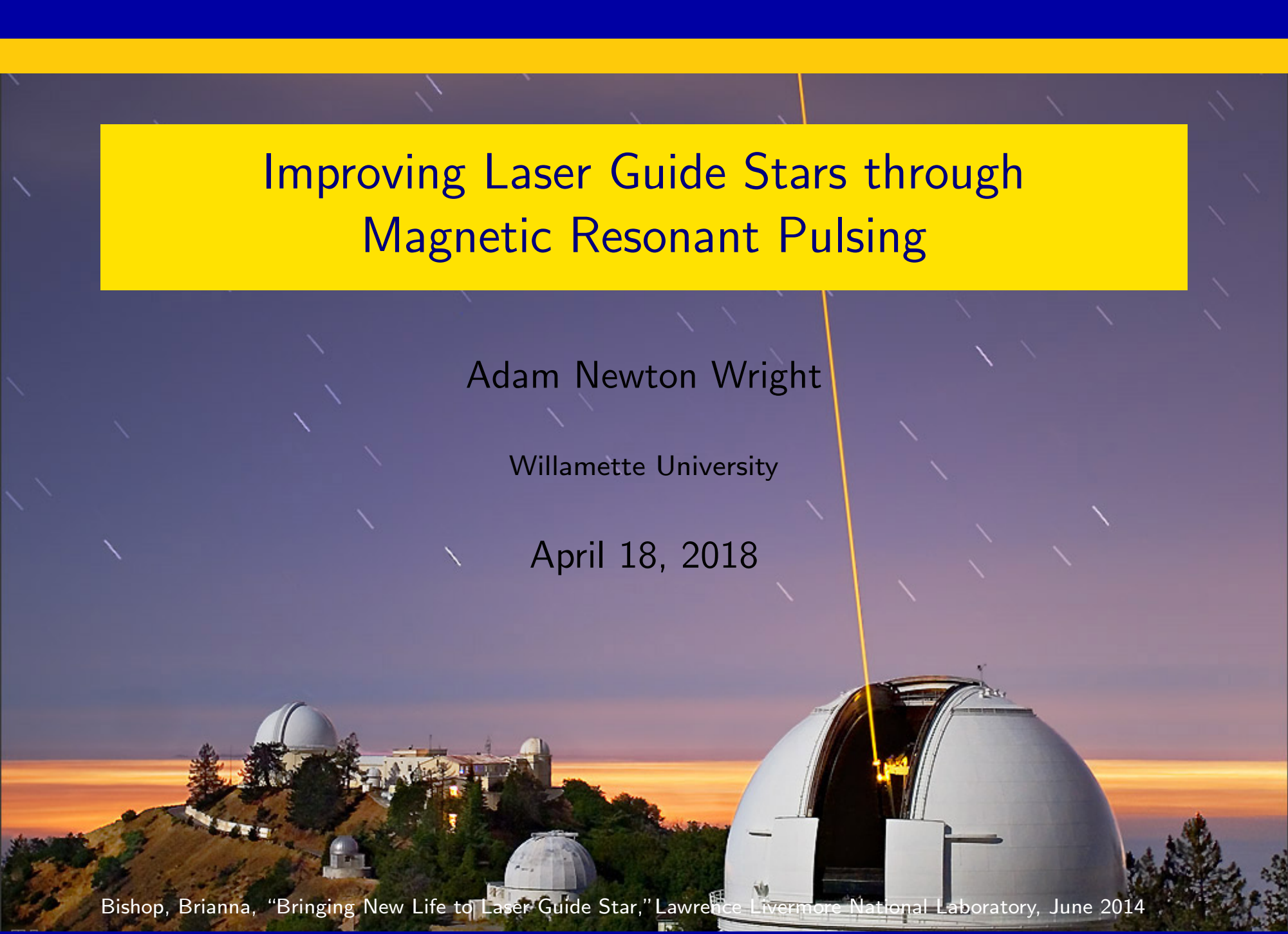
Improving Laser Guide Stars through Magnetic Resonant Pulsing

Adam Newton Wright

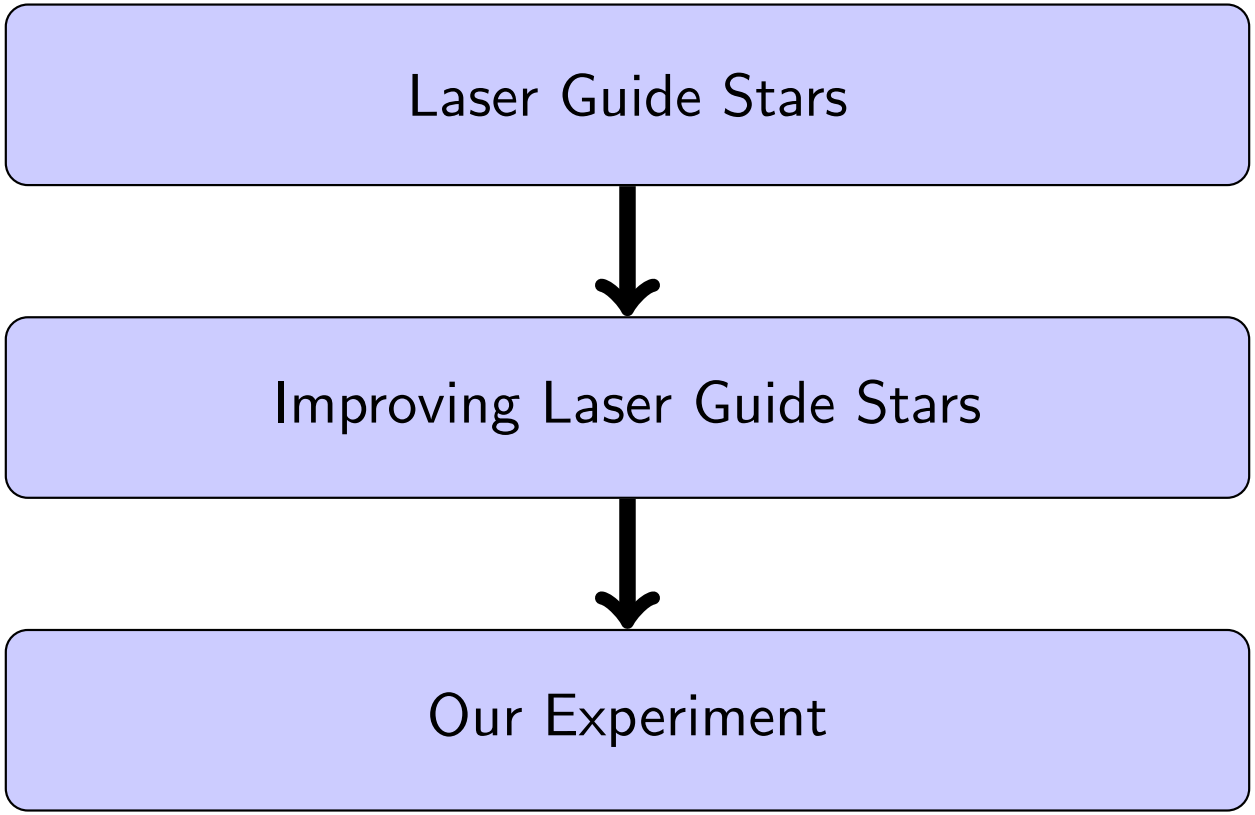
Willamette University

April 18, 2018



Bishop, Brianna, "Bringing New Life to Laser Guide Star," Lawrence Livermore National Laboratory, June 2014

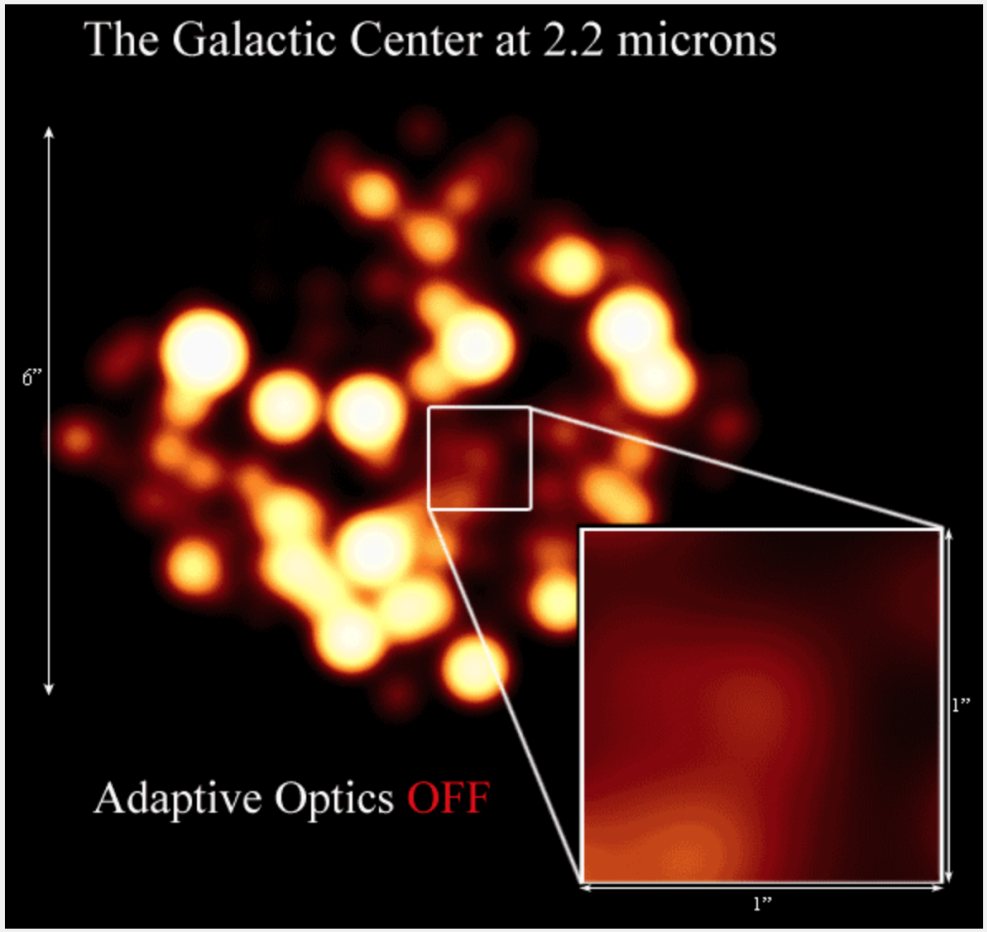
Overview


Laser Guide Stars
Improving Laser Guide Stars
Our Experiment

Bishop, Brianna, "Bringing New Life to Laser Guide Star," Lawrence Livermore National Laboratory, June 2014

Telescopic Imaging

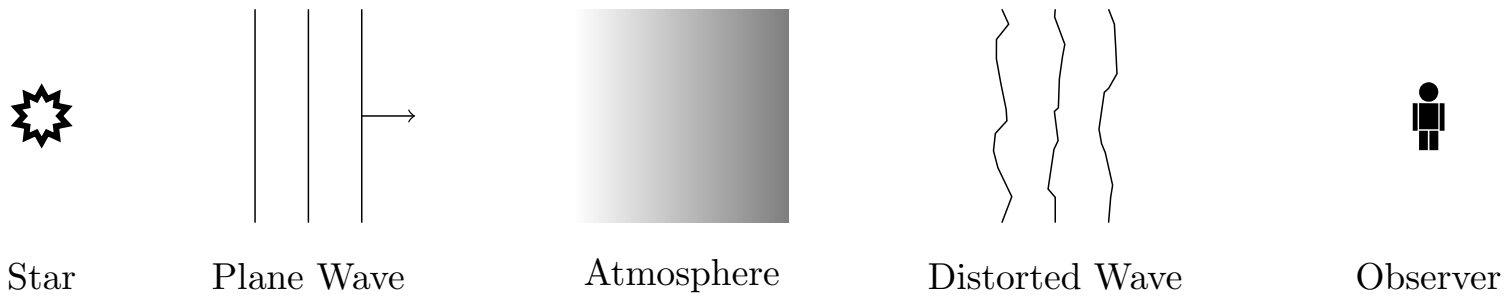
Concerned with Highest Resolution



UCLA Galactic Center Group / W. M. Keck Observatory Laser Team

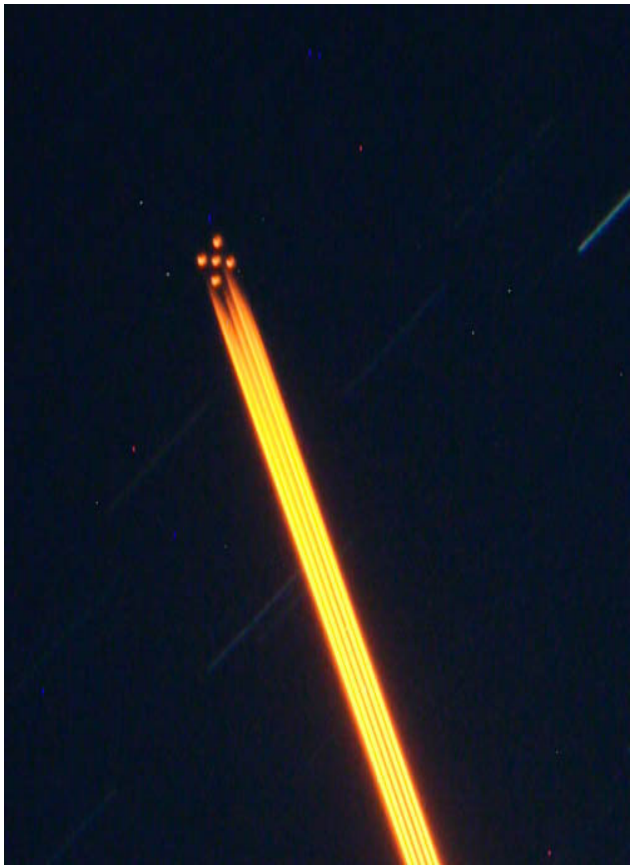
Atmospheric Distortion

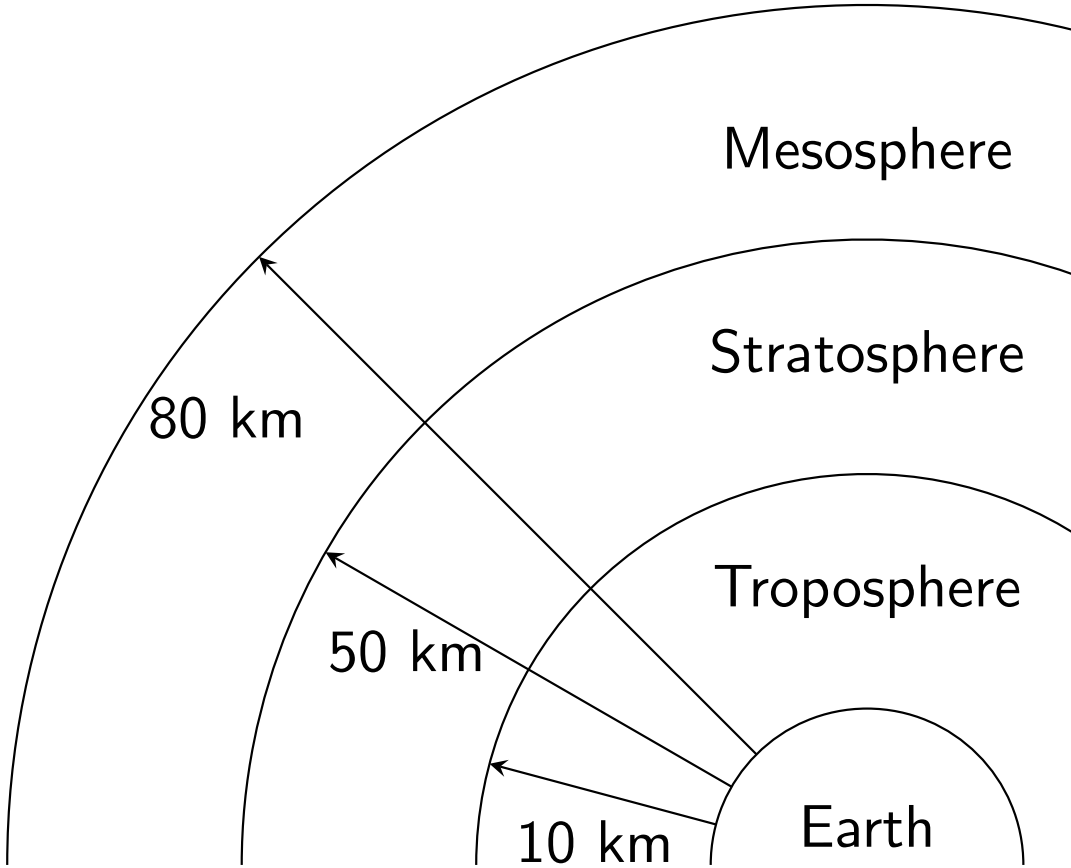
Causes reduced quality in telescopic imaging



Laser Guide Stars

Aid in correcting distorted images through adaptive optics[2]



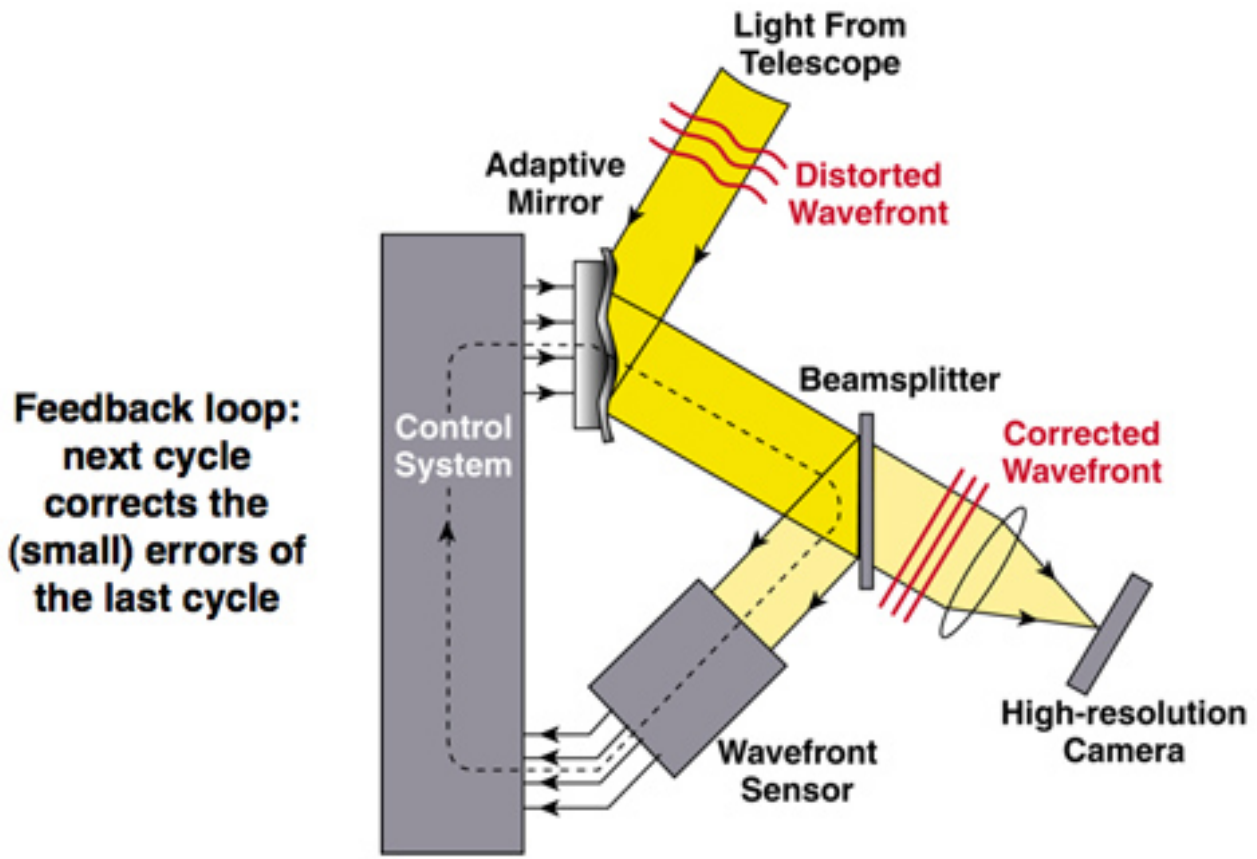


[2] "Laser Guide Star," RP Photonics, 2016

"Laser-Guide Star HD Videos and Imagesi," Gemini Observatory/AURA, gemini.edu, 2013

Adaptive Optics

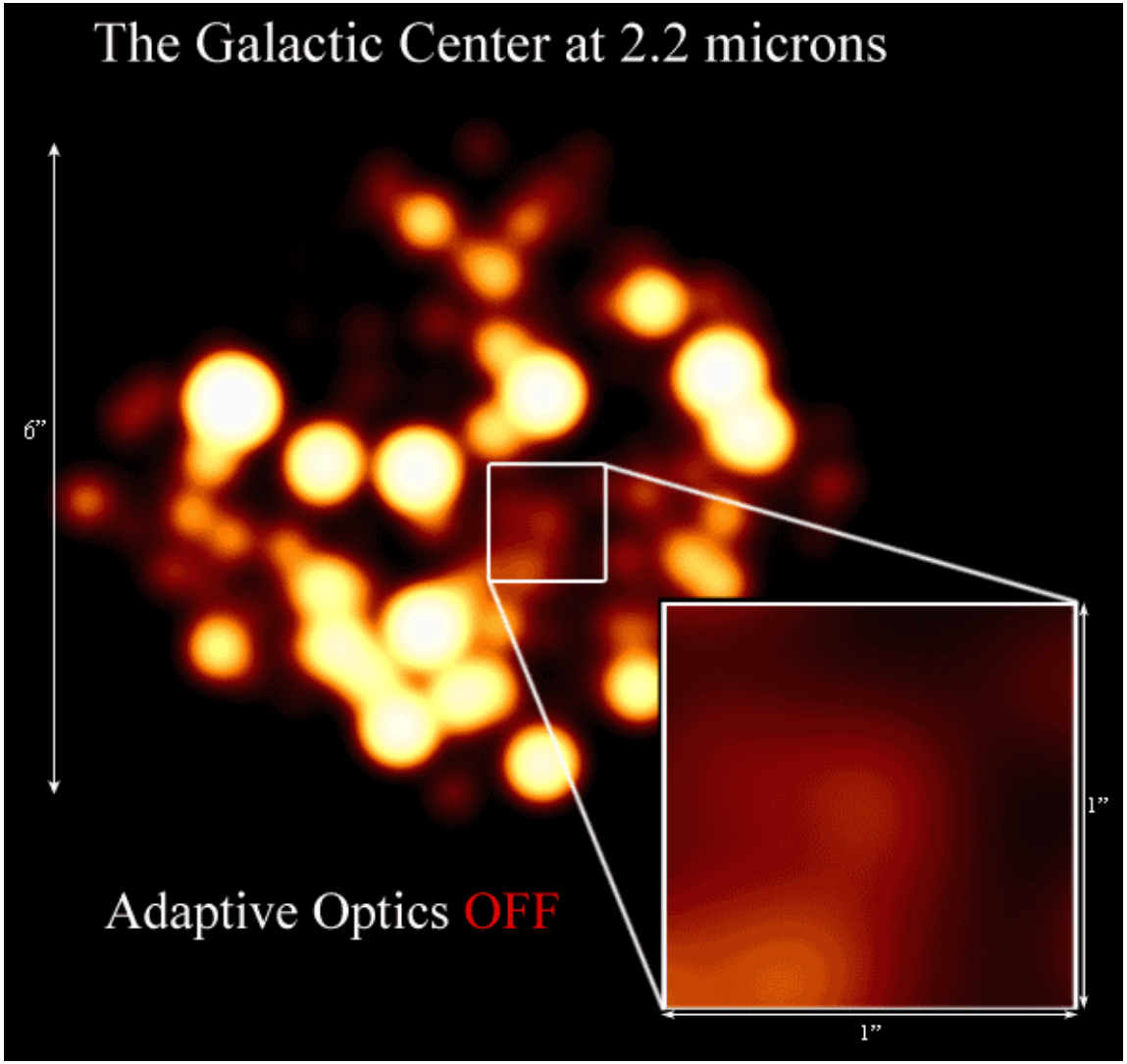
Correct distortions from atmosphere



C. Max, Center for Adaptive Optics, Lawrence Livermore National Laboratory and NSF Center for Adaptive Optics, 2016

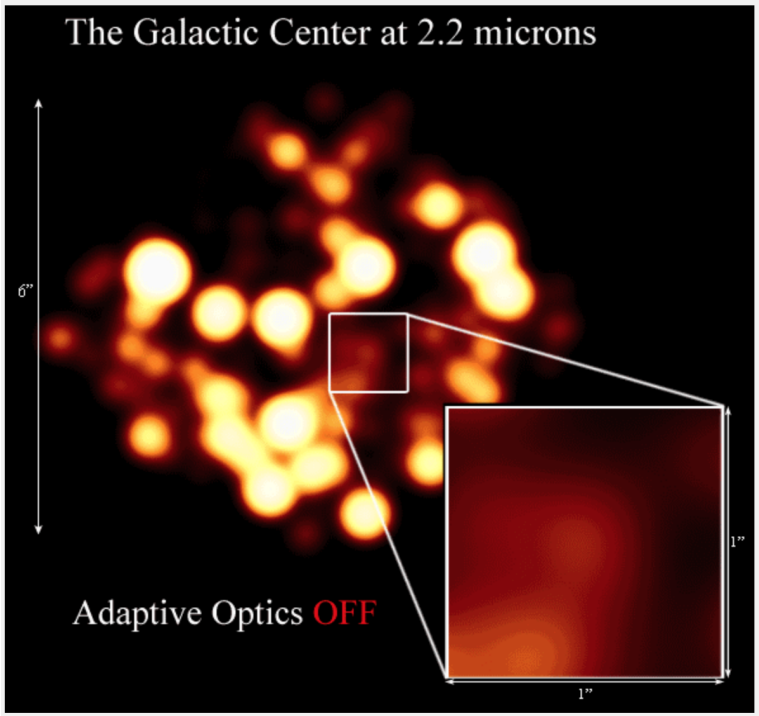
Adaptive Optics and LGS

Correct distortions from atmosphere

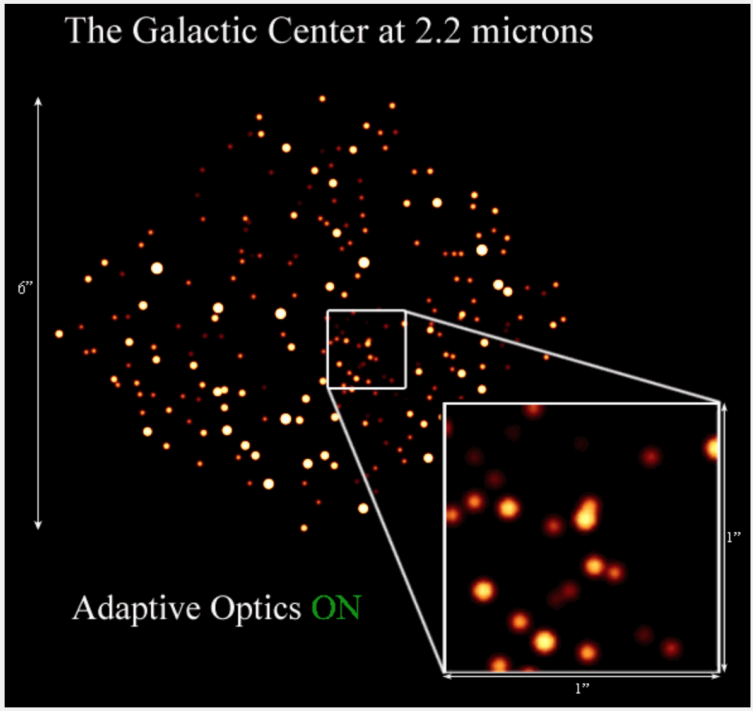


Adaptive Optics and LGS

Correct distortions from atmosphere



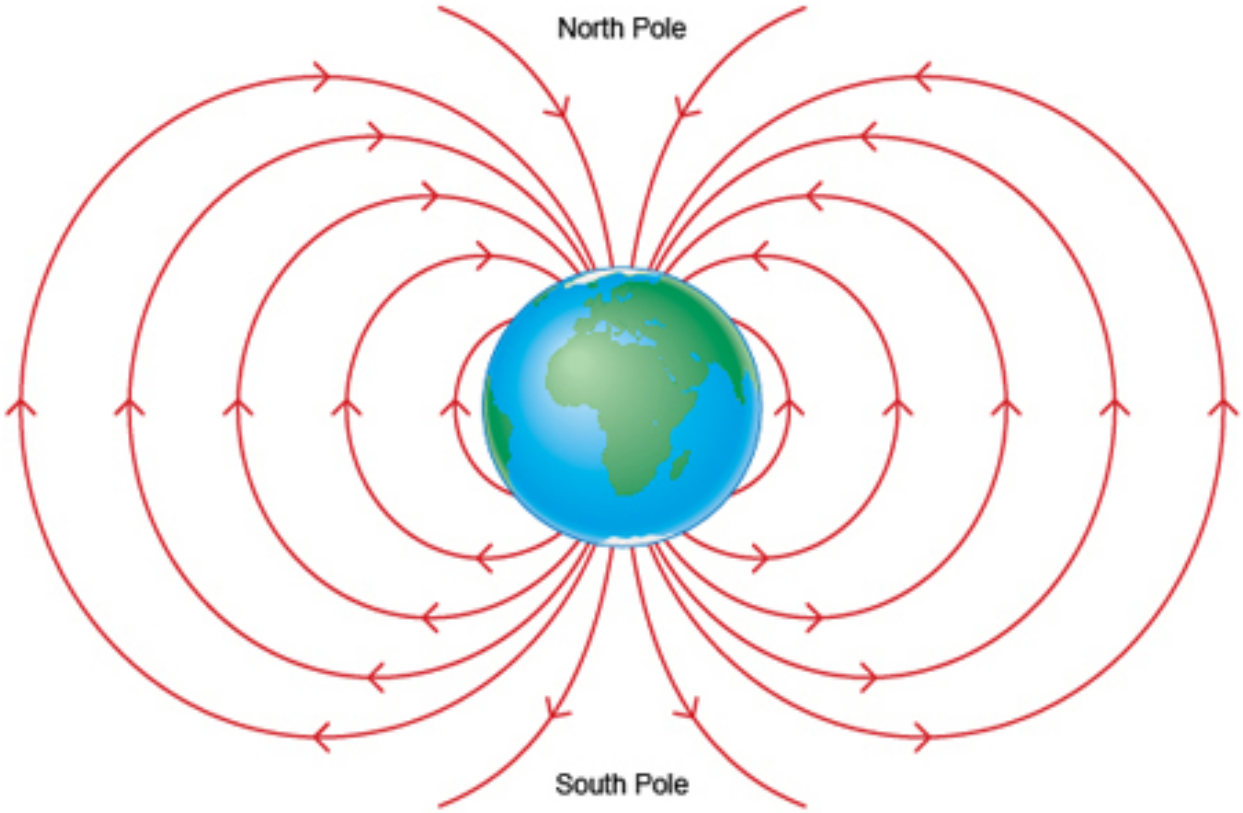
UCLA Galactic Center Group / W. M. Keck Observatory Laser Team



UCLA Galactic Center Group / W. M. Keck Observatory Laser Team

Geomagnetic Field

Reduces the benefits of Optical Pumping[5]



[5]Rampy, Rachel, Donald Gavel, Simon M. Rochester, and Ronald Holzlhner. "Toward optimization of pulsed sodium laser guide stars." JOSA B32, no. 12 (2015): 2425-2434.

TesTeach.com, Geomagnetic Field

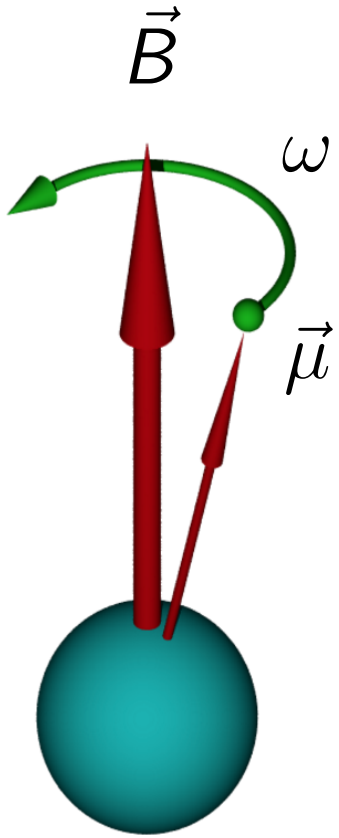
Optical Pumping

Larmor Precession

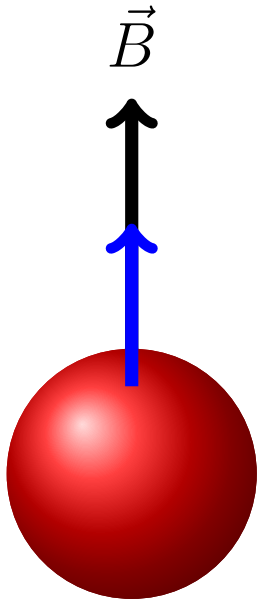
$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

$$\omega = -\gamma B$$

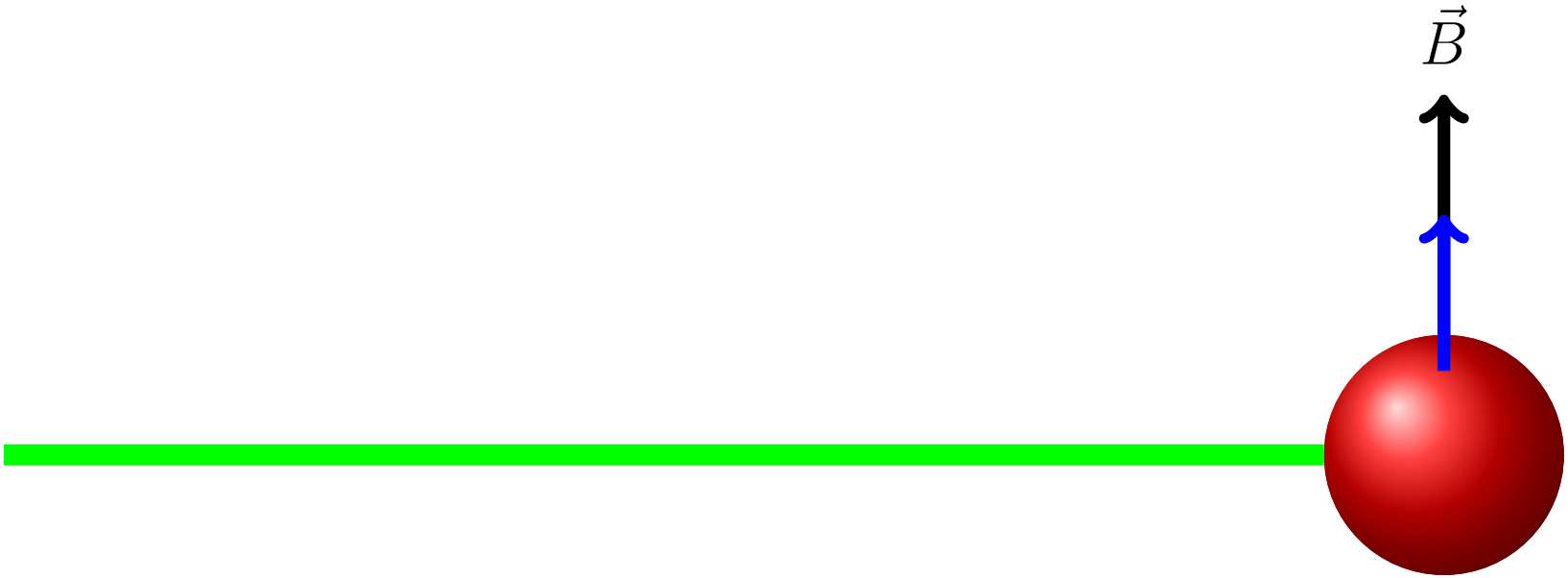
$$\gamma = \frac{eg}{2m}$$



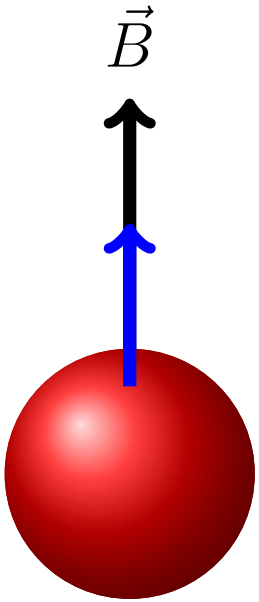
Larmor Precession



Continuous Wave Pumping

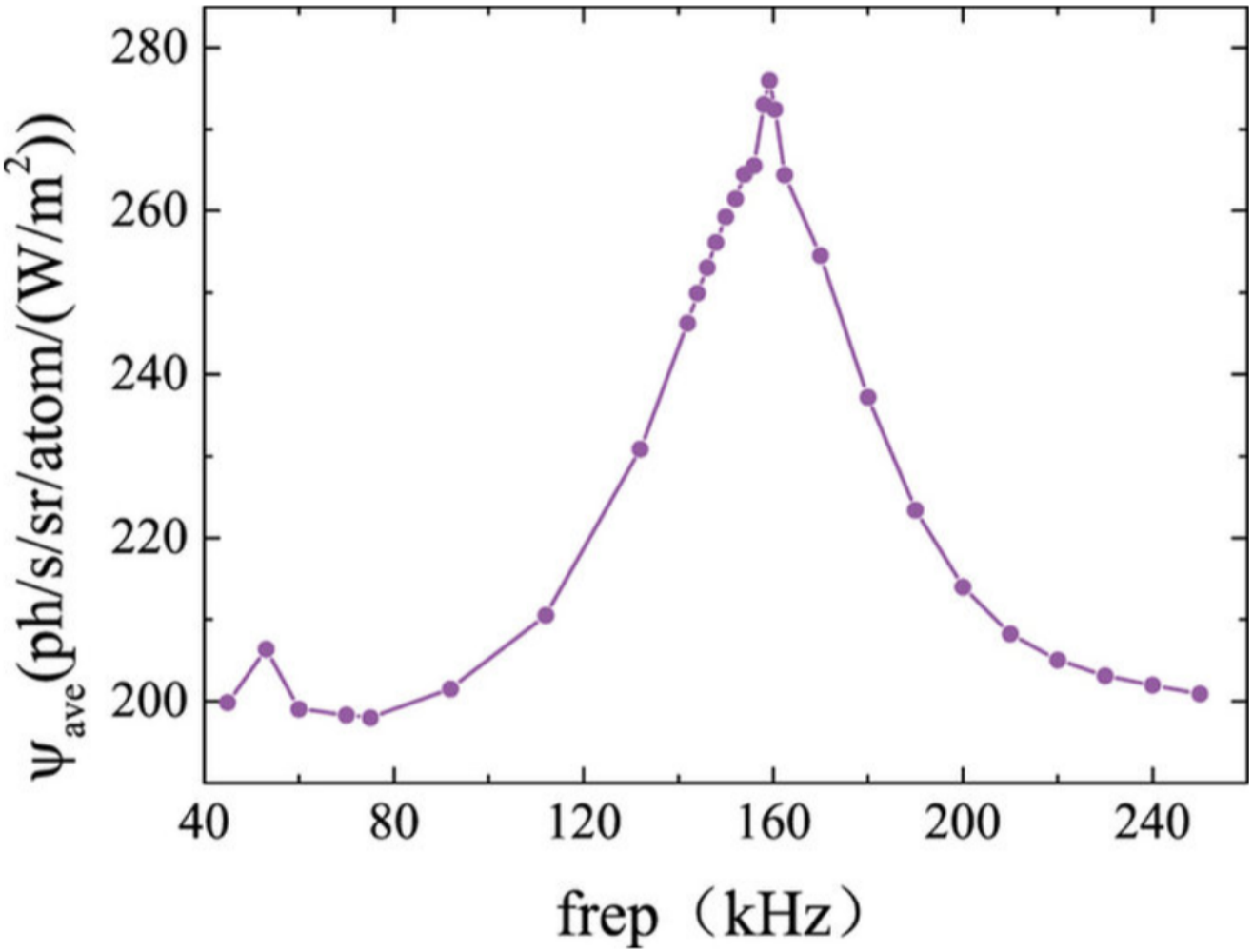


Magnetic Resonant Pulsing



Expected Results

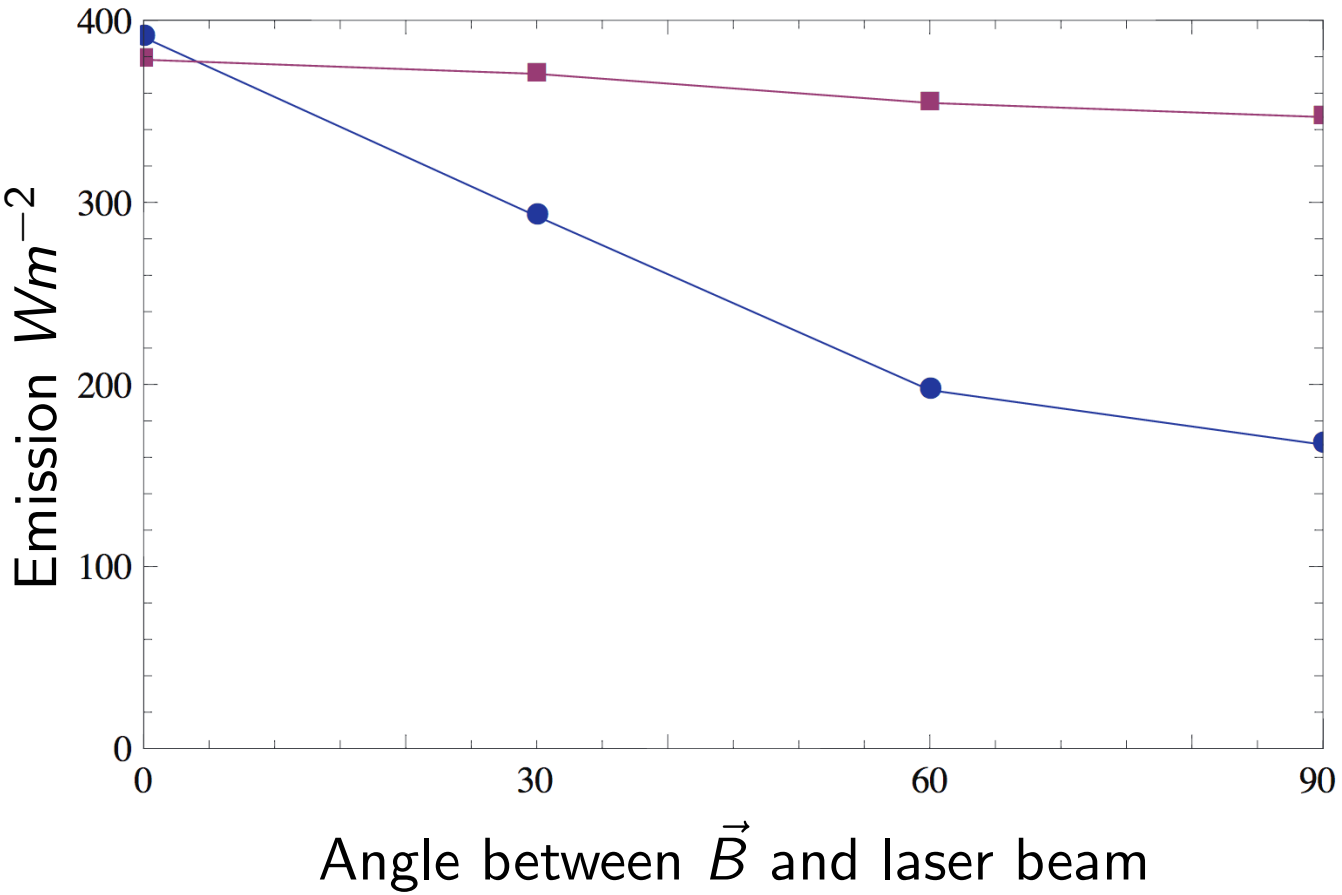
Polarization Switching



Fan Improving Sodium LGS through Polarization Switching, Scientific Papers

Expected Results

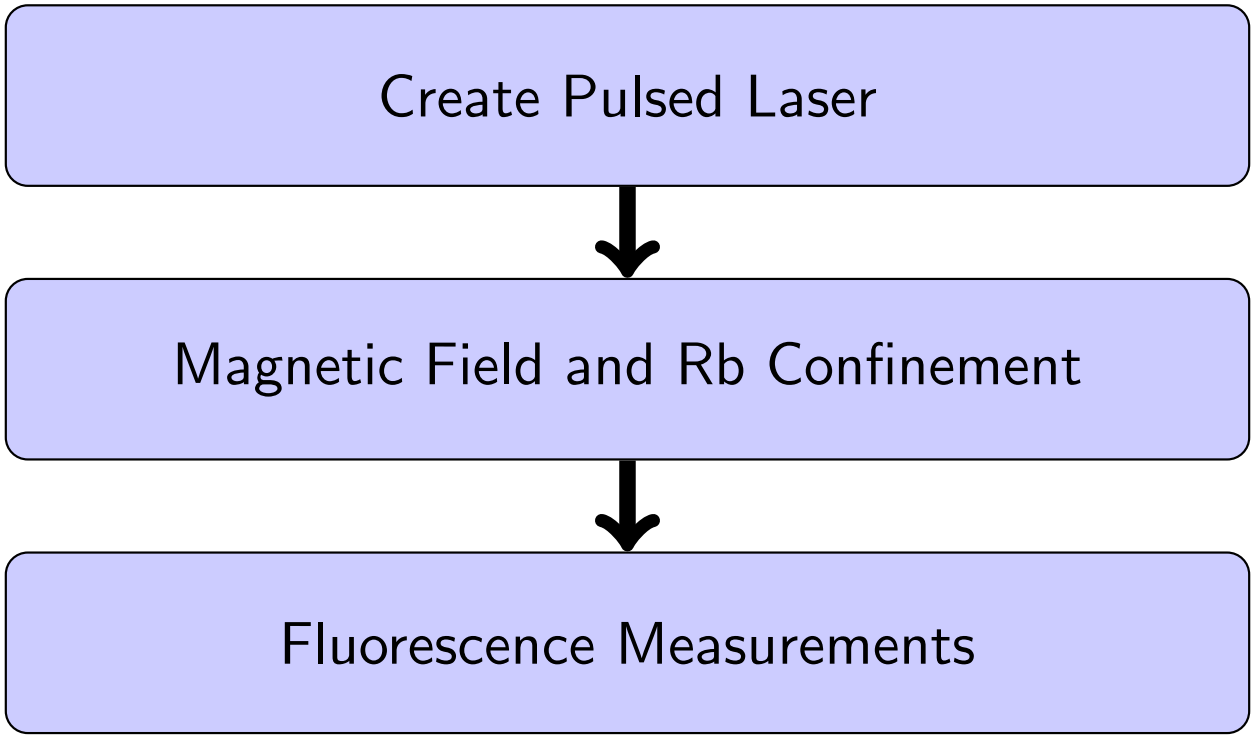
Magnetic Resonant Pulsing



Kane, "Pulsed laser architecture for enhancing backscatter from sodium." SPIE Astronomical Telescopes.

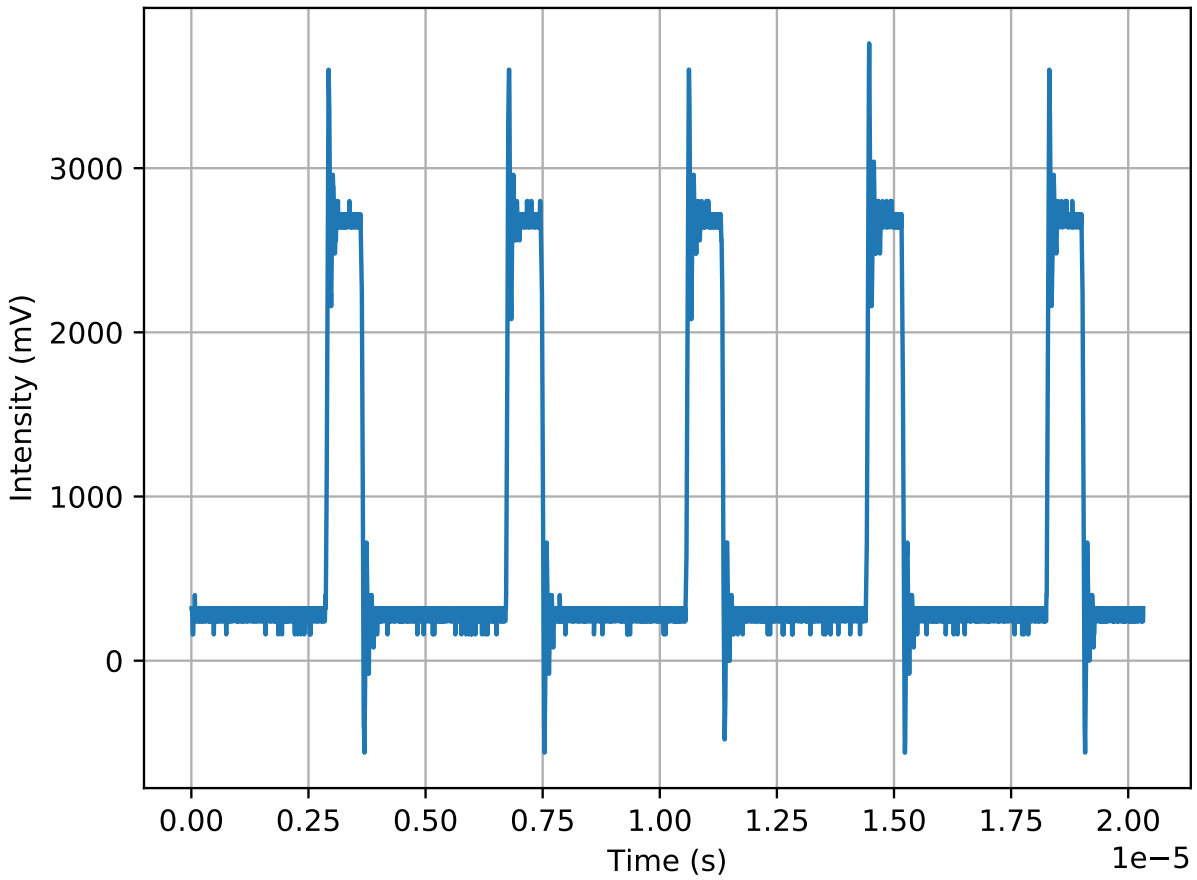
Our Experiment

Outline



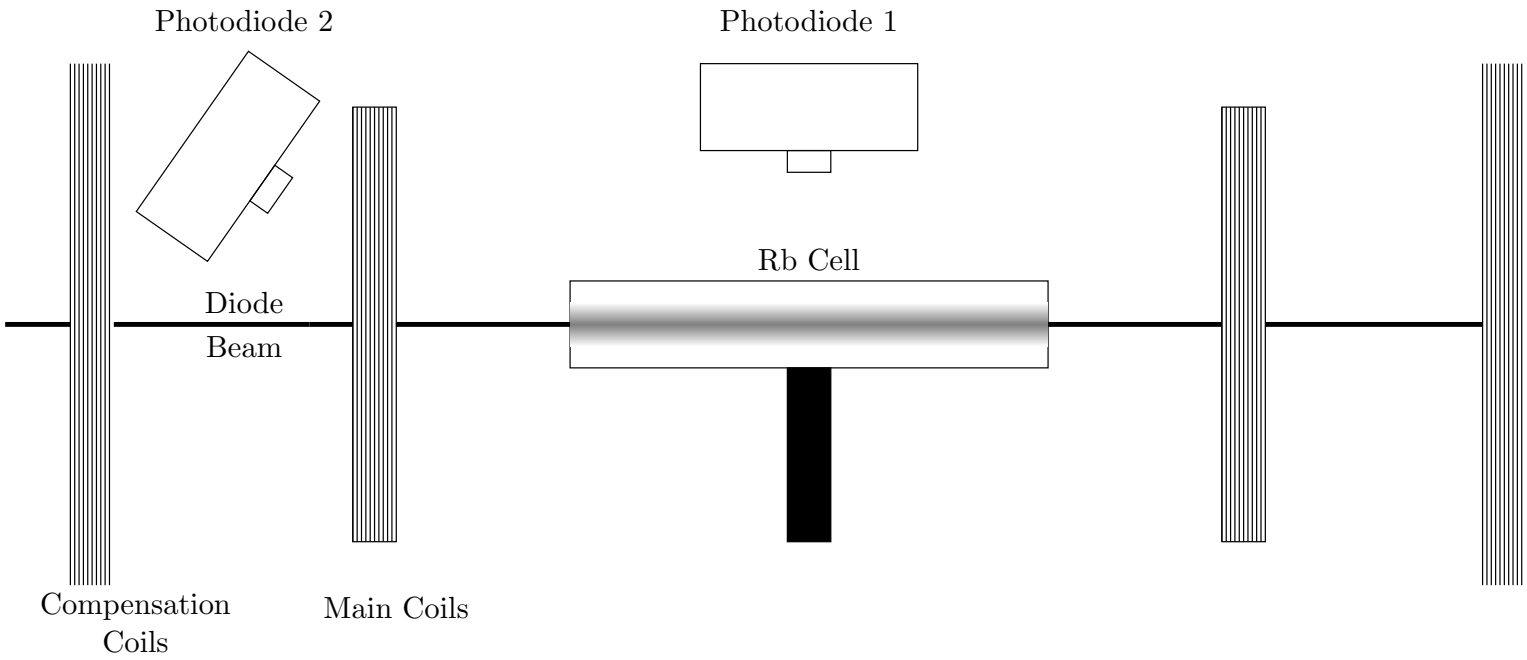
Laser System

Created with diode laser and AOM



Our Experiment

Rubidium Housing and Magnetic Field



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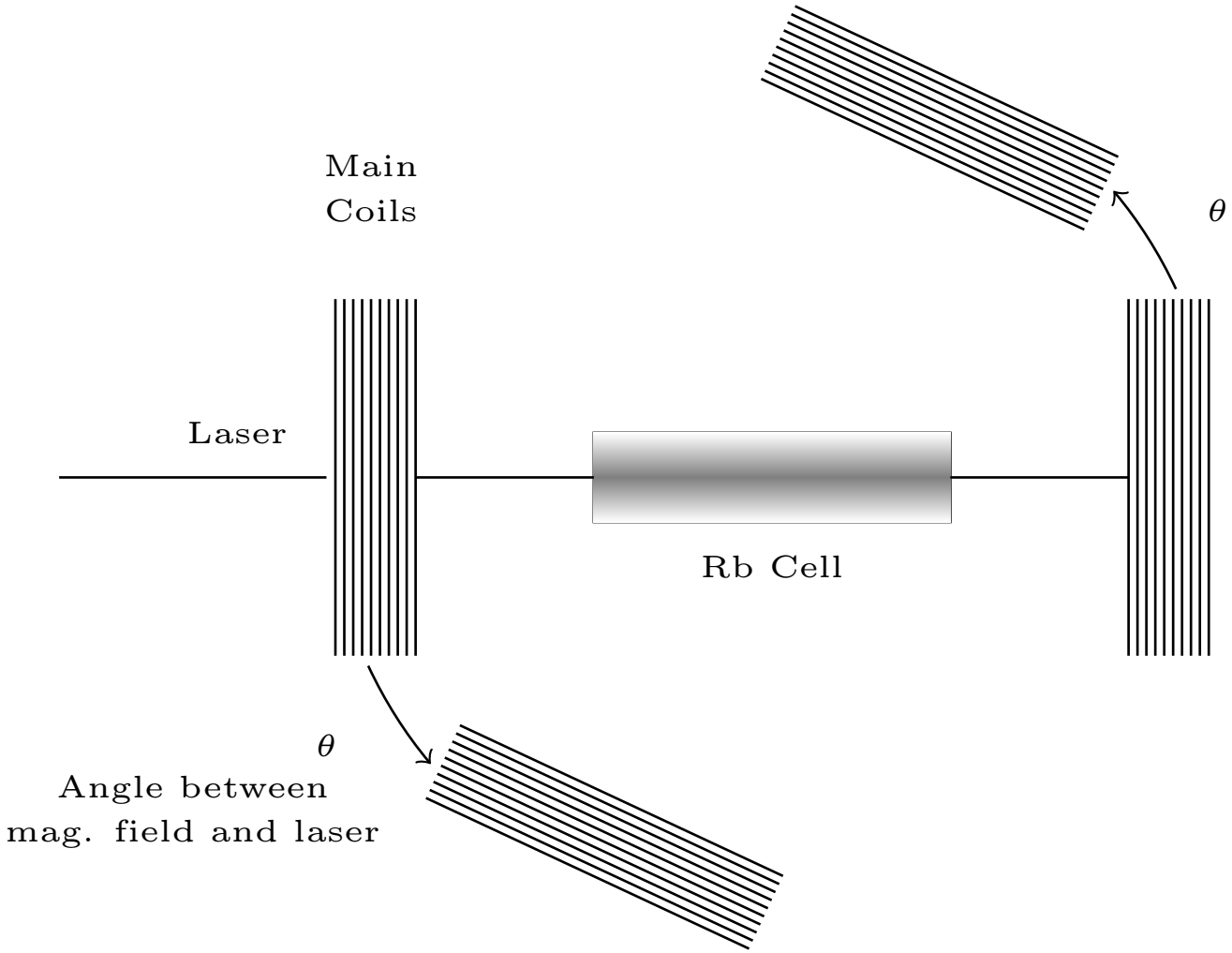
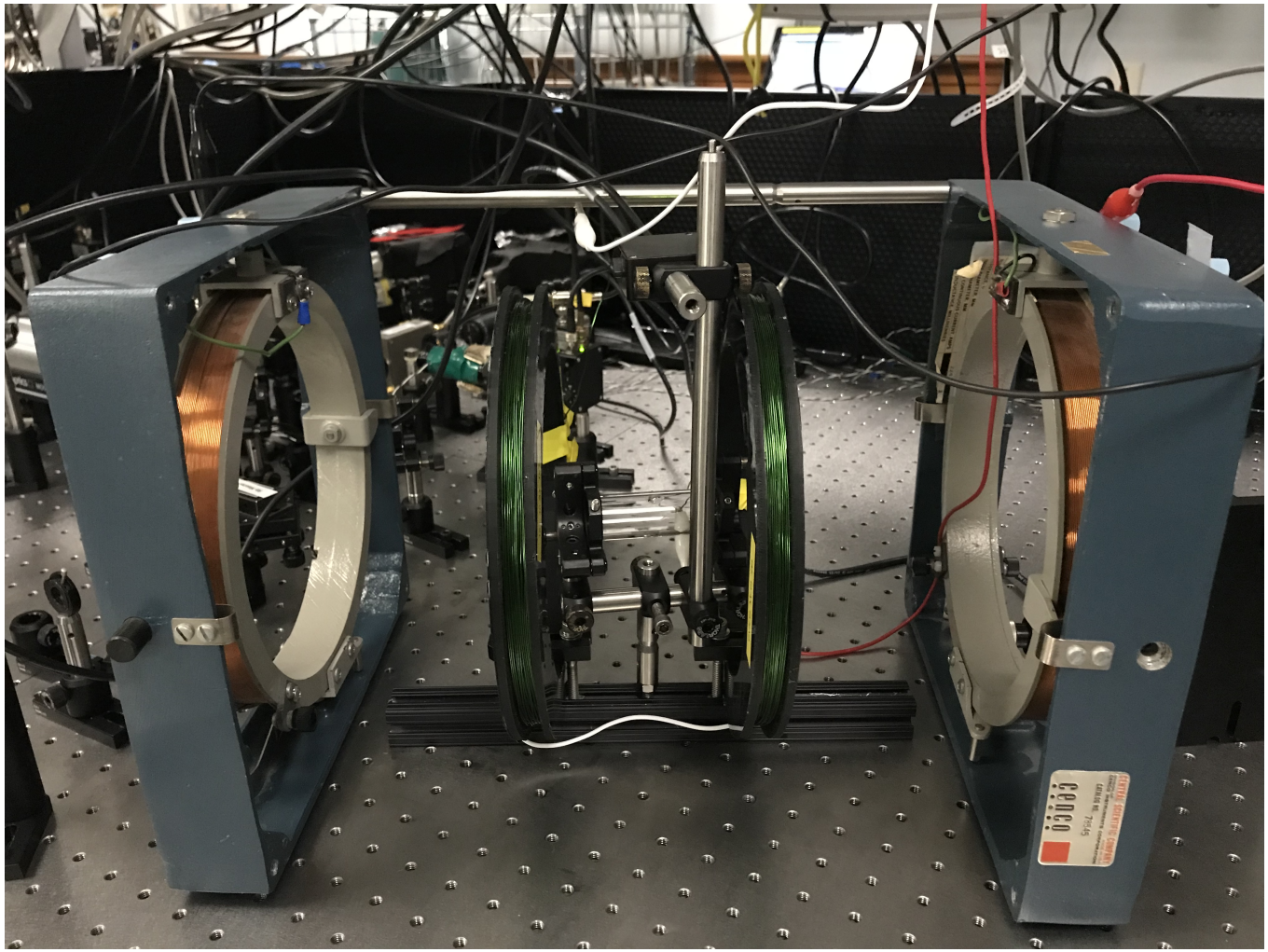
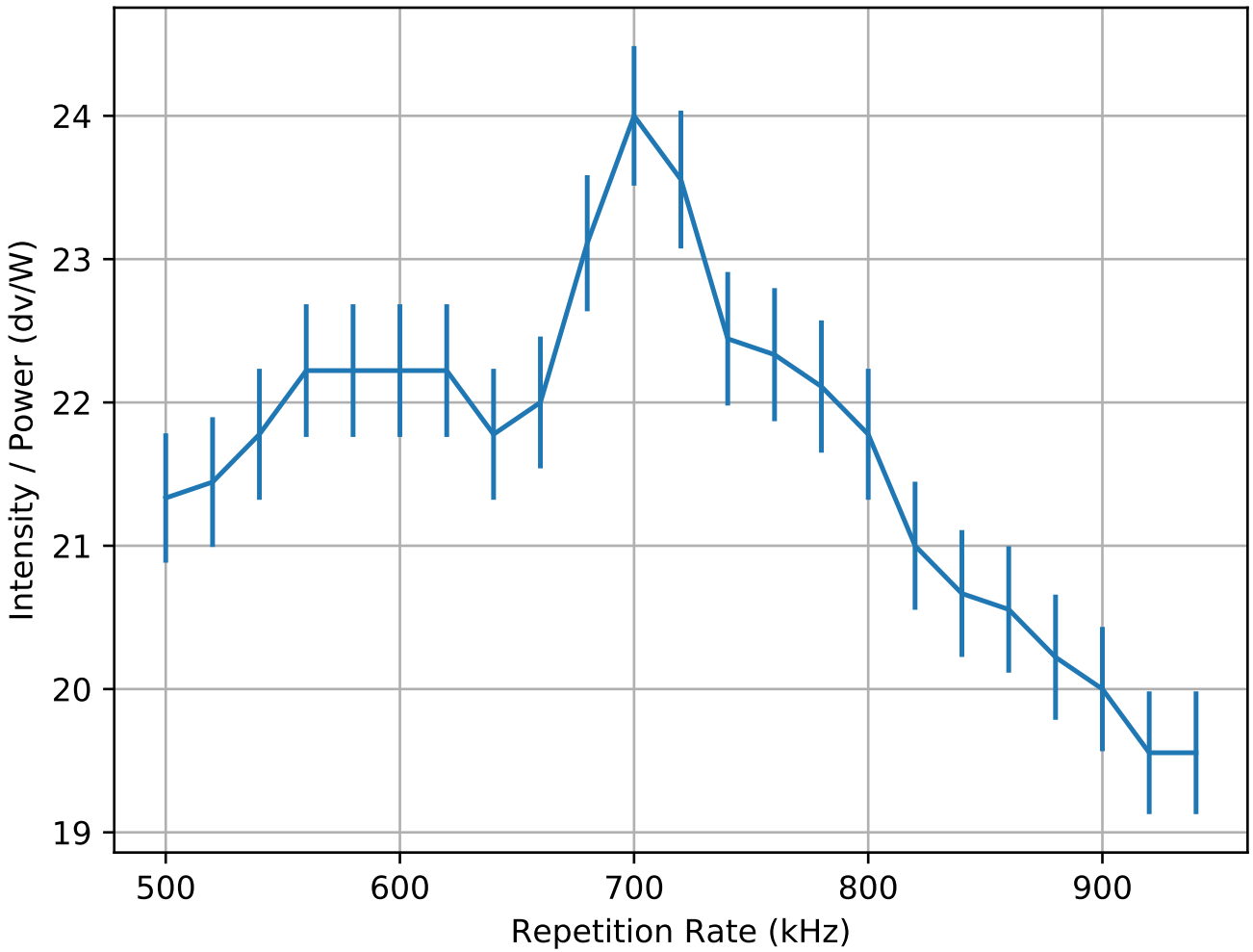


Our Experiment

Rubidium Housing and Magnetic Field

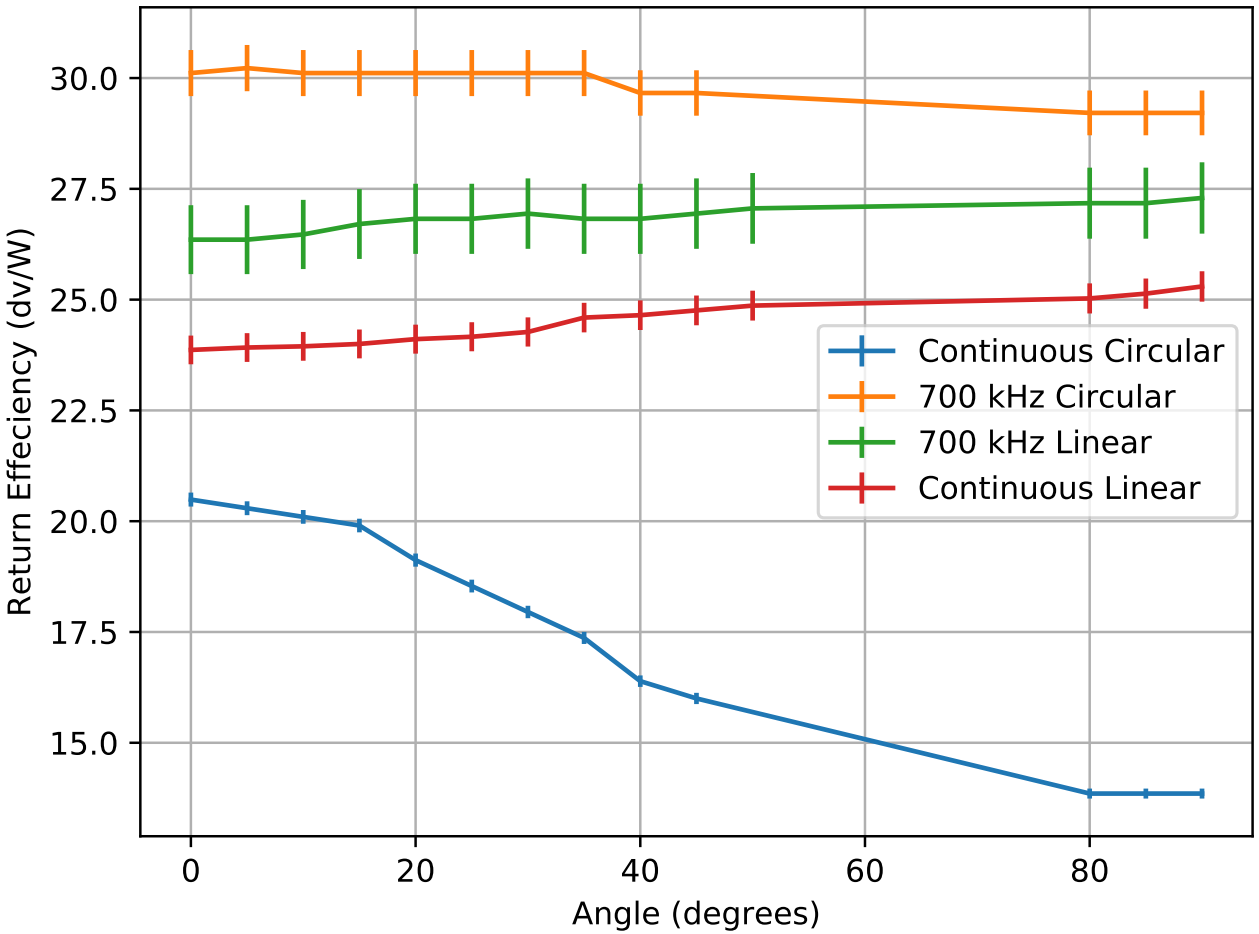


Fluorescence versus Repetition Rate of Laser



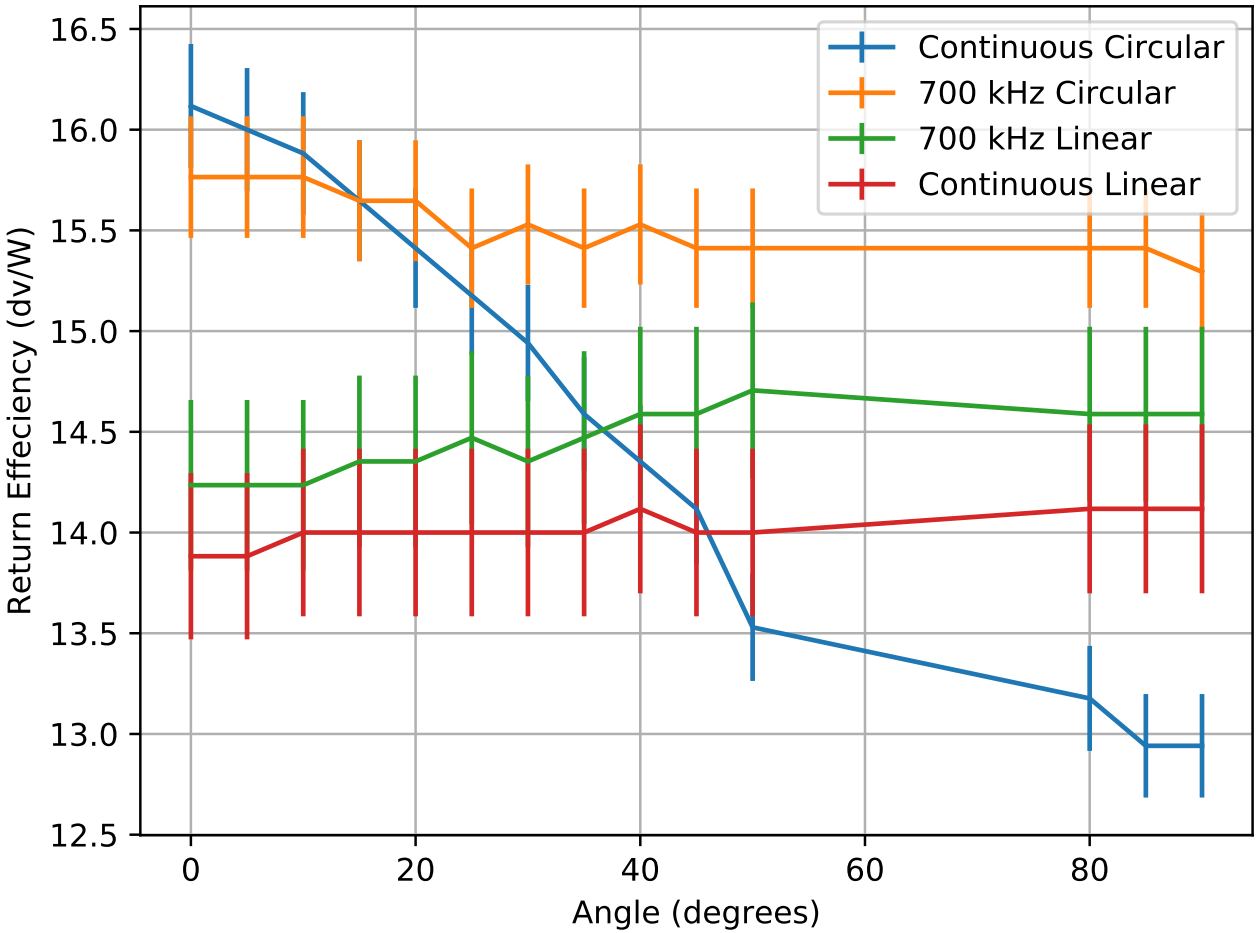
Fluorescence versus Angle between Laser and Mag. Field

High Intensity



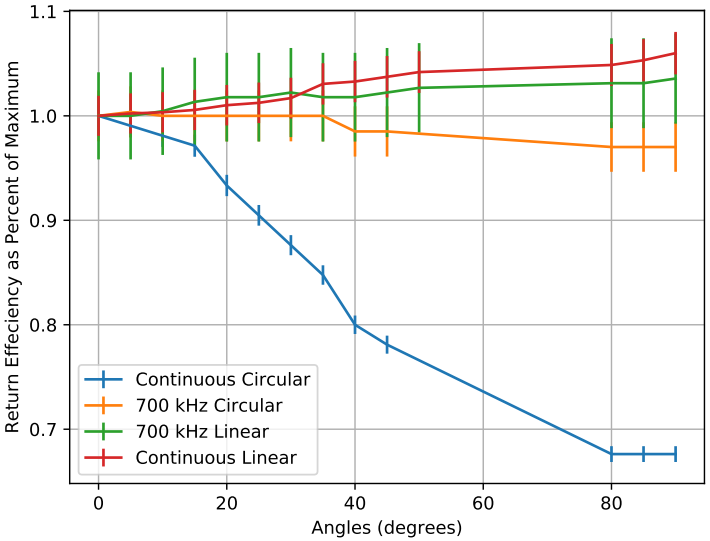
Fluorescence versus Angle between Laser and Mag. Field

Low Intensity

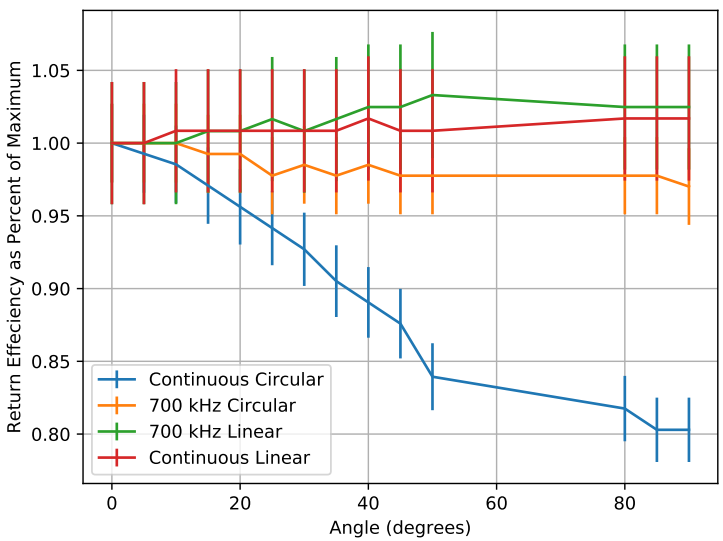


Percent Changes in Fluorescence

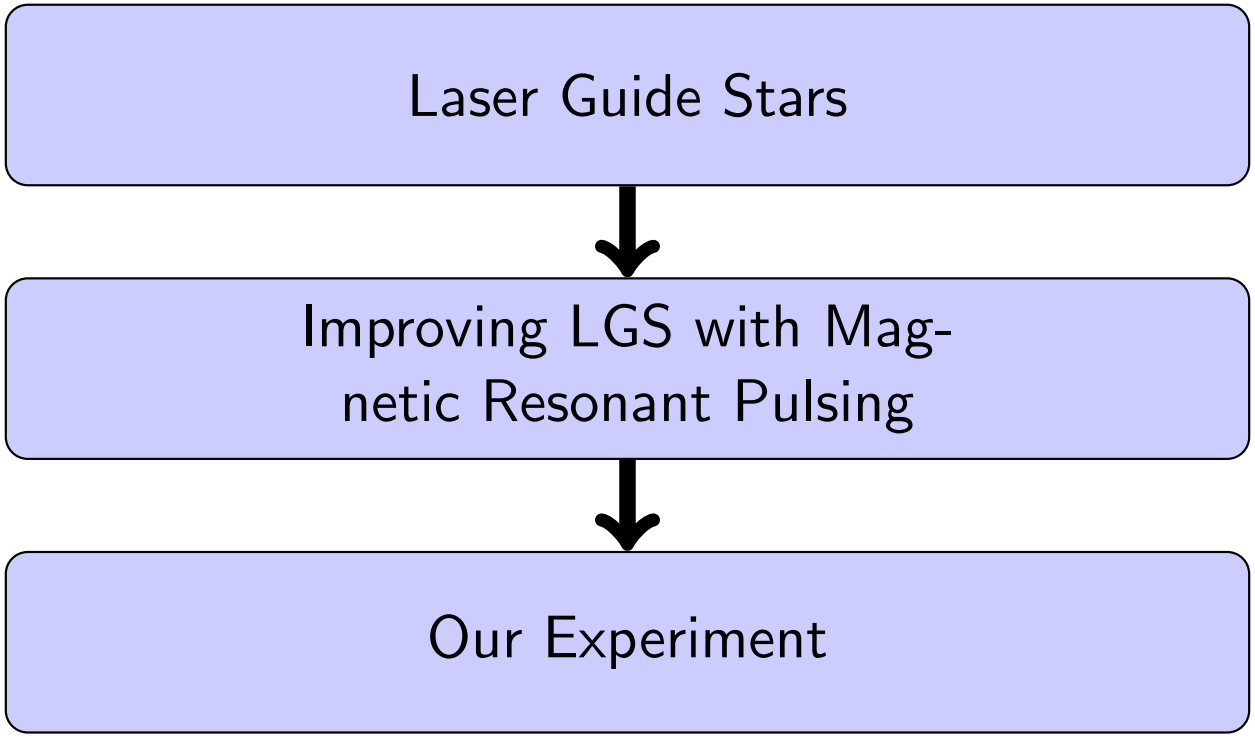
High Intensity



Low Intensity



Summary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Improving LGS with Mag-
netic Resonant Pulsing
Our Experiment

Questions??

"Straight to the Milky Way's Heart," Scientific Computing, 2011

Extras

Subtitle

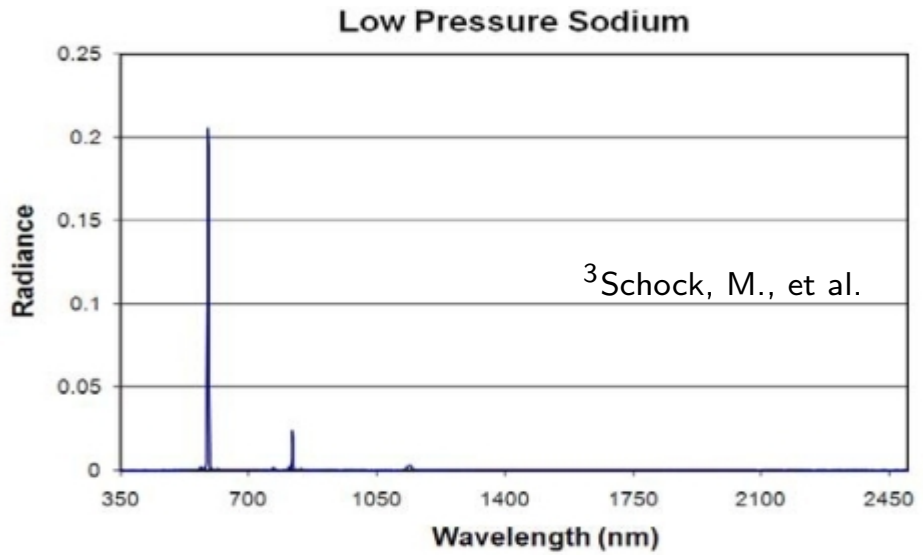
Slide Body

Laser Guide Stars (LGS)

Sodium LGS

Sodium Laser Guide Star System

- Mesospheric sodium layer: 10 km thick and 90 km in altitude
  - Created by the ablation of meteors
- Wavelength $\lambda = 589.593$ nm
- Intensity[3] $I \approx 10 Wm^{-2}$
- Circularly polarized light σ^+



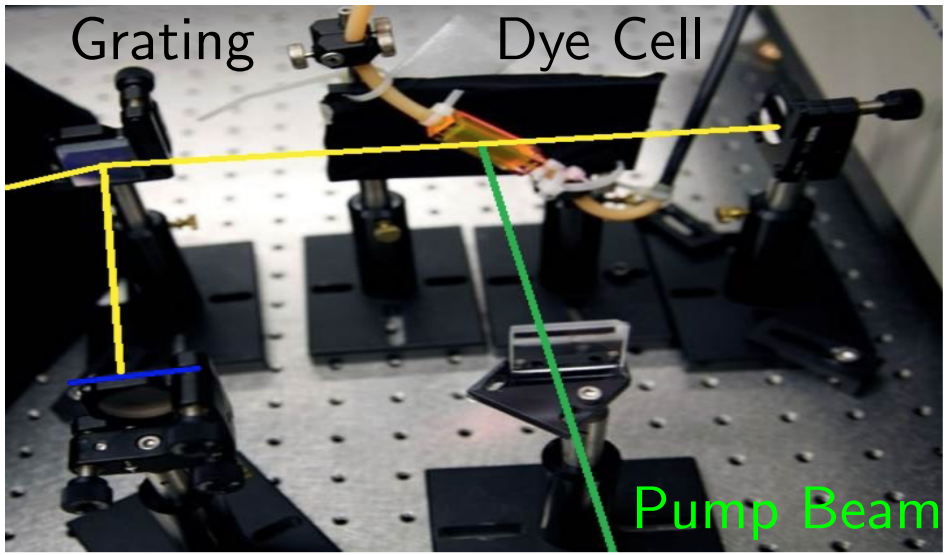
"Performance analysis of polychromatic laser guide stars used for wavefront tilt sensing." Monthly Notices of the Royal Astronomical Society 337.3 (2002)

Elvidge CD et al, "Spectral identification of lighting type and character." Earth Observation Group

Our Experiment

Dye Lasers

- Excellent tunability over close to one hundred nanometers
- Lasing medium: organic fluid dye solution
- Pumping: Laser light excites dye solution
- Cavity: Two mirrors and a diffraction grating
- Diffraction grating allows wavelength to be selected



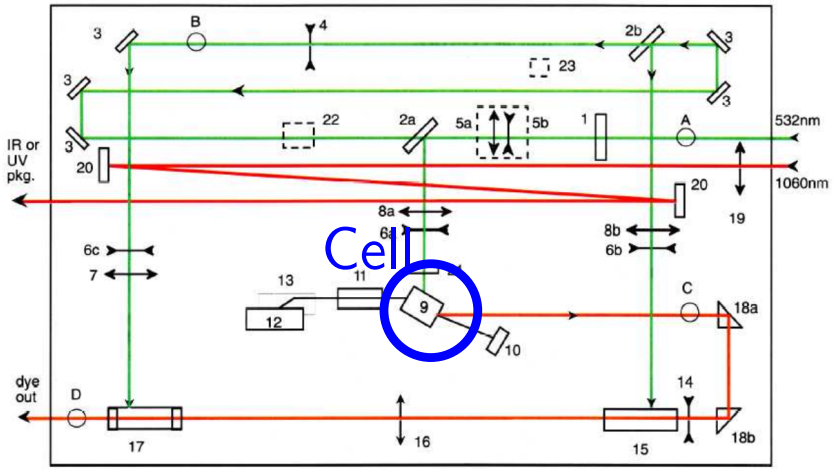
"Construction of a Dye Laser for Use in Detecting Ultracold RbCa," Hayley Whitson, Willamette University, 2012'

Our Experiment

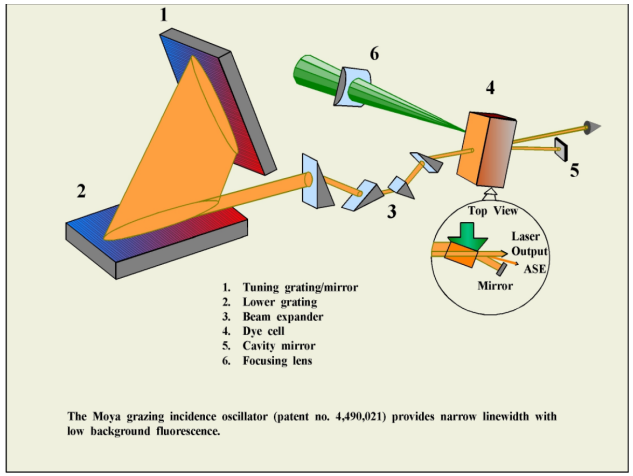
Our Dye Laser

- Moya cavity creates lasing and minimizes spontaneous emission
- Two amplification cells intensify output beam
- Pump with kilohertz, picosecond pump beam

Dye laser schematic



Moya cavity

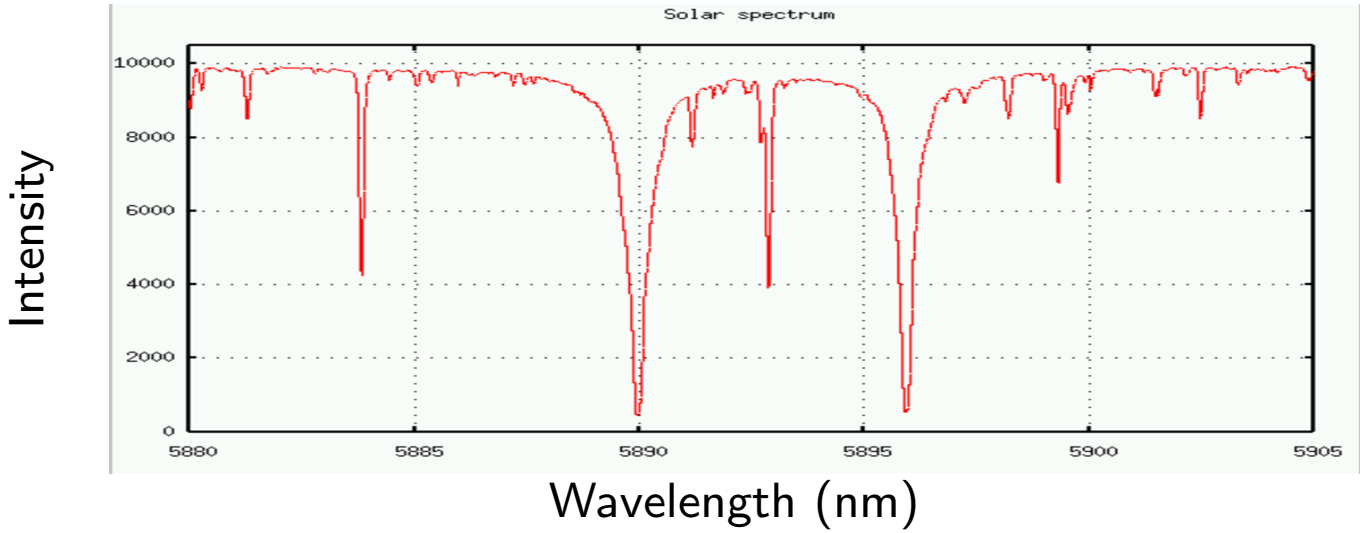


" ND6K User Manual," Contiuum Lasers, 1994

Our Experiment

Absorption Measurements

- Take absorption spectroscopy measurements
  - $\vec{B}$ along one direction
  - Measure absorption as λ changes
  - Change direction of $\vec{B}$ and repeat



Michael Richmond, Rochester Institute of Technology, *spiff.rit.edu/classes/phys440/lectures/curve*

Our Experiment

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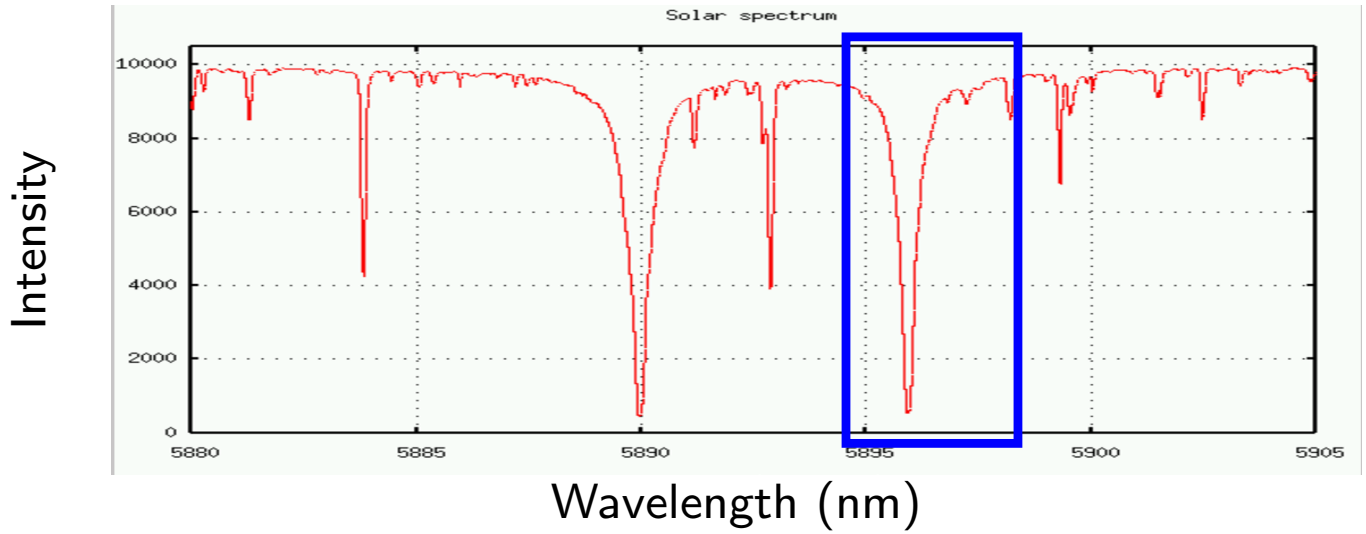
589.6 nm



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Optical Pumping