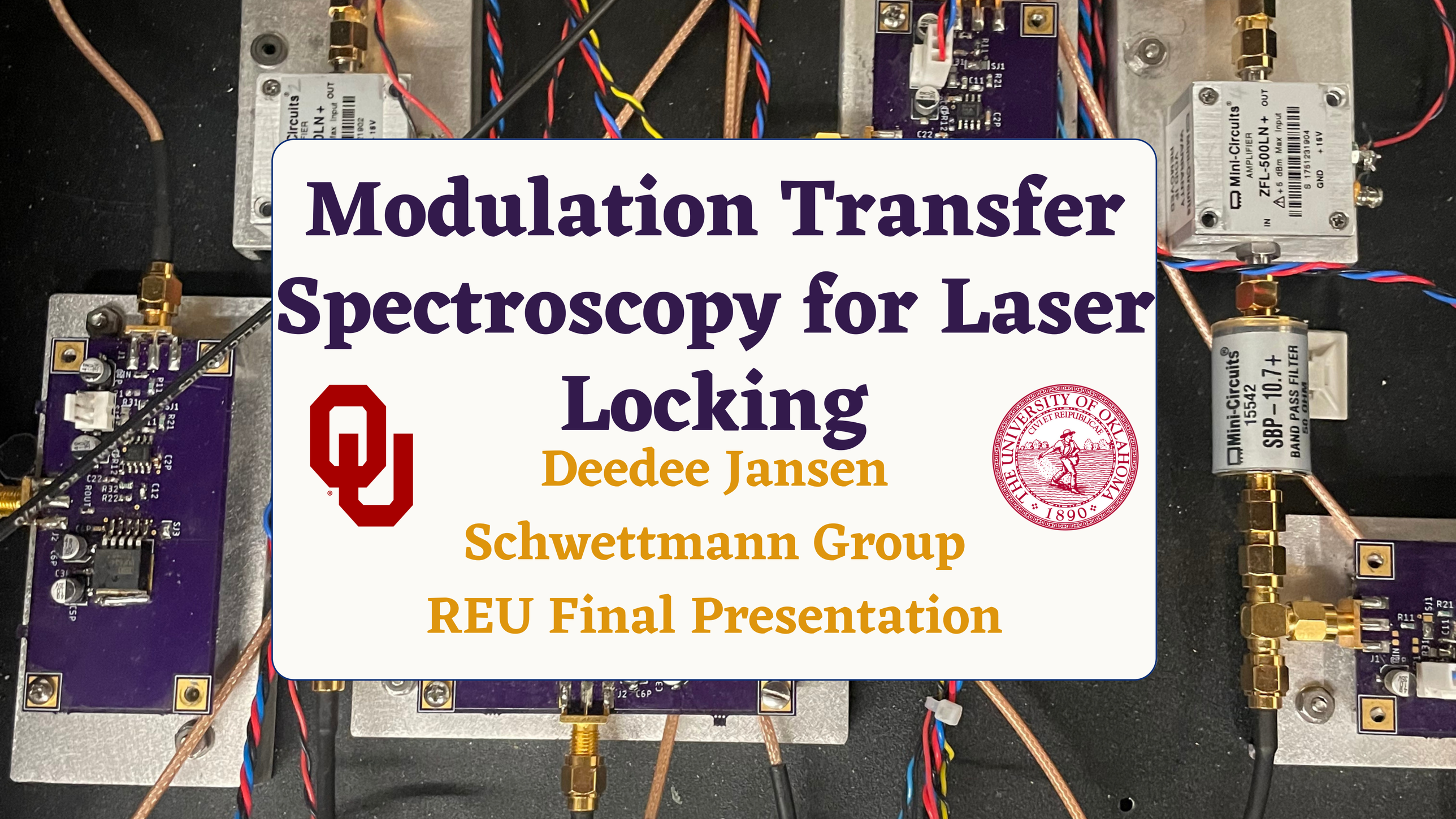
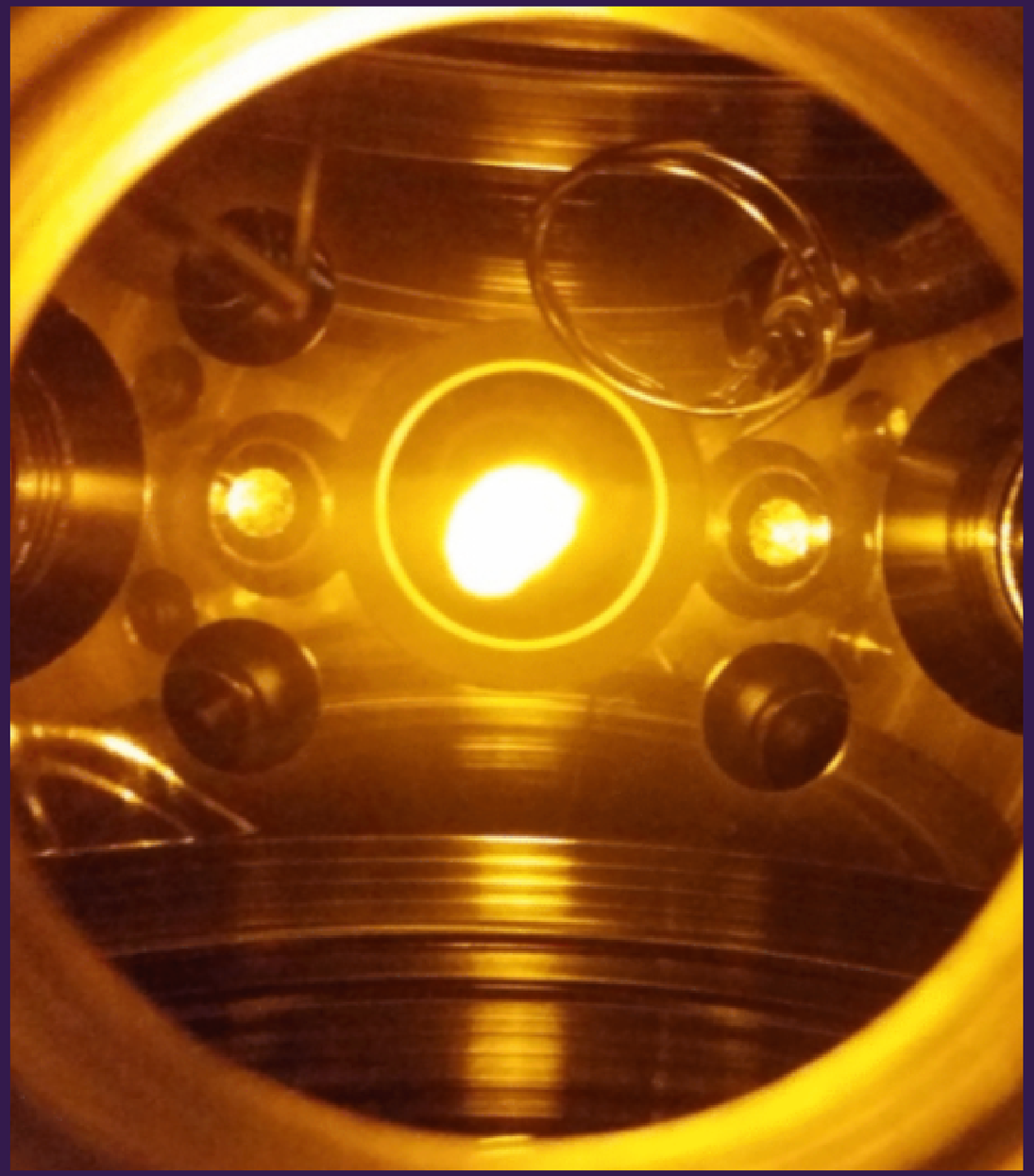


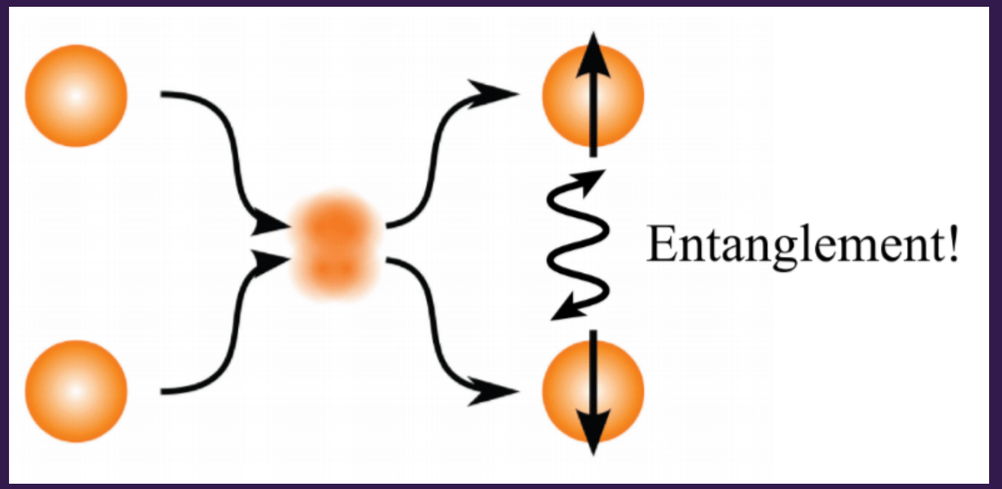
Modulation Transfer Spectroscopy for Laser Locking

Deedee Jansen

Schwettmann Group

REU Final Presentation



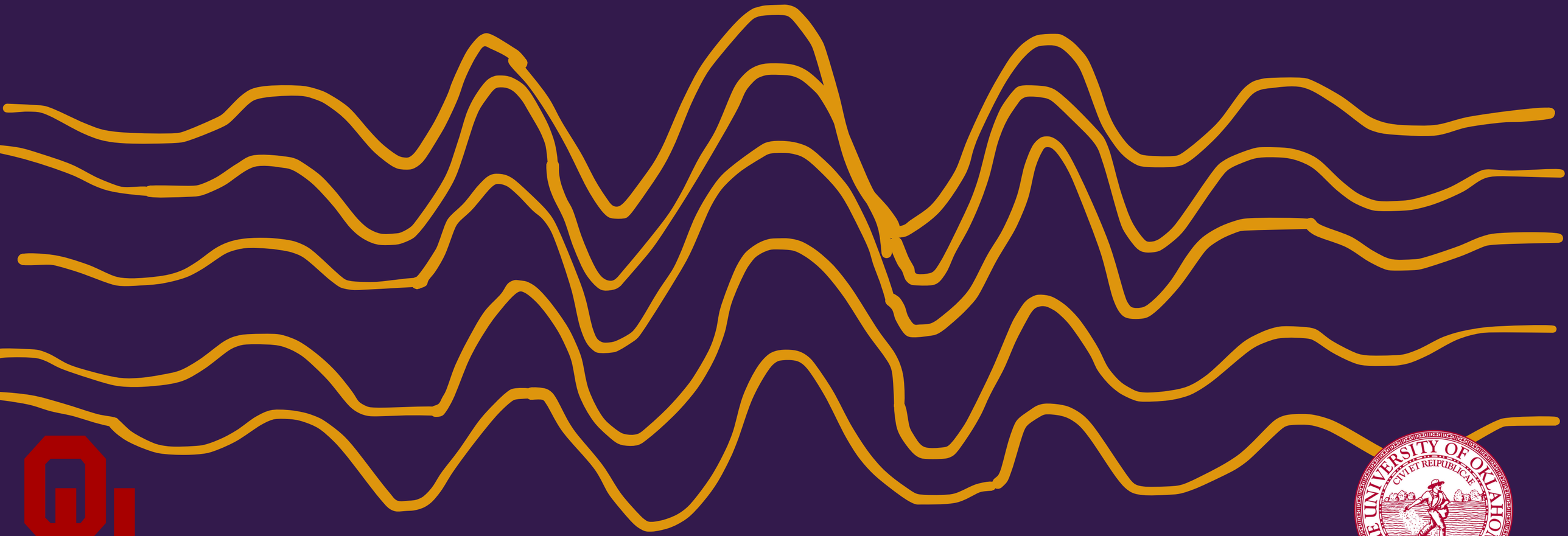


- Ultra Cold Gases of Sodium
- Spin Exchange Collisions are Controllable
- Reduced errors in measurements

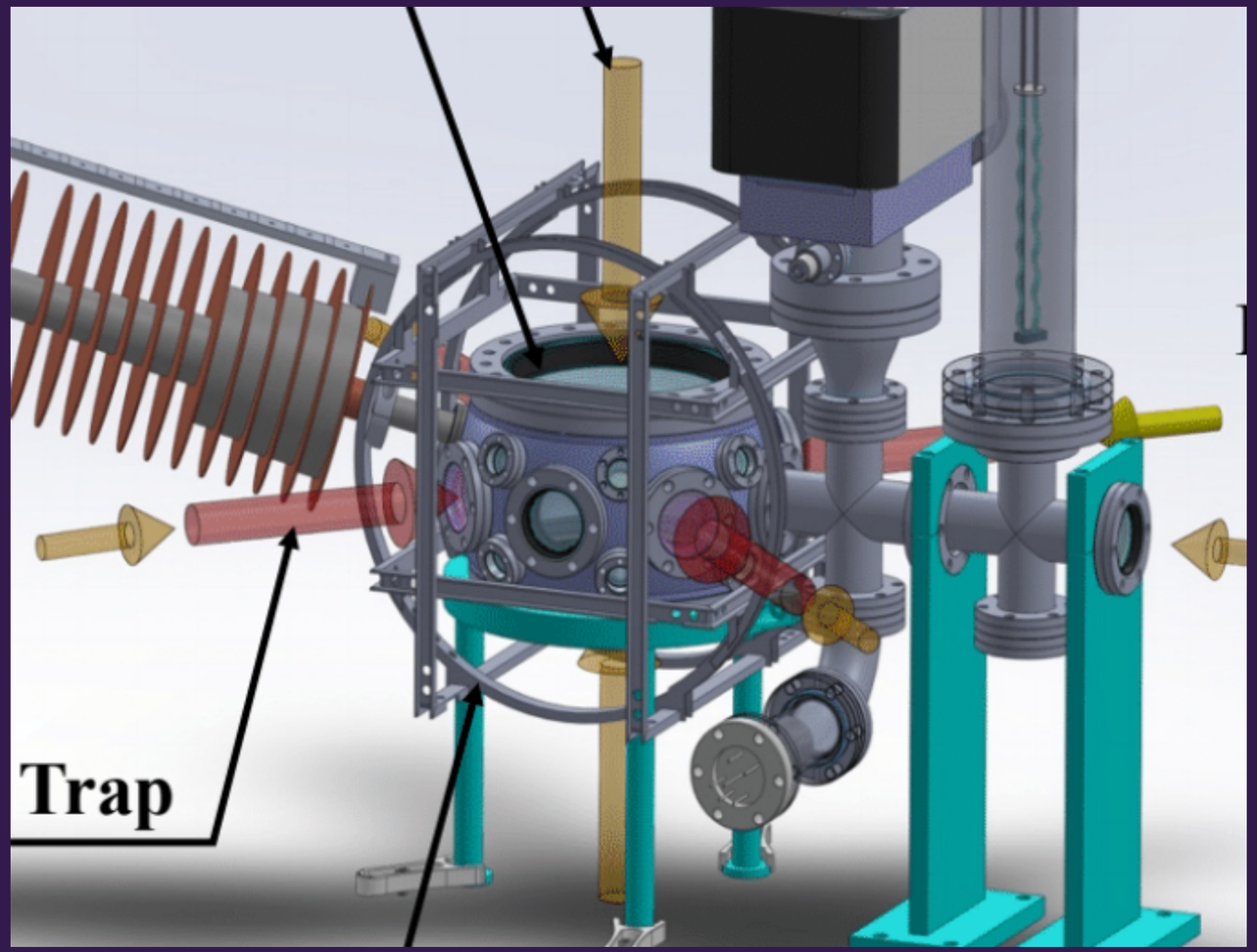
S. Zhong, H. G. Ooi, S. Prajapati, Q. Zhang, and A. Schwettmann, "Seeded spin-mixing interferometry with long-time evolution in microwave-dressed sodium spinor Bose-Einstein condensates," J. Phys. B: At. Mol. Opt. Phys. 56, 085502 (2023).

Giant Coherent Matter Wave

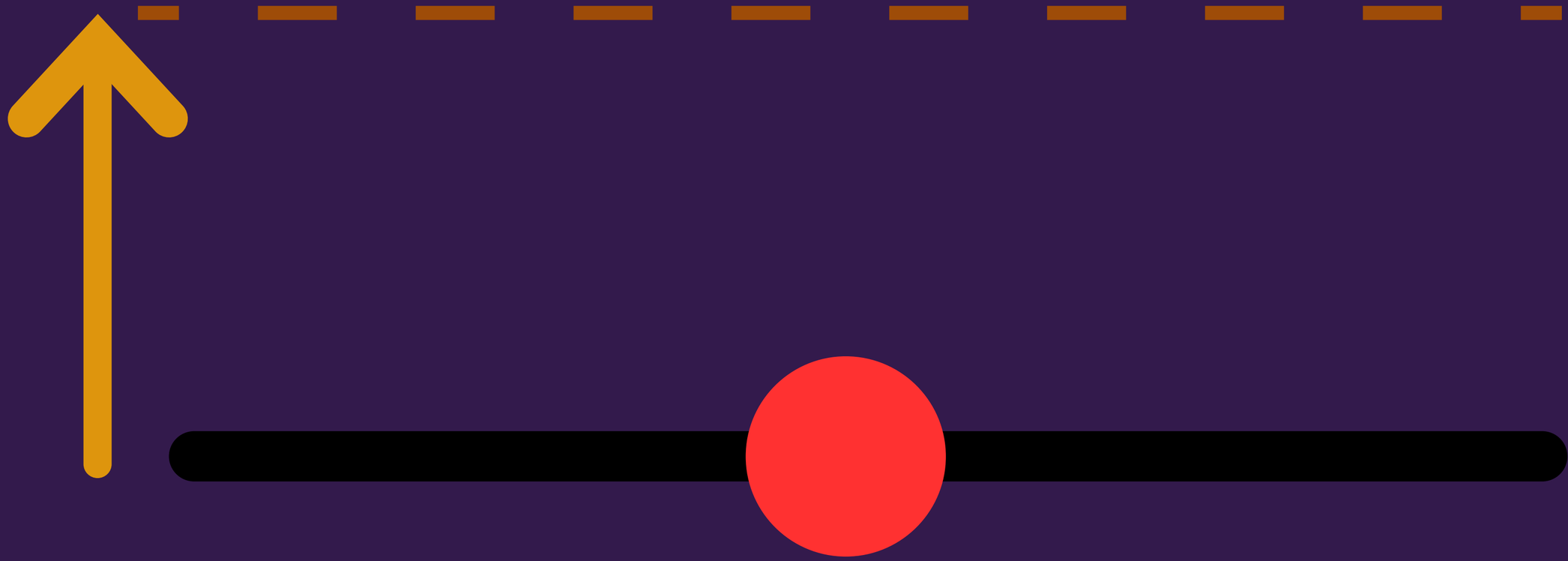
Giant Coherent Matter Wave



Magneto-Optical Trap (MOT): Doppler Cooling and Magnetic Field

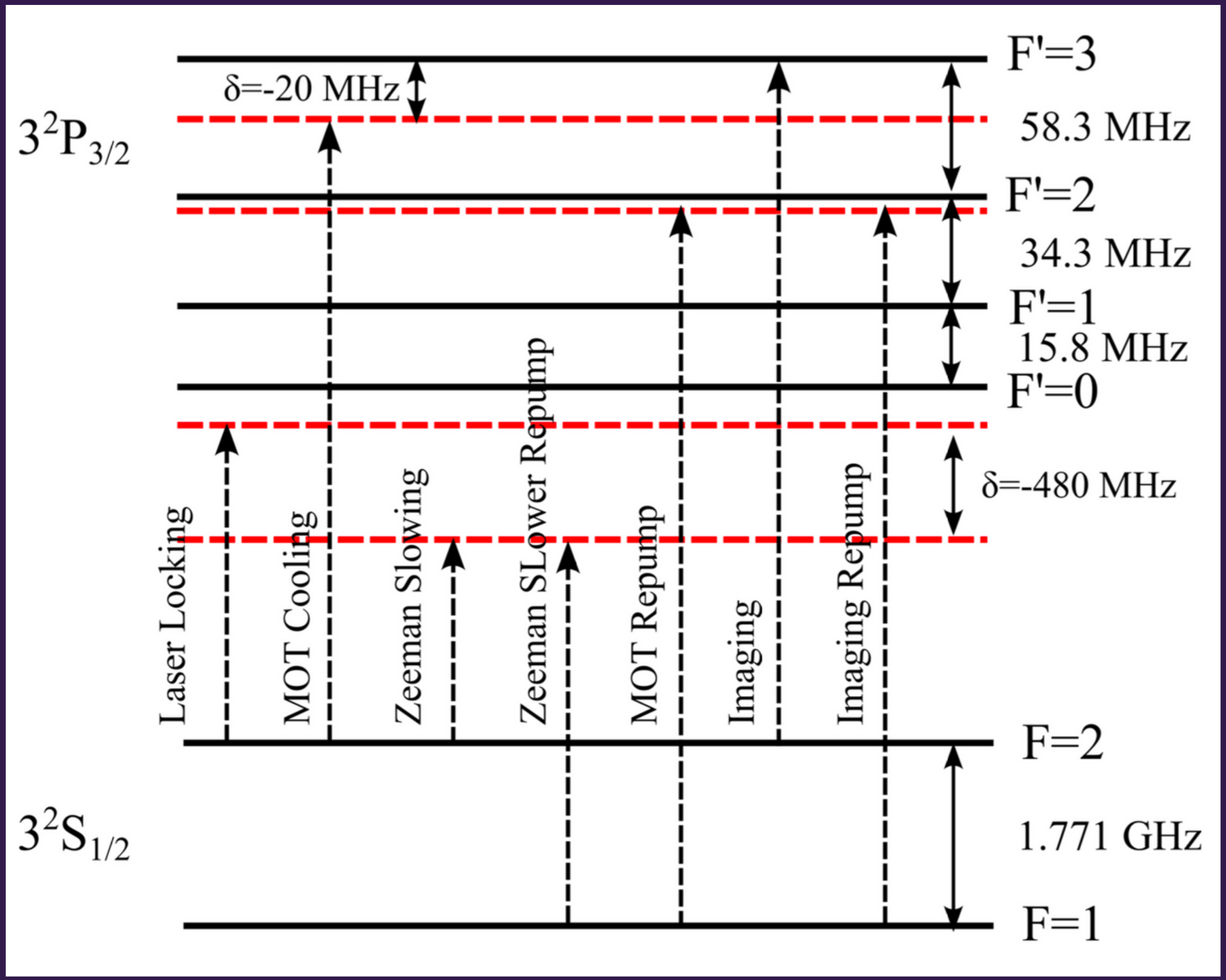


1st Excited State



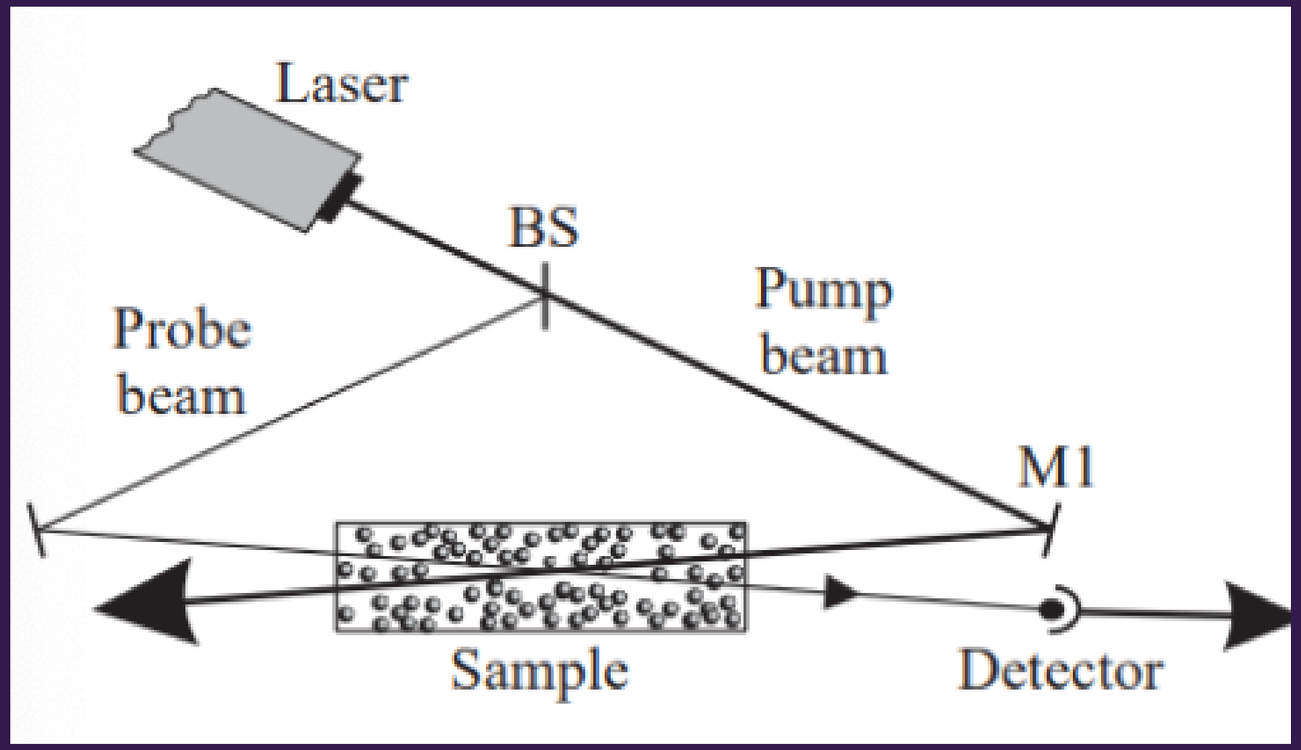
Energy Gap that Determines Color

Sodium - Orange (589 nm)


$3^2P_{3/2}$
F'=3
δ=-20 MHz
58.3 MHz
F'=2
34.3 MHz
F'=1
15.8 MHz
F'=0
δ=-480 MHz
Laser Locking
MOT Cooling
Zeeman Slowing
Zeeman SLower Repump
MOT Repump
Imaging
Imaging Repump
F=2
1.771 GHz
F=1
$3^2S_{1/2}$

Modulation Transfer Spectroscopy (MTS)

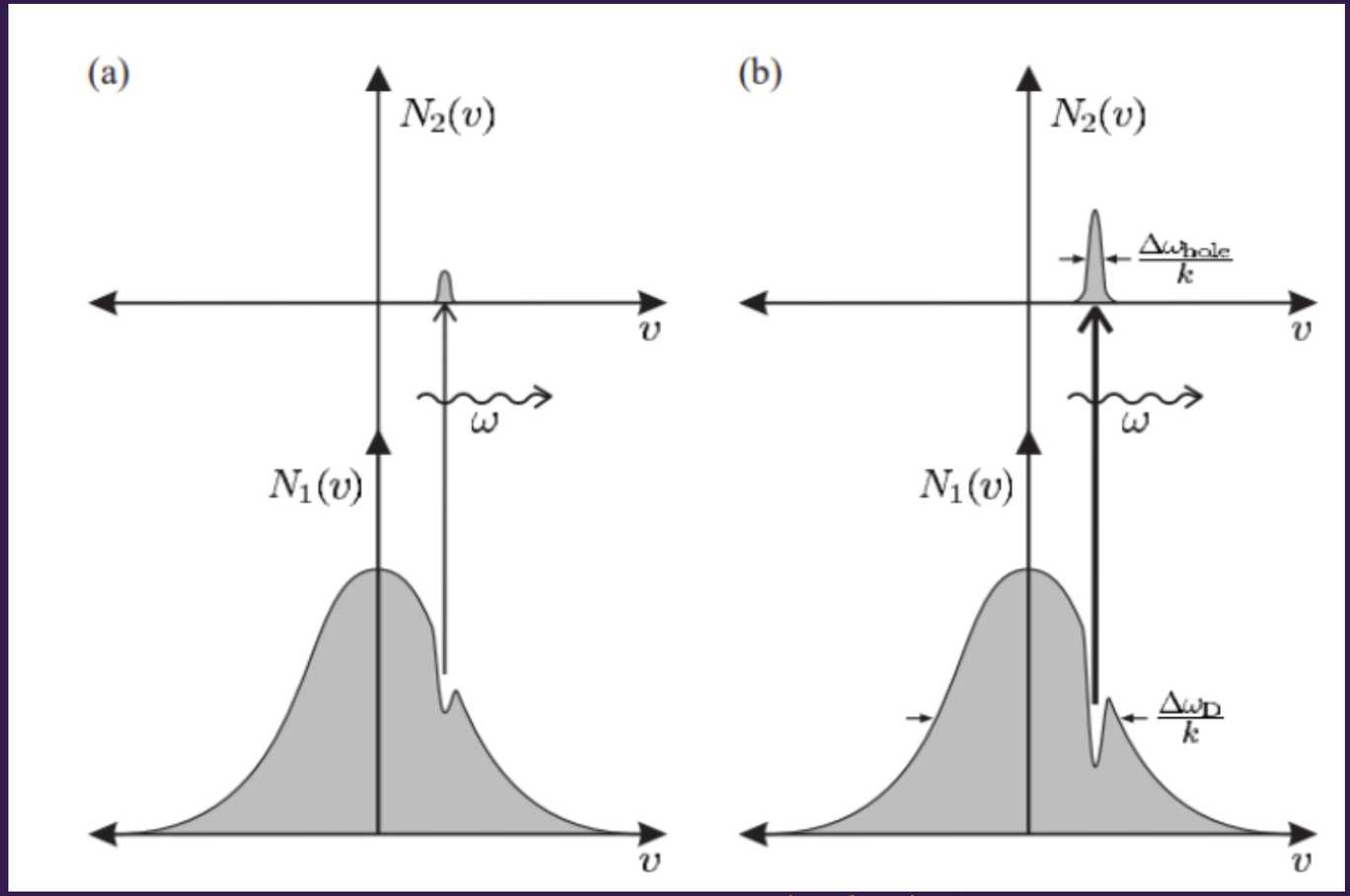
Movement from SAS to MTS



From C. Foot, "Atomic Physics"

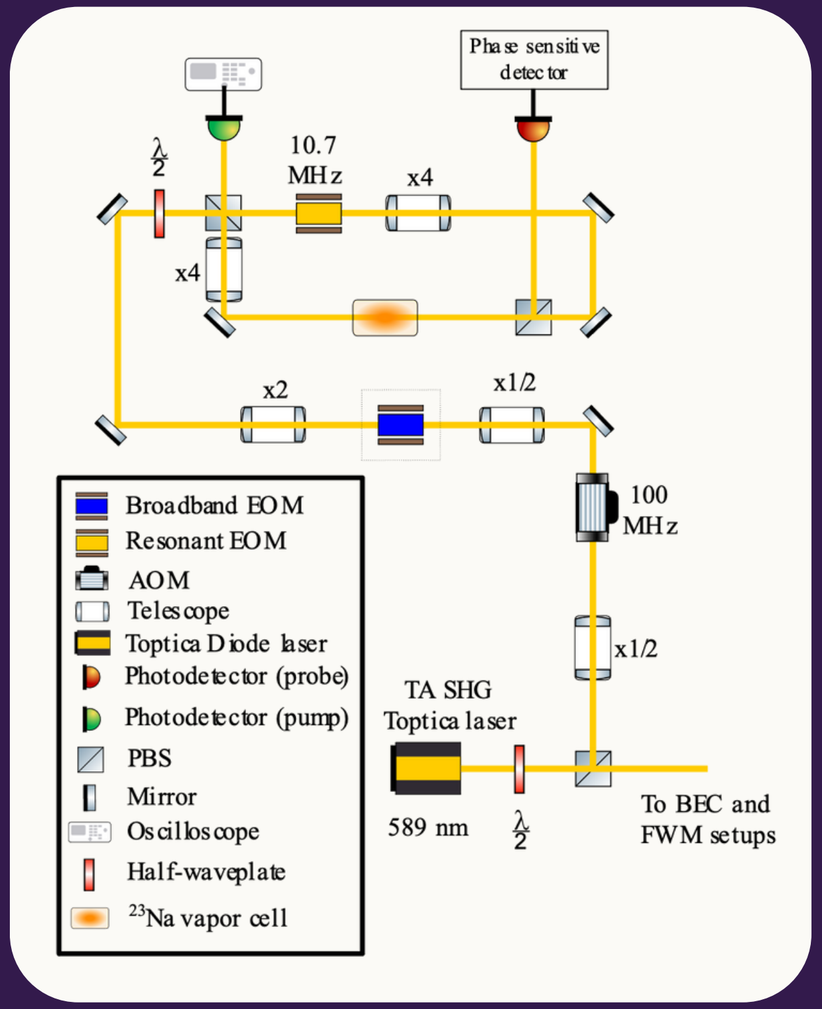
D. J. McCarron, S. A. King and S. L. Cornish, Meas. Sci. Technol. 19 105601 (2008)

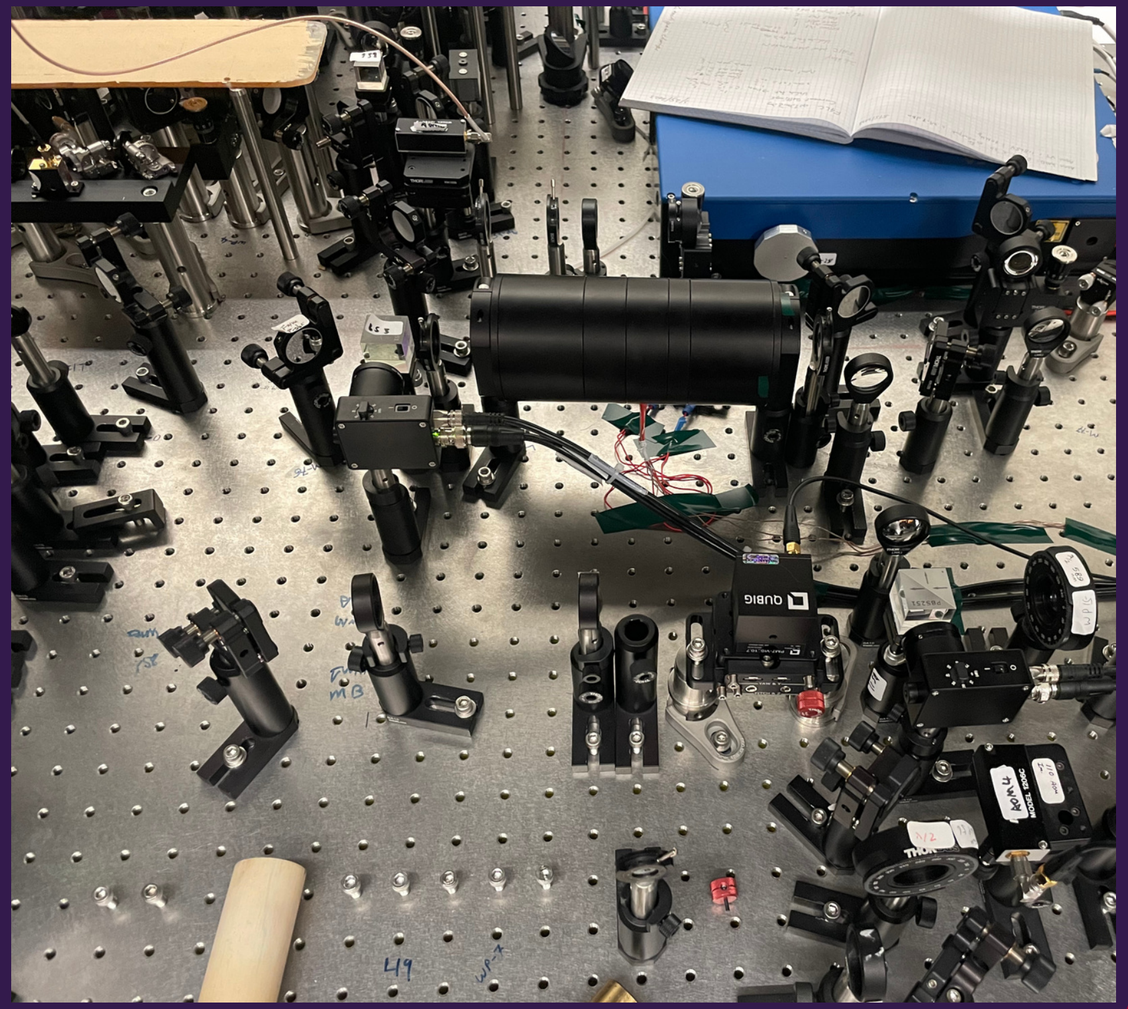
How it Works



From C. Foot, "Atomic Physics"

The Optics

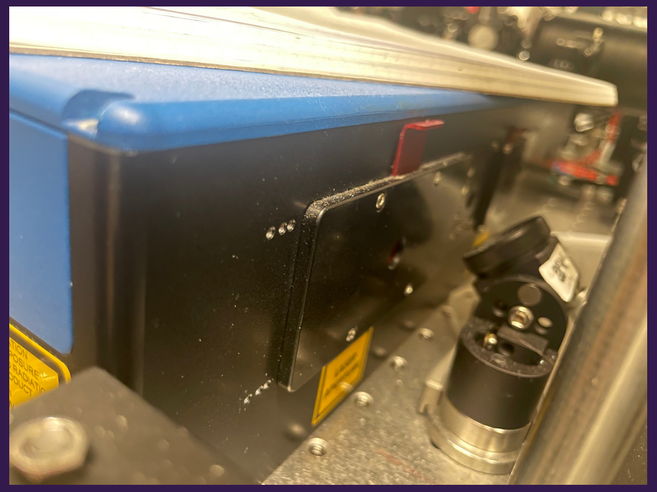


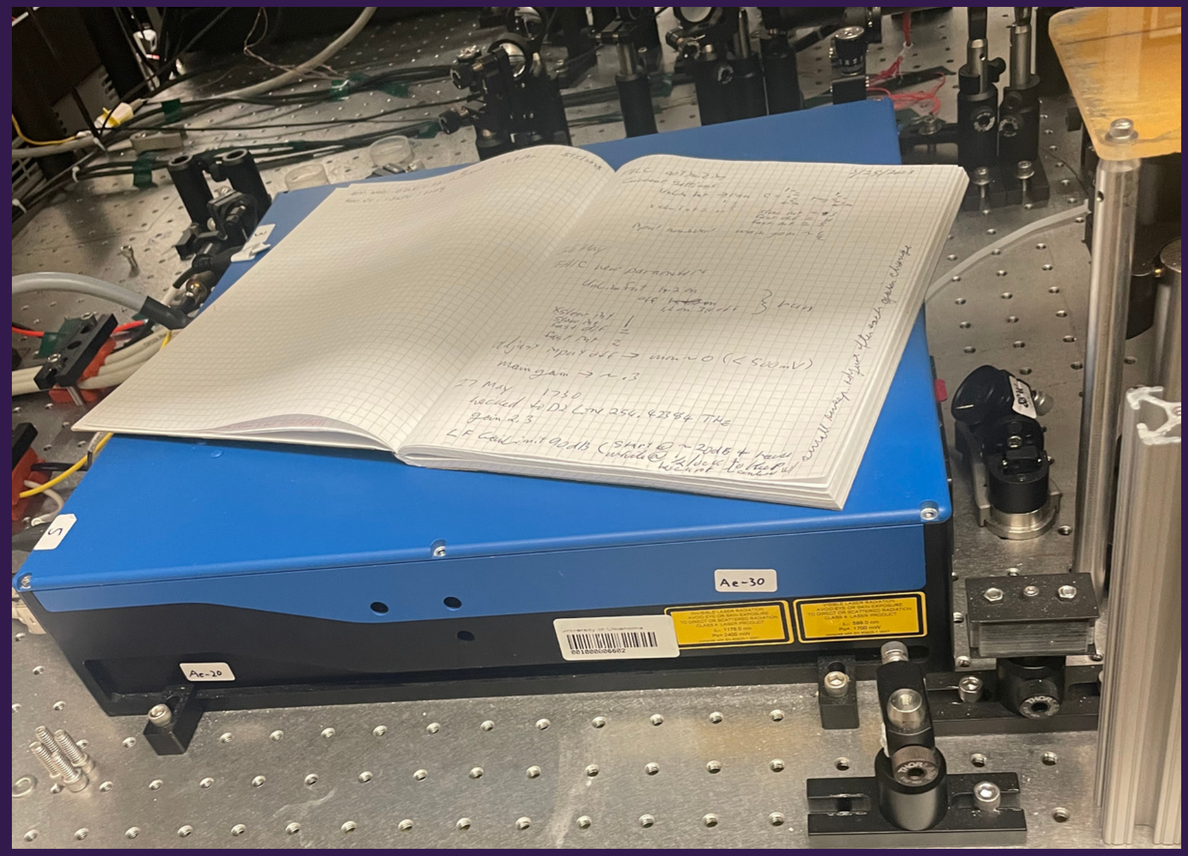


H. G. Ooi, A Dynamic Locking System for Bose-Einstein Condensation and Four-Wave Mixing Experiments

LASER

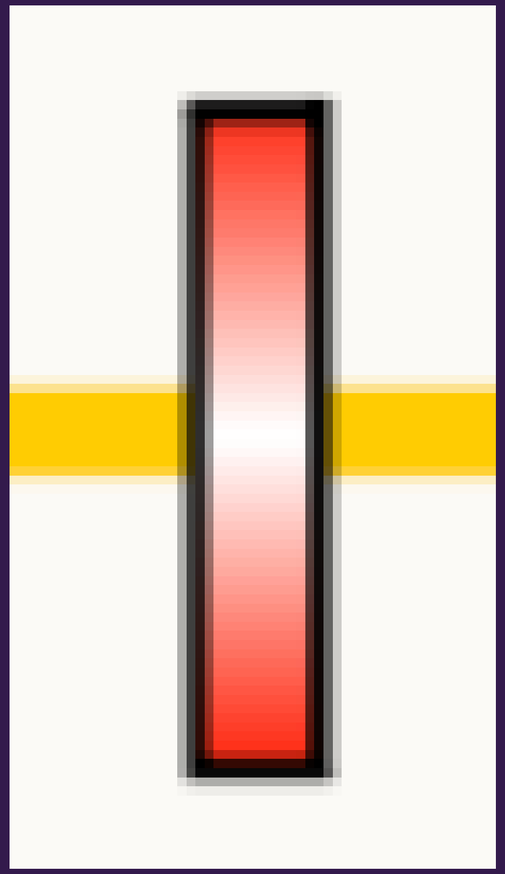
Our TOPTICA SHG 589 nm laser (1 Watt CW)
The beam waist of the light beam generated from the laser is ~2 mm

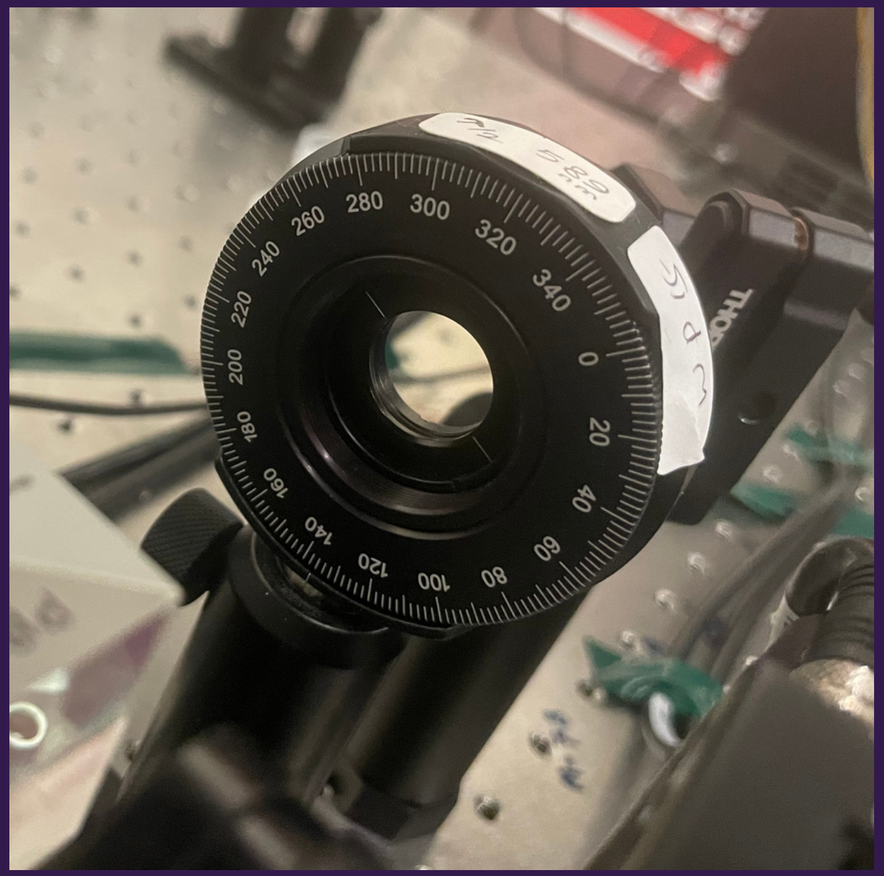




Half-Waveplate

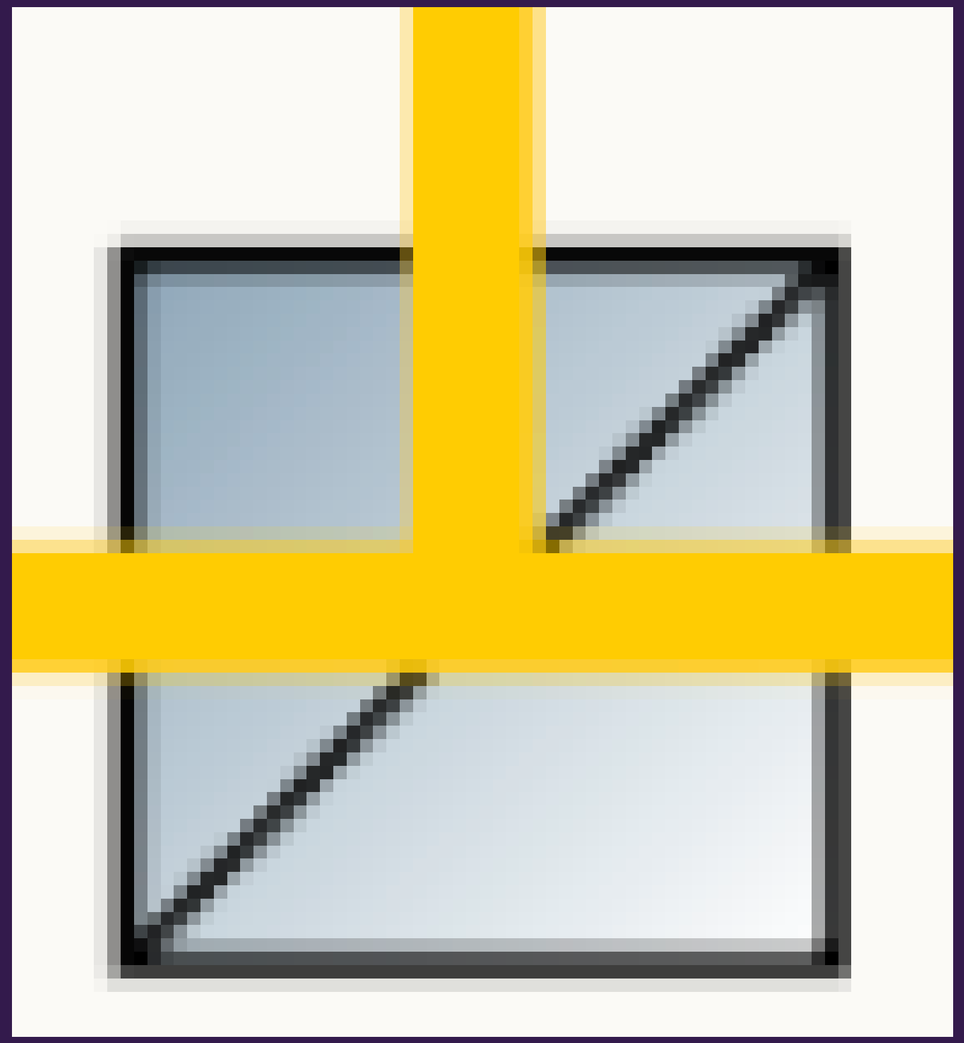
Rotates the linear polarization of the light
Controls intensity of beams when used with PBS

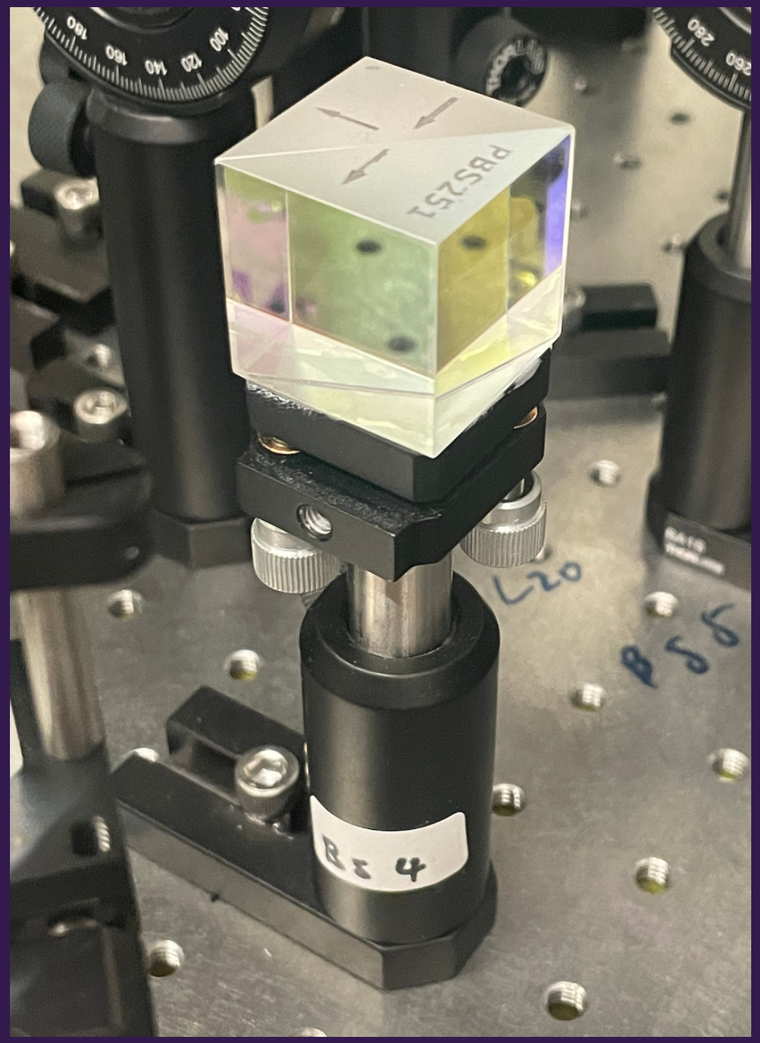




Polarizing Beam Splitter (PBS).

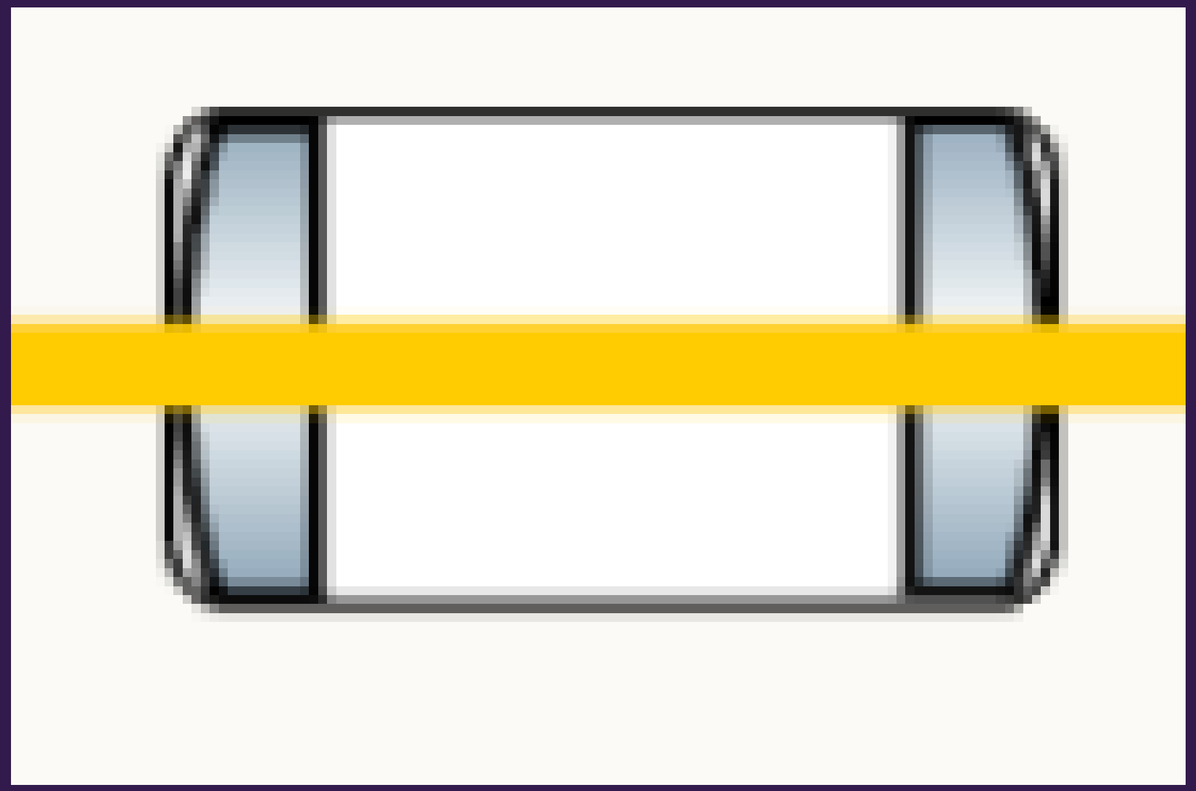
The beam is split into two beams, pump and probe beams
Intensity ratio can be adjusted with incoming polarization

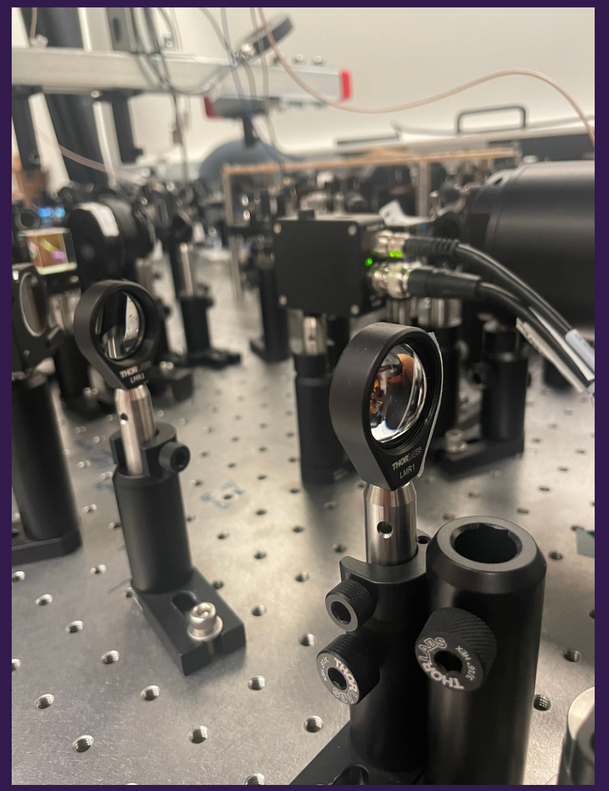




Telescopes

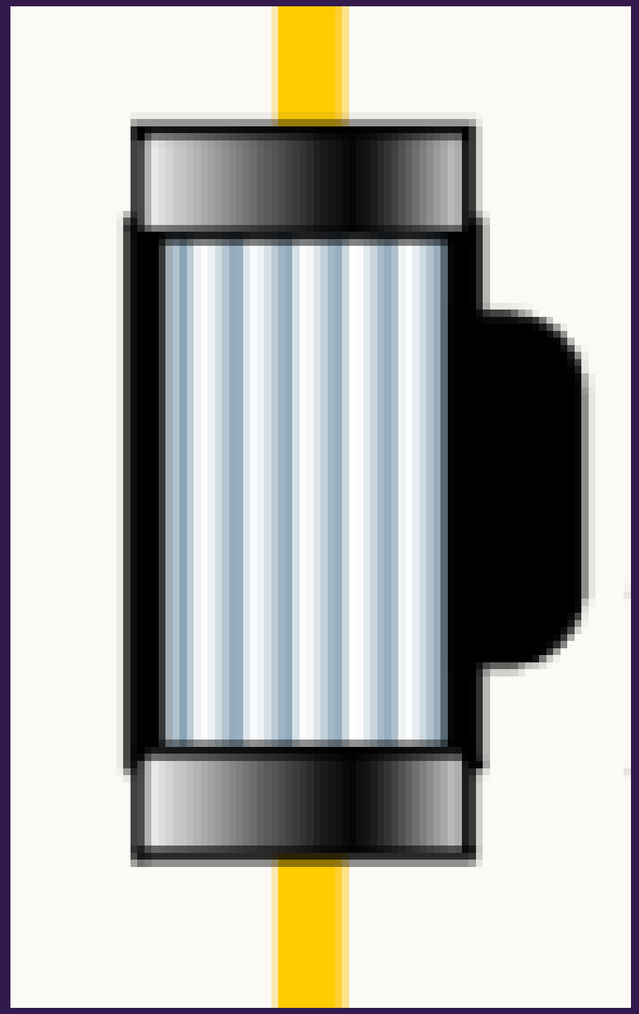
The telescopes are used to downsize or enlarge the beam diameter to satisfy requirements of devices





Acousto-Optic Modulator (AMO)

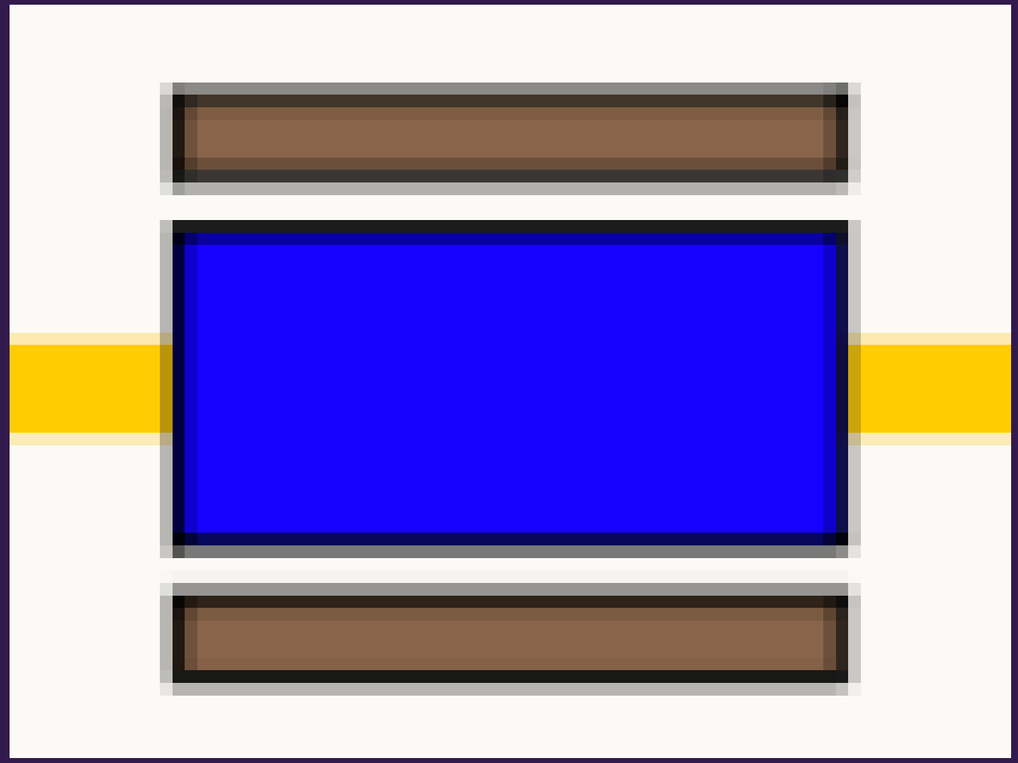
A sound wave in a crystal acts a grating to change the frequency and direction of light



Mirrors

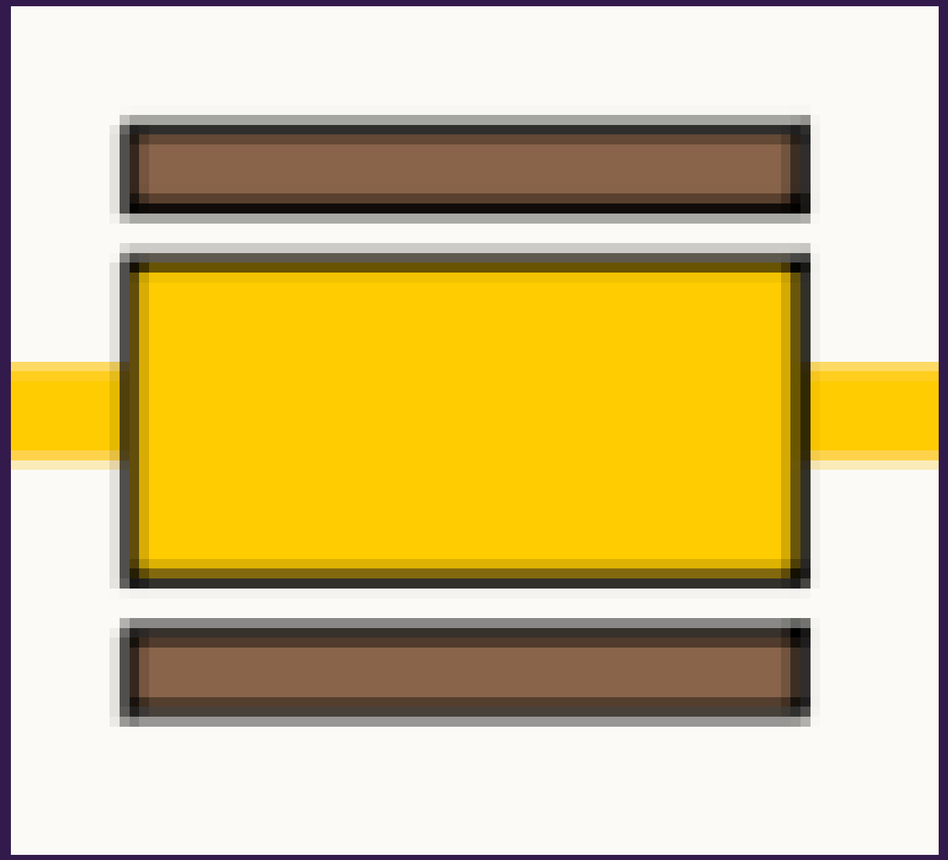
Broadband EOM

The free-space electro-optic (EO) phase modulator is used to shift the frequency by a large amount between 1 and 2 GHz



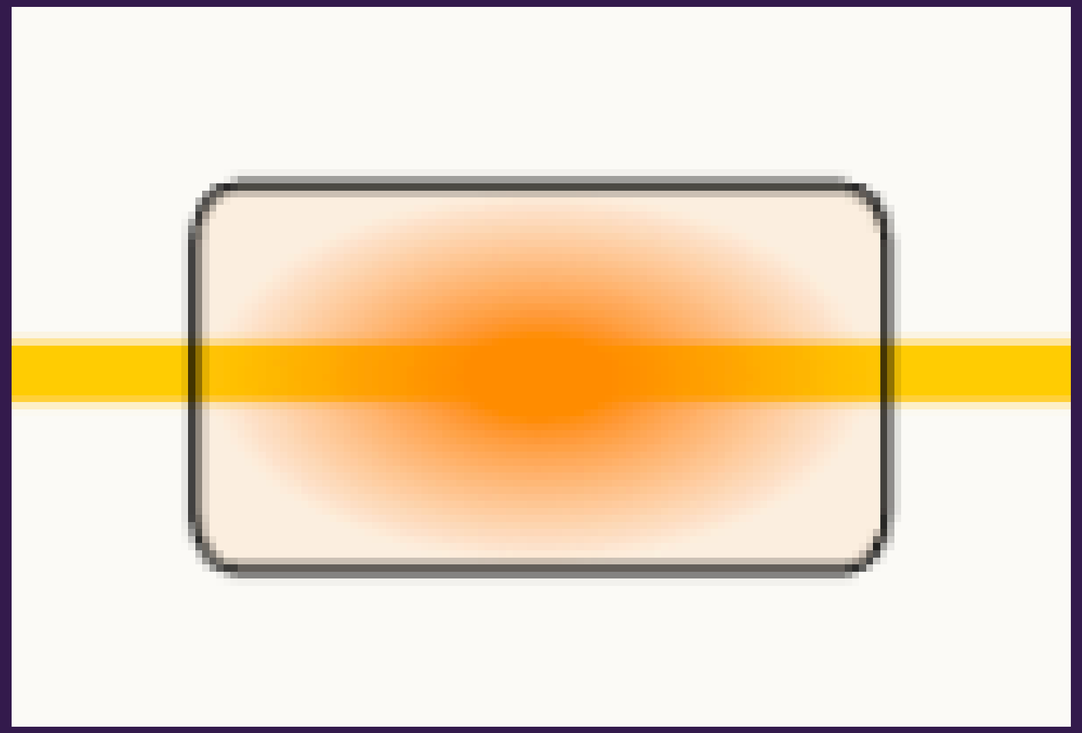
Resonant EOM

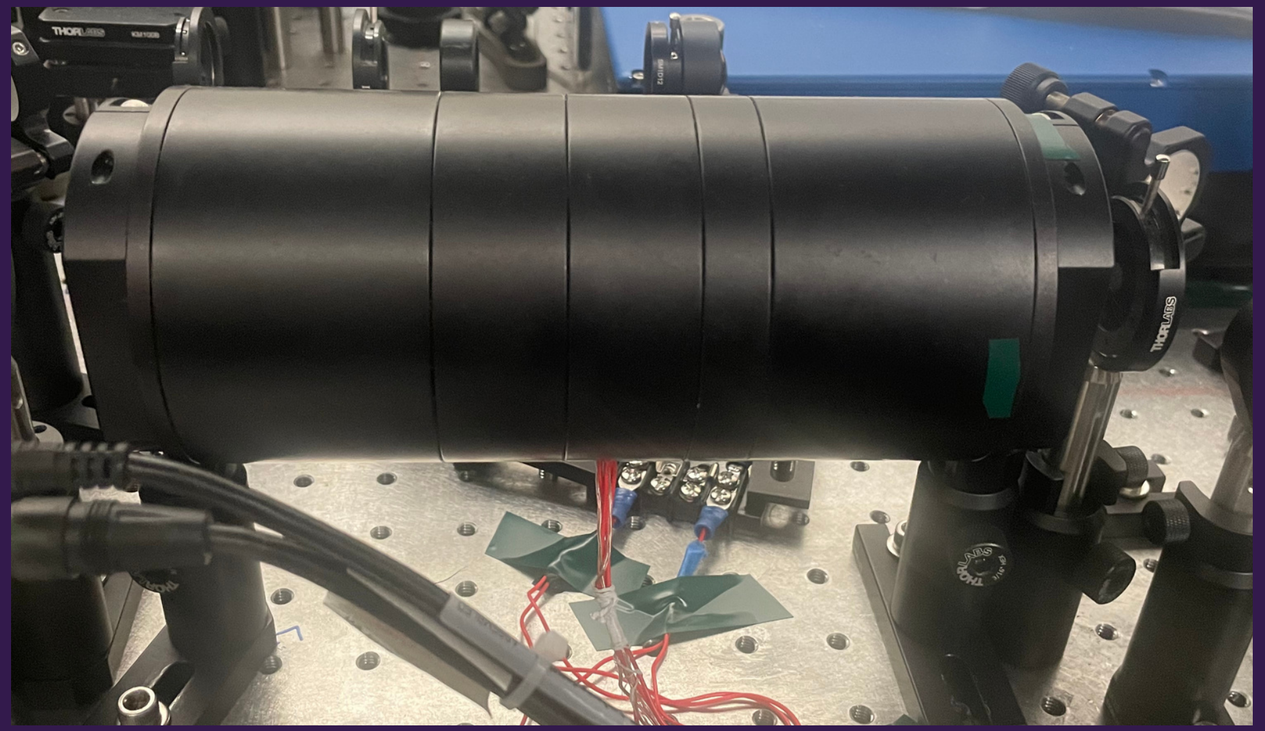
The pump beam is phase-modulated in an EO phase modulator at 10.63 MHz
Used for lock-in (phase sensitive) detection



NA Vapor Cell

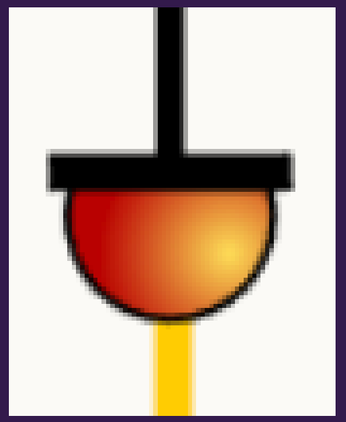
The two beams enter the non-linear medium of hot sodium vapor in a glass cell at ~ 110 C





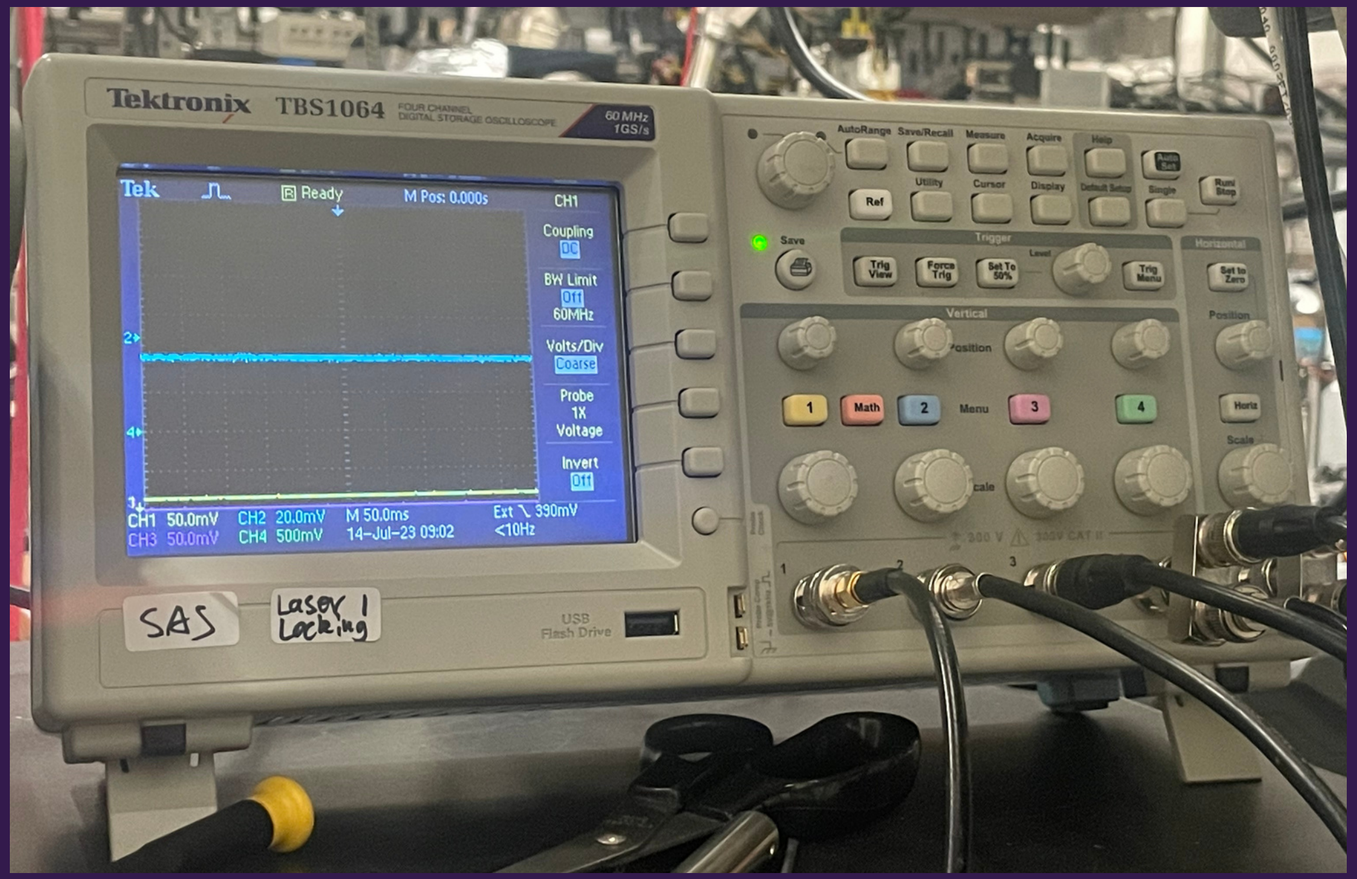
Photodetectors

Both beams are collected by their respective photodetector.

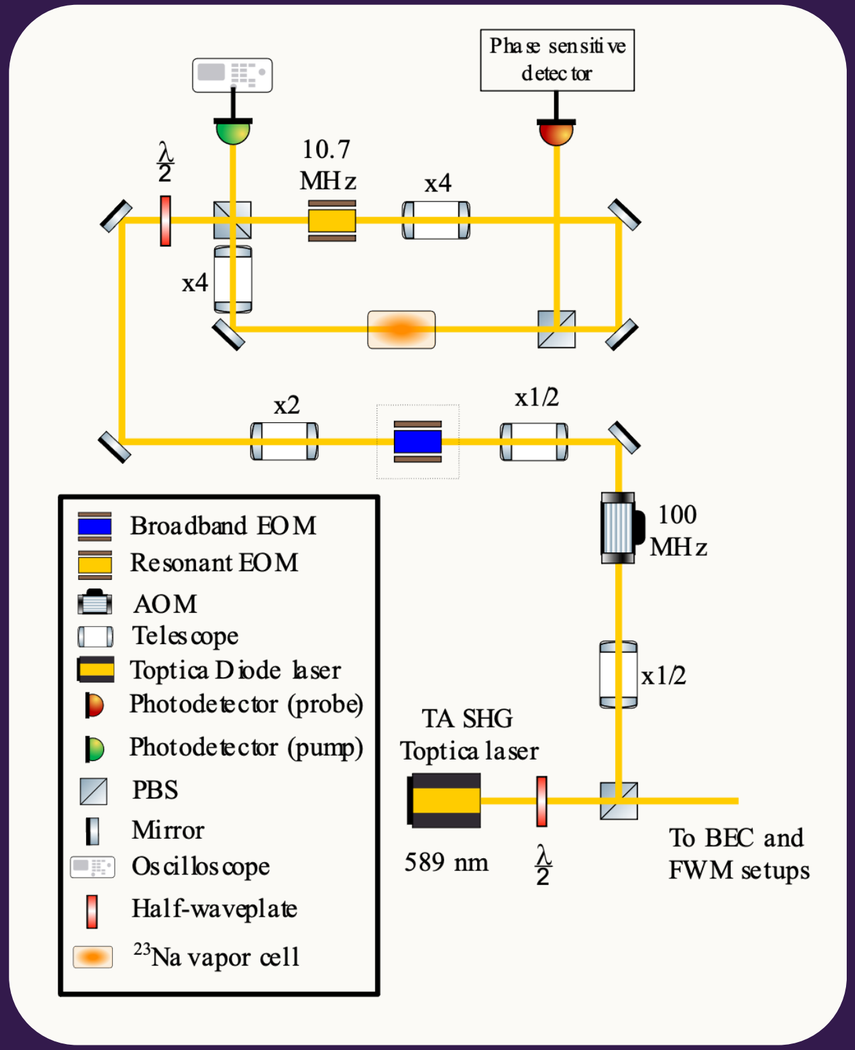


Oscilloscope

The MTS, pump and probe signals are monitored and measured via an oscilloscope.

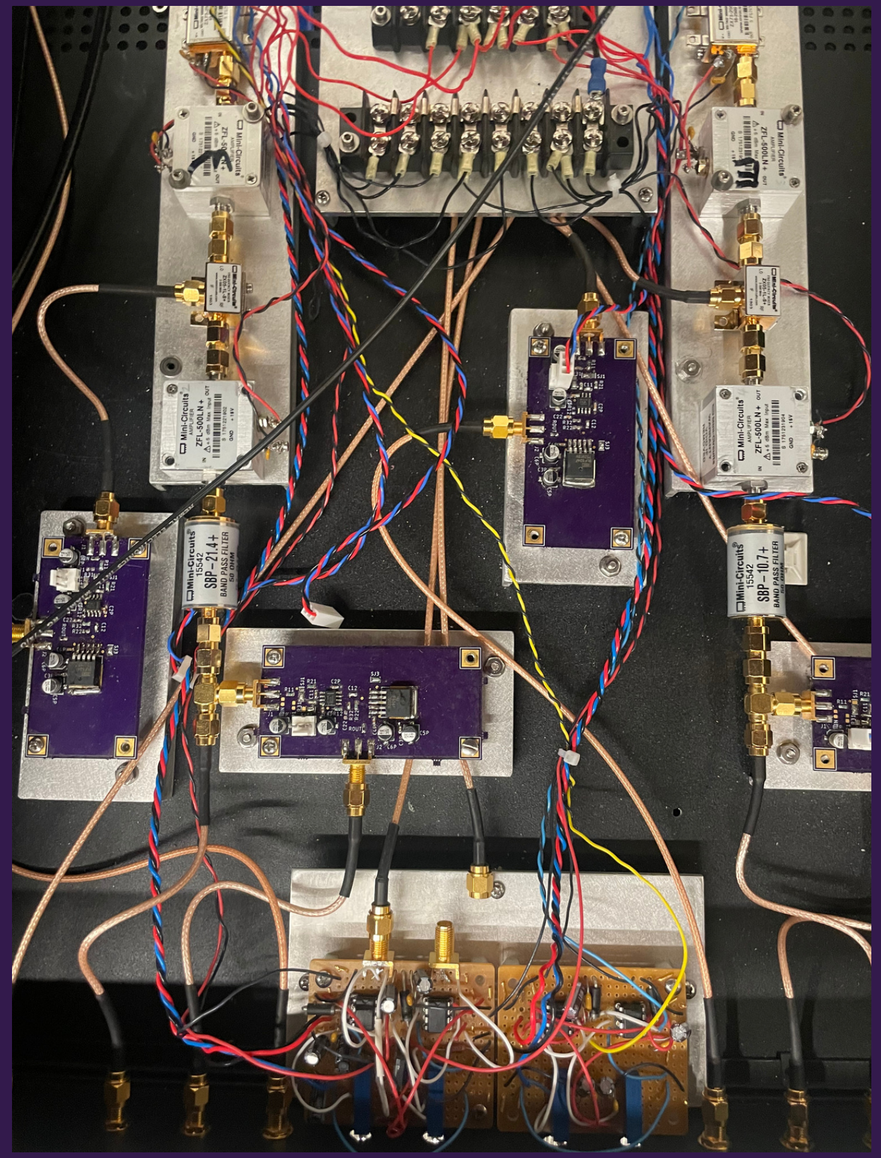


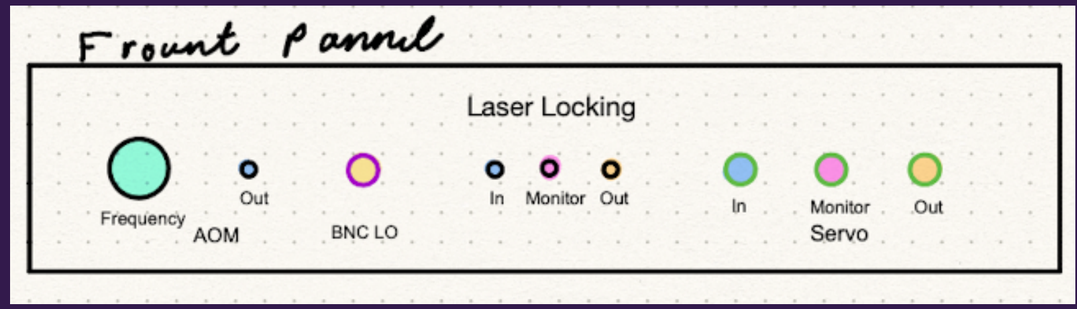
The Optics

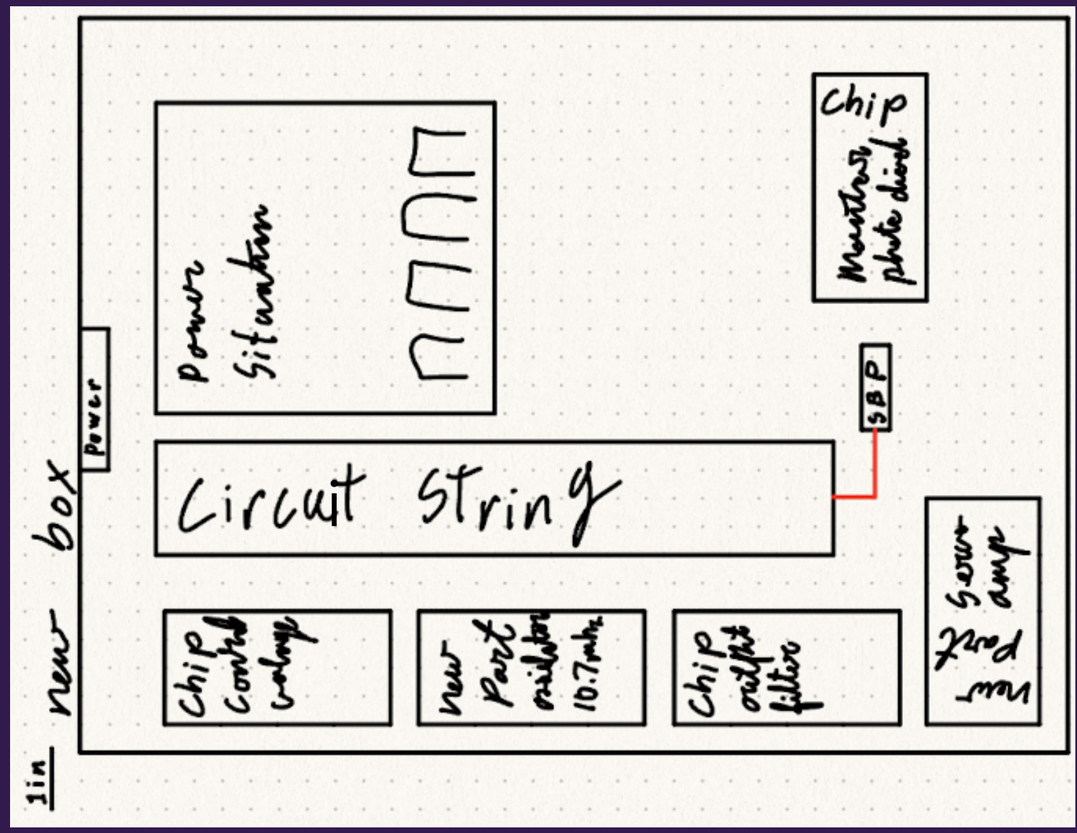


H. G. Ooi, A Dynamic Locking System for Bose-Einstein Condensation and Four-wave Mixing Experiments

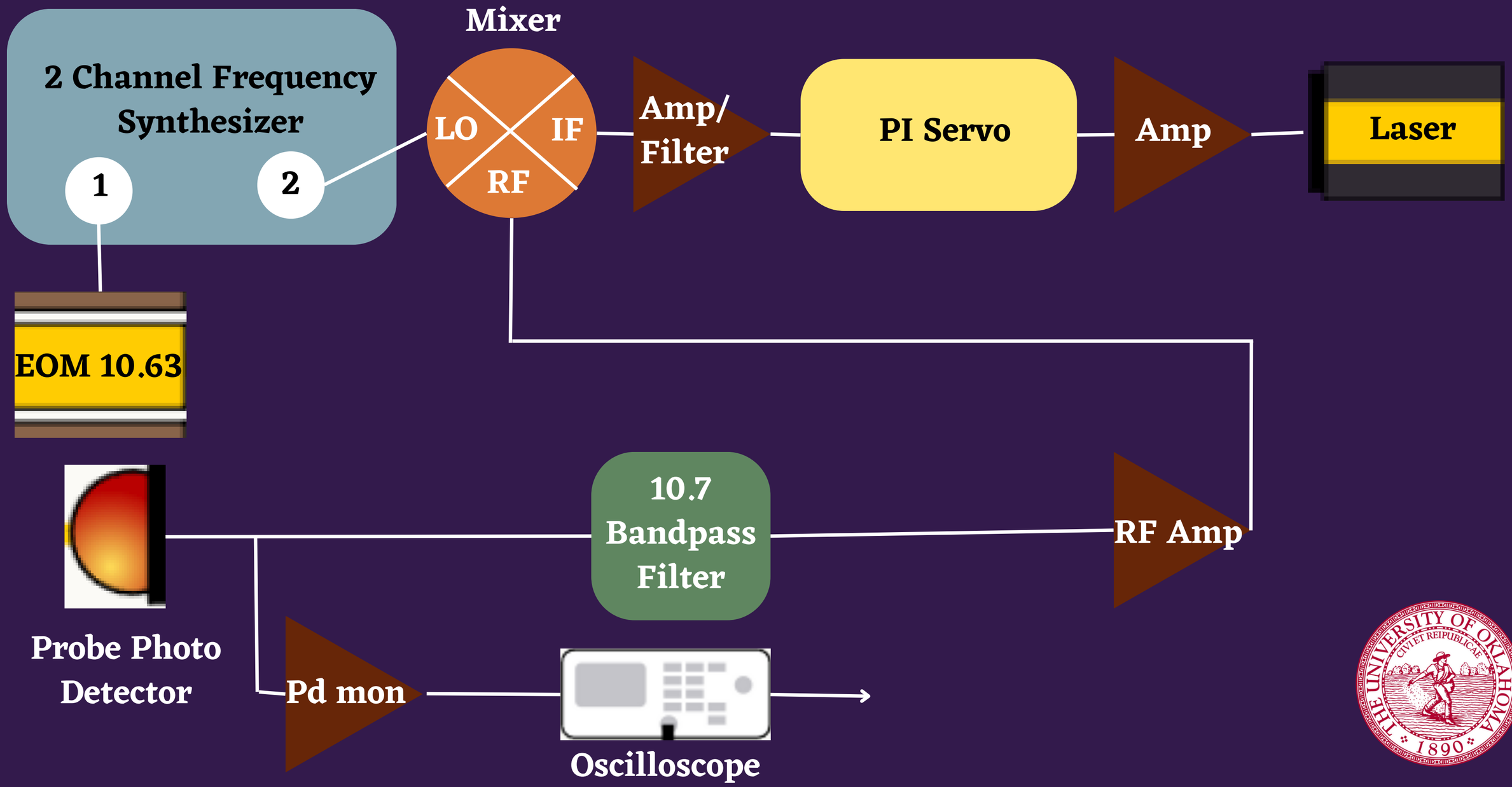
The Electronics





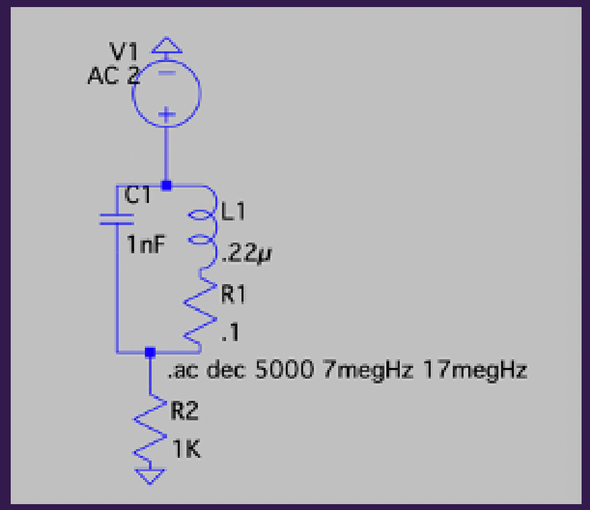


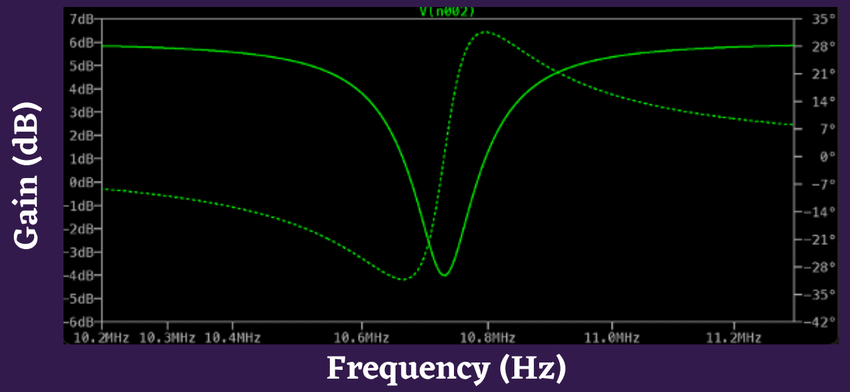
The Electronics



2 Channel Frequency Synthesizer

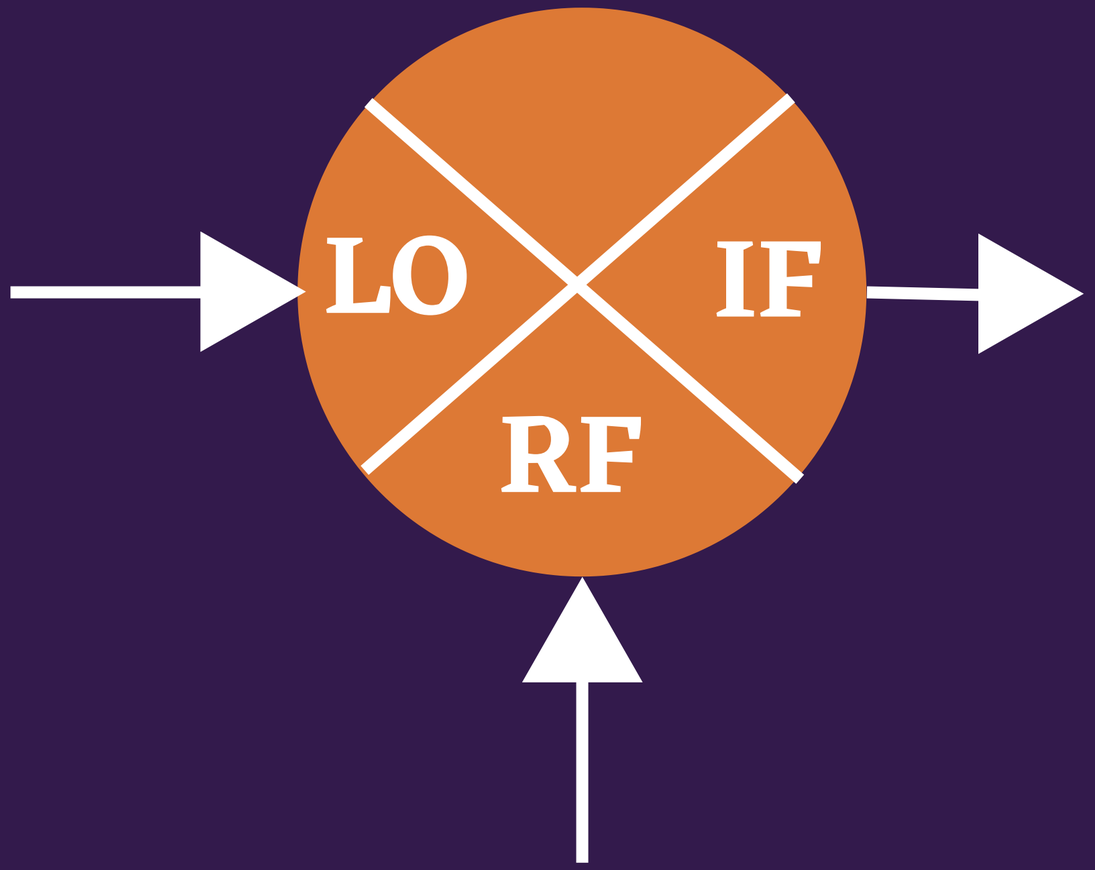
Frequency Synthesizer is cheaper and more reliable than a crystal oscillator/amplifier





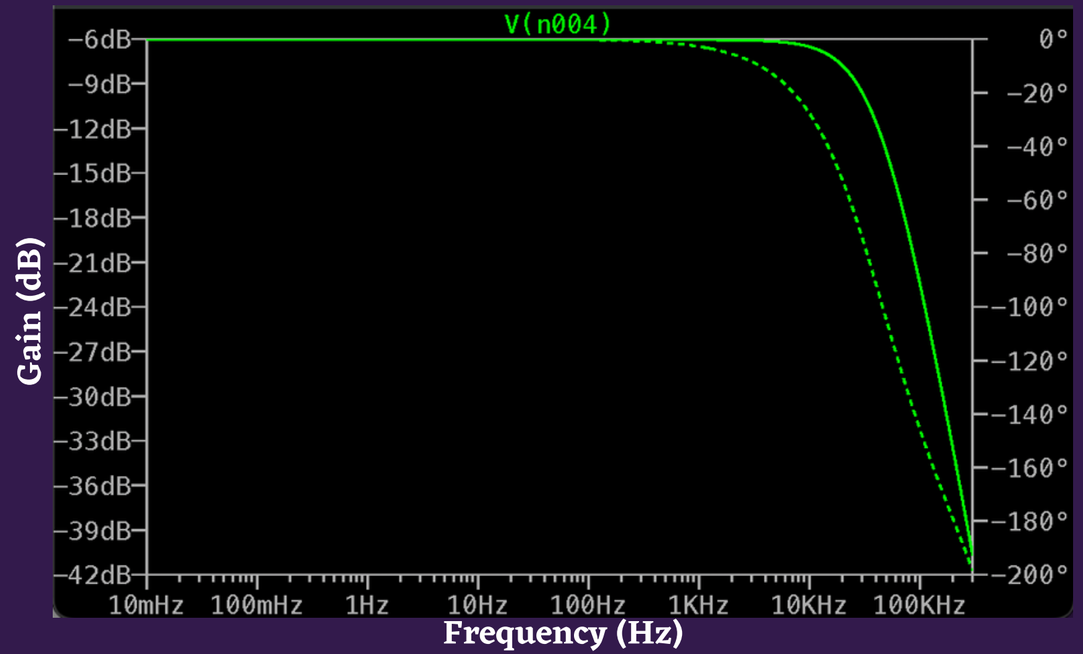
Radio Frequency (RF) Mixers

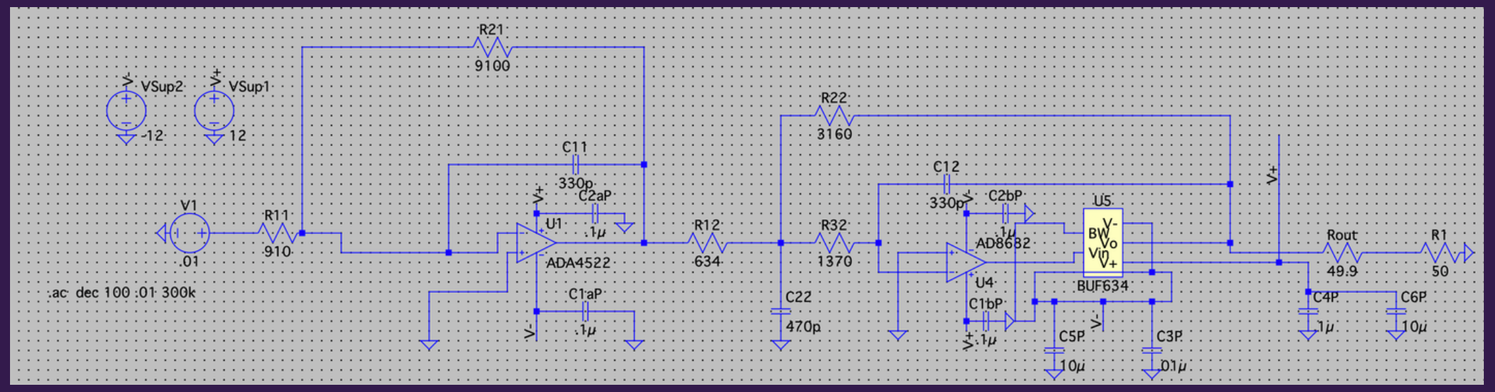
Takes in two input signals with different frequencies and produces an output signal that contains both the sum and difference frequencies

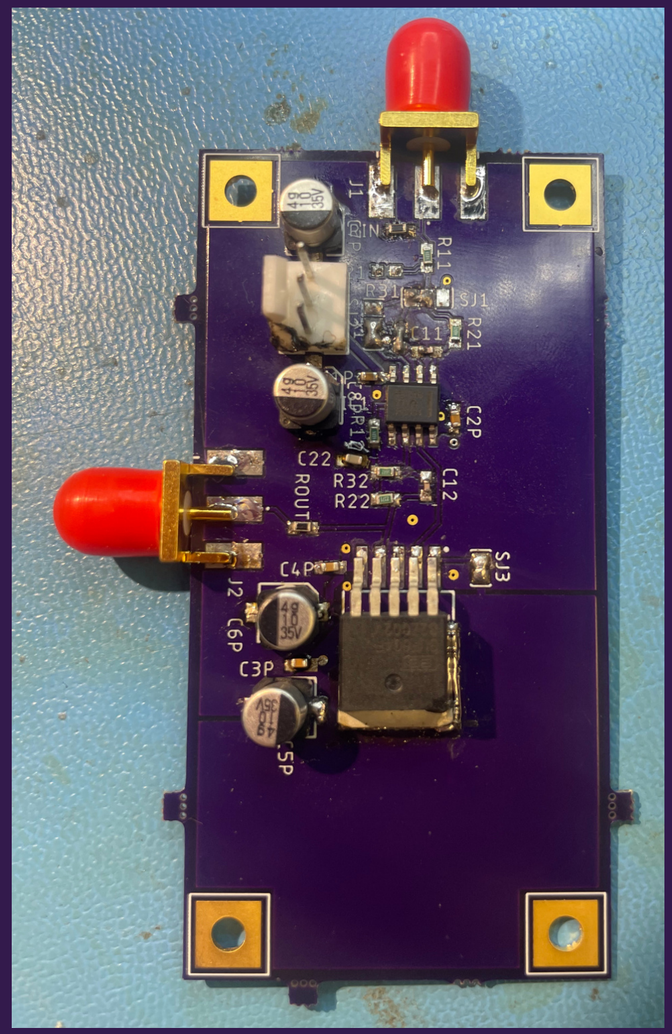


Output Filter

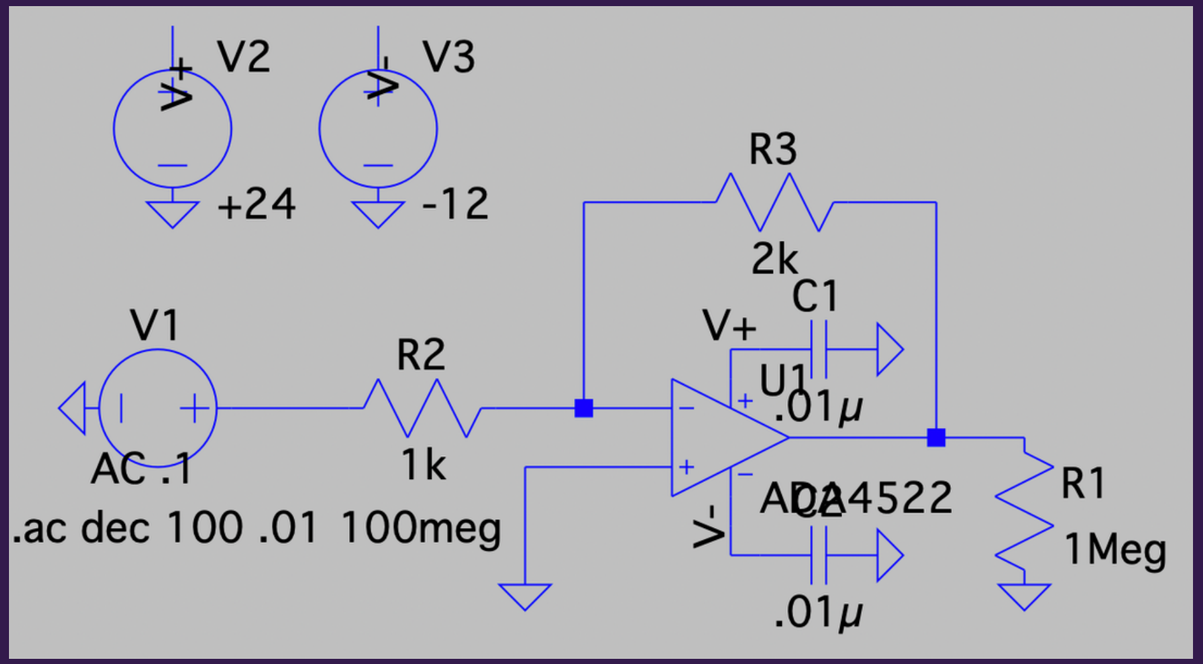
The Output Filter cuts out signals that are greater than the frequency we want.

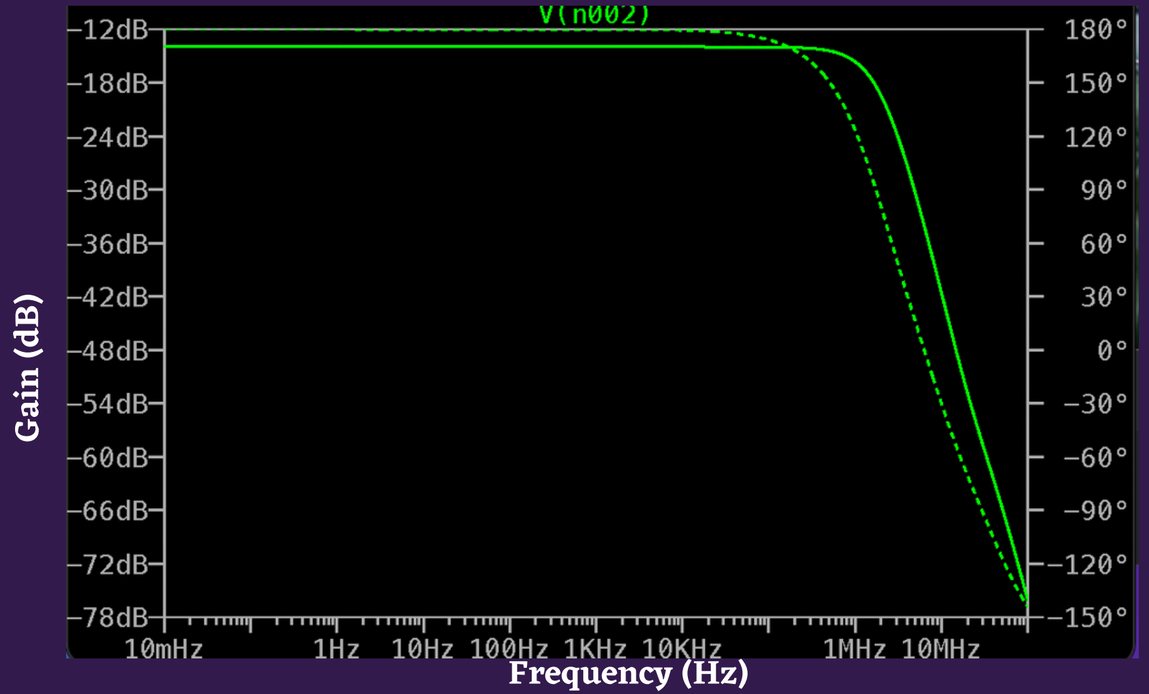




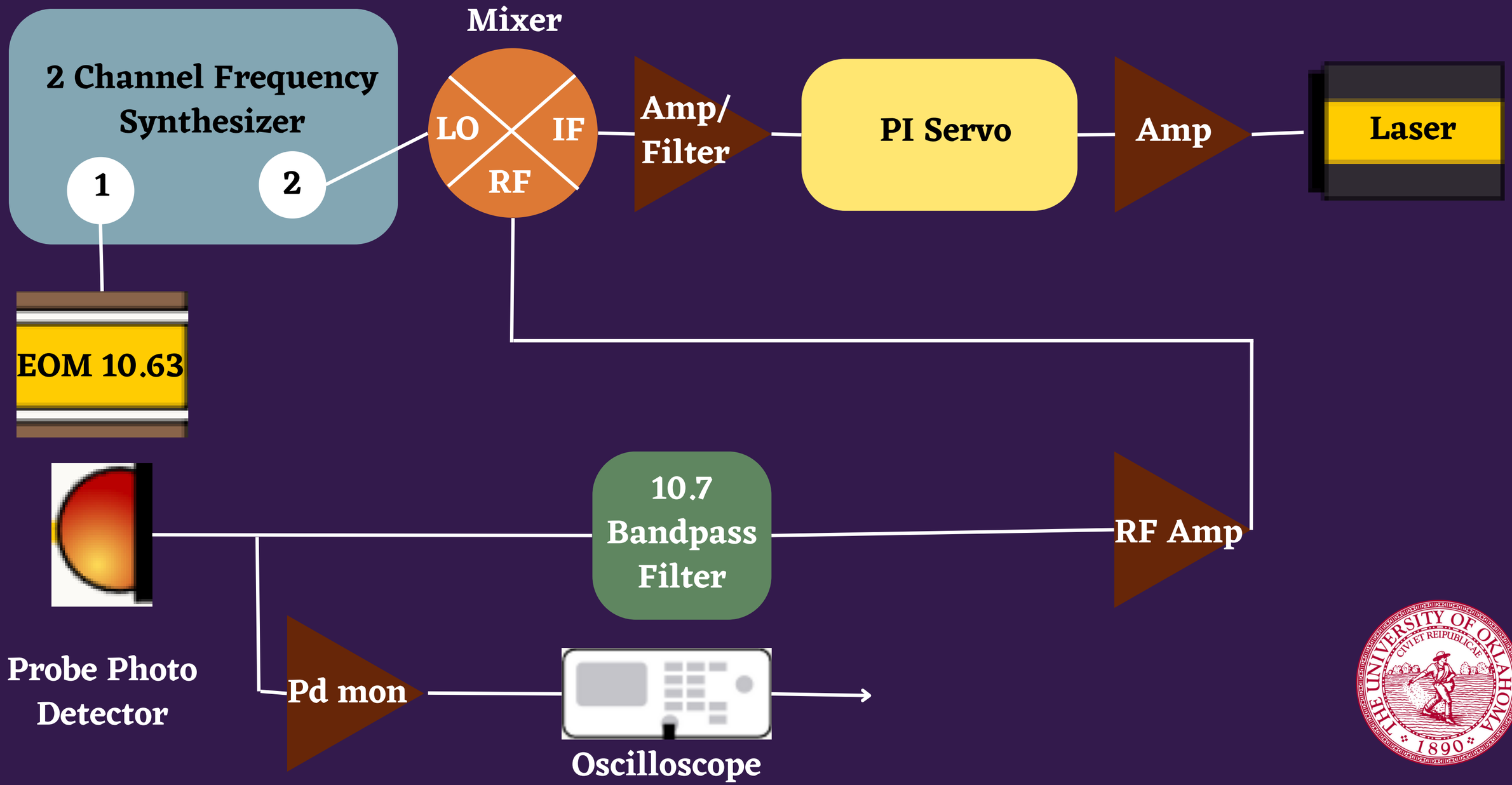


Servo and Amplifier

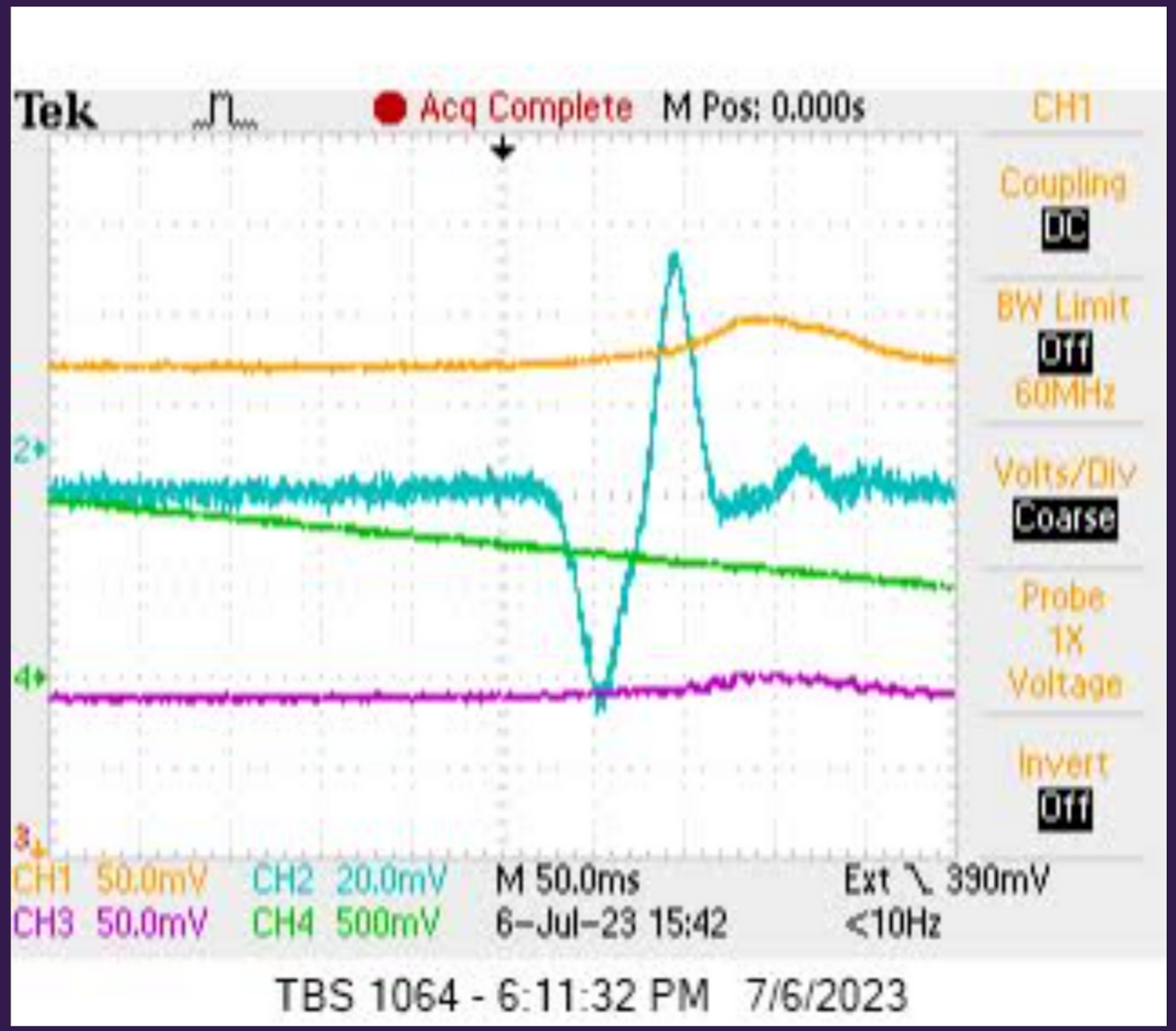




The Electronics



Results



Error Signal (Volts)

Frequency (arb. u.)

Conclusion

- Presented the new Modulation Transfer Spectroscopy (MTS) instead of previously used SAS to improve the frequency lock of our main cooling laser
- Aligned optics For MTS
- Designed, simulated, and built necessary electronics
- Obtained error signal for improved laser stabilization using MTS

Outlook

- Assembling electronics in box
- Aligning the Broadband EOM
- Characterize the laser lock over several days

Acknowledgments

I want to thank Dr. Arne Schwettmann, Dr. John Moore-Furneaux, Caleb Griffith, Kusal Abeywickrama, Sam Manley, Cordelia Meixsel, Hio Ooi, and Sankalp Prajapati for helping me in the lab, explaining topics and teaching me along the way.