

Improving Laser Guide Stars through Magnetic Resonant Pulsing

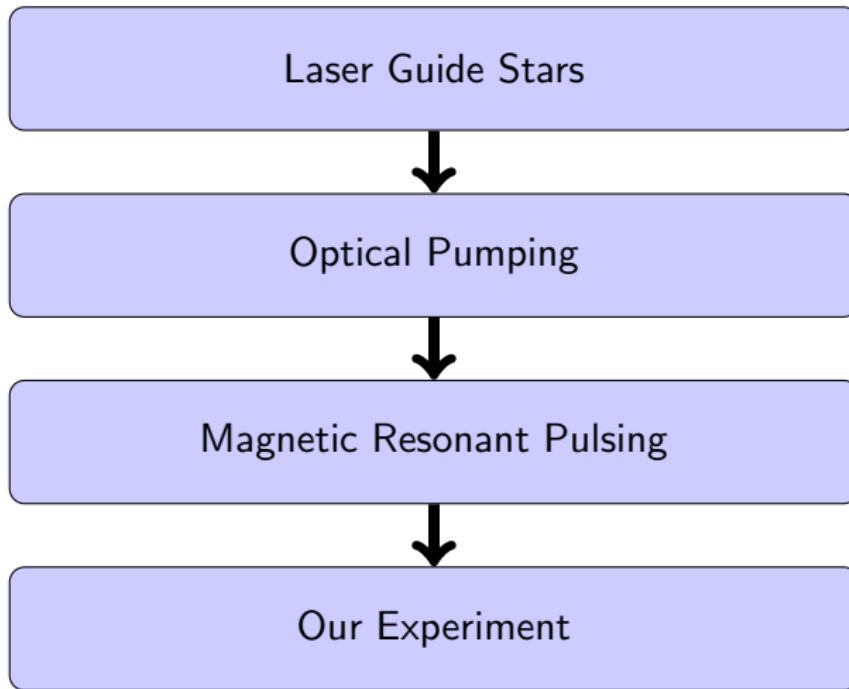
Adam Newton Wright

Willamette University

December 6, 2017

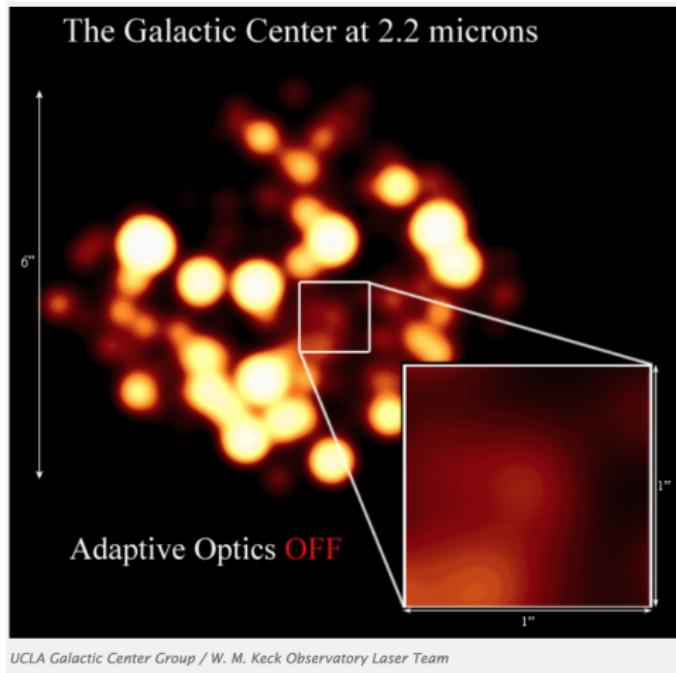
Bishop, Brianna, "Bringing New Life to Laser Guide Star," Lawrence Livermore National Laboratory, June 2014

Overview



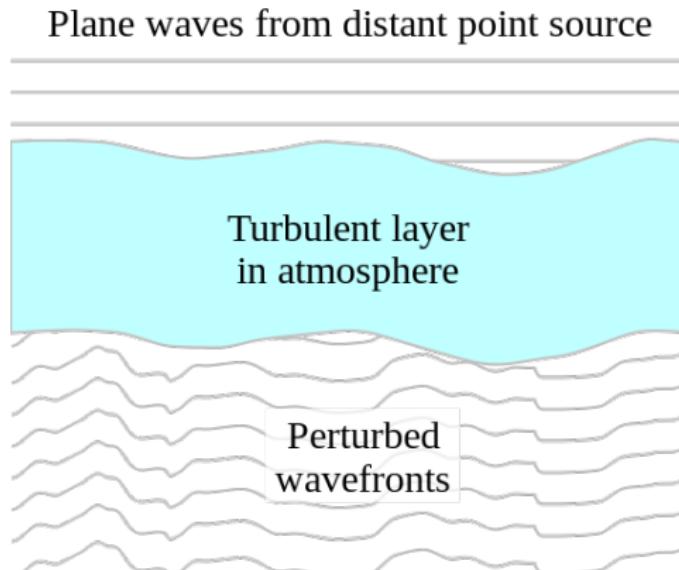
Telescopic Imaging

Concerned with Highest Resolution



Atmospheric Distortion

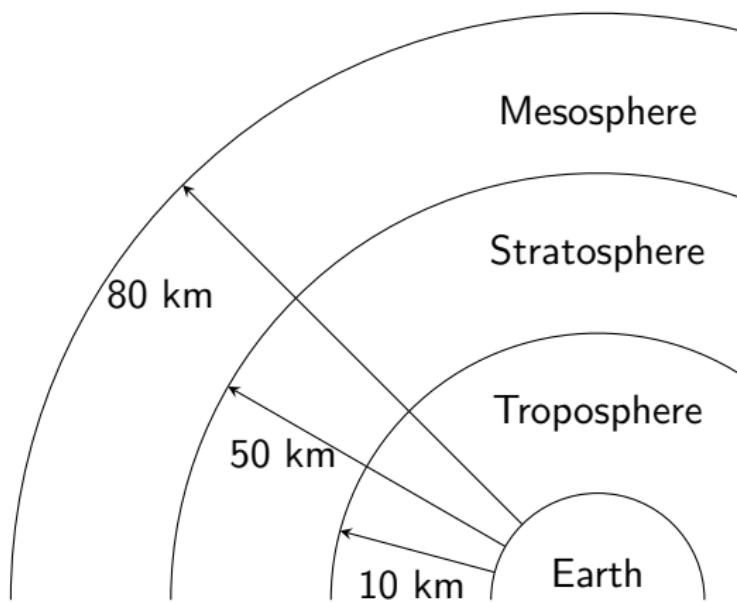
Causes reduced quality in telescopic imaging



¹Wizinowich, "The WM Keck Observatory laser guide star adaptive optics system: overview." Publications of the Astronomical Society of the Pacific 118, no. 840 (2006): 297.

Laser Guide Stars

Aid in correcting distorted images through adaptive optics²



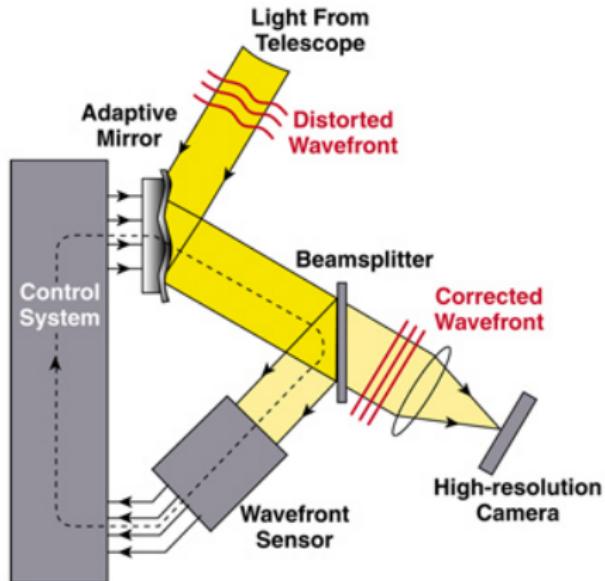
² "Laser Guide Star," RP Photonics, 2016

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

Adaptive Optics

Correct distortions from atmosphere

Feedback loop:
next cycle
corrects the
(small) errors of
the last cycle



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

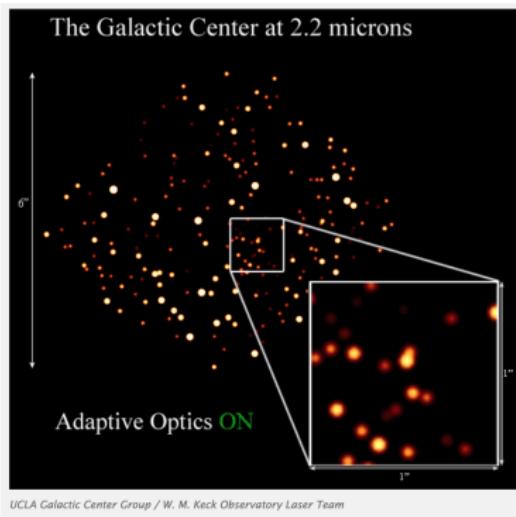
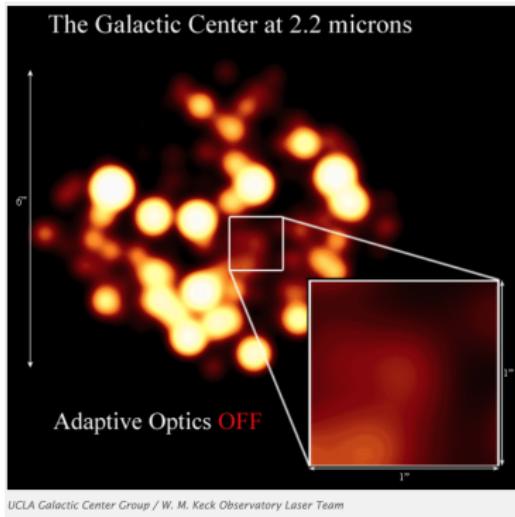
2016

Adaptive Optics and LGS

Correct distortions from atmosphere

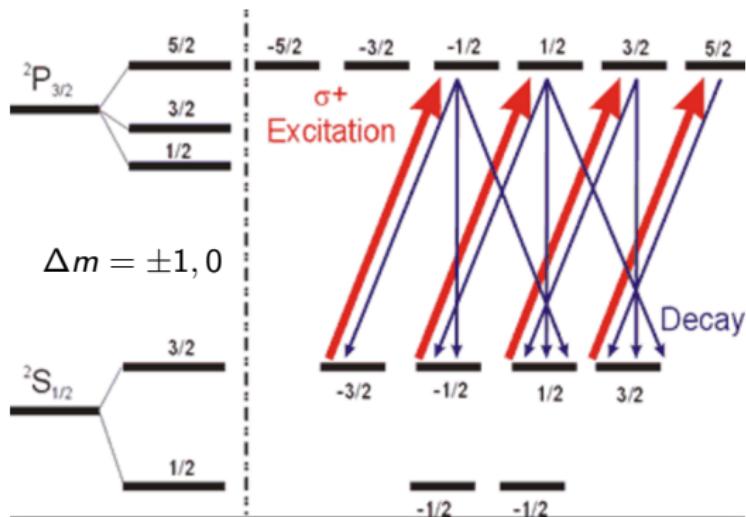
Adaptive Optics and LGS

Correct distortions from atmosphere



Optical Pumping

Increases brightness of LGS using circularly polarized light⁴

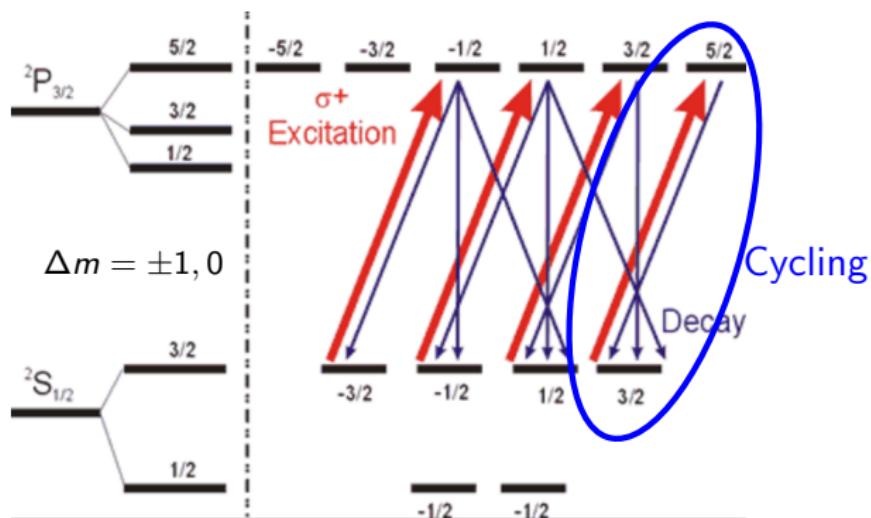


⁴Kane, "Pulsed laser architecture for enhancing backscatter from sodium." SPIE Astronomical Telescopes+ Instrumentation. International Society for Optics and Photonics, 2014. "Spin polarization by optical pumping,"

Colinear Laser Spectroscopy, 2013

Optical Pumping

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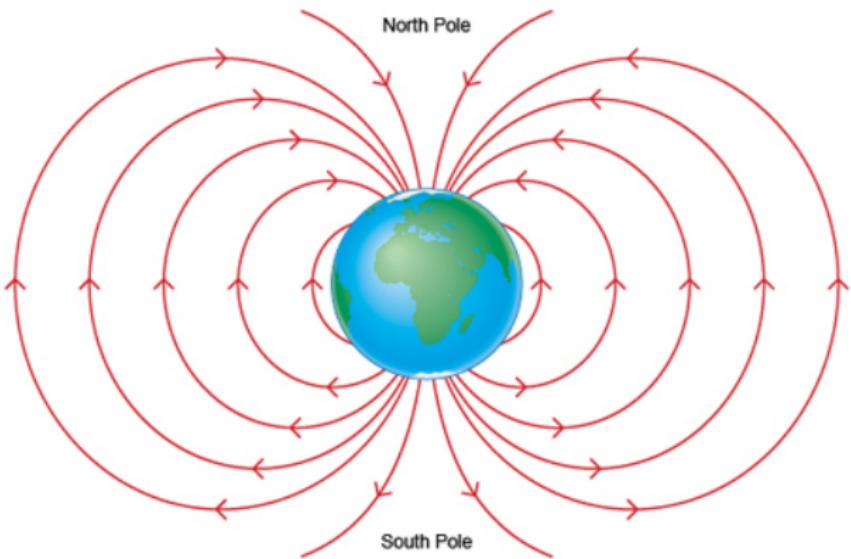


⁴Kane, "Pulsed laser architecture for enhancing backscatter from sodium." SPIE Astronomical Telescopes+ Instrumentation. International Society for Optics and Photonics, 2014. "Spin polarization by optical pumping,"

Colinear Laser Spectroscopy, 2013

Geomagnetic Field

Reduces the benefits of Optical Pumping⁵



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

Optical Pumping

Larmor Precession

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

$$\omega = -\gamma B$$

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



Magnetic Resonant Pulsing

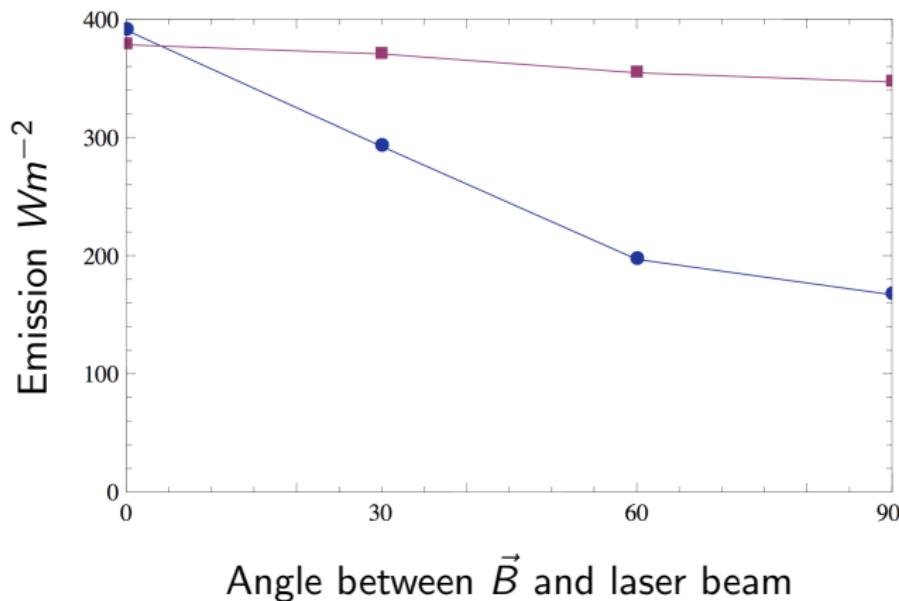
Increases Photon Return in Magnetic Field

- ▶ Magnetic Resonant Pulsing:⁶
 - ▶ Laser is pulsed at a frequency corresponding to atom's Larmor frequency
 - ▶ Light only interacts with atom at one point in precession cycle
 - ▶ Benefits of Optical Pumping Reestablished

⁶Kane, "Pulsed laser architecture for enhancing backscatter from sodium." SPIE Astronomical Telescopes+ Instrumentation. International Society for Optics and Photonics, 2014.

Magnetic Resonant Pulsing

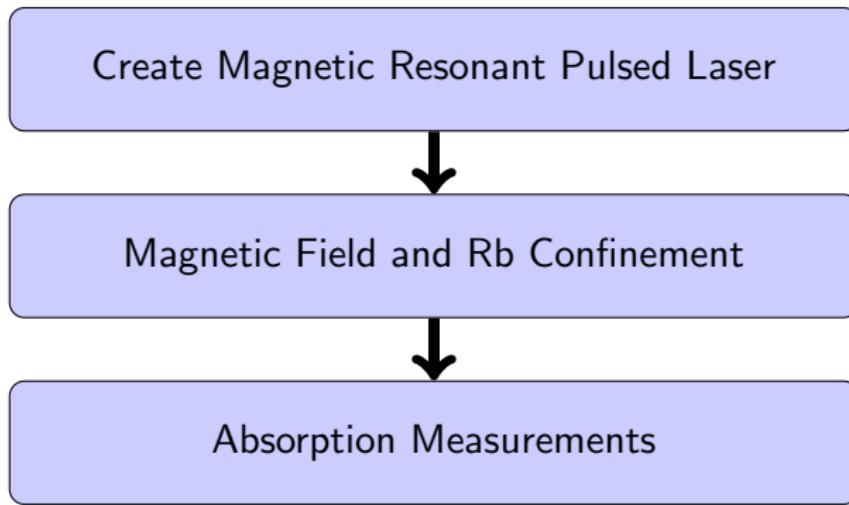
Magnetic Resonant Pulsing Simulation



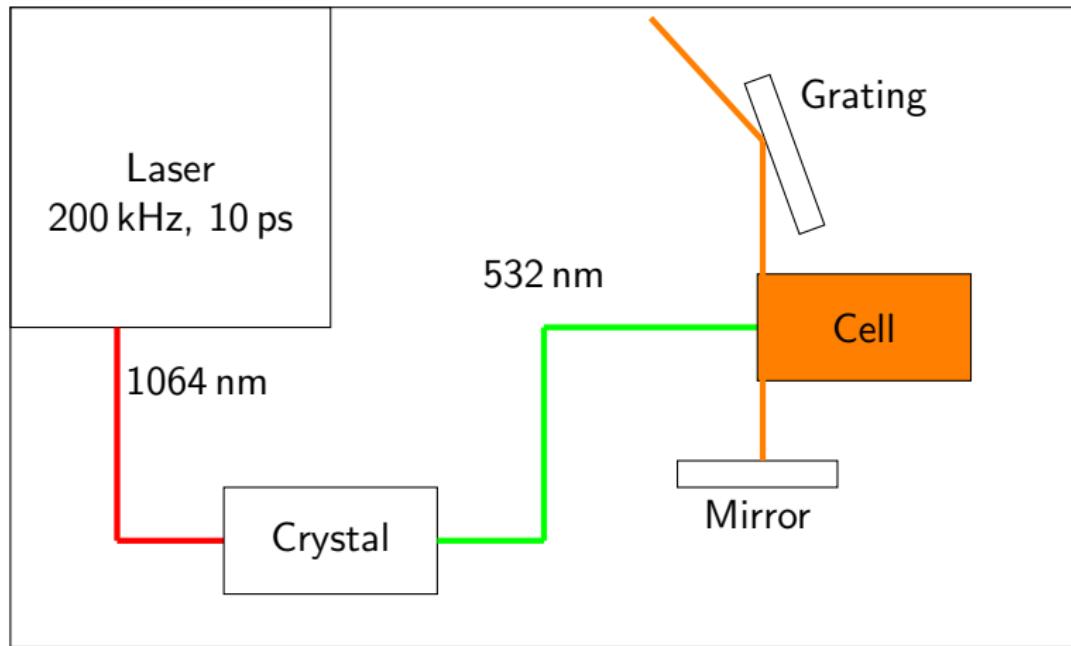
Kane, "Pulsed laser architecture for enhancing backscatter from sodium." SPIE Astronomical Telescopes+ Instrumentation. International Society for Optics and Photonics, 2014.

Our Experiment

Outline



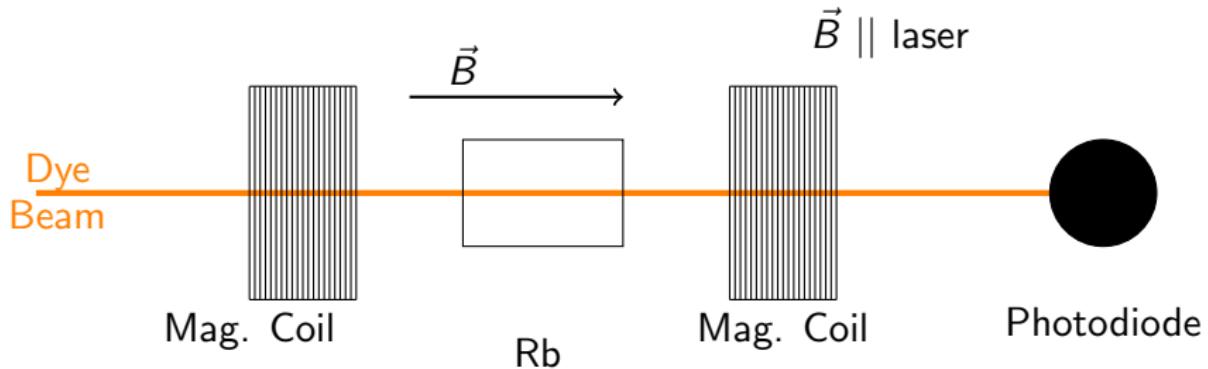
Experimental Schematic



Our Experiment

Rubidium Housing and Magnetic Field

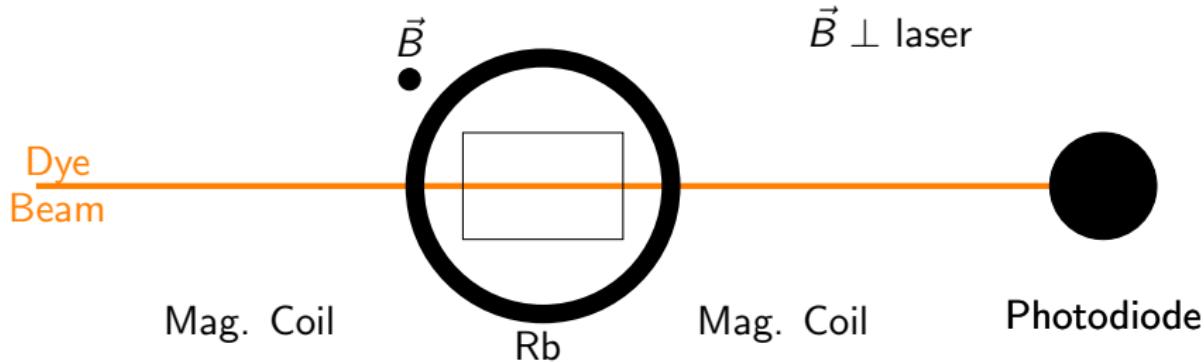
- ▶ Magnetic coils on either side of reference frame
 - ▶ Rotate to change angle between laser and \vec{B}
- ▶ Dye laser shone into reference cell and collected by photodiode



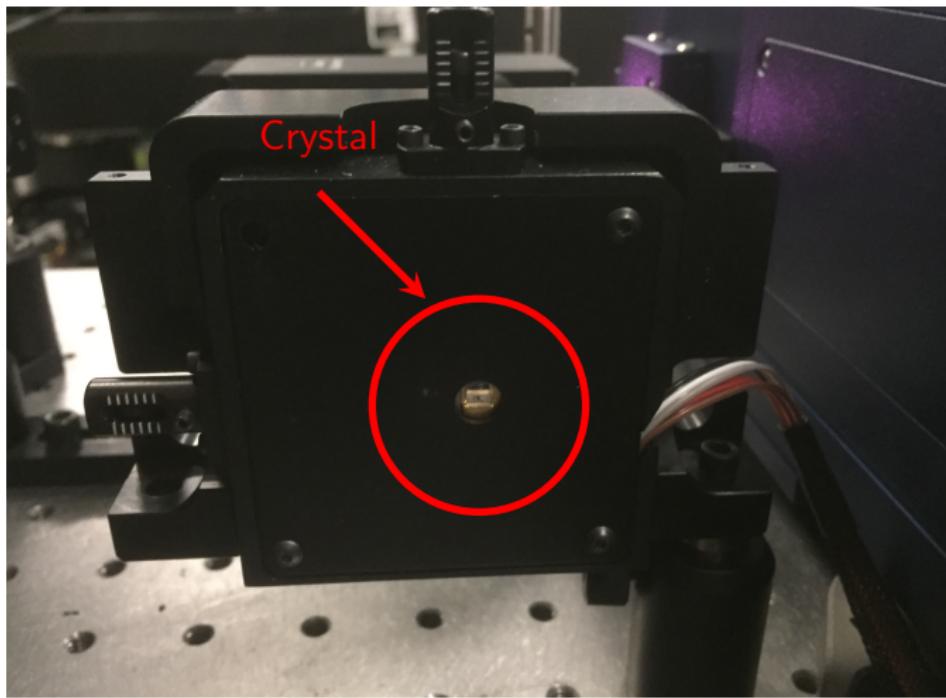
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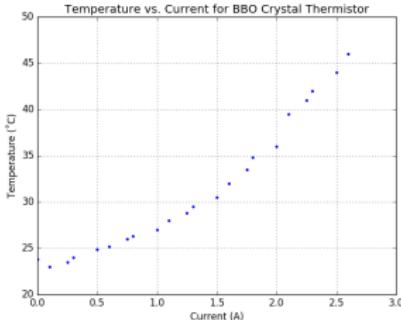
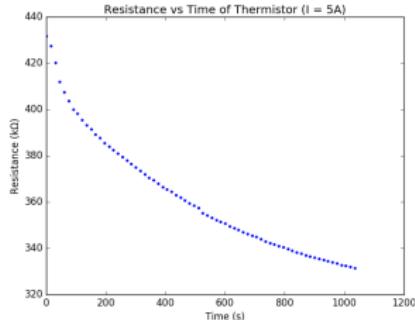
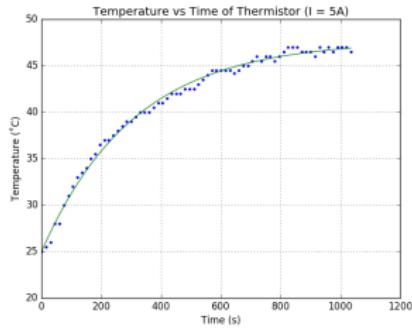
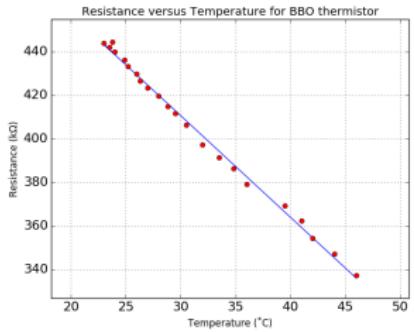


Crystal



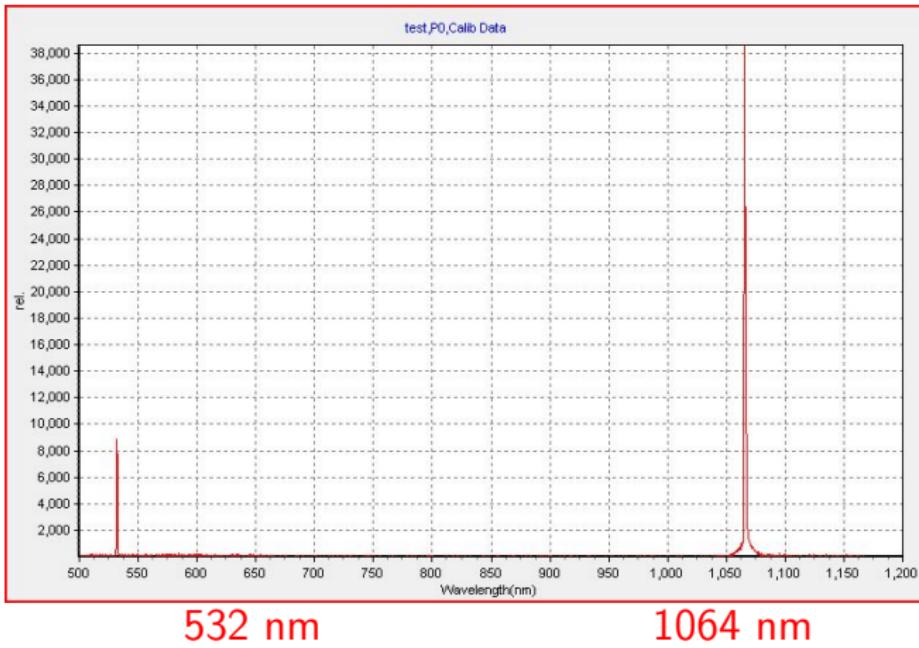
Results

Resistance Measurements



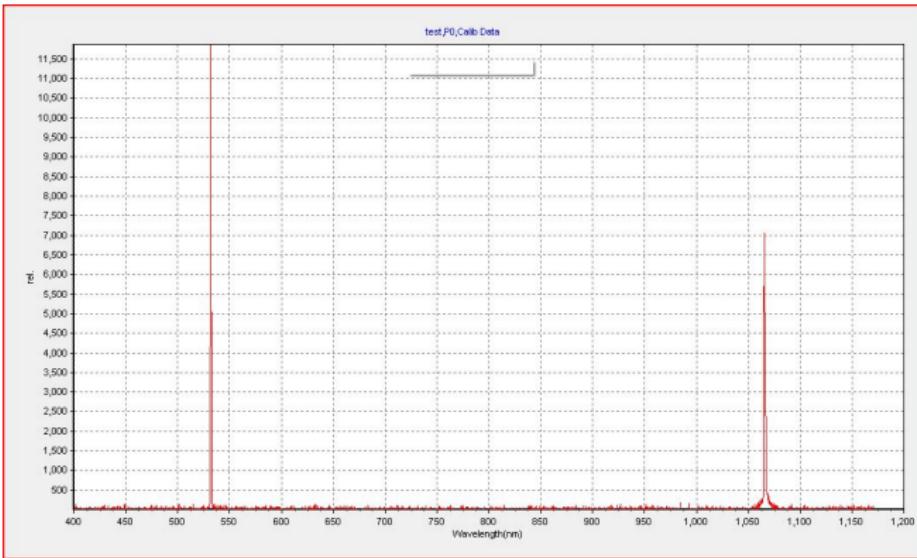
Results

Frequency Doubling



Results

Frequency Doubling

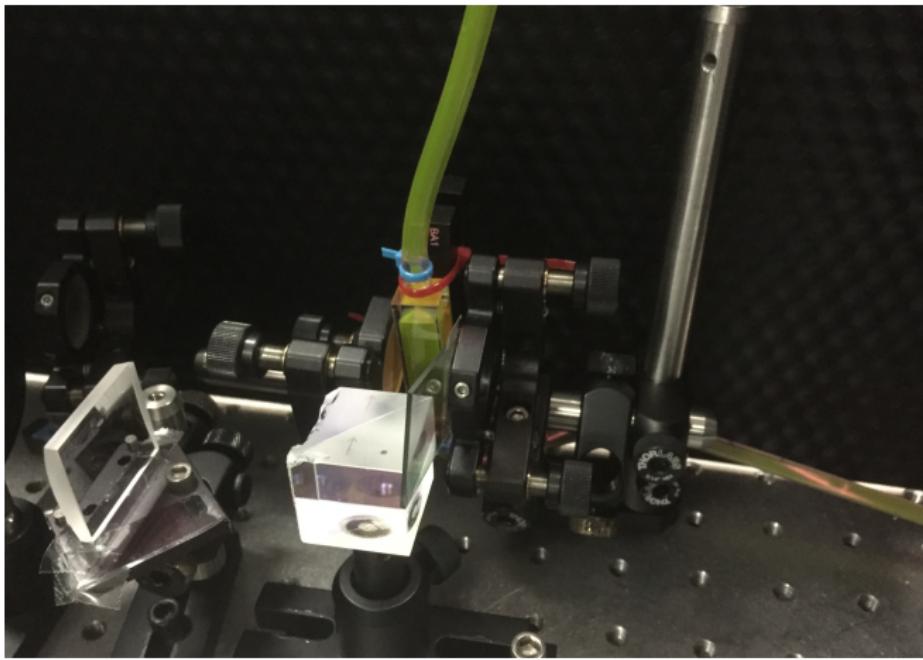


532 nm

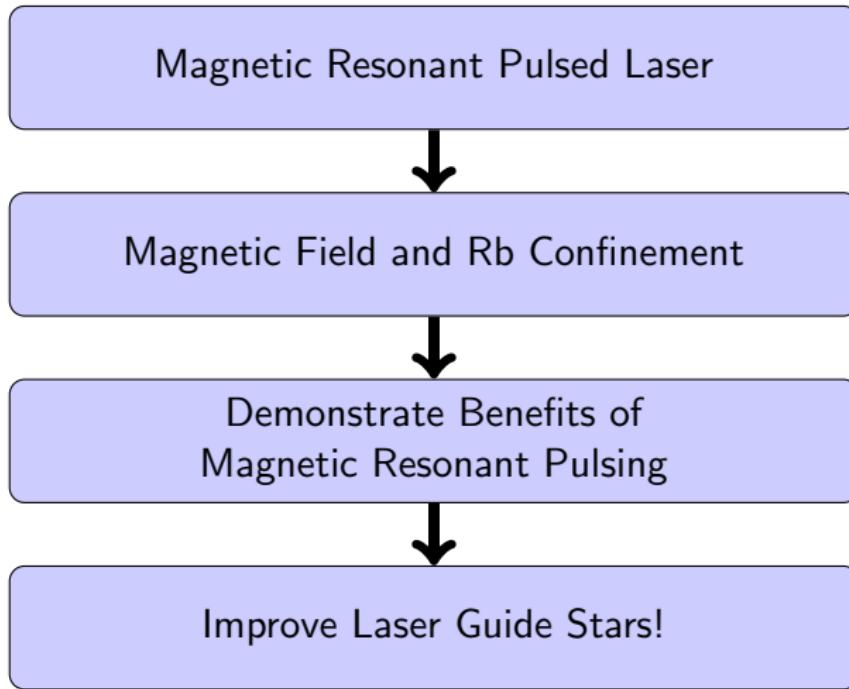
1064 nm

Dye Laser

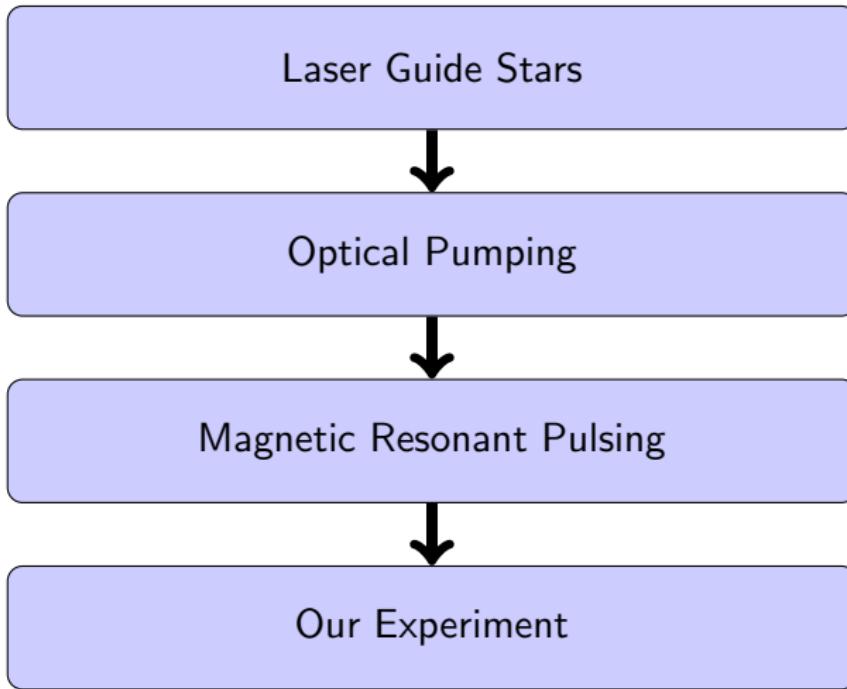
Setup



Outlook



Summary



Questions



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

Extras

Subtitle

Slide Body

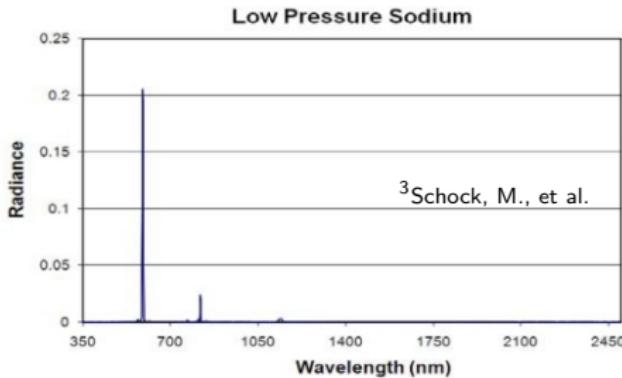
Laser Guide Stars (LGS)

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 $\lambda = 589.593 \text{ nm}$
- ▶ Intensity³ $I \approx 10 \text{ W m}^{-2}$
- ▶ Circularly polarized light σ^+



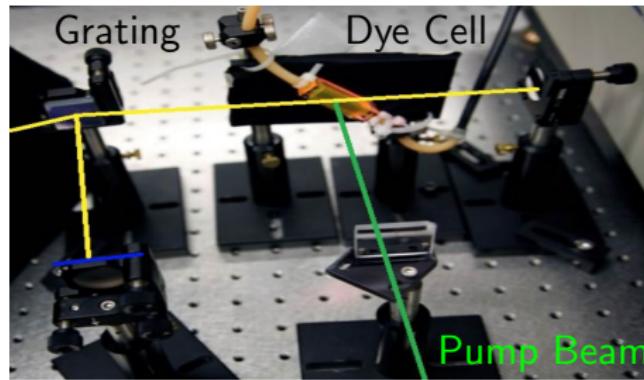
"Performance analysis of polychromatic laser guide stars used for wavefront tilt sensing." Monthly Notices of the Royal Astronomical Society 337.3 (2002)

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



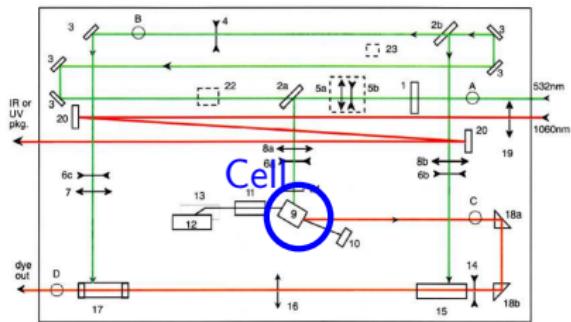
"Construction of a Dye Laser for Use in Detecting Ultracold RbCa," Hayley Whitson, Willamette University, 2012'

Our Experiment

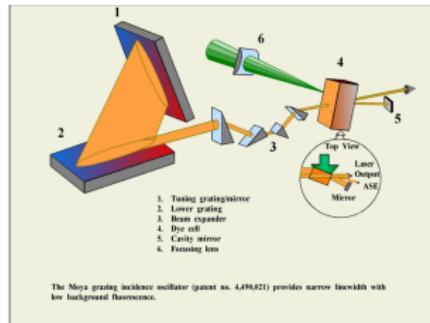
Our Dye Laser

- ▶ 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

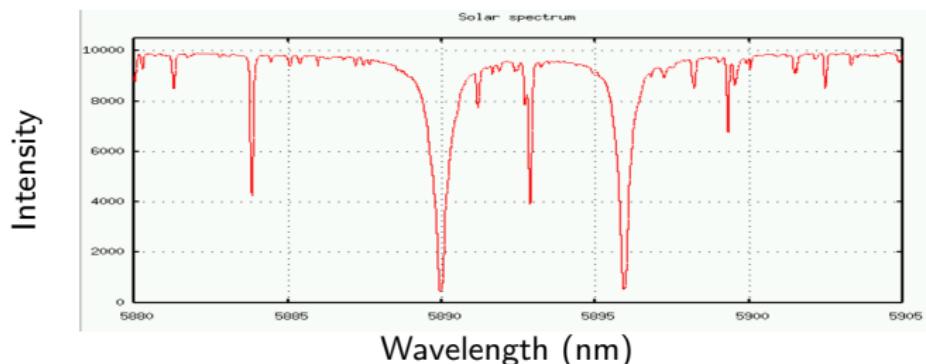


" ND6K User Manual," Continuum Lasers, 1994

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



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