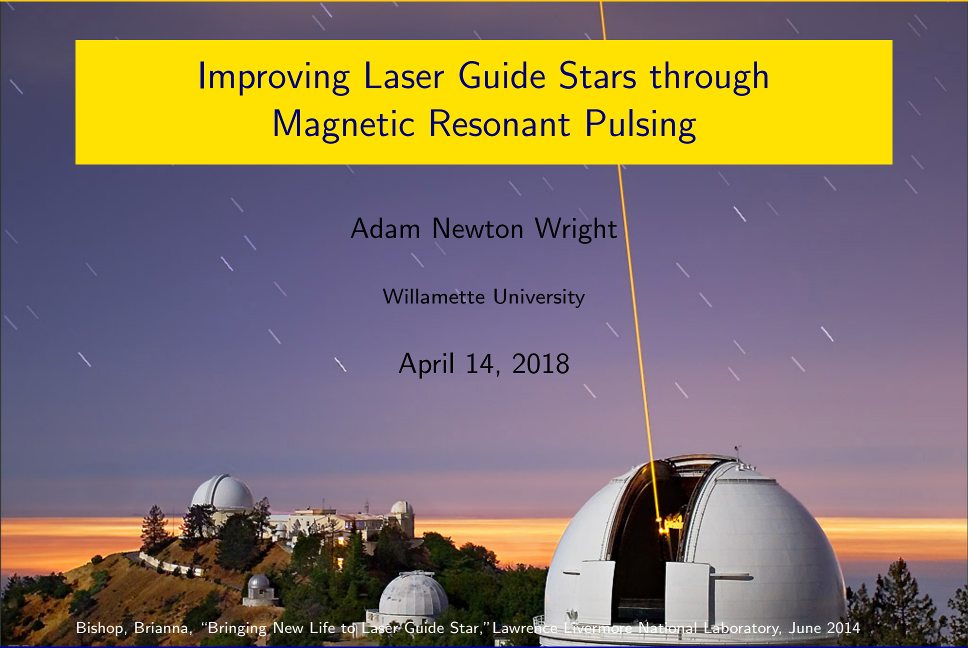
Improving Laser Guide Stars through Magnetic Resonant Pulsing

Adam Newton Wright

Willamette University

April 14, 2018



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

Overview

Laser Guide Stars

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Optical Pumping

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Magnetic Resonant Pulsing

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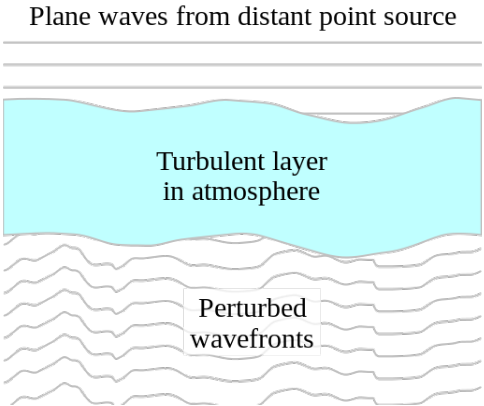
Our Experiment

Telescopic Imaging

Concerned with Highest Resolution

Atmospheric Distortion

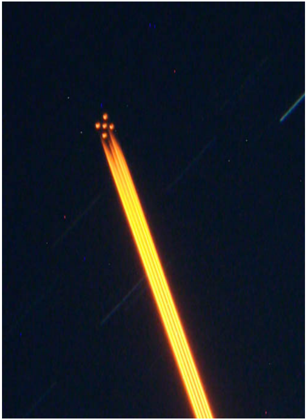
Causes reduced quality in telescopic imaging

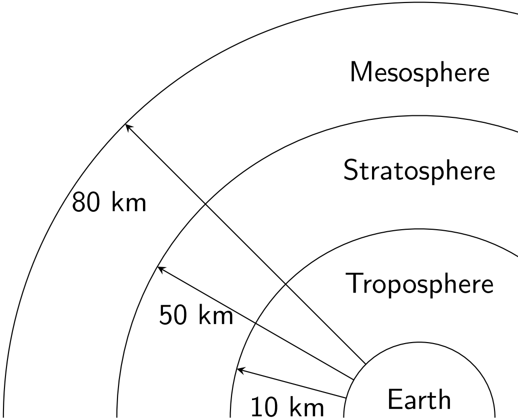


[1]Wizinowich, "The WM Keck Observatory laser guide star adaptive optics system: overview."Publications of the Astronomical Society of the Pacific118, no. 840 (2006): 297.

Laser Guide Stars

Aid in correcting distorted images through adaptive optics[2]



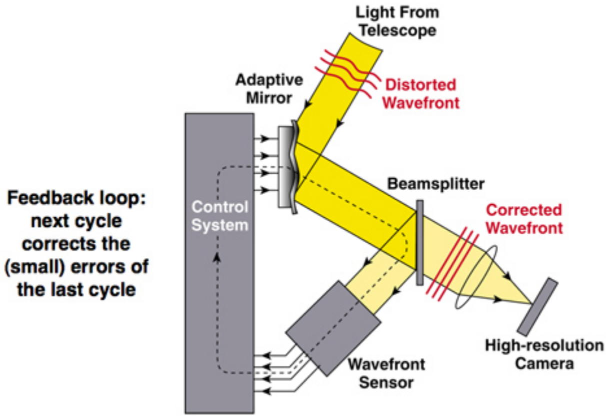


[2] "Laser Guide Star," RP Photonics, 2016

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

Adaptive Optics

Correct distortions from atmsophere



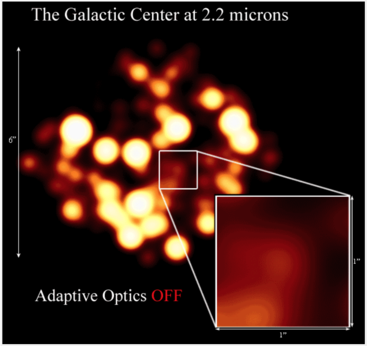
C. Max, Center for Adaptive Optics, Lawrence Livermore National Laboratory and NSF Center for Adaptive Optics, 2016

Adaptive Optics and LGS

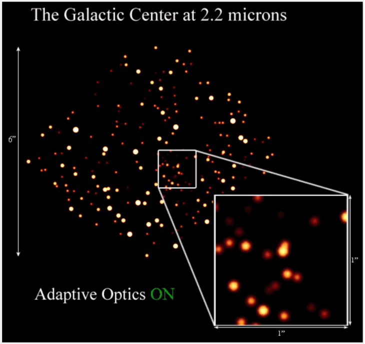
Correct distortions from atmsophere

Adaptive Optics and LGS

Correct distortions from atmsophere



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



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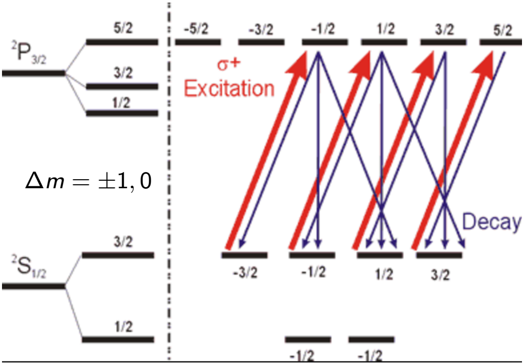
Optical Pumping

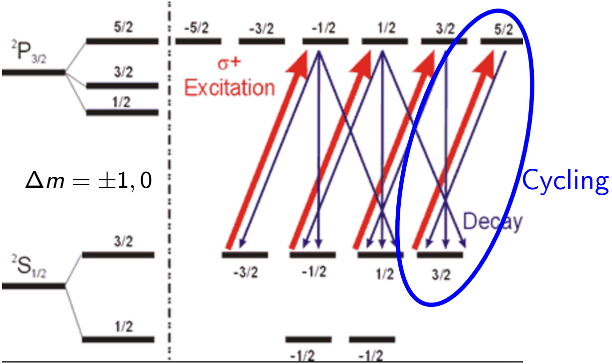
Increases brightness of LGS using circularly polarized light[4]



[4] Kane, "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

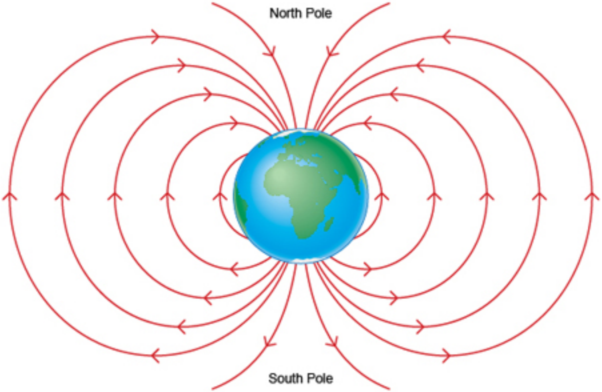
Increases brightness of LGS using circularly polarized light[4]



[4] Kane, "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 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

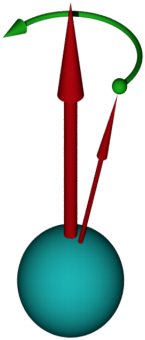
Optical Pumping

Larmor Precession

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

$$\omega = -\gamma B$$

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



Magnetic Resonant Pulsing

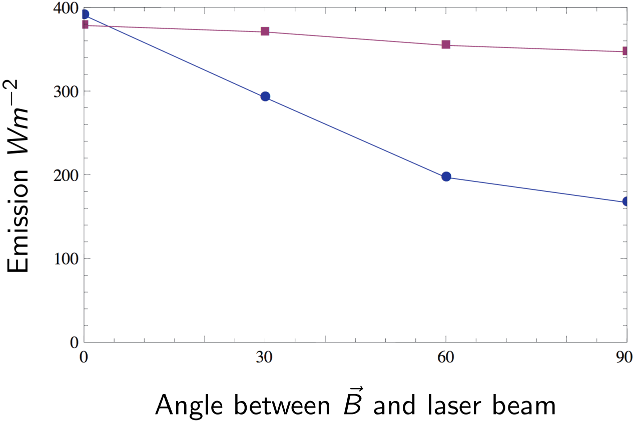
Increases Photon Return in Magnetic Field

- 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

[6] Kane, "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

Create Magnetic Resonant Pulsed Laser

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Magnetic Field and Rb Confinement

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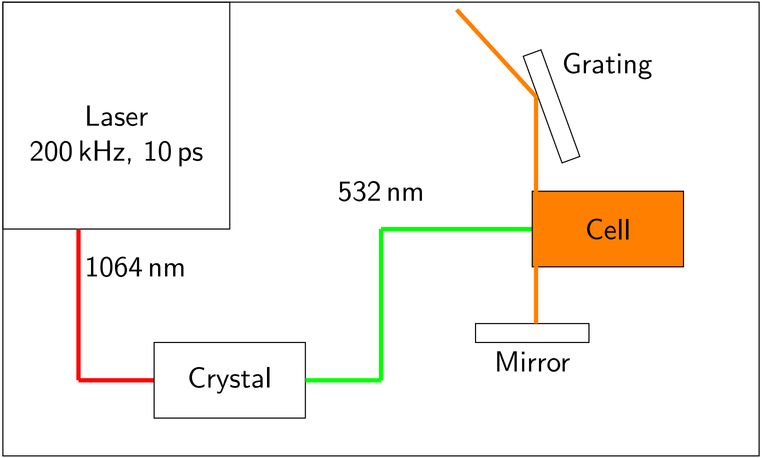
Absorption Measurements

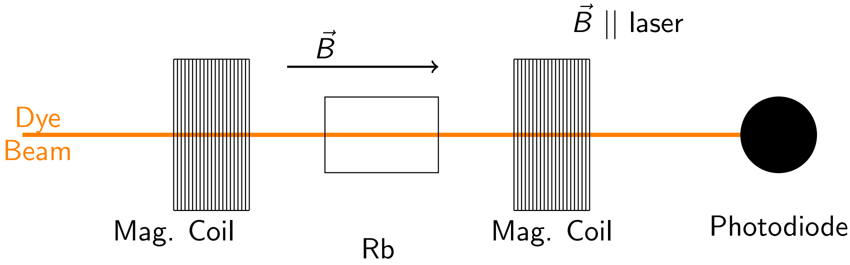
Experimental Schematic



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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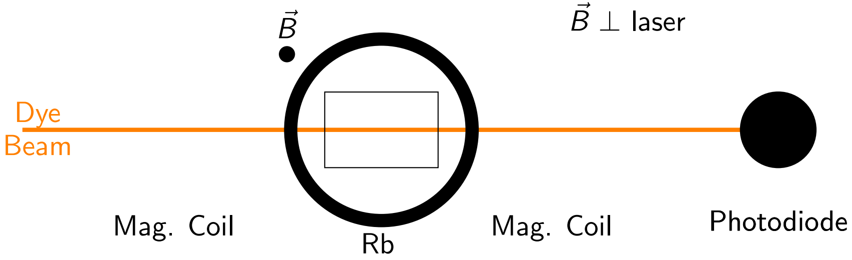
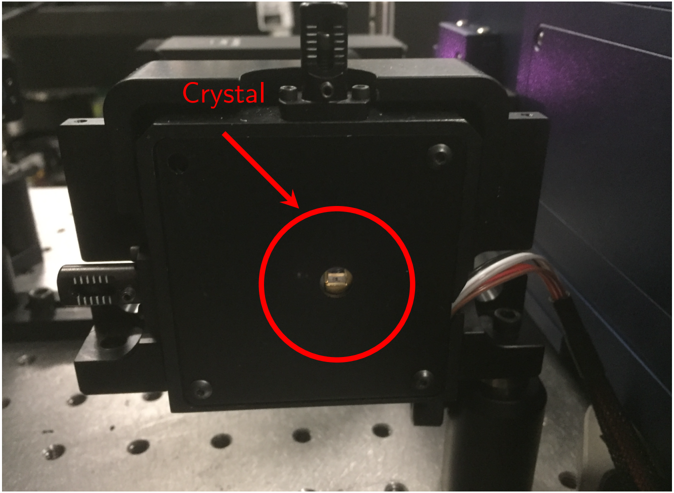
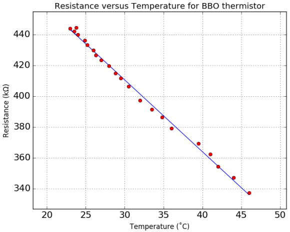


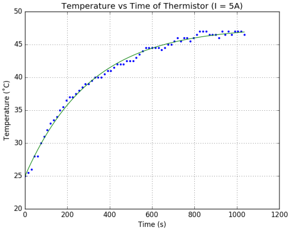
Crystal

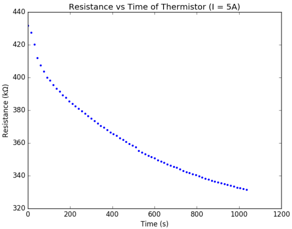


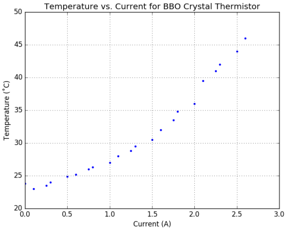
Results

Resistance Measurements



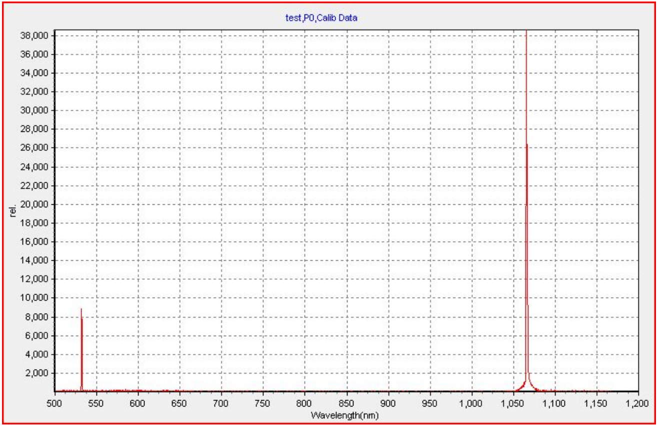






Results

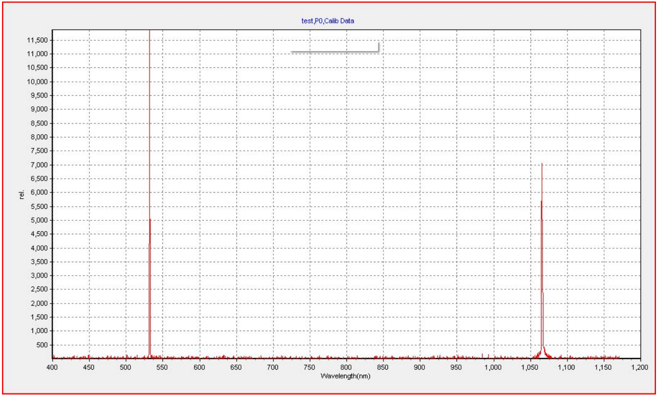
Frequency Doubling



532 nm 1064 nm

Results

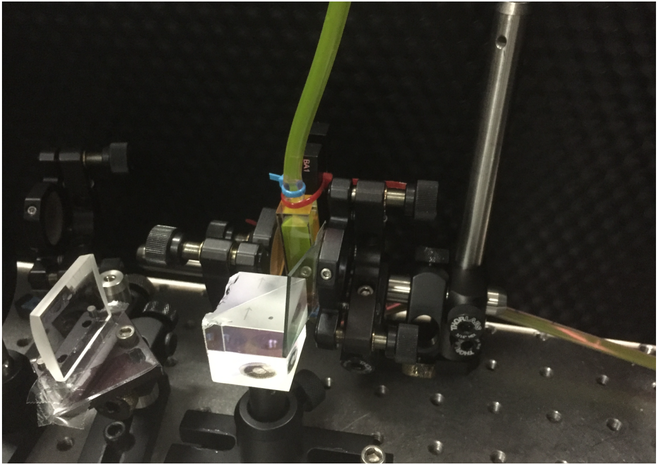
Frequency Doubling



532 nm 1064 nm

Dye Laser

Setup



Outlook

Magnetic Resonant Pulsed Laser

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Magnetic Field and Rb Confinement

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Demonstrate Benefits of
Magnetic Resonant Pulsing

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Improve Laser Guide Stars!

Summary

Laser Guide Stars

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Optical Pumping

↓

Magnetic Resonant Pulsing

↓

Our Experiment

Questions

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

Extras

Subtitle

Slide Body

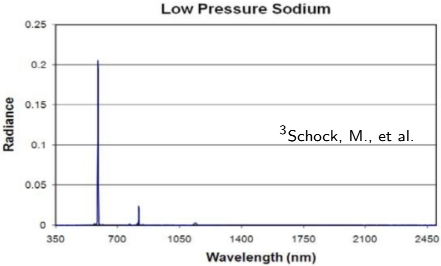
Laser Guide Stars (LGS)

Sodium LGS

Sodium Laser Guide Star System

- Mesospheric sodium layer: 10 km thick and 90 km in altitude
  - Created by the ablation of meteors

- Wavenlength $\lambda =$ 589.593 nm
- Intensity[3] $I \approx 10 W m^{-2}$
- Circularly polarized light σ^{+}



[3]Schock, M., et al.

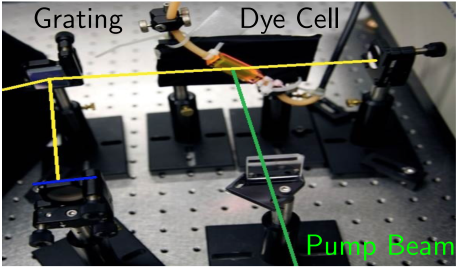
"Performance analysis of polychromatic laser guide stars used for wavefront tilt sensing." Monthly Notices of the Royal Astronomical Society 337.3 (2002)

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



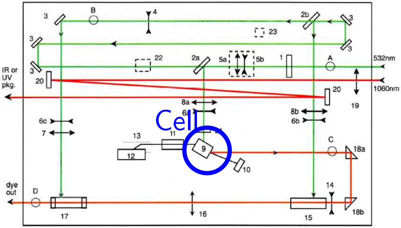
"Construction of a Dye Laser for Use in Detecting Ultracold RbCa," Hayley Whitson, Willamette University, 2012'

Our Experiment

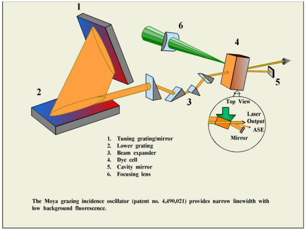
Our Dye Laser

- 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

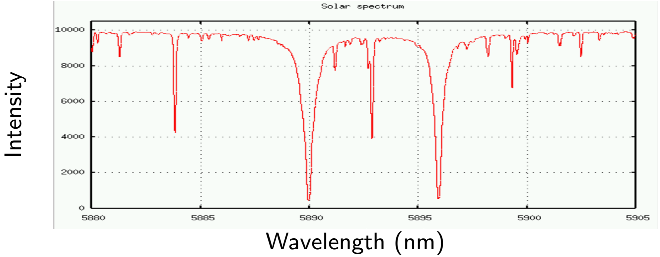


" ND6K User Manual," Contiuum Lasers, 1994

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*

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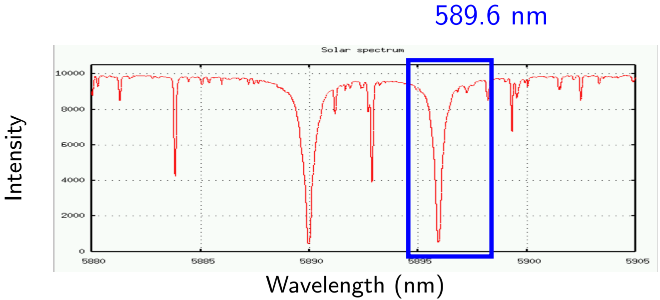

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