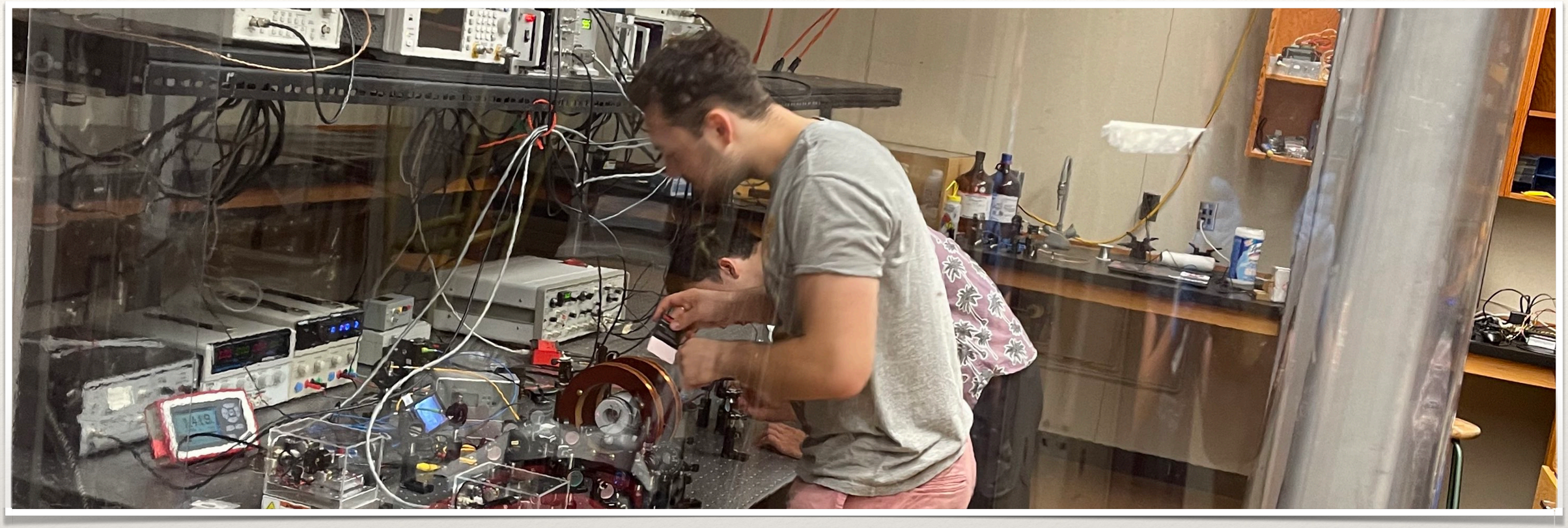

Andrew MacRae, University of Victoria

The Research Lab as a Teaching Tool

CAP Congress 2023
June 22, 2023

From Learning Physics to Doing Physics

Physics is learned … by **doing** physics.

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Physics is learned … by **doing** physics.

"New graduate students would come to work in my laboratory after 17 years of extraordinary success in classes, but … often it seemed that they didn't even really understand what physics was.

But then an amazing thing happened: After just a few years of working in my research lab, interacting with me and the other students, they were transformed. I'd suddenly realize they were now expert physicists, genuine colleagues."

Carl Wieman, "*Why not try a scientific approach to science education?*" CHANGE, Sept/Oct 2007

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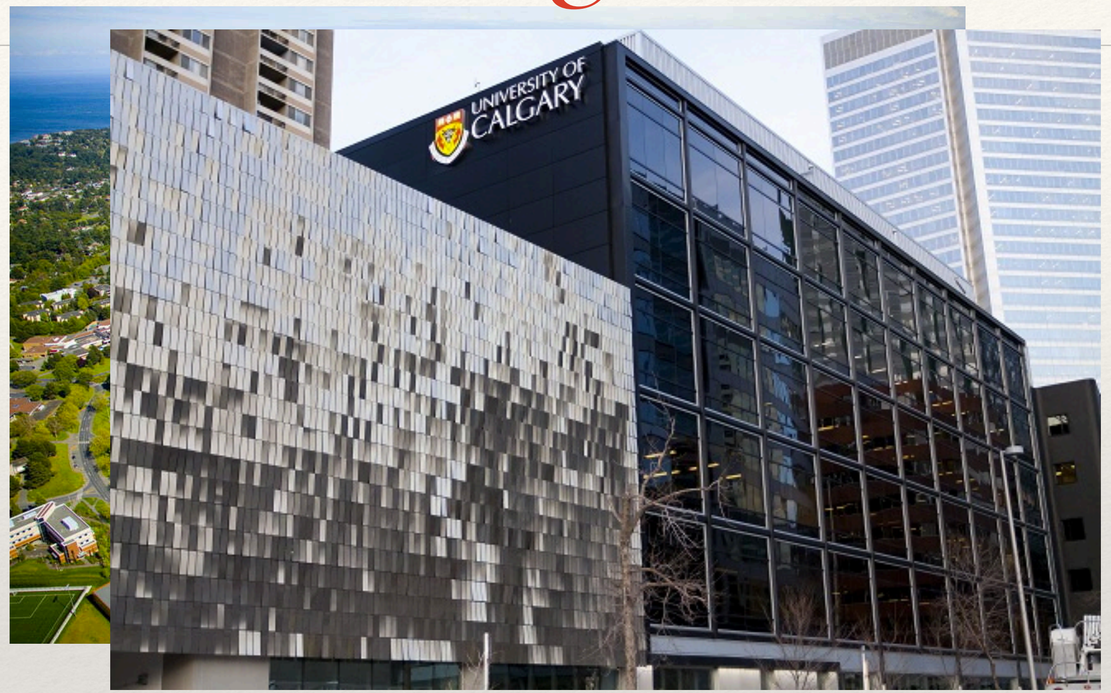

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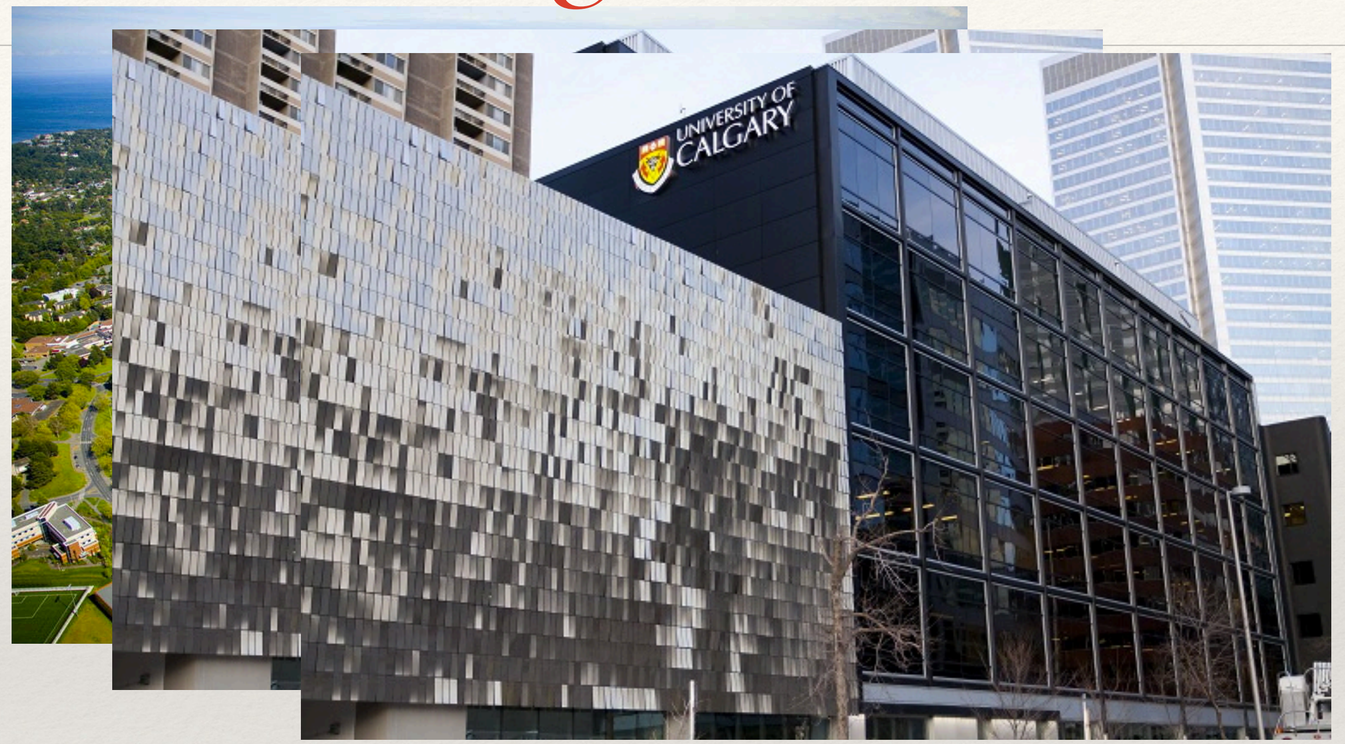

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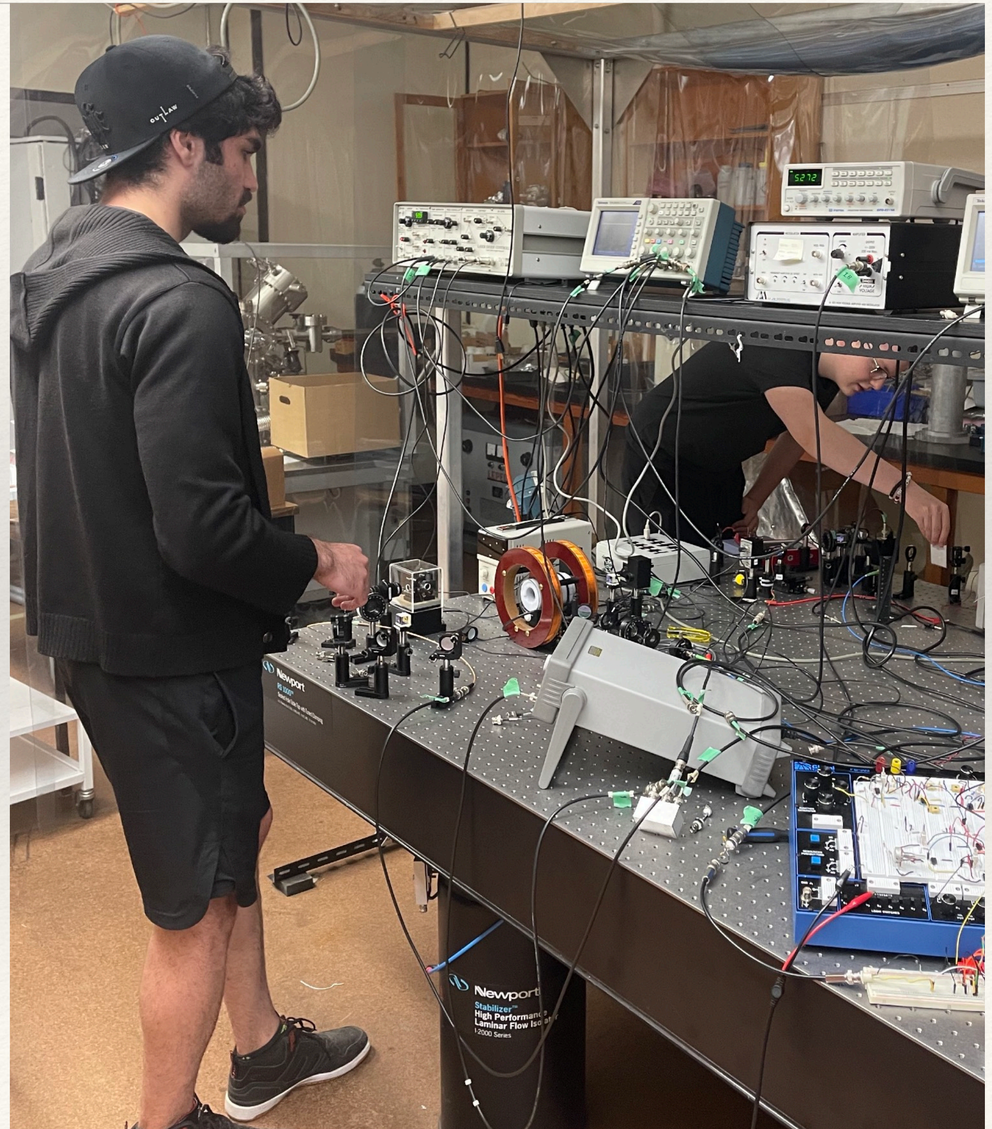
AMO Physics: The Perfect Level of Complexity



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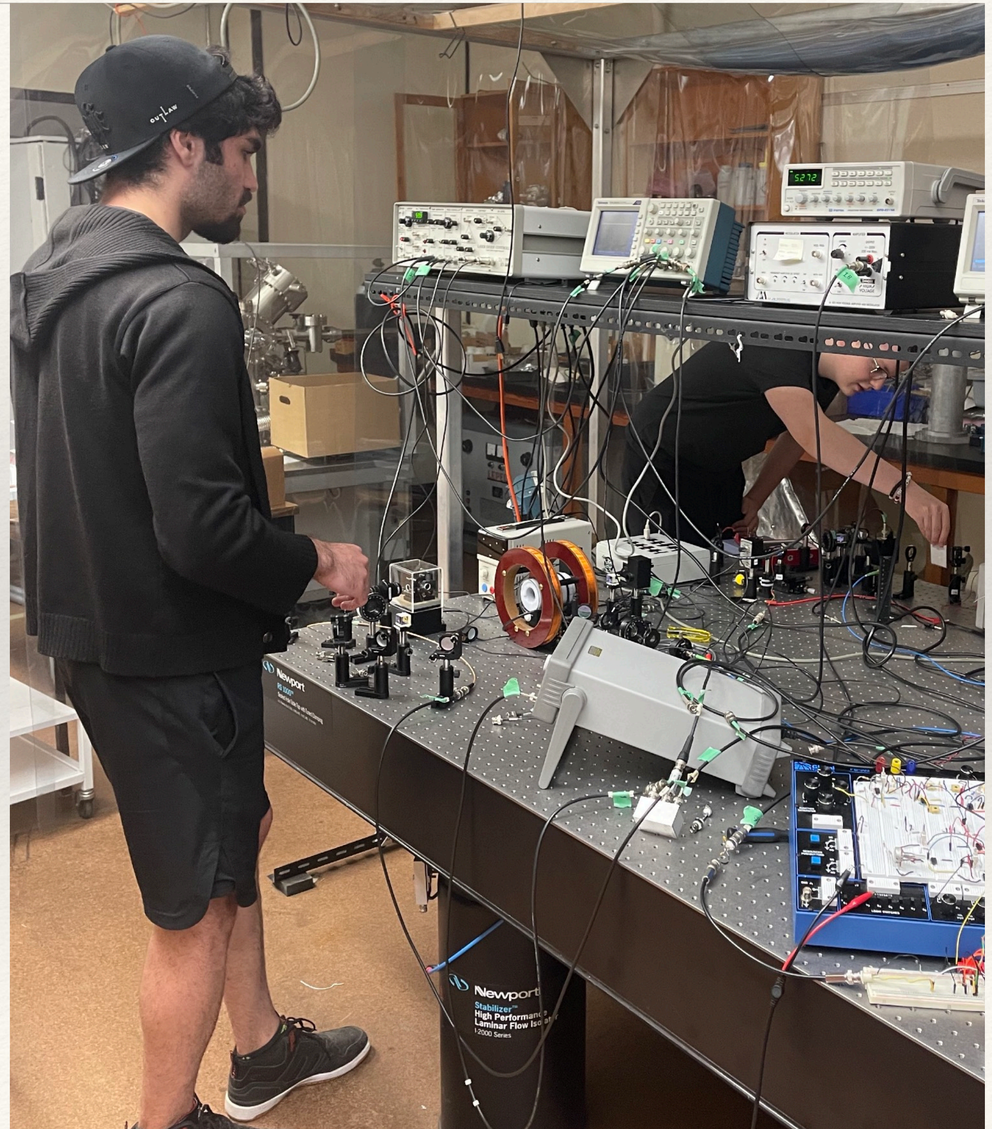
- Typically small teams, “tabletop physics”
  - Great for modular projects



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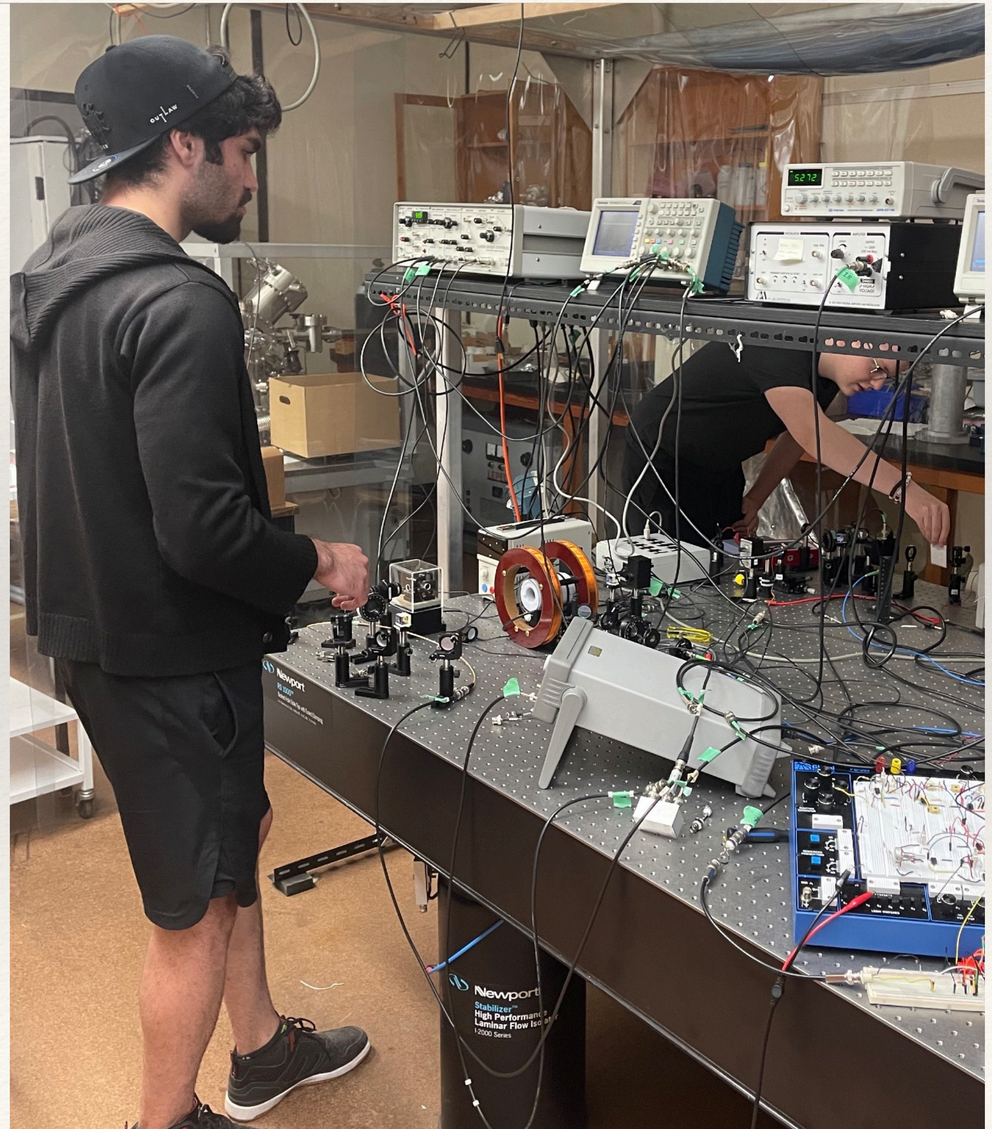

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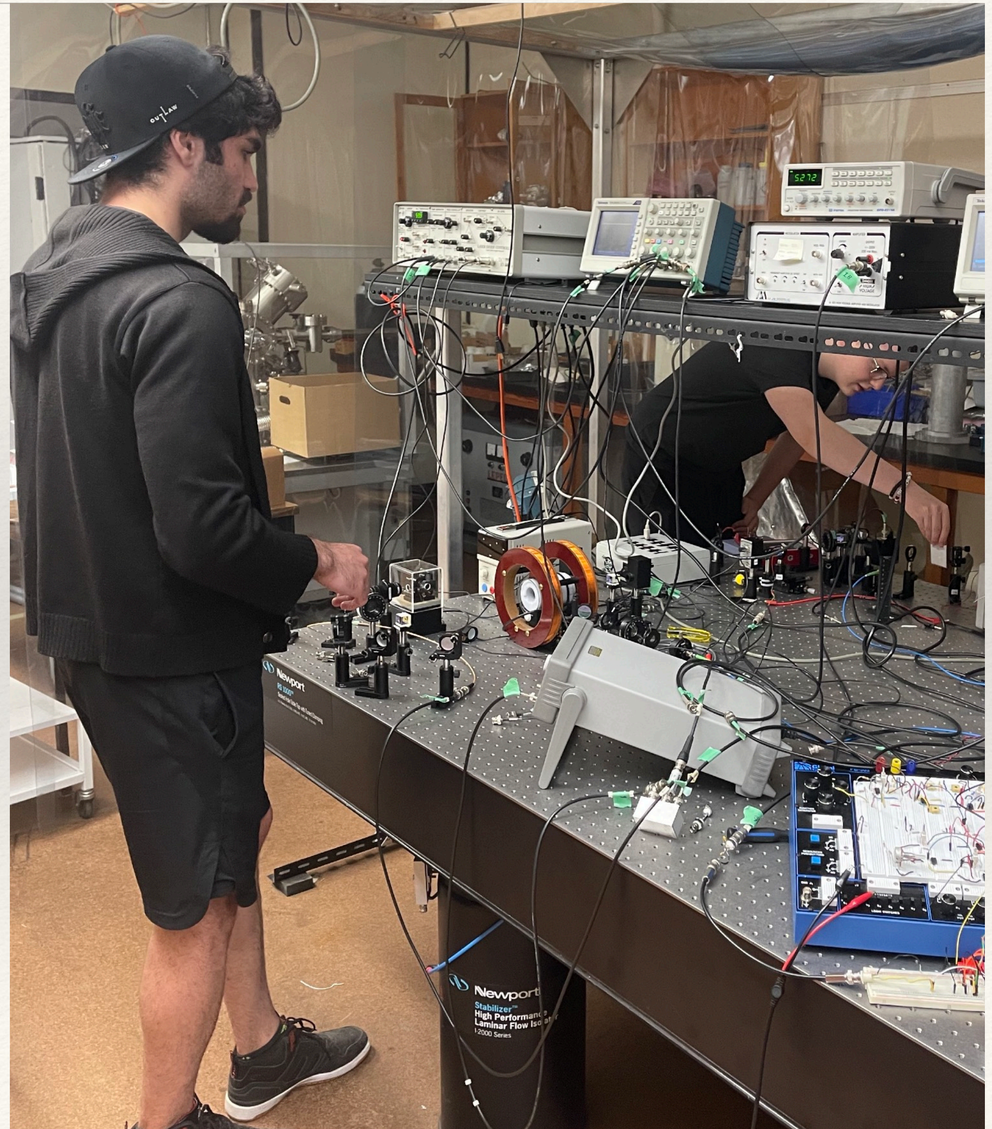

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- Knowledge base of DIY equipment
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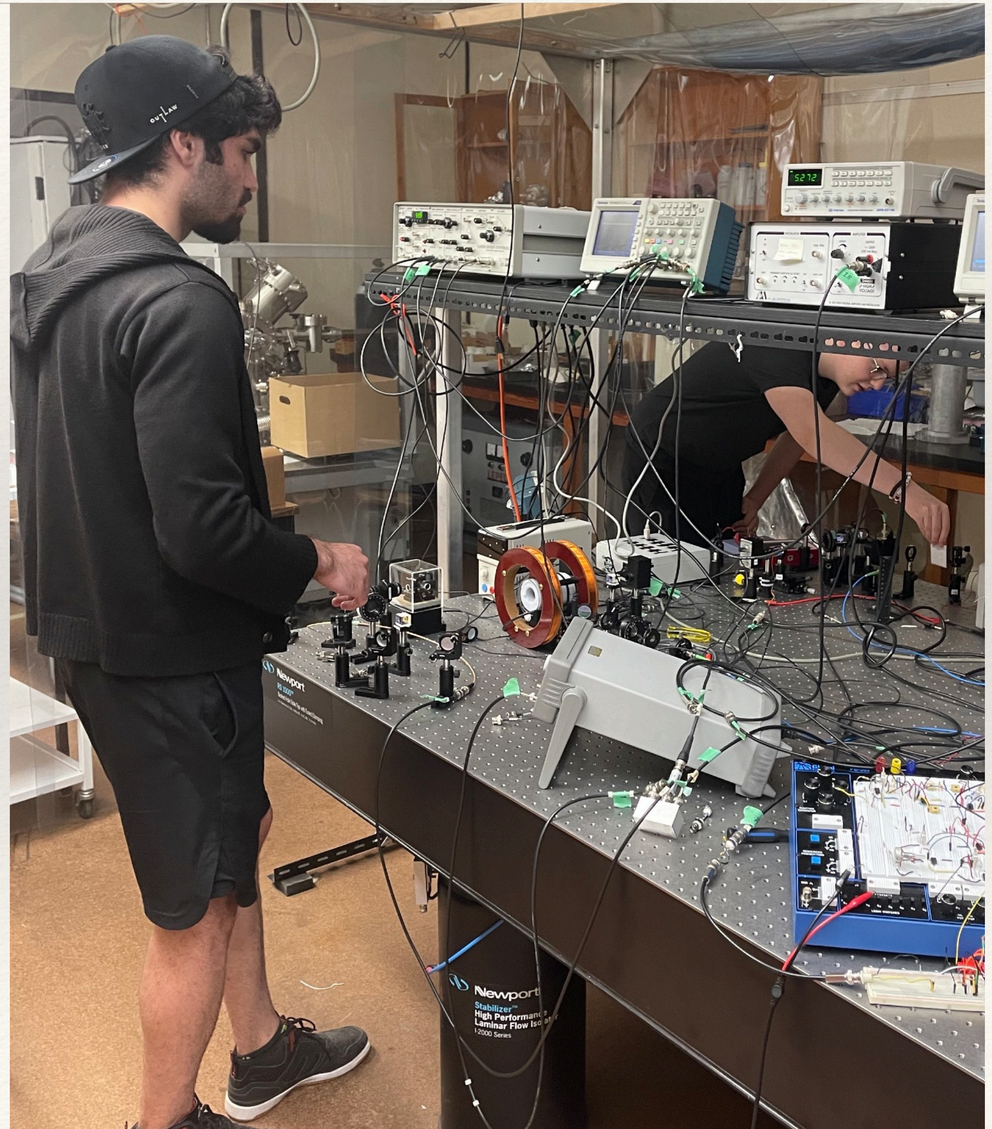
- Combination of often available equipment and self built hardware
  - **Cutting edge science on a budget!**



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GOAL:

"Provide mentorship, materials, and projects for interested students looking to gain research experience in a real research environment."

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MODEL:

Students will incrementally build the lab via a set of well-thought out, modular sub-projects.

The *Quantum Teaching Lab*

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BASIC REQUIREMENTS:

- Basic lab space
  - Optical Components
  - Optical Table
- Lasers
- Set of experiments
- Local expertise
- *Some Funding* ($5k P.A.)

The *Quantum Teaching Lab*

Basic Funding

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- Applied for every grant under the sun (NSERC DG, USRA, …)
  - Mostly unaccessible to non-faculty / staff

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- Adjunct Status (2020)
  - NSERC Discovery Grant (2021-2026)

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Lab Space and Optical Table:

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It never hurts to ask …

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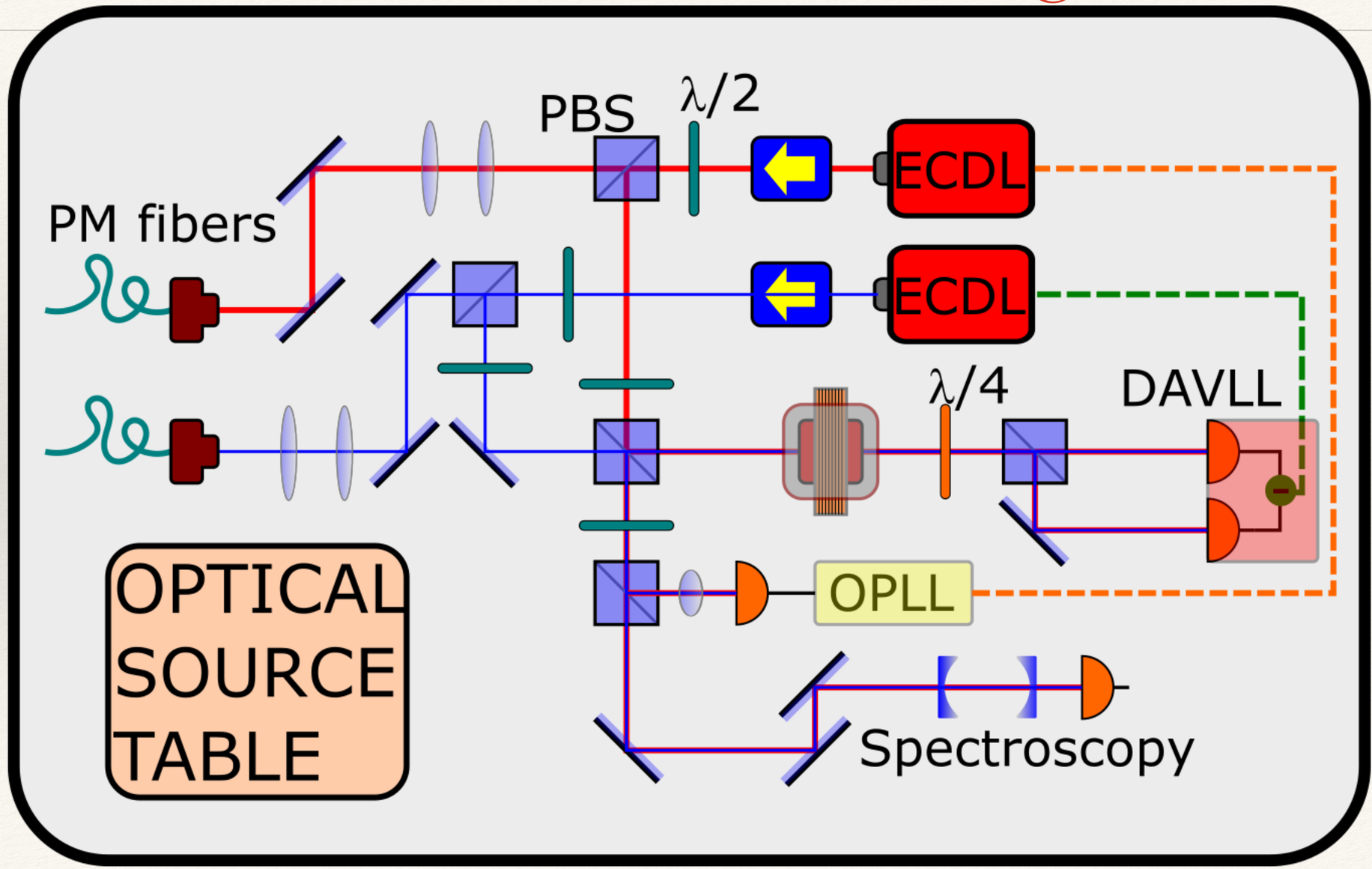
Oversized “desk” from Engineering Student Society

The *Quantum Teaching Lab*



A Smattering of QTL Projects

- Dichroic Atomic Vapour Laser Lock
- Optical Metamaterials
- Photon Entanglement Generation
- FPGA based laser Feedback
- Improved Muon Lifetime
- Pound Drever Hall Lock
- Spinning Waveplate Polarimeter
- Scanning Fabry Perot Cavity
- Custom Rubidium Cell Ovens
- External Cavity Laser Diodes
- Laser Drivers
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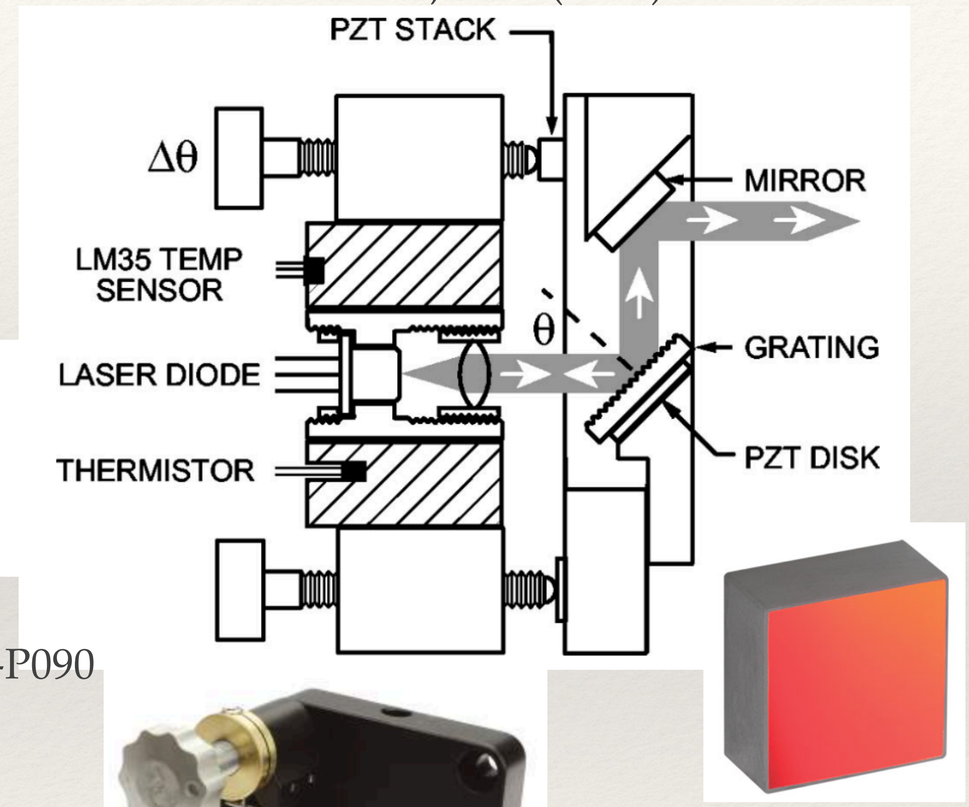
Custom External Cavity Diode Lasers

Hawthorn, et al Rev. Sci. Instrum. **72**, 4477 (2001)

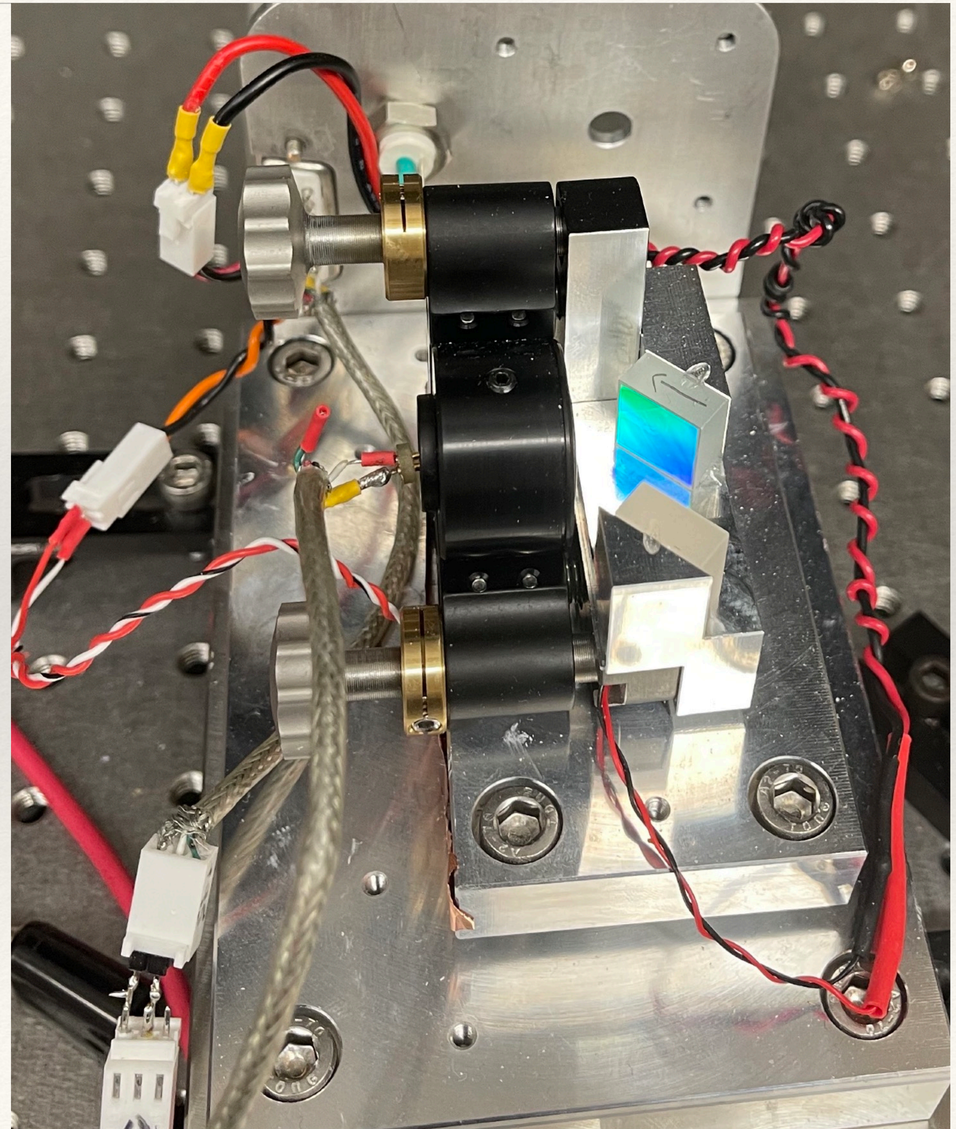
Thorlabs L785-P090



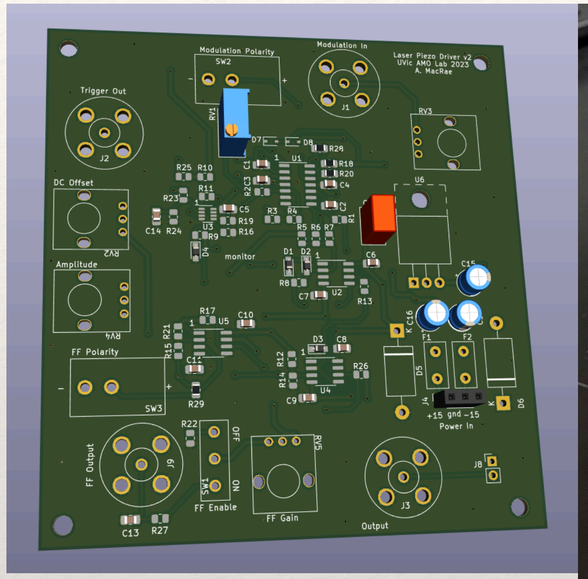
Thorlabs GH13-18V

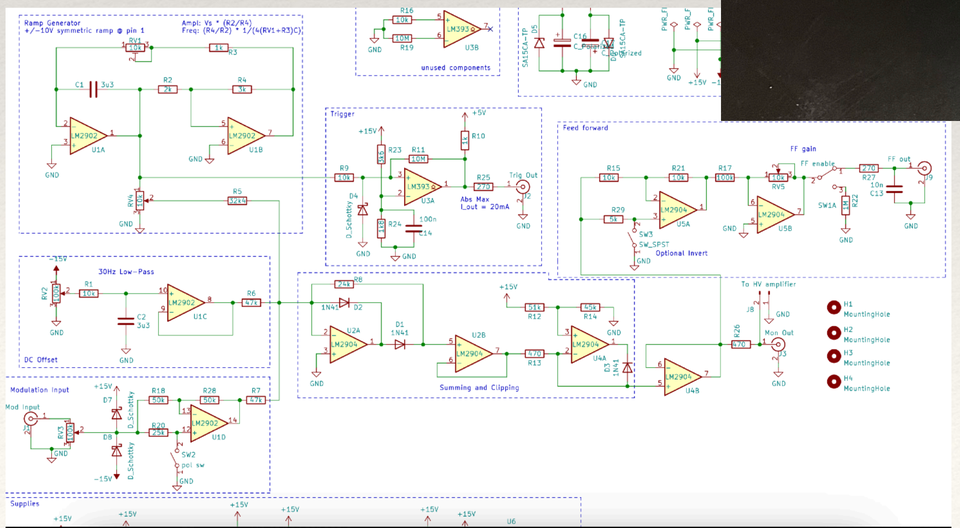
Newport

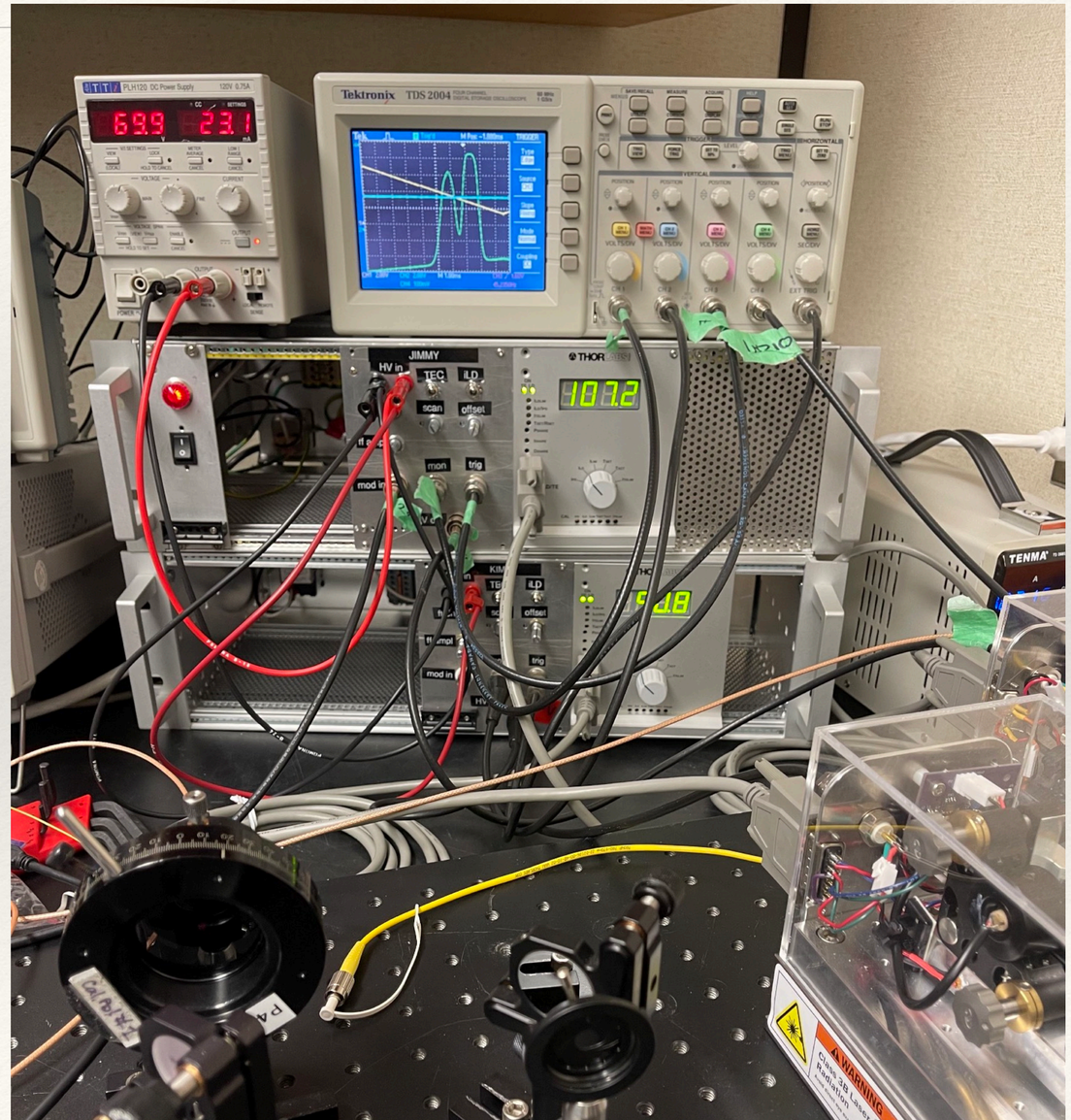
U100-P2K



Custom External Cavity Diode Lasers







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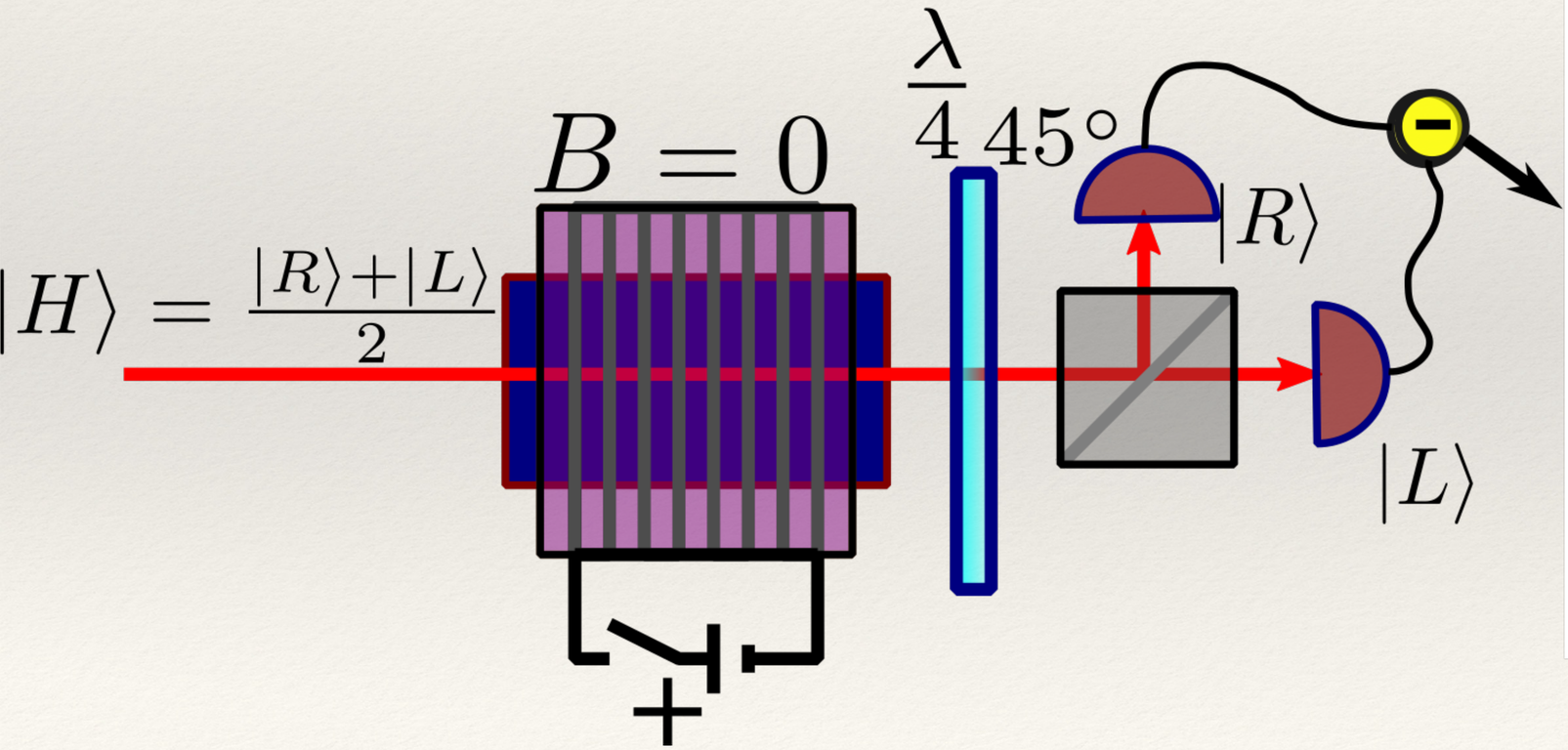
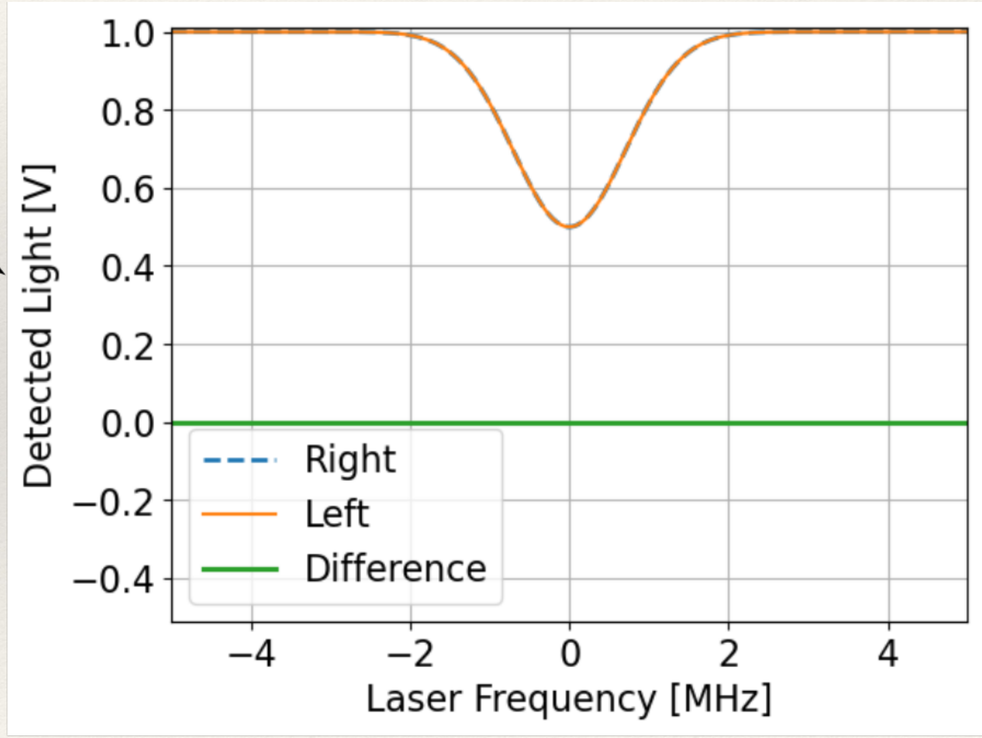
Goal: Stabilize Laser to an atomic Transition

Can exploit circular dichroism, induced by **B** field!





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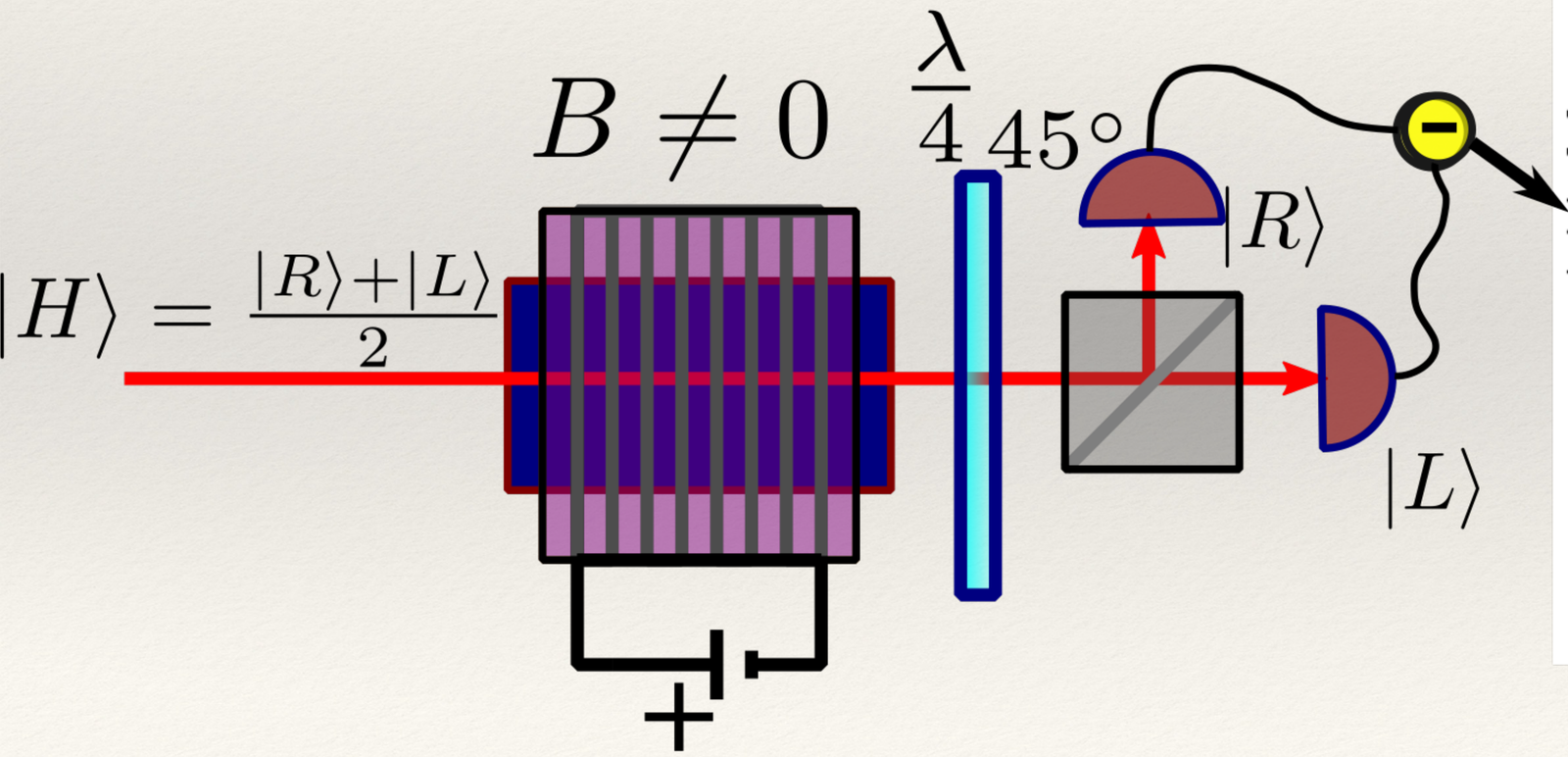

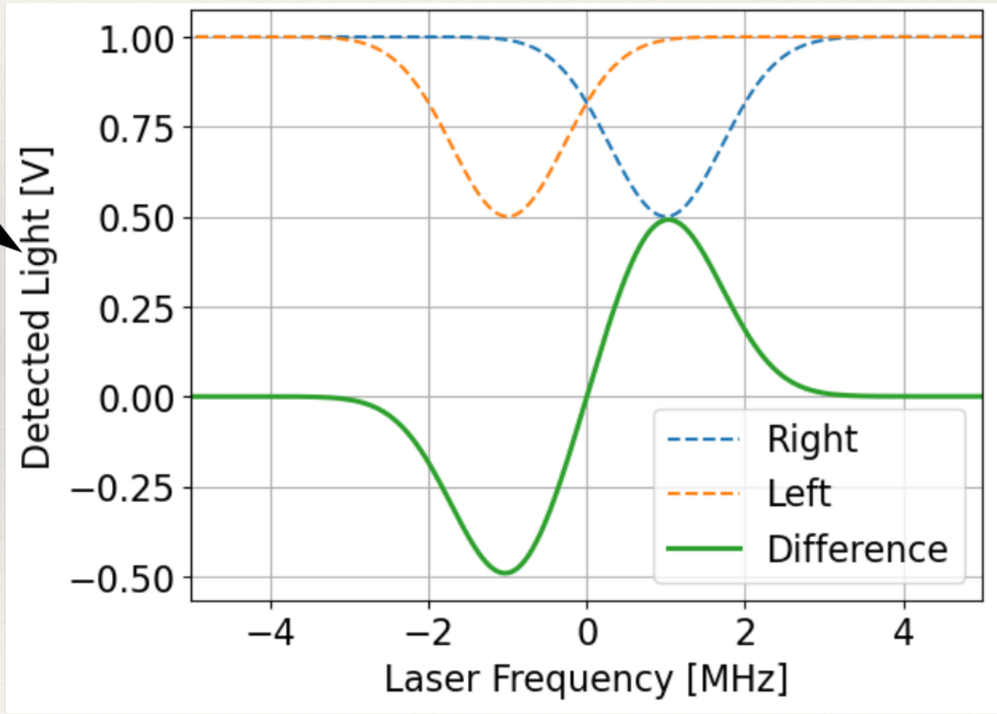

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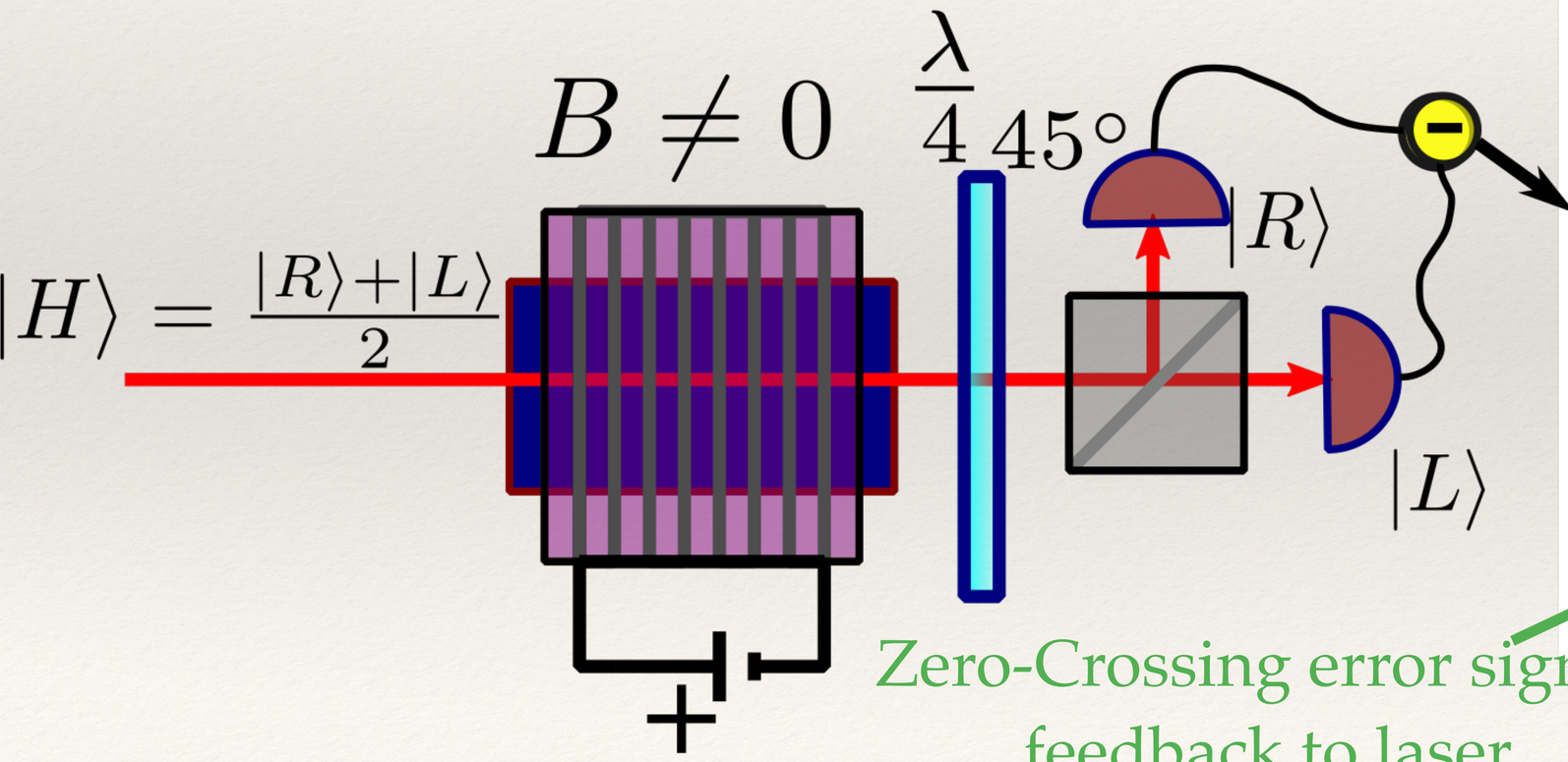
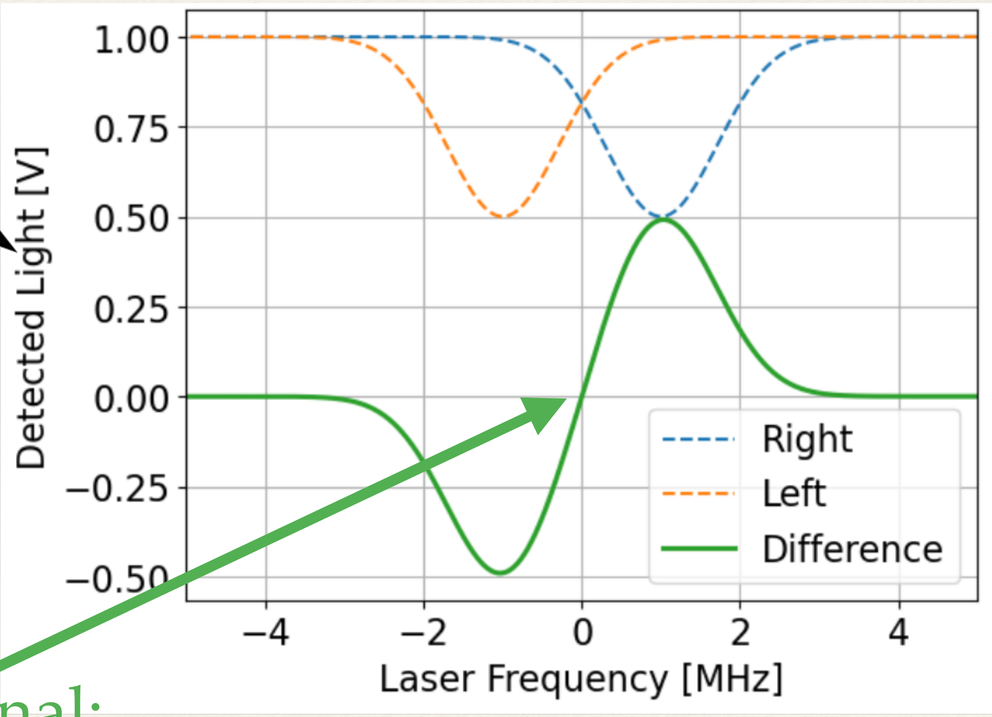
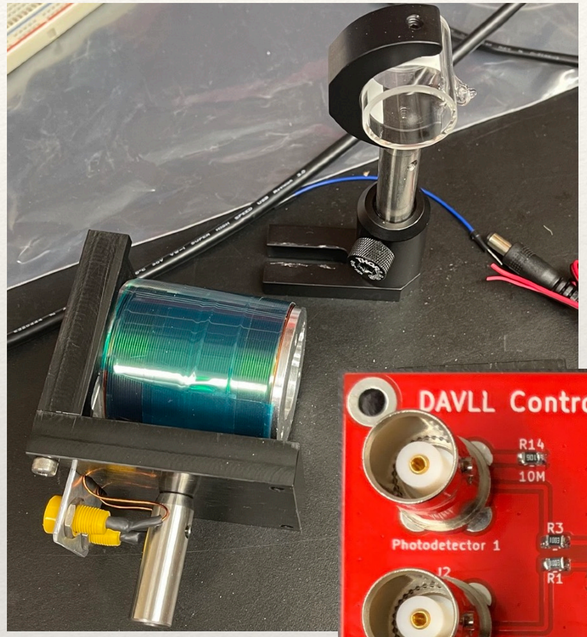
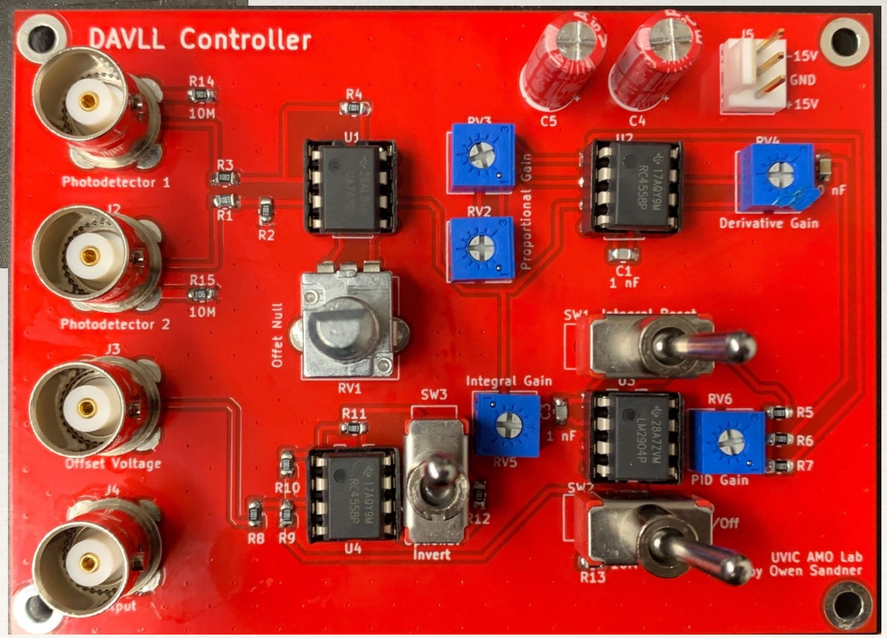




Zero-Crossing error signal: feedback to laser

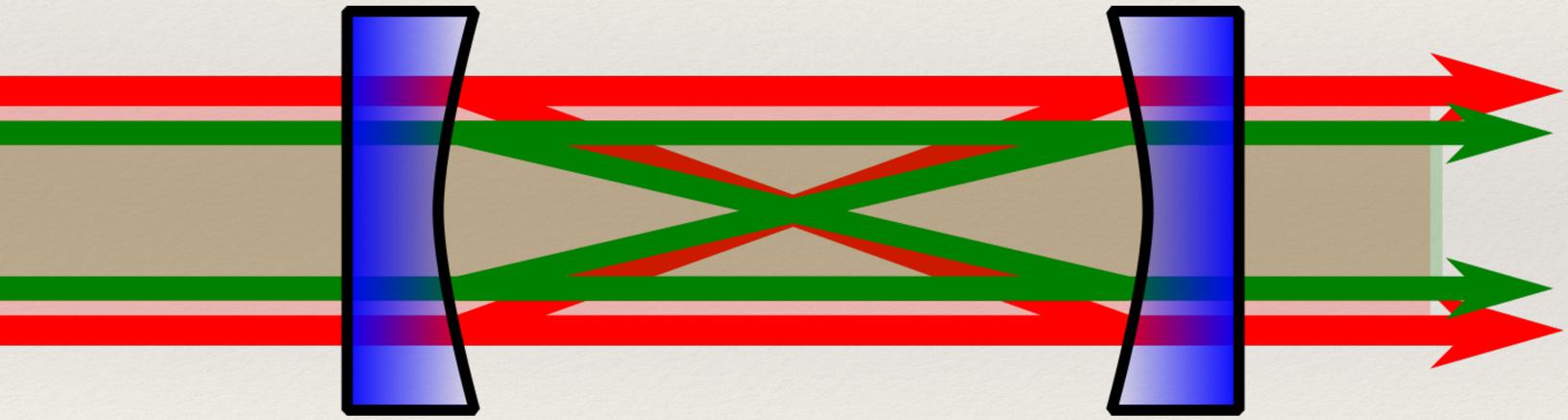
Dichroic Atomic Vapour Laser Lock

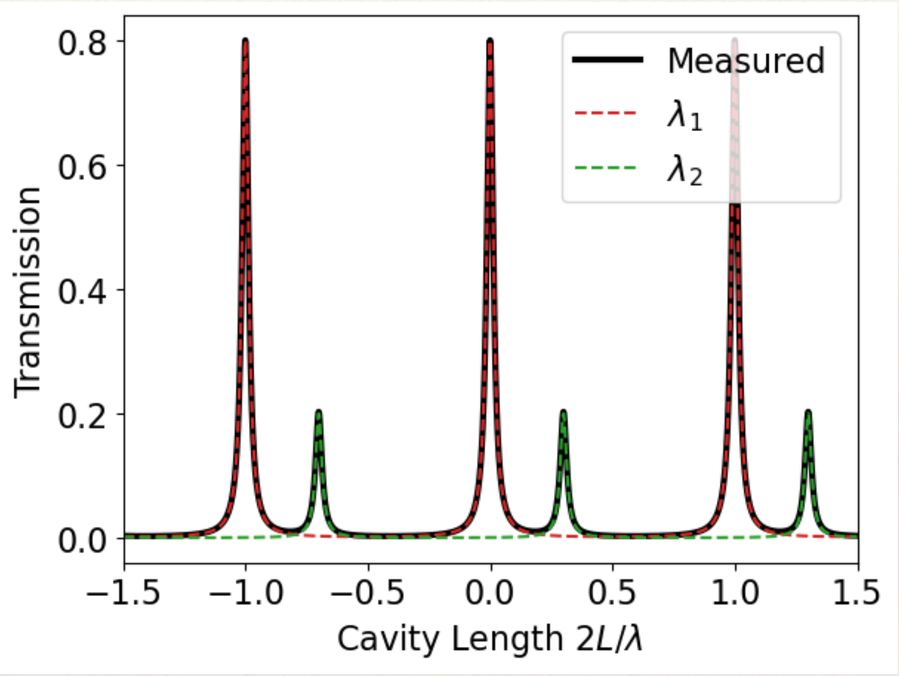




Scanning Fabry Perot Interferometer

Goal: Assess frequency content/stability of Lasers





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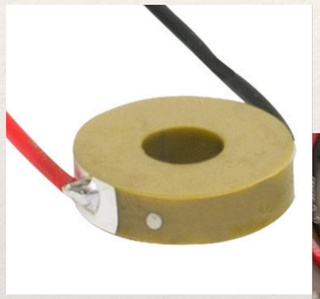
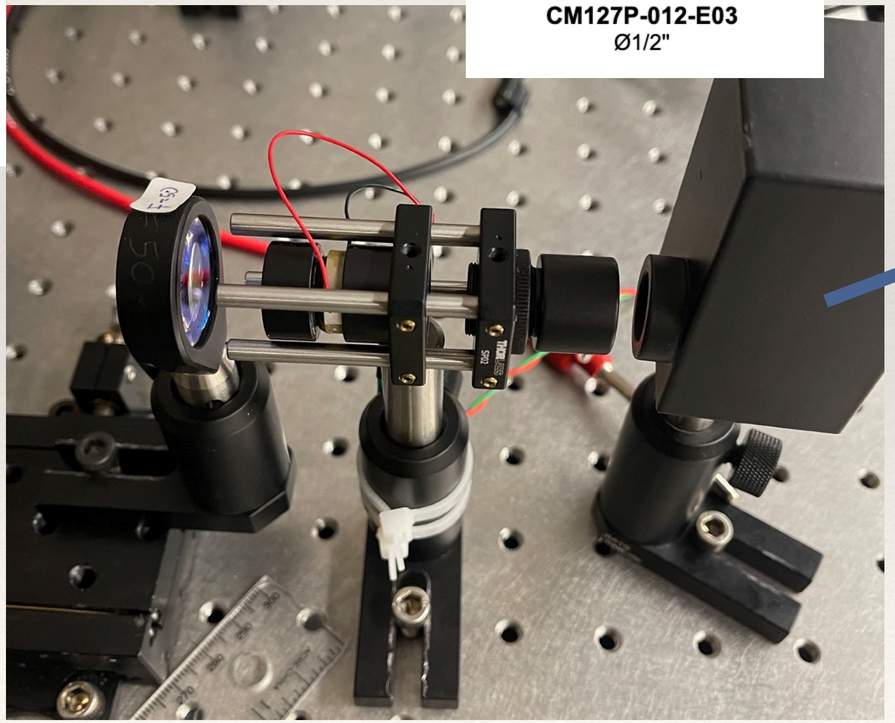
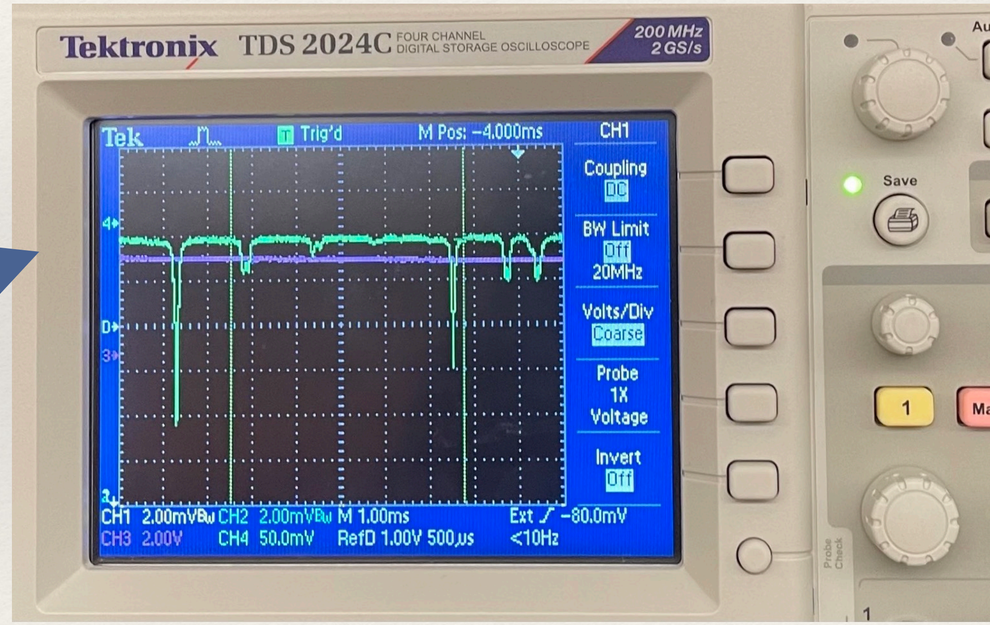


CM127P-012-E03
Ø1/2"





Spinning Waveplate Polarimeter

Goal: Visualize instantaneous state of polarization

Quantifying Polarization

Stokes Parameters

$$S_0 = I_H + I_V$$

$$S_1 = I_H - I_V$$

$$S_2 = I_+ - I_-$$

$$S_3 = I_R - I_L$$

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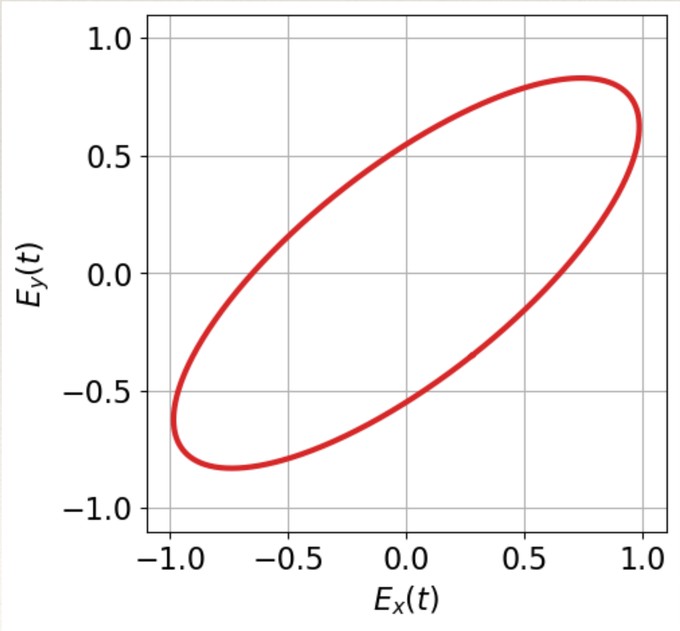

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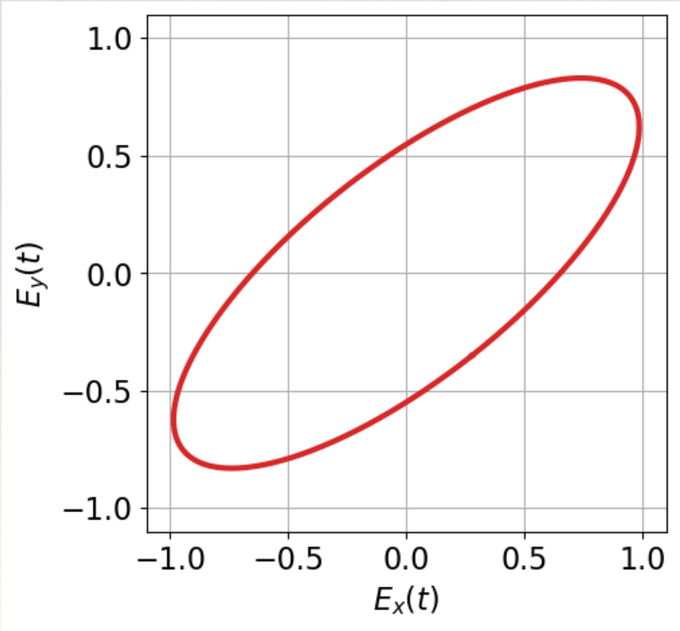
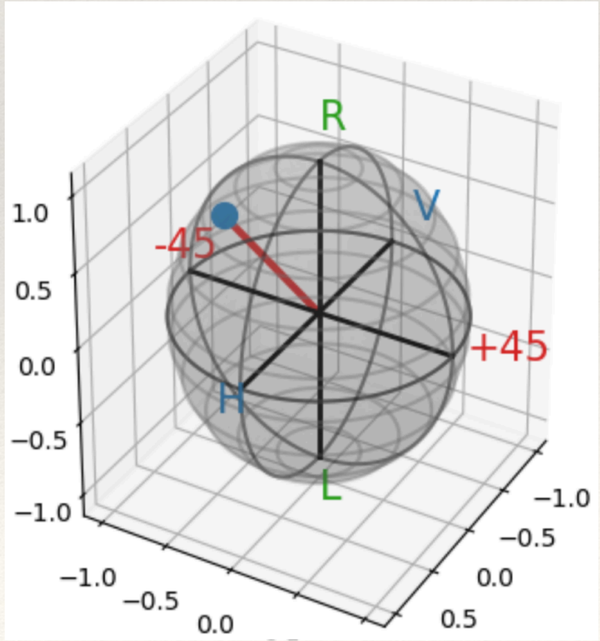


Poincaré Sphere



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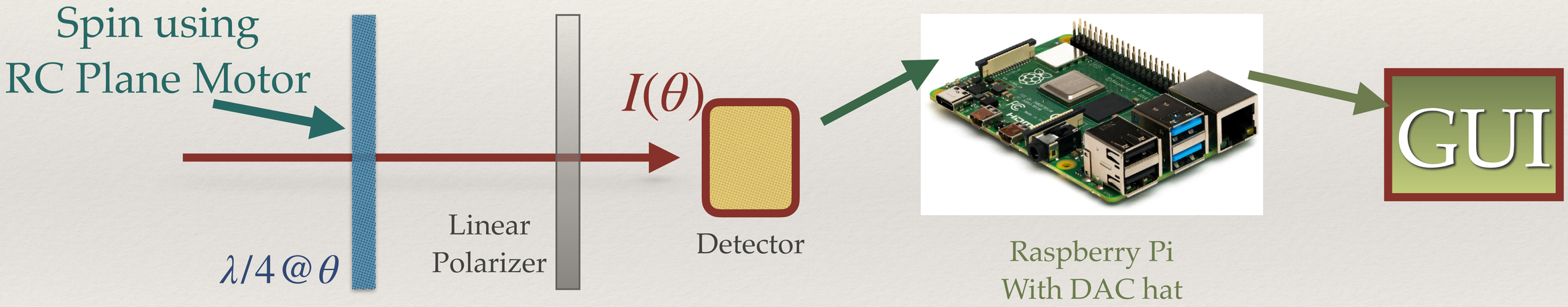
Measuring **S** with a Waveplate and Polarizer



$$I(\theta) = \frac{2S_0 + S_1}{4} + \frac{S_3}{2}\sin 2\theta + \frac{S_1}{4}\cos 4\theta + \frac{S_2}{4}\sin 4\theta$$

H. G. Berry, G. Gabrielse, and A. Livingston, Applied optics 16, 3200 (1977)

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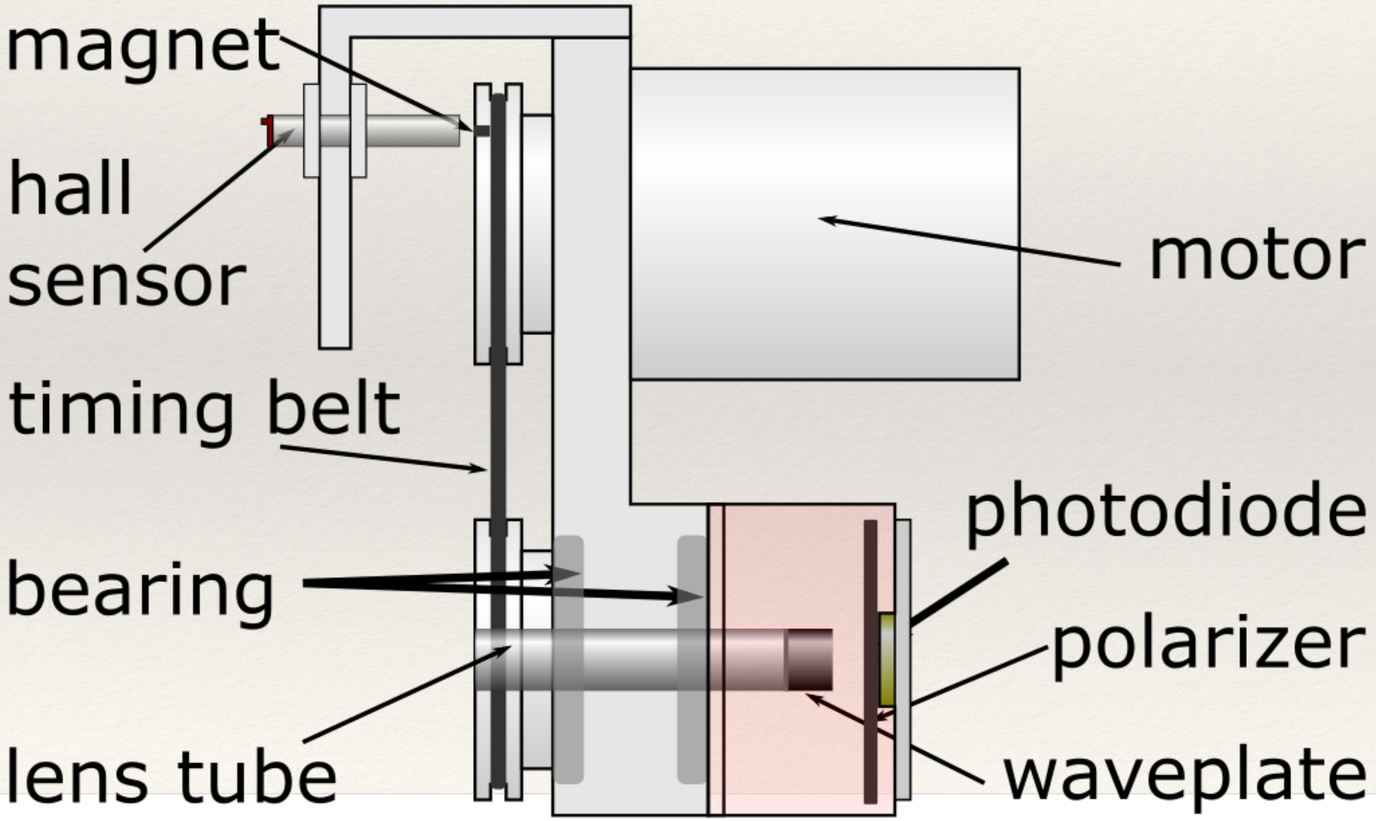
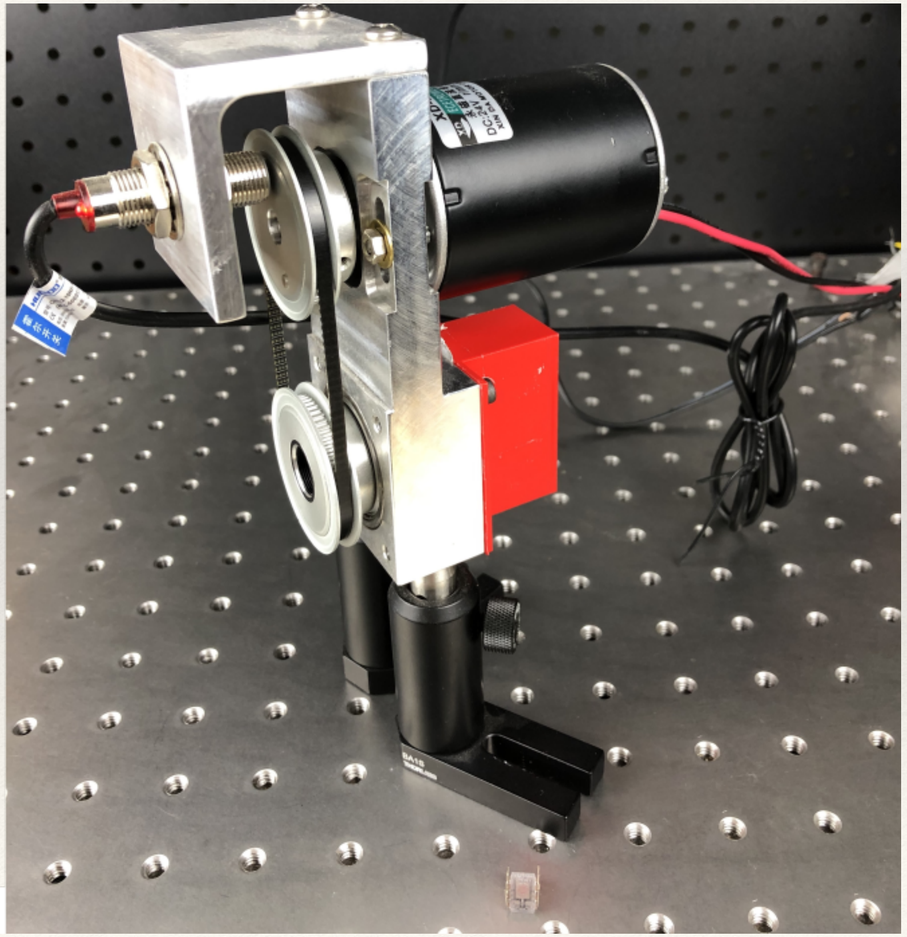


b)



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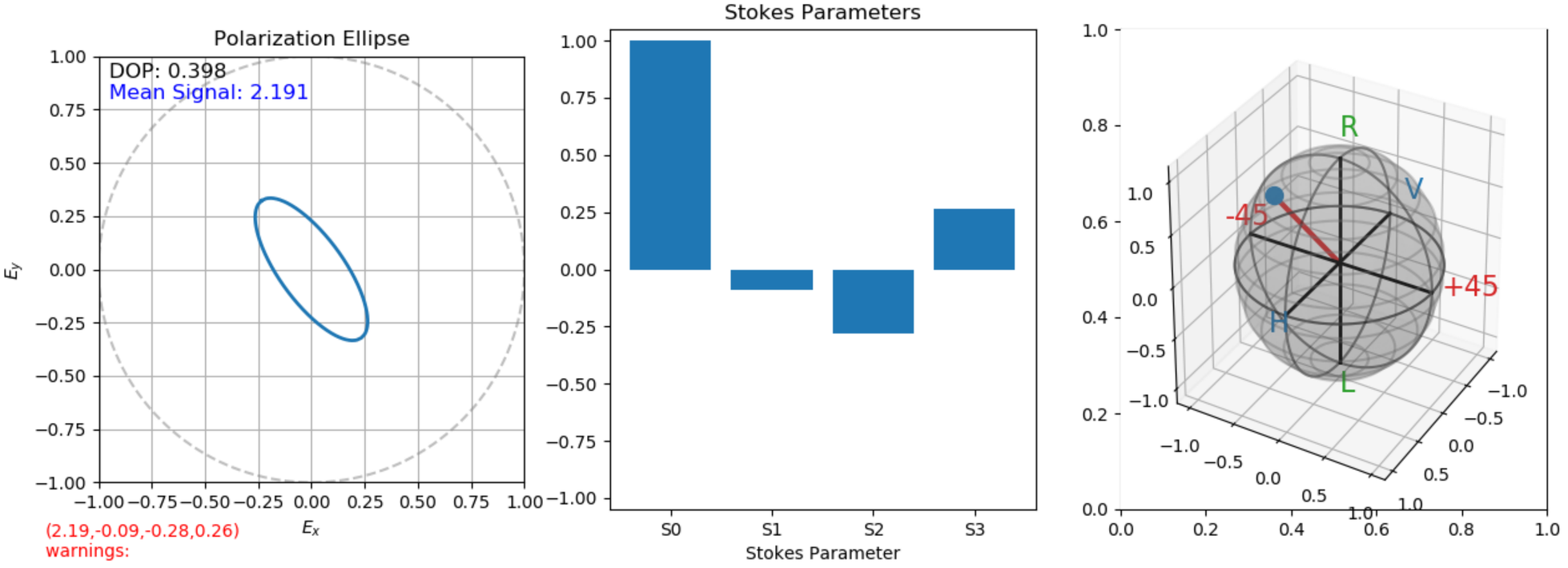

Spinning Waveplate Polarimeter

Portable Real-Time Polarimeter: for Partially and Fully Polarized Light

Scott Wilkinson, Aydan McKay, Nicolas Braam, Chris Secord, and Andrew MacRae*
Department of Physics and Astronomy, University of Victoria, British Columbia, Canada
(Dated: February 11, 2021)

We present a spinning waveplate polarimeter capable of producing real-time visualization of the polarization state of completely or partially polarized light. Our system utilizes a Raspberry Pi computer for a fully online, real-time analysis and visualization of the polarization state. This completely integrated approach provides an efficient tool for modern optics research labs and is well-suited for educational demonstrations.

I. INTRODUCTION

Optical polarization plays a key role in the quantification of numerous physical processes with applications in Atomic and Molecular Optical Physics [1], Astronomy [2], Imaging [3], and Material Science [4]. Monitoring the polarization of time dependent light from a process can reveal insight into a physical system. Furthermore, several optical technologies, such as optical isolators and photonic waveguides require a precise tuning of the input polarization state. Having a portable, real-time po-

The polarization ellipse evolves at optical frequencies of hundreds of THz, and thus can not be imaged directly, but can be completely specified by the *Stokes parameters*. Denoting $I_{H(V)}$, $I_{+(-)}$, and $I_{R(L)}$ as the intensity of the Horizontal(Vertical), $+45°(-45°)$, and Right(Left) circular polarizations respectively, these parameters are given by [5]:

$$S_0 = \langle E_x E_x^* \rangle + \langle E_y E_y^* \rangle \quad = I_H + I_V \quad (2a)$$
$$S_1 = \langle E_x E_x^* \rangle - \langle E_y E_y^* \rangle \quad = I_H - I_V \quad (2b)$$

arXiv:2102.06114 (2021)

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  - Outreach & Industry (Observatory Outreach, Software Dev, Government)

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  - Laser Safety and alignment (Paraskevi Lagaditis)

The 2023 QTL Group

Hayden Snauwaert Owen Sandner Arsh Singh Will Stokes Brendan Mackey Zaina Siddiqui

Jamal Khani Sajjad Kashani AM Rowan Meronek Matt Newton Diana Gao Ash Enefer