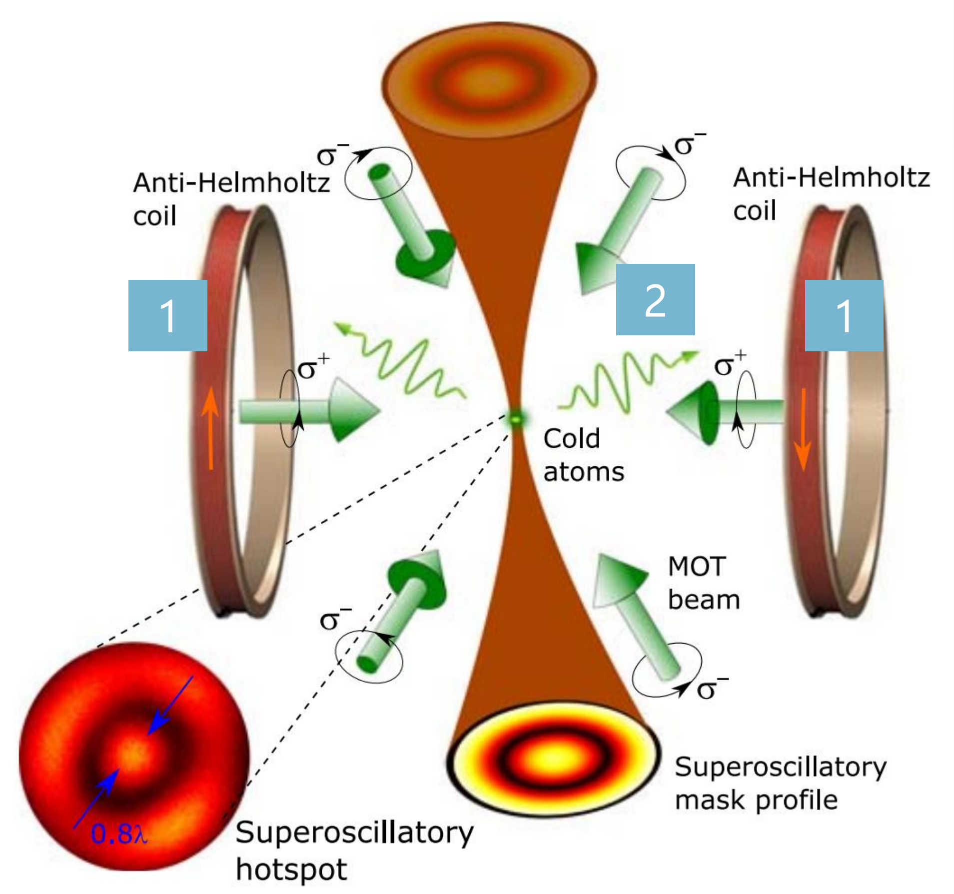
Superoscillation → Subwavelength features

Methods

EXPERIMENTAL DETAILS

Set Up

EXPERIMENTAL DETAILS

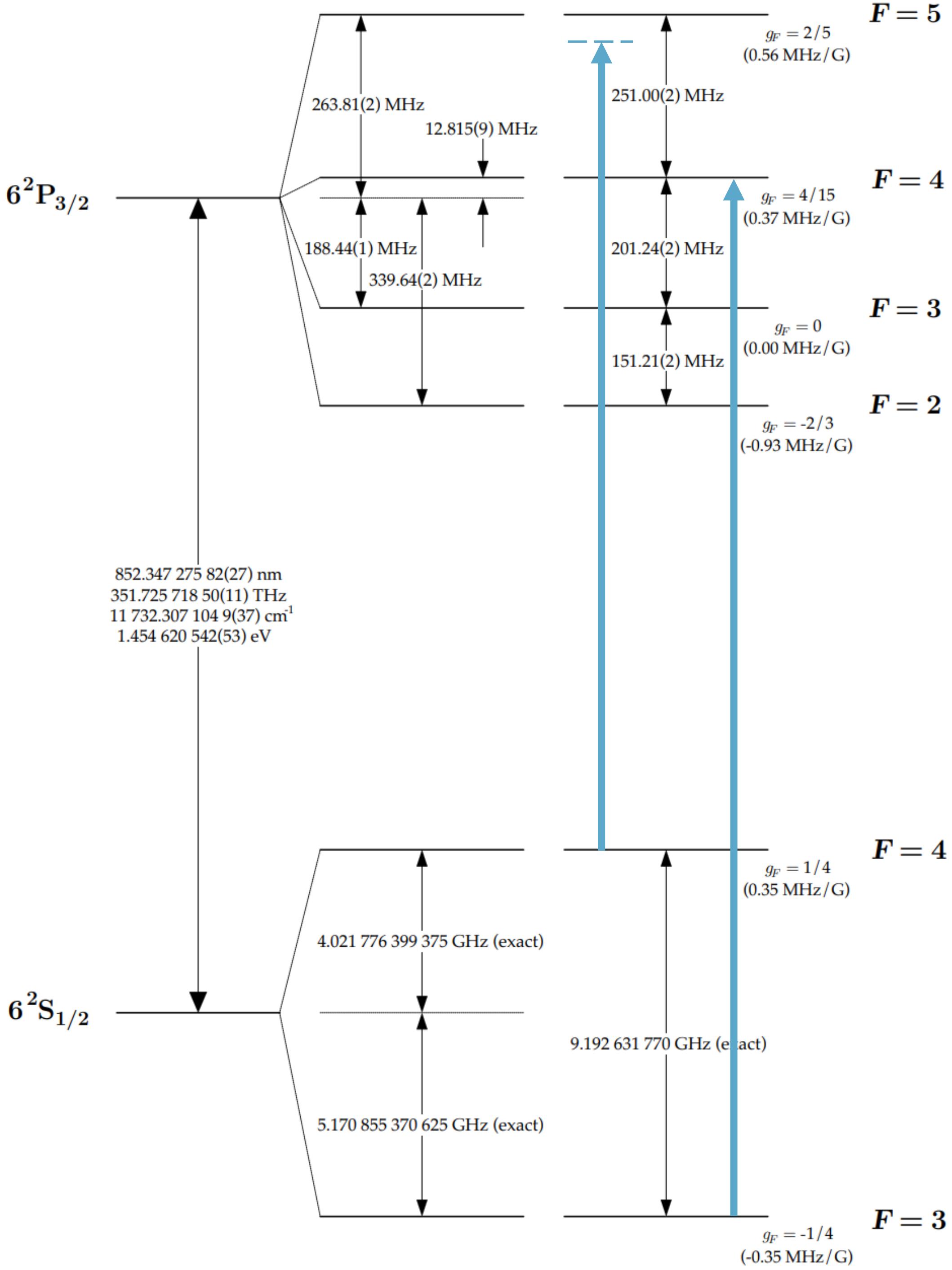


3D Magnetic-optical Trap (MOT)

1. A pair of anti-Helmholtz coils
2. Six circularly polarized beams (green arrows)

   Detuning with respect to $\lambda = 852\ \mathrm{nm}$
3. Superoscillatory trap beam (brown cone)

   Far-off-resonant laser beam $\lambda = 1064\ \mathrm{nm}$



Magnetic-optical Trap (MOT)

EXPERIMENTAL DETAILS

$$6S_{1/2}(F = 4) \rightarrow 6P_{3/2}(F = 5)$$

Detuning: -4Γ

Linewidth: $\Gamma/2\pi = 5.2\ \mathrm{MHz}$

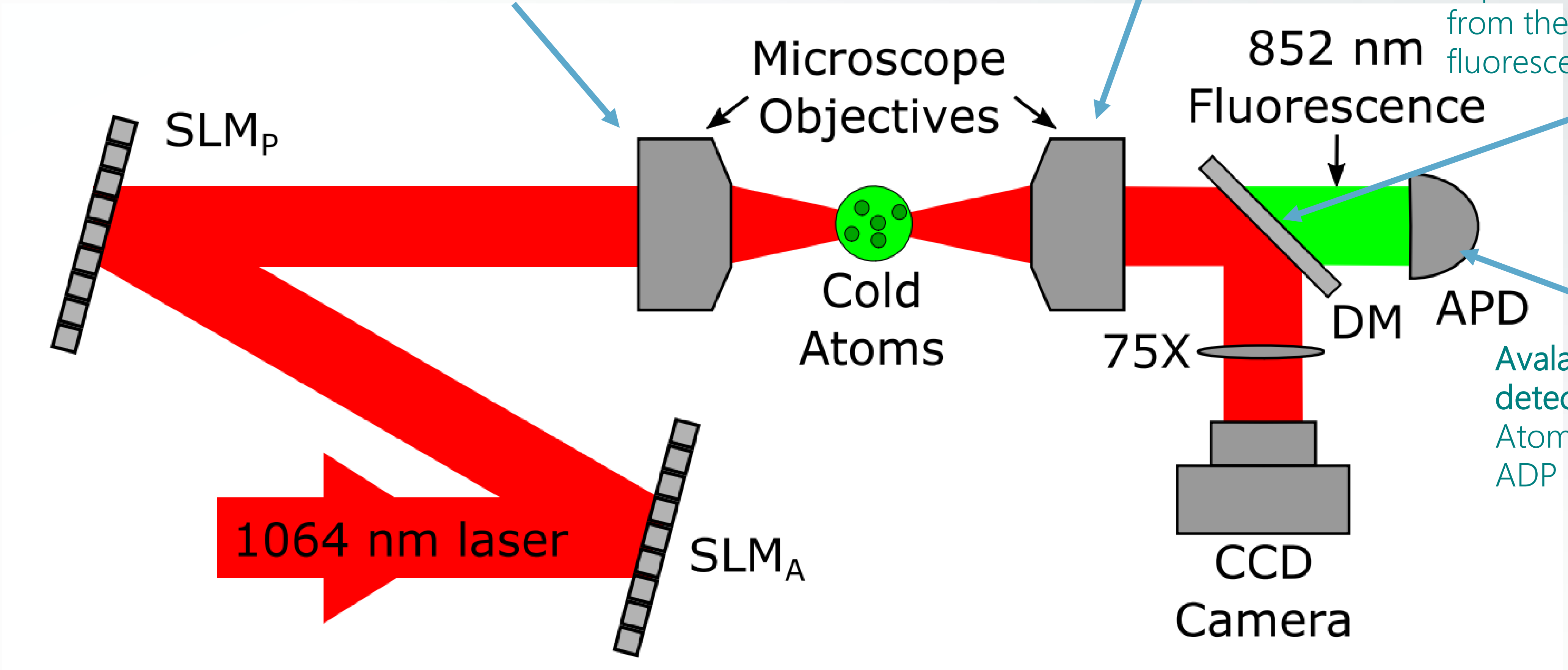
$$6S_{1/2}(F = 3) \rightarrow 6P_{3/2}(F = 4)$$

Resonance; no detuning

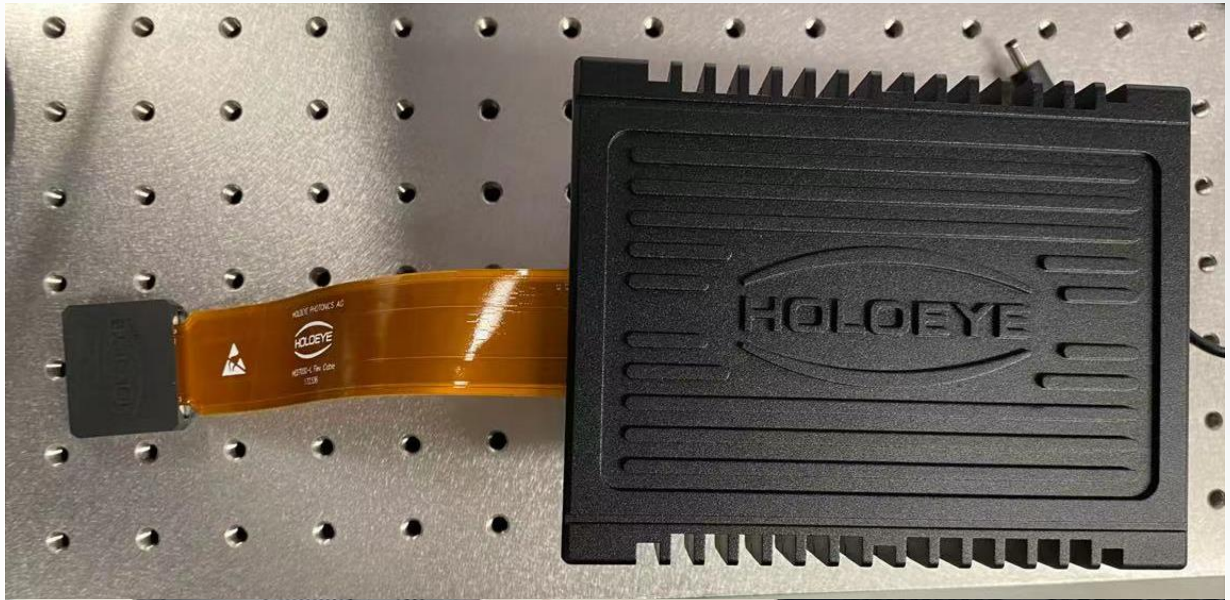
First lens
Focusing 1064 nm optical trap beam at the cold atoms cloud position

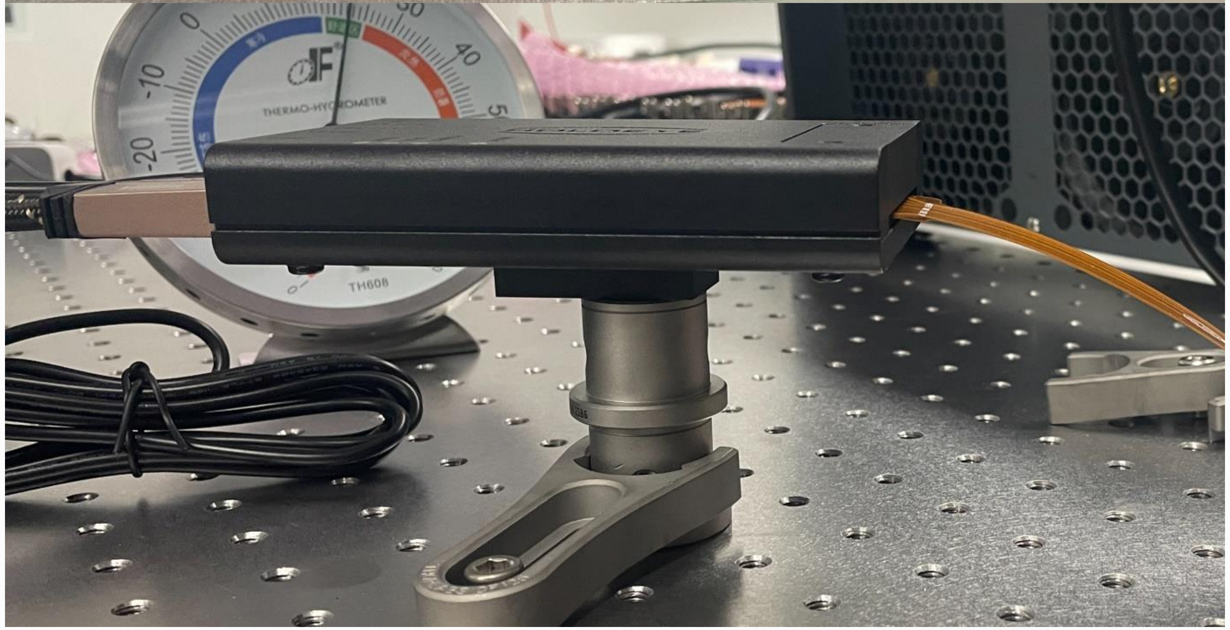
Second lens
Collecting the fluorescence signal at 852 nm

Dichroic mirror (DM)
Separate the 1064 nm beam from the atomic fluorescence



Avalanche photodiode detector (APD)
Atom population
ADP photo-count > 100





Spatial Light Modulator (SLM)

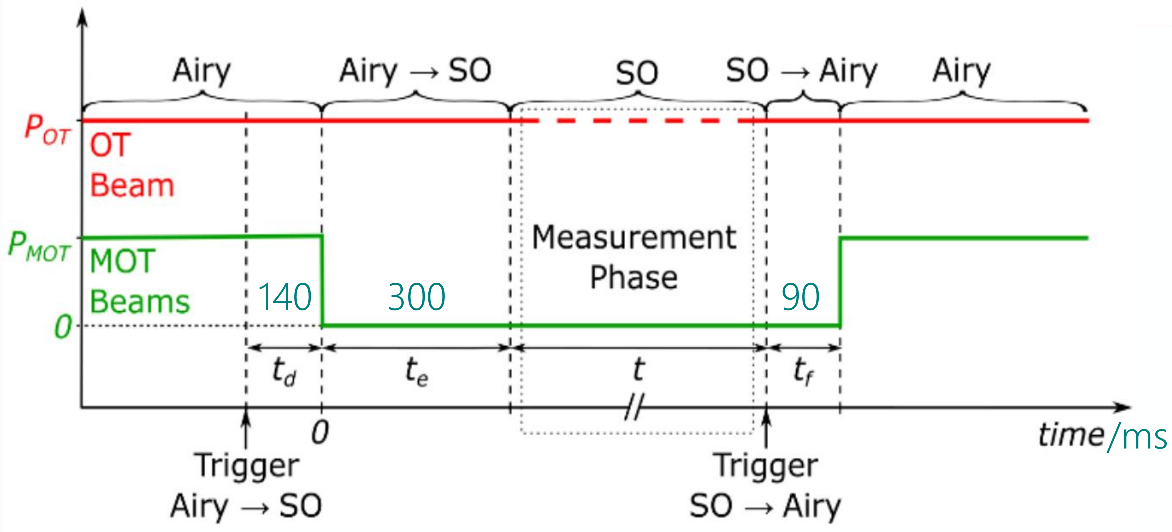
EXPERIMENTAL DETAILS

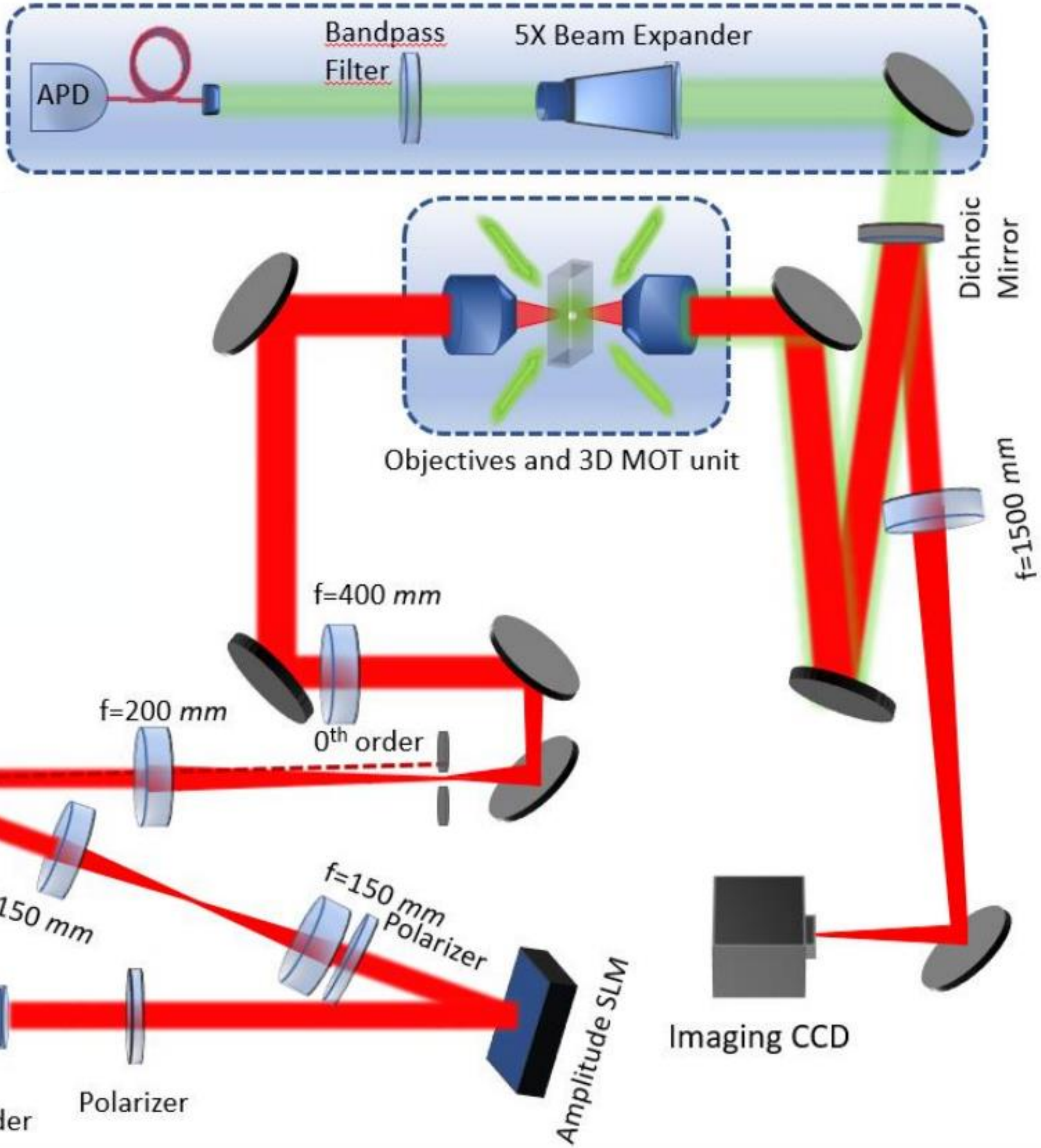
Consists of an array of pixels, each pixel can:

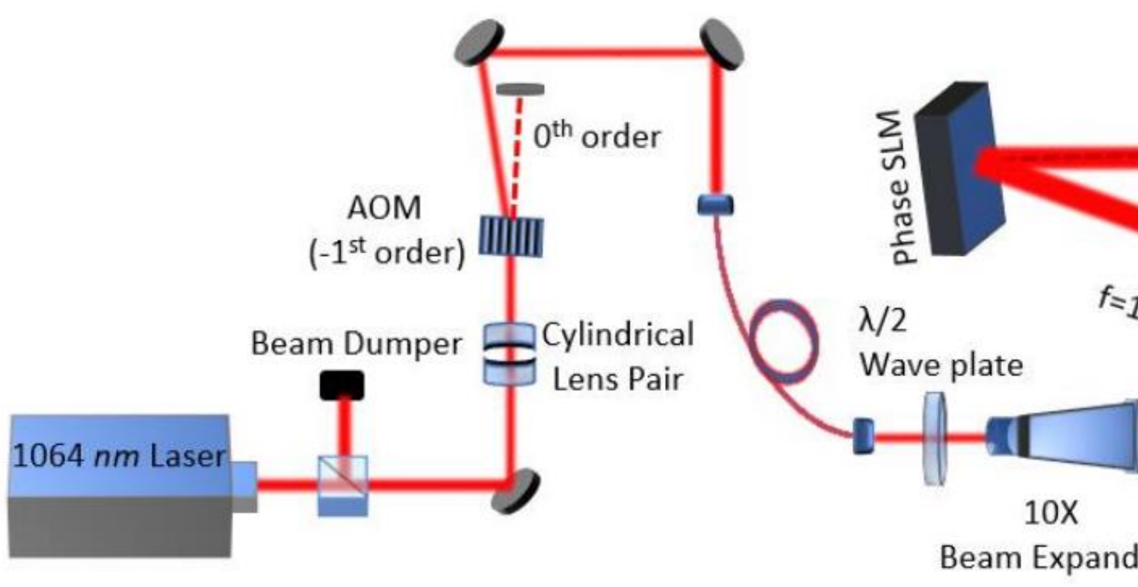
- Introduce a specific phase shift to the light
- Attenuate or amplify the light

Supplementary Information

EXPERIMENTAL DETAILS





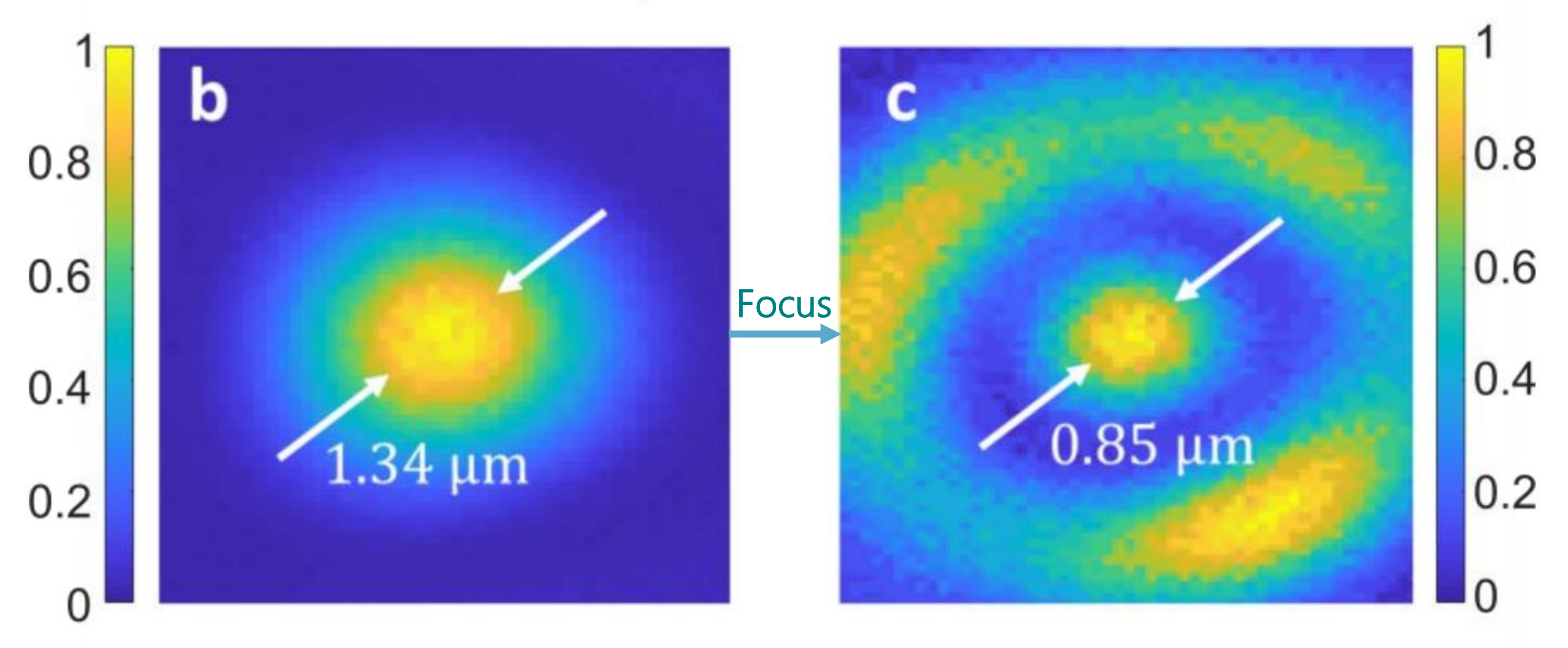


Results

DATA AND ANALYSIS

Normalized Images

DATA AND ANALYSIS



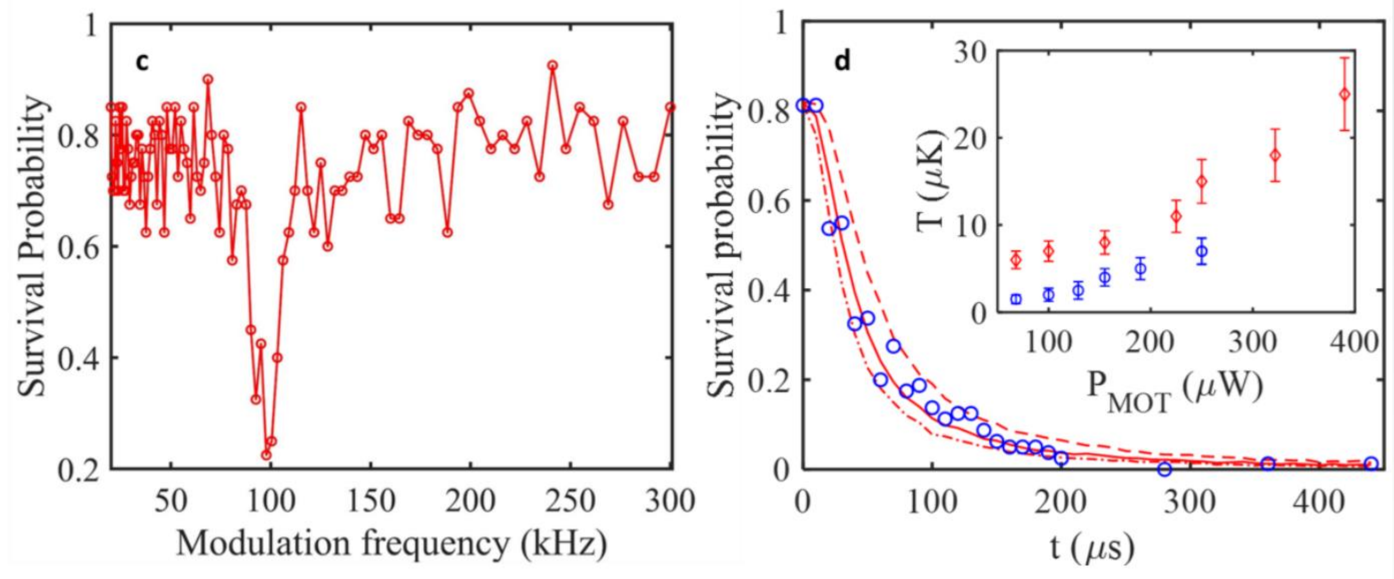
Airy profile

Superoscillatory profile

Sharper peak, narrower central lobe and higher intensity

Trapping Frequency

DATA AND ANALYSIS



Optical power per MOT beam

$f \sim 50$ kHz, $\quad P = 1.1$ mW

Outlook

IMPROVEMENT AND APPLICATION

Outlook

IMPROVEMENTS

- The optical field outside the hotspot shall be spatially spread to reduce the peak energy density in outer rings
- Create an optical trap array with Gaussian beams
- Try to avoid spurious interference

Thanks for your listening!

Any questions?