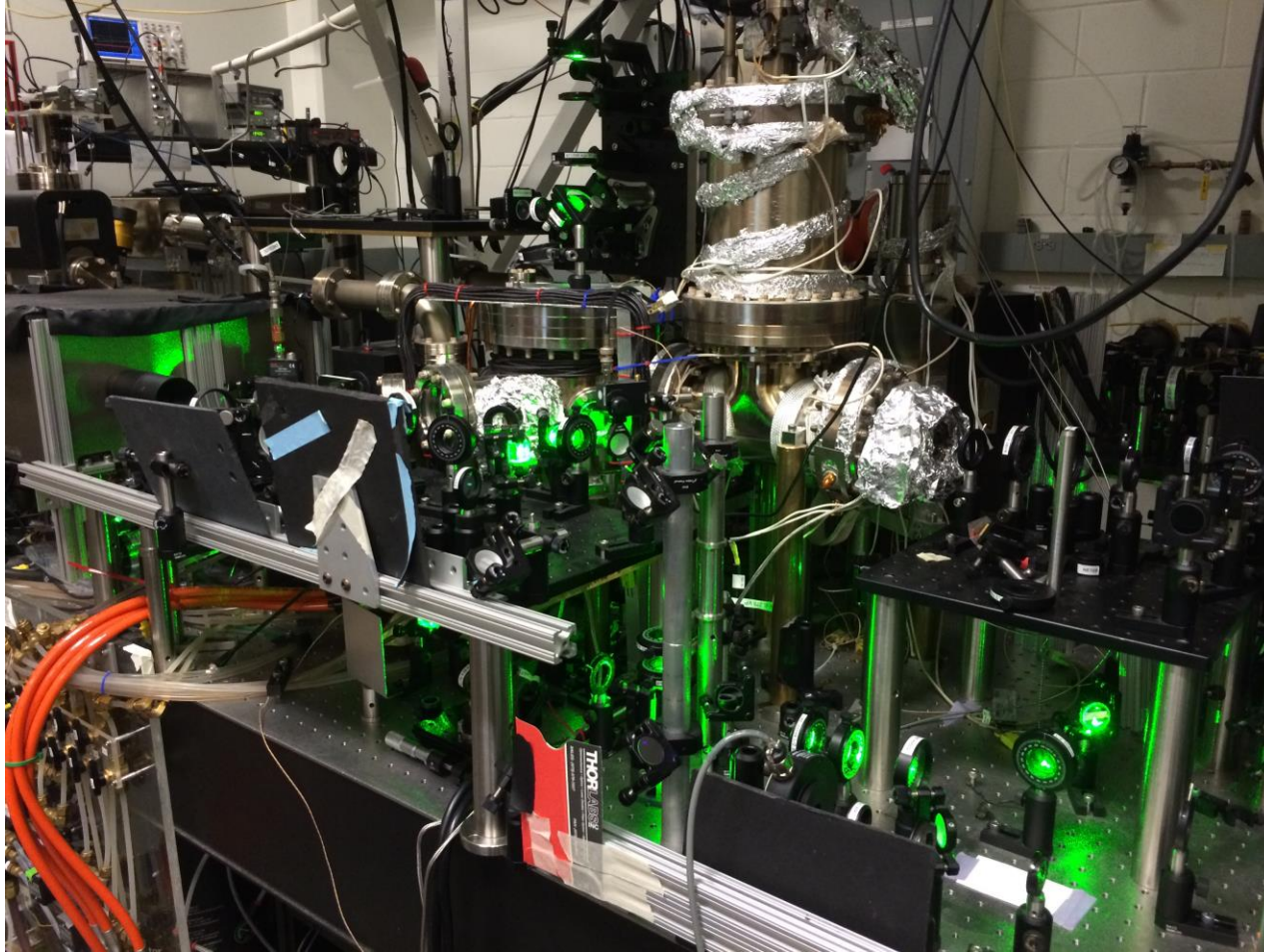


# Second Generation ECDLs for Li-Yb PA Experiments



Stephen Dilorio  
UW NSF-INT PHY REU  
August 21, 2014

# Outline

- Introduction
  - Why Cold Atoms?
  - Benefits of Cold Molecules
  - Precision Lasers
  - Photoassociation Spectroscopy
- ECDL
  - Old ECDL and Stability
  - New ECDL and Stability
  - Protection Circuit
- Locking PA Laser

# Laser-Trapped Atoms

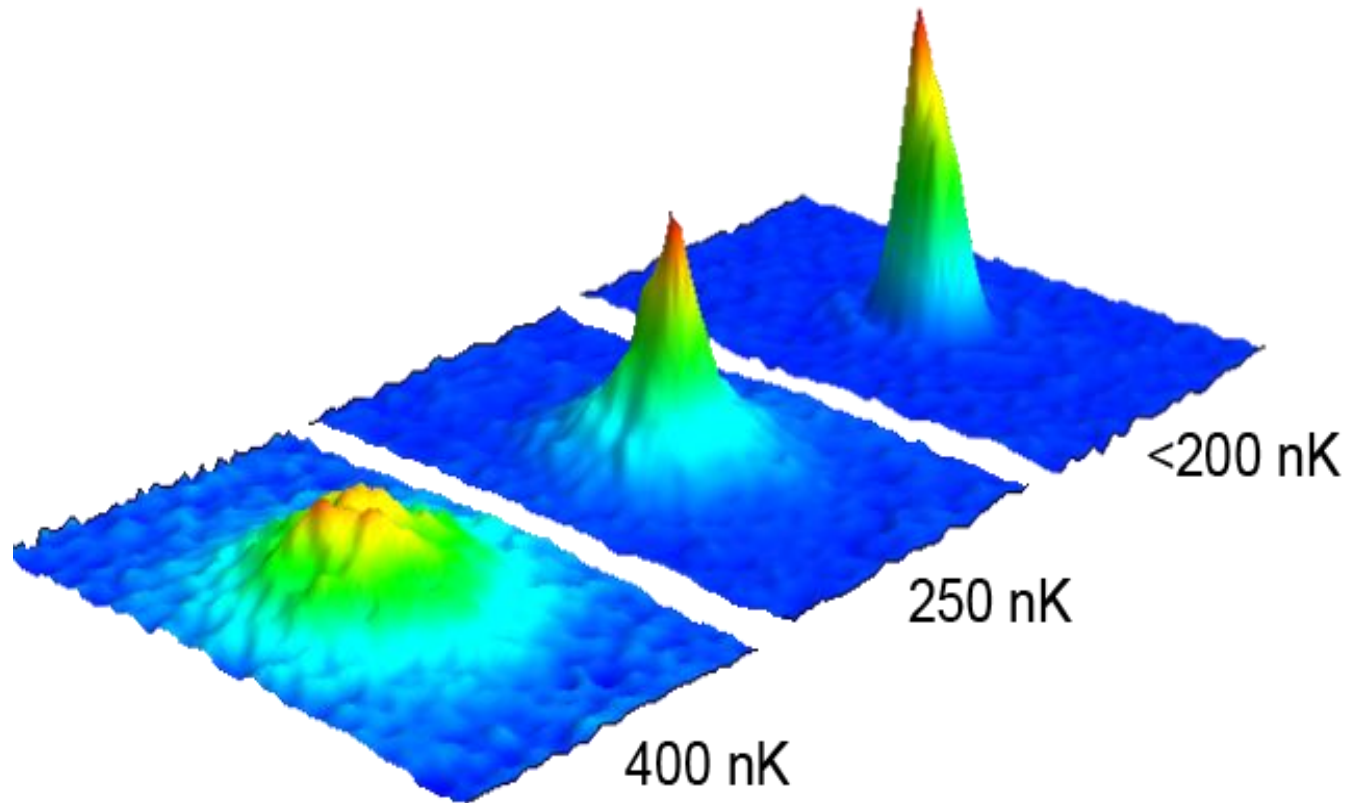
hydrogen 1 <b>H</b> 1.0079																	helium 2 <b>He</b> 4.0026						
<b>lithium</b> 3 <b>Li</b> 6.941	beryllium 4 <b>Be</b> 9.0122																	boron 5 <b>B</b> 10.811	carbon 6 <b>C</b> 12.011	nitrogen 7 <b>N</b> 14.007	oxygen 8 <b>O</b> 15.999	fluorine 9 <b>F</b> 18.998	neon 10 <b>Ne</b> 20.180
sodium 11 <b>Na</b> 22.990	magnesium 12 <b>Mg</b> 24.305																	aluminium 13 <b>Al</b> 26.982	silicon 14 <b>Si</b> 28.086	phosphorus 15 <b>P</b> 30.974	sulfur 16 <b>S</b> 32.065	chlorine 17 <b>Cl</b> 35.453	argon 18 <b>Ar</b> 39.948
potassium 19 <b>K</b> 39.098	calcium 20 <b>Ca</b> 40.078	scandium 21 <b>Sc</b> 44.956	titanium 22 <b>Ti</b> 47.867	vanadium 23 <b>V</b> 50.942	<b>chromium</b> 24 <b>Cr</b> 51.996	manganese 25 <b>Mn</b> 54.938	iron 26 <b>Fe</b> 55.845	cobalt 27 <b>Co</b> 58.933	nickel 28 <b>Ni</b> 58.693	copper 29 <b>Cu</b> 63.546	zinc 30 <b>Zn</b> 65.39	gallium 31 <b>Ga</b> 69.723	germanium 32 <b>Ge</b> 72.61	arsenic 33 <b>As</b> 74.922	selenium 34 <b>Se</b> 78.96	bromine 35 <b>Br</b> 79.904	krypton 36 <b>Kr</b> 83.80						
rubidium 37 <b>Rb</b> 85.468	strontium 38 <b>Sr</b> 87.62	yttrium 39 <b>Y</b> 88.906	zirconium 40 <b>Zr</b> 91.224	niobium 41 <b>Nb</b> 92.906	molybdenum 42 <b>Mo</b> 95.94	technetium 43 <b>Tc</b> [98]	ruthenium 44 <b>Ru</b> 101.07	rhodium 45 <b>Rh</b> 102.91	palladium 46 <b>Pd</b> 106.42	<b>silver</b> 47 <b>Ag</b> 107.87	<b>cadmium</b> 48 <b>Cd</b> 112.41	indium 49 <b>In</b> 114.82	tin 50 <b>Sn</b> 118.71	antimony 51 <b>Sb</b> 121.76	tellurium 52 <b>Te</b> 127.60	iodine 53 <b>I</b> 126.90	xenon 54 <b>Xe</b> 131.29						
caesium 55 <b>Cs</b> 132.91	barium 56 <b>Ba</b> 137.33	57-70 *	lutetium 71 <b>Lu</b> 174.97	hafnium 72 <b>Hf</b> 178.49	tantalum 73 <b>Ta</b> 180.95	tungsten 74 <b>W</b> 183.84	rhenium 75 <b>Re</b> 186.21	osmium 76 <b>Os</b> 190.23	iridium 77 <b>Ir</b> 192.22	platinum 78 <b>Pt</b> 195.08	gold 79 <b>Au</b> 196.97	mercury 80 <b>Hg</b> 200.59	thallium 81 <b>Tl</b> 204.38	lead 82 <b>Pb</b> 207.2	bismuth 83 <b>Bi</b> 208.98	polonium 84 <b>Po</b> [209]	astatine 85 <b>At</b> [210]	radon 86 <b>Rn</b> [222]					
francium 87 <b>Fr</b> [223]	radium 88 <b>Ra</b> [226]	89-102 **	lawrencium 103 <b>Lr</b> [262]	rutherfordium 104 <b>Rf</b> [261]	dubnium 105 <b>Db</b> [262]	seaborgium 106 <b>Sg</b> [266]	bohrium 107 <b>Bh</b> [264]	hassium 108 <b>Hs</b> [269]	meitnerium 109 <b>Mt</b> [268]	ununnium 110 <b>Uun</b> [271]	ununium 111 <b>Uuu</b> [272]	unubium 112 <b>Uub</b> [277]		ununquadium 114 <b>Uuq</b> [289]									

\* Lanthanide series

lanthanum 57 <b>La</b> 138.91	cerium 58 <b>Ce</b> 140.12	praseodymium 59 <b>Pr</b> 140.91	neodymium 60 <b>Nd</b> 144.24	promethium 61 <b>Pm</b> [145]	samarium 62 <b>Sm</b> 150.36	europium 63 <b>Eu</b> 151.96	gadolinium 64 <b>Gd</b> 157.25	terbium 65 <b>Tb</b> 158.93	<b>dysprosium</b> 66 <b>Dy</b> 162.50	holmium 67 <b>Ho</b> 164.93	<b>erbium</b> 68 <b>Er</b> 167.26	<b>thulium</b> 69 <b>Tm</b> 168.93	<b>ytterbium</b> 70 <b>Yb</b> 173.04
actinium 89 <b>Ac</b> [227]	thorium 90 <b>Th</b> 232.04	protactinium 91 <b>Pa</b> 231.04	uranium 92 <b>U</b> 238.03	neptunium 93 <b>Np</b> [237]	plutonium 94 <b>Pu</b> [244]	americium 95 <b>Am</b> [243]	curium 96 <b>Cm</b> [247]	berkelium 97 <b>Bk</b> [247]	californium 98 <b>Cf</b> [251]	einsteinium 99 <b>Es</b> [252]	fermium 100 <b>Fm</b> [257]	mendelevium 101 <b>Md</b> [258]	nobelium 102 <b>No</b> [259]

\*\* Actinide series

# Bose-Einstein Condensates

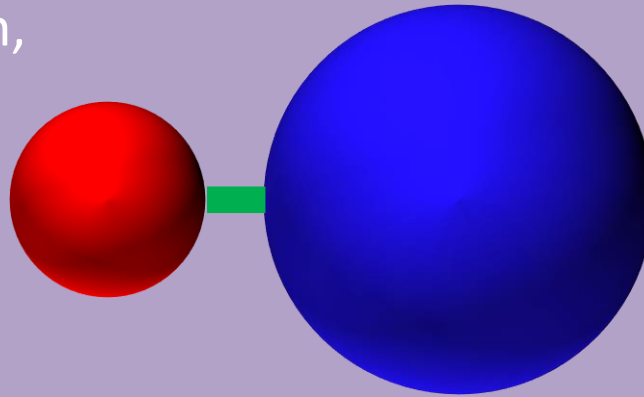


# Ultracold Molecules

Gain control of new  
degrees of freedom

Long-range interactions  
( $1/r^3$  vs  $1/r^6$ )

Atom: electric, motion,  
magnetic, nuclear



Candidate for scale-able  
quantum information  
processing

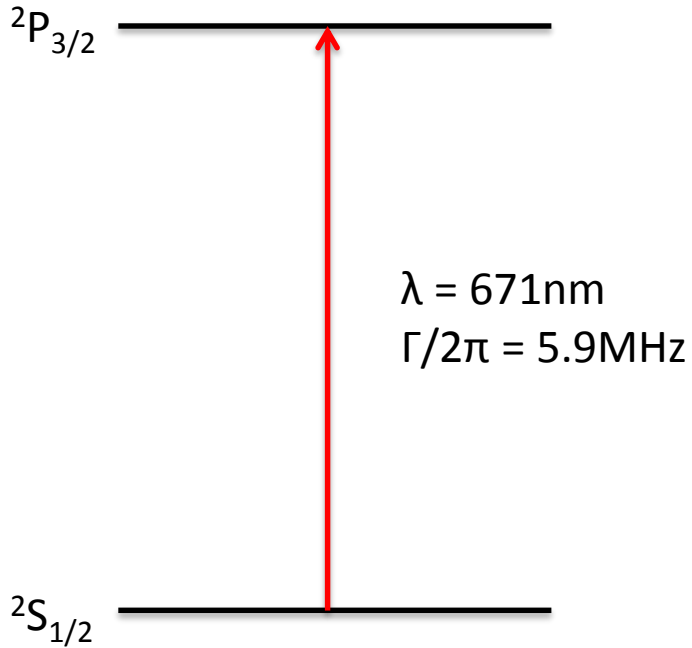
Molecule: Vibrational, rotational,  
molecular dipoles

Precision Spectroscopies  
for  $m_p/m_e$  time variation

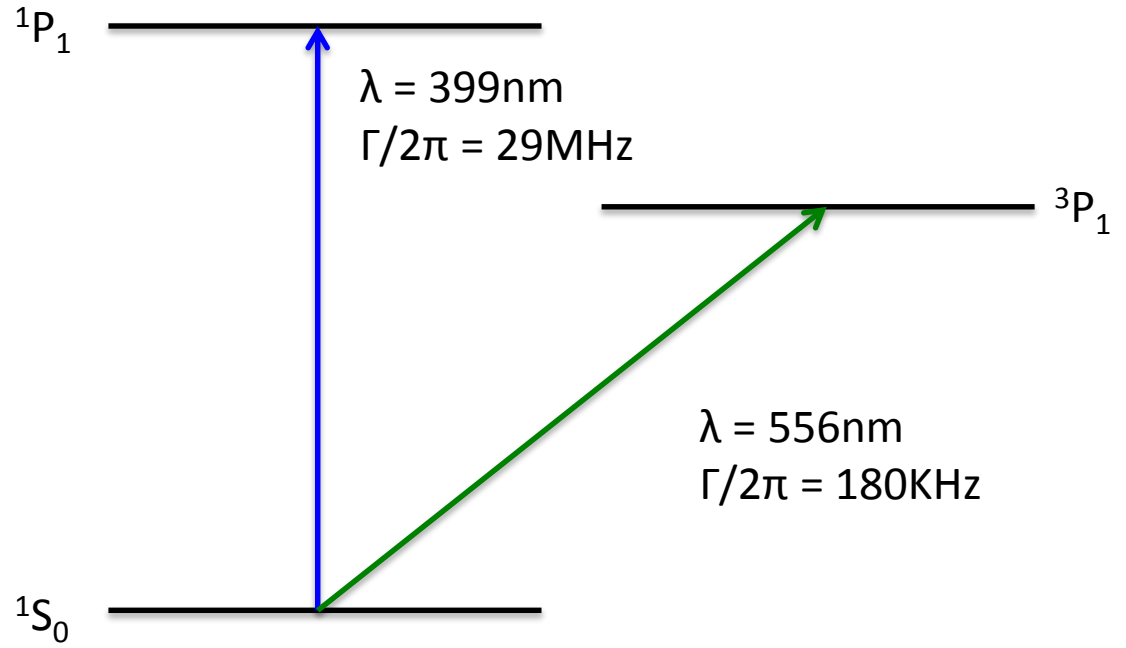
Controlled ultracold  
chemical reactions

# 2-Level System

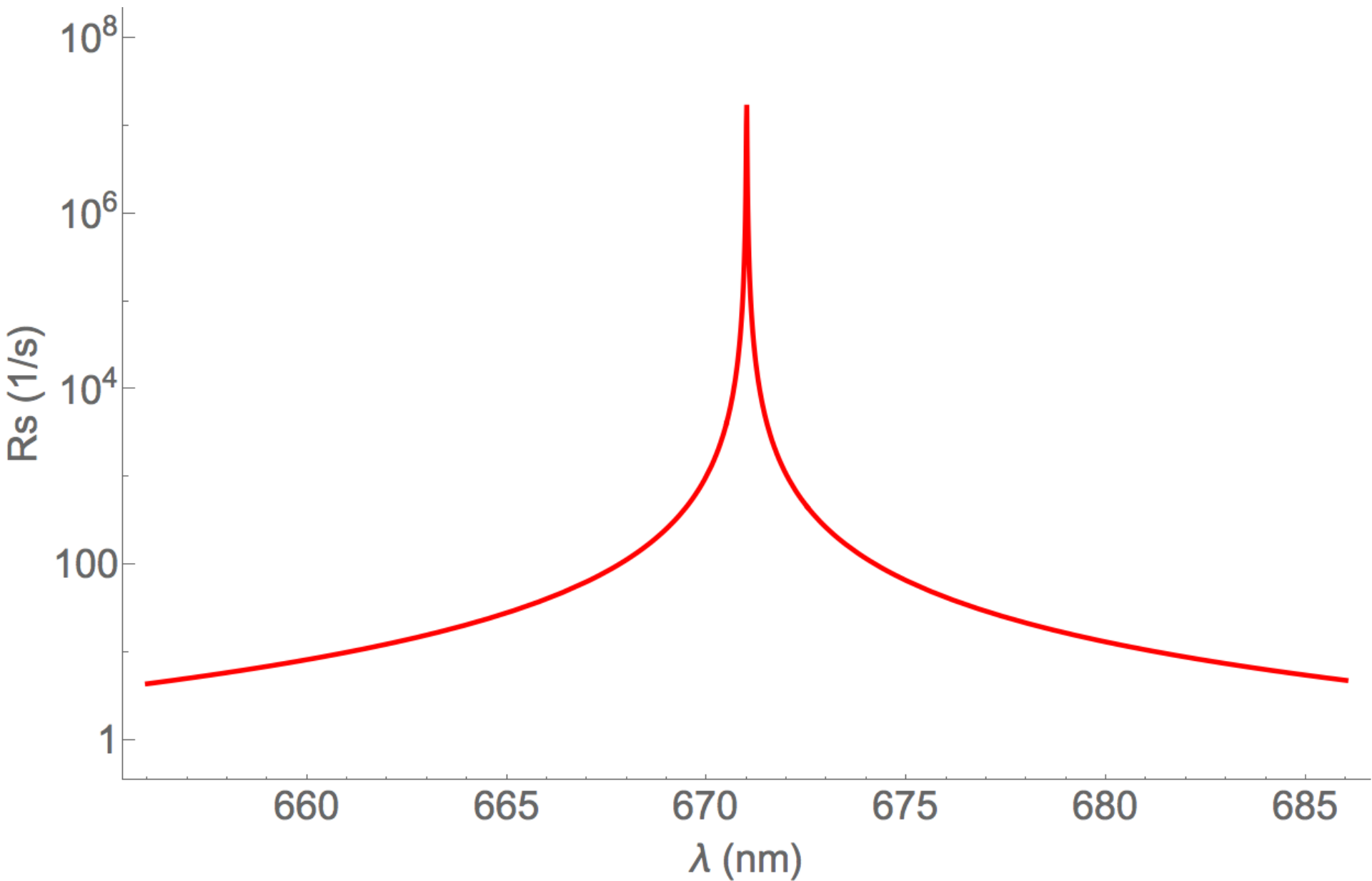
Li



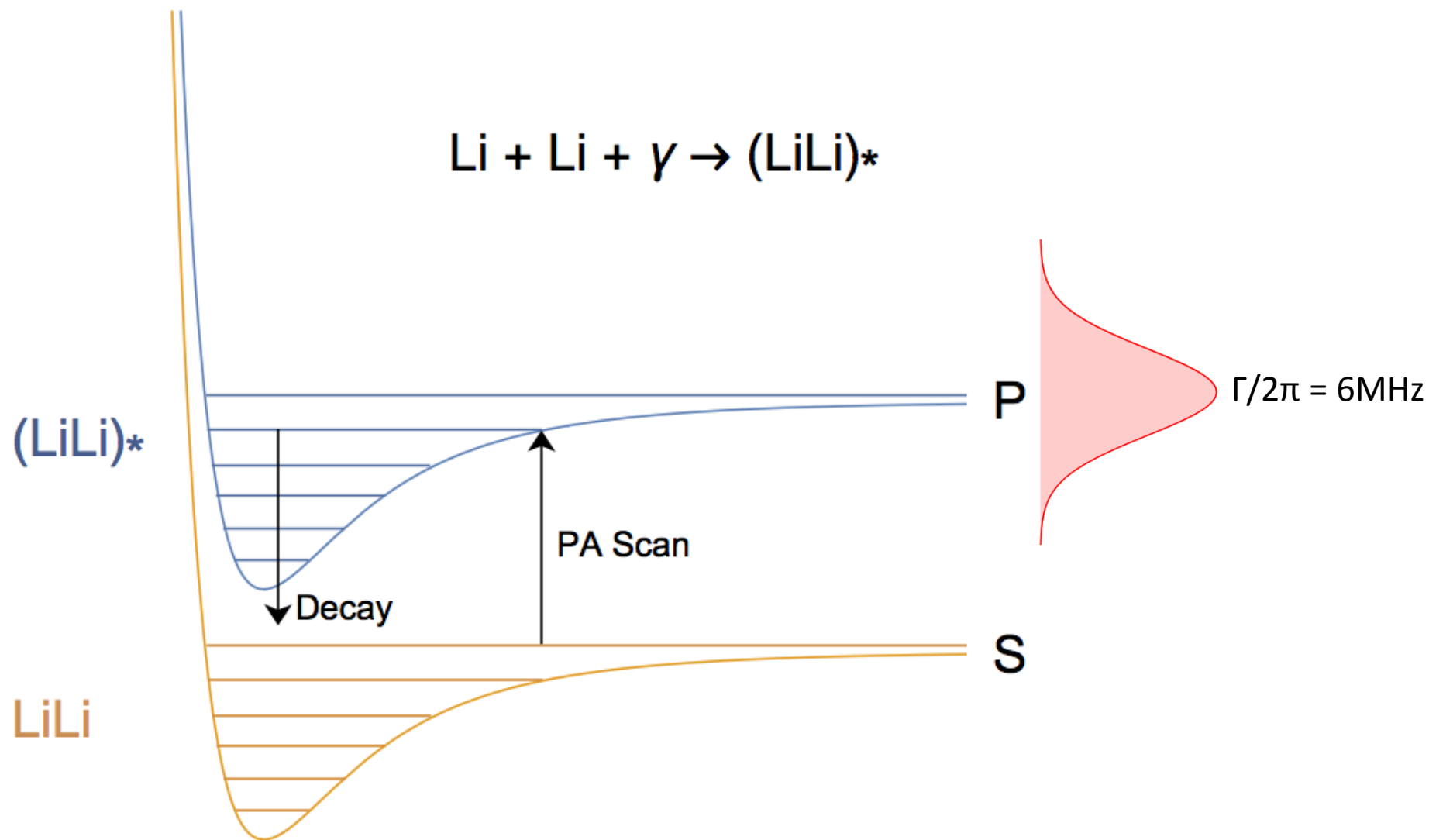
Yb



# 2-Level System

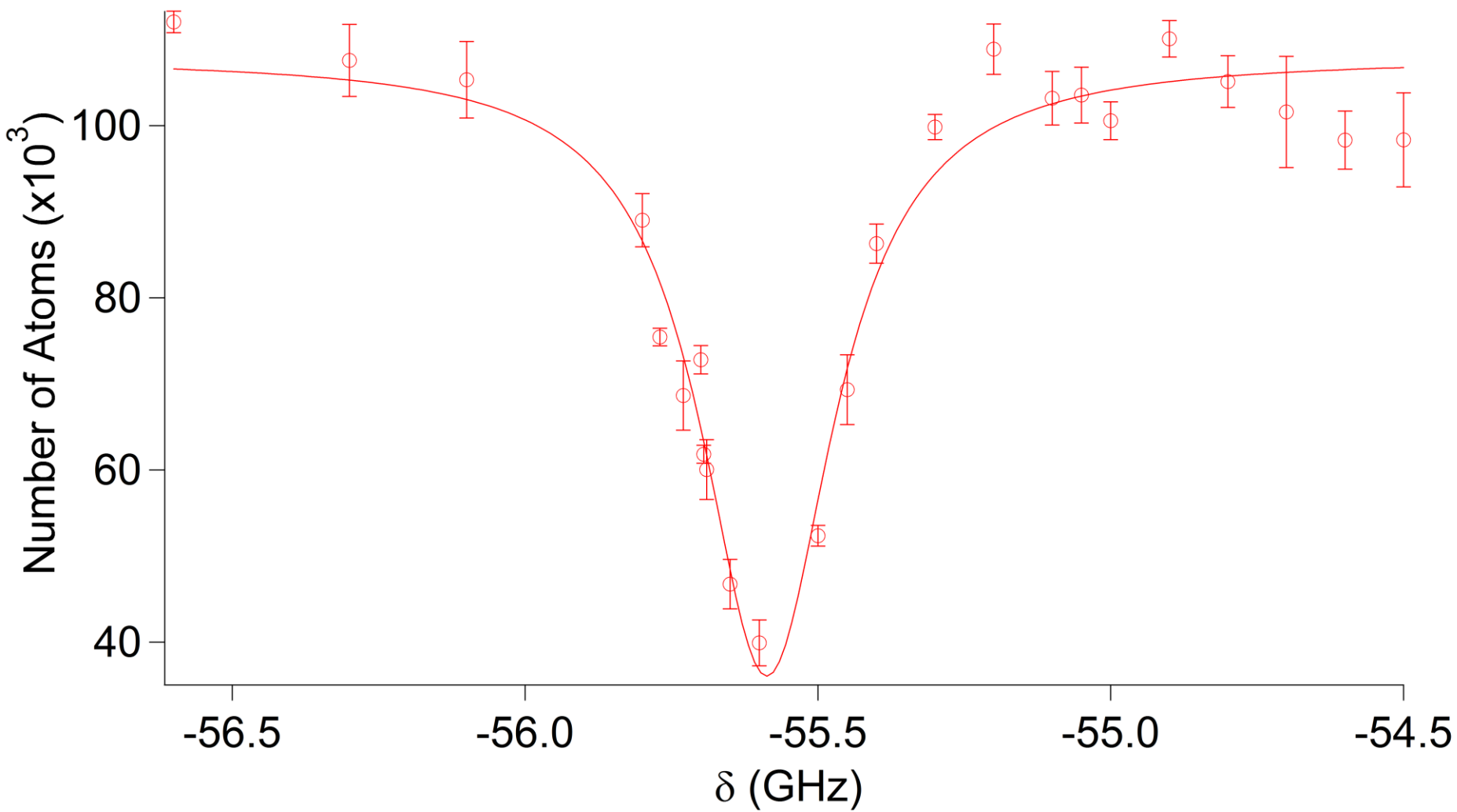


# Photoassociation Resonance



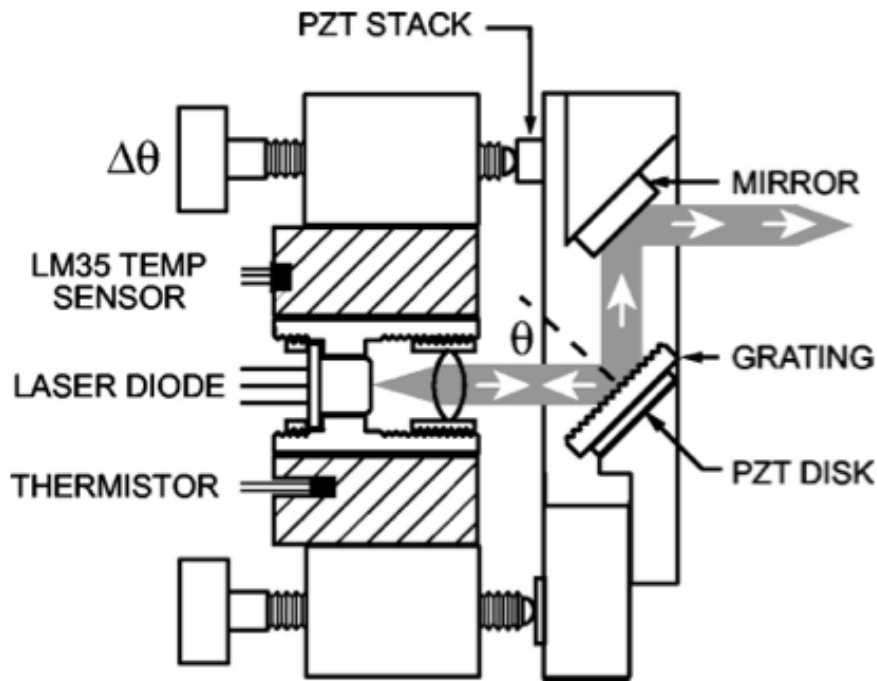


# Photoassociation Spectroscopy



# External Cavity Diode Laser

Littrow configuration



Frequency selective optical feedback

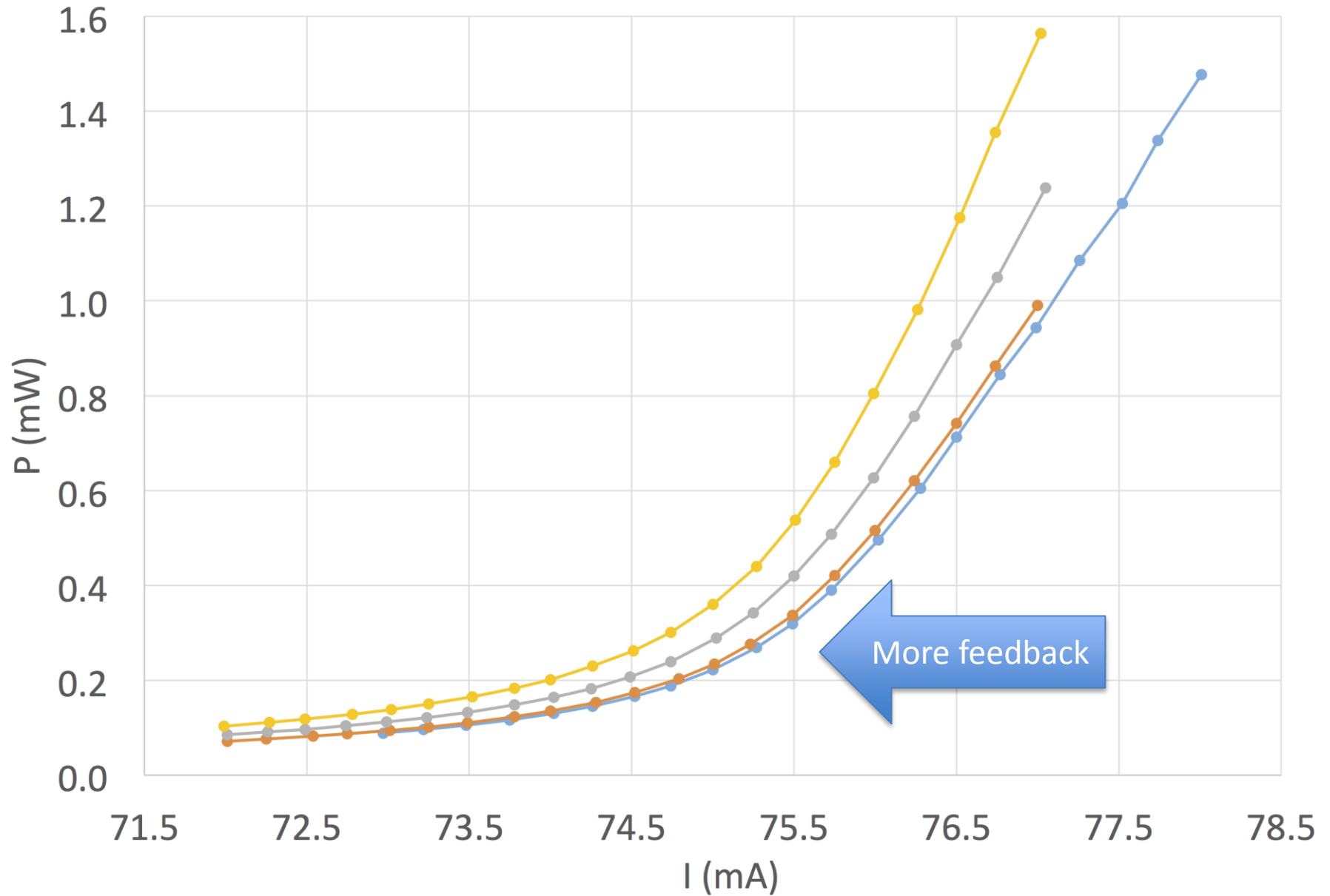
Fixed direction output beam (with minimal power loss)

Reflect 1<sup>st</sup> order beam to diode  
0<sup>th</sup> order beam as output

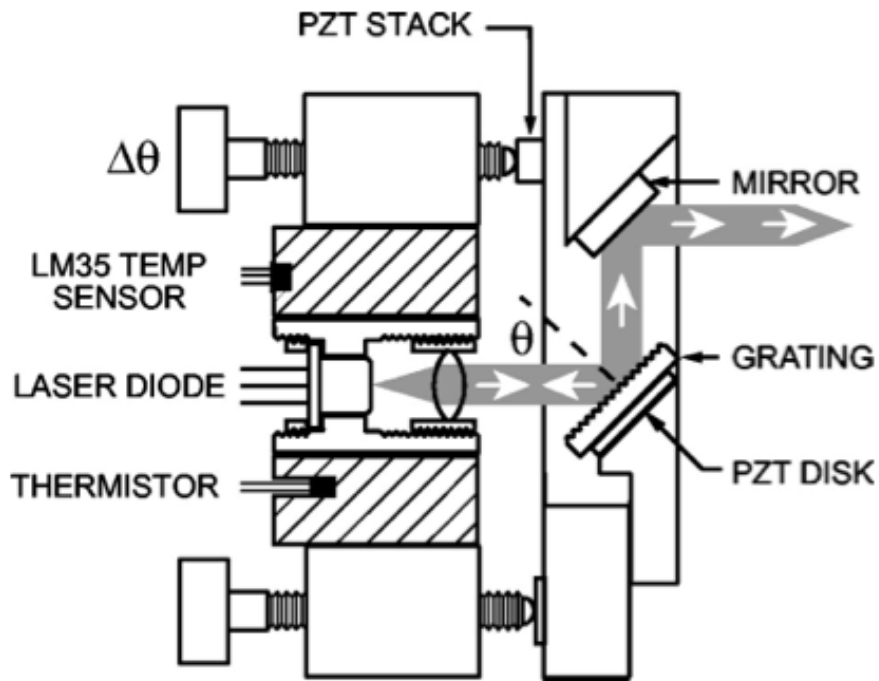
$$\theta = \arcsin(\lambda / 2d)$$

Hawthorn, C. J., K. P. Weber, and R. E. Scholten. "Littrow configuration tunable external cavity diode laser with fixed direction output beam." *Review of scientific instruments* 72.12 (2001): 4477-4479.

# External Cavity Diode Laser



# External Cavity Diode Laser

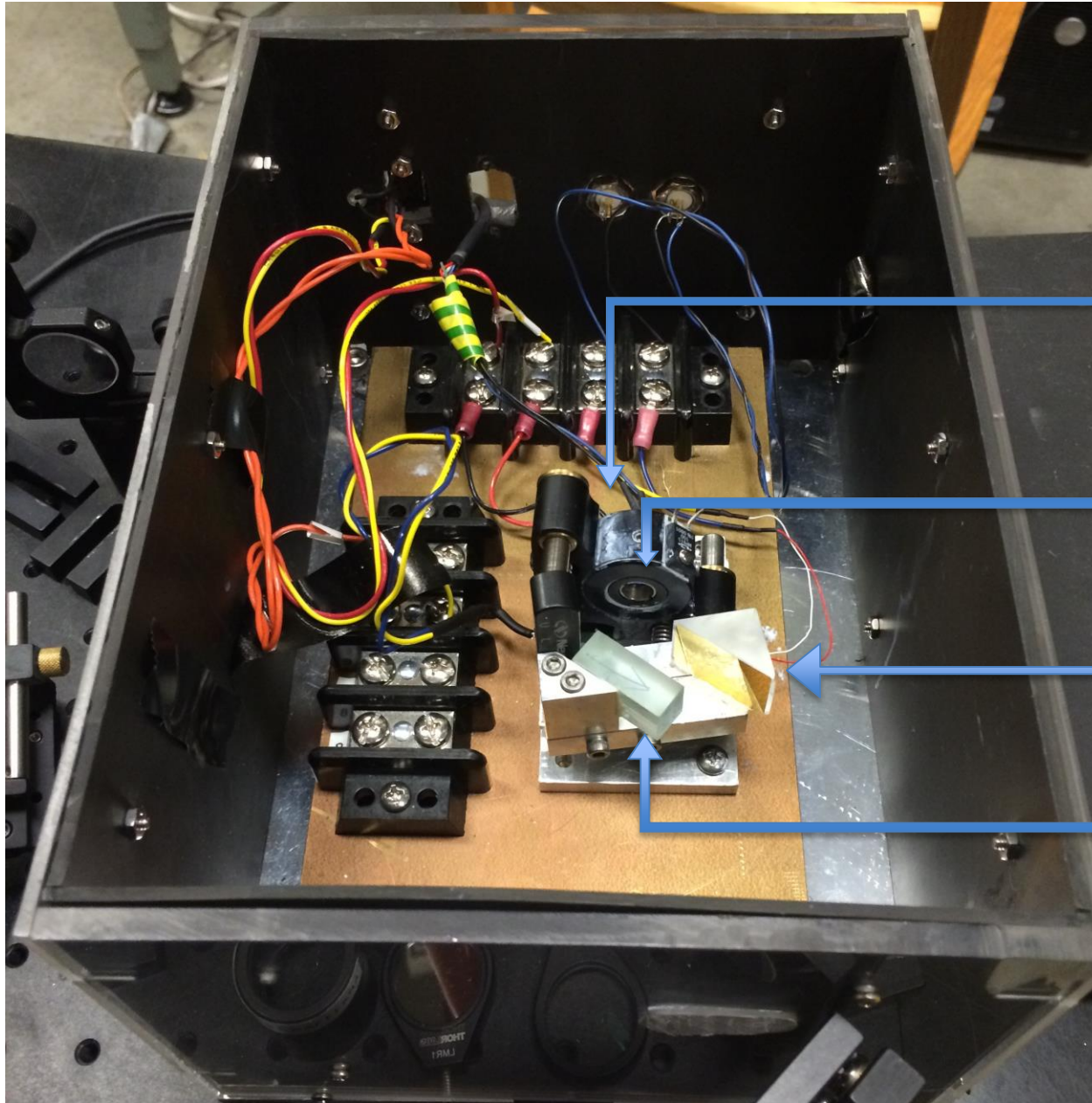


Interested in:

- Particular wavelength
- Long-term and short-term stability
- Diode protection

Hawthorn, C. J., K. P. Weber, and R. E. Scholten. "Littrow configuration tunable external cavity diode laser with fixed direction output beam." *Review of scientific instruments* 72.12 (2001): 4477-4479.

# Old ECDL



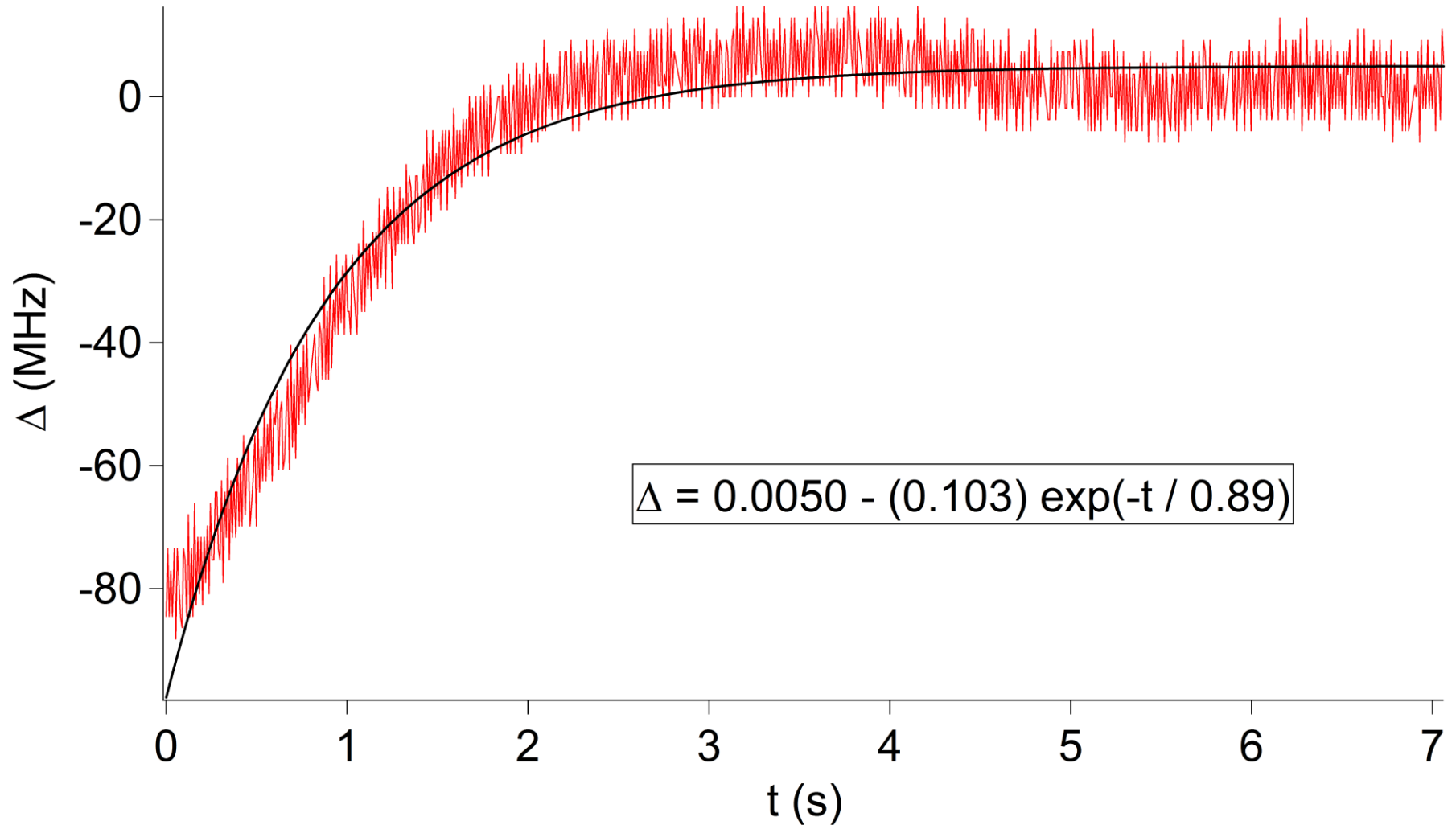
Thermistor & TEC

Diode

Mirror

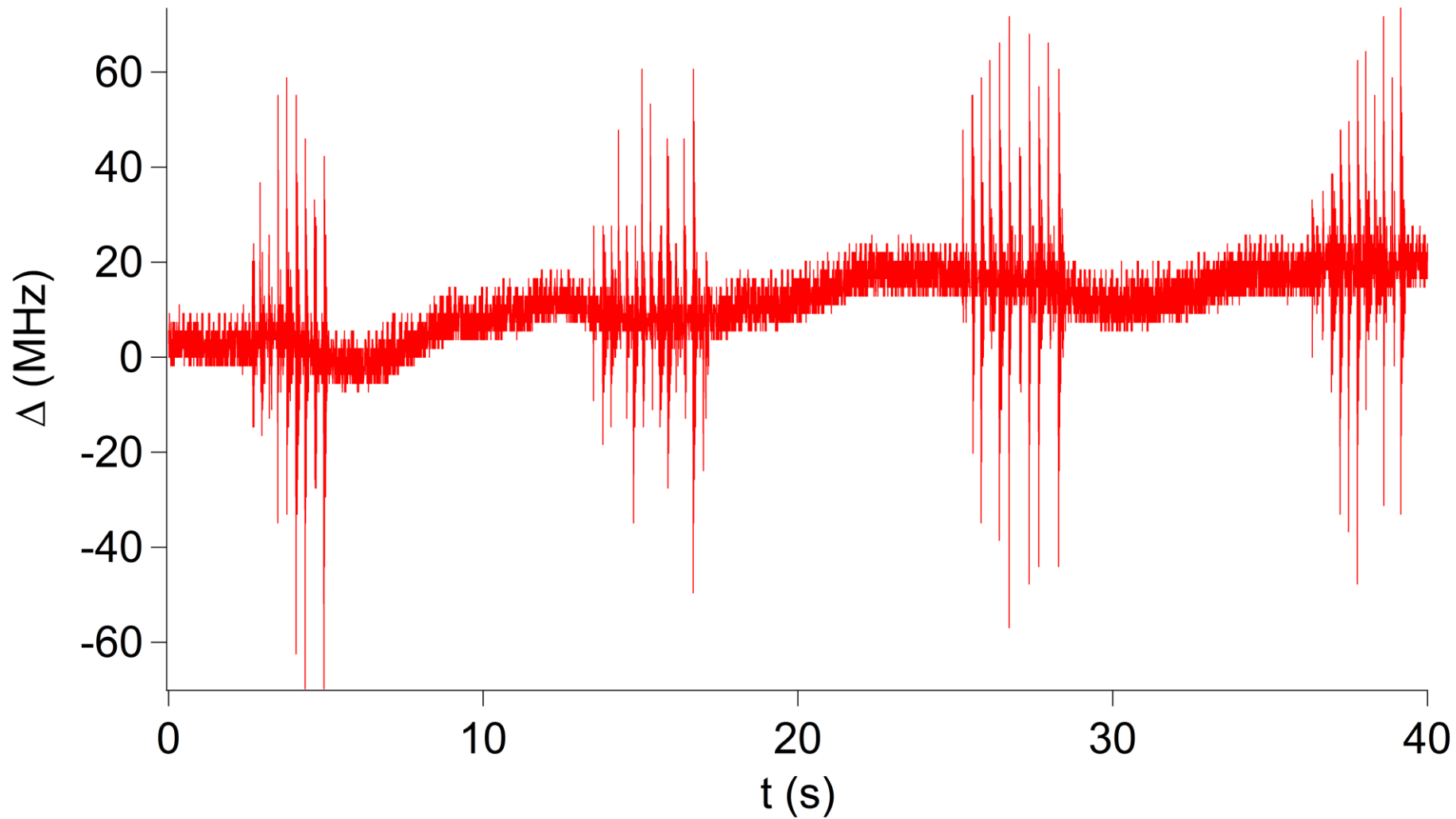
Grating

# Old ECDL – Air Currents

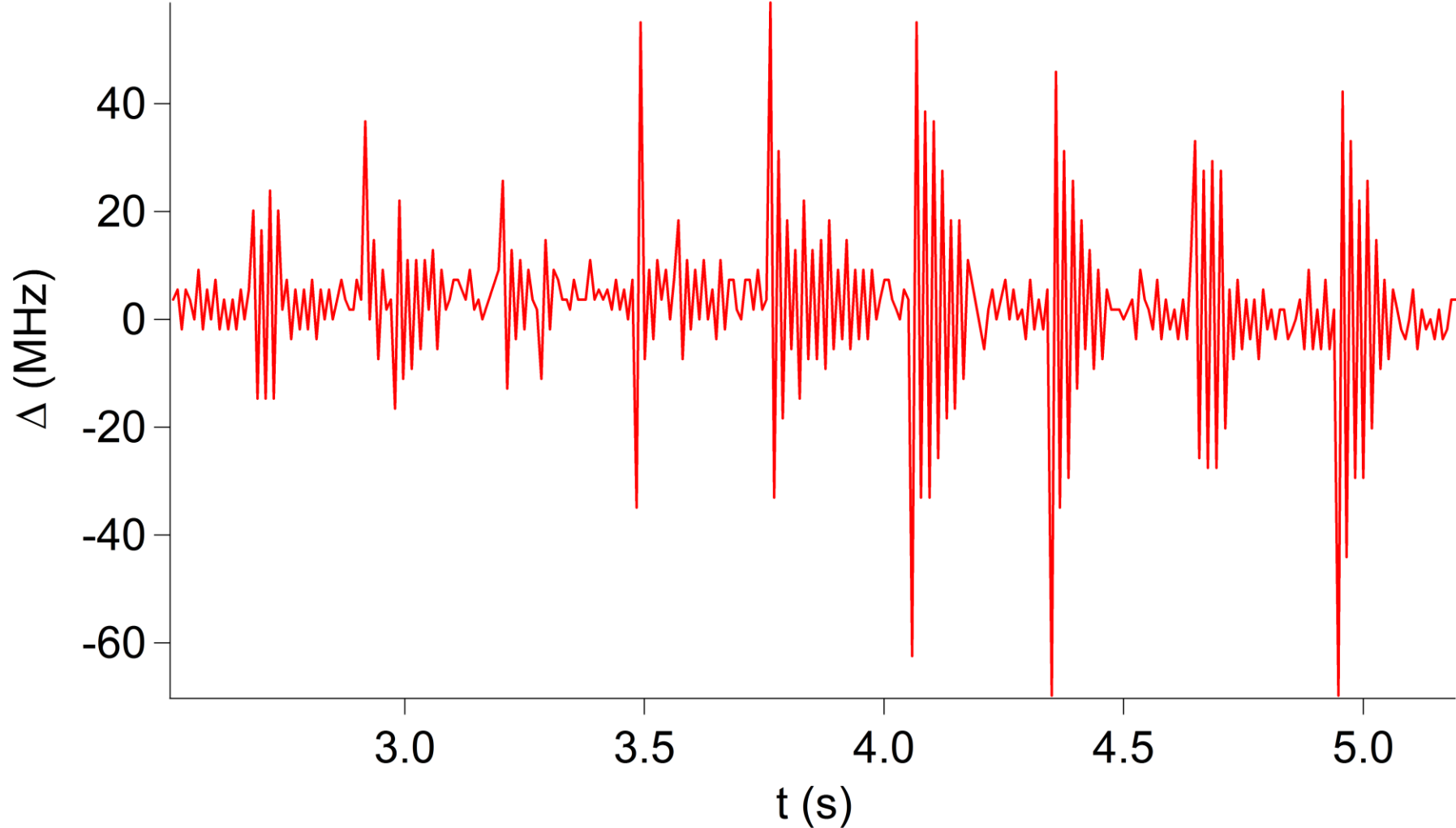


Roughly  $\sim 2.5$ s to equalize

# Old ECDL – Vibrations



# Old ECDL – Vibrations

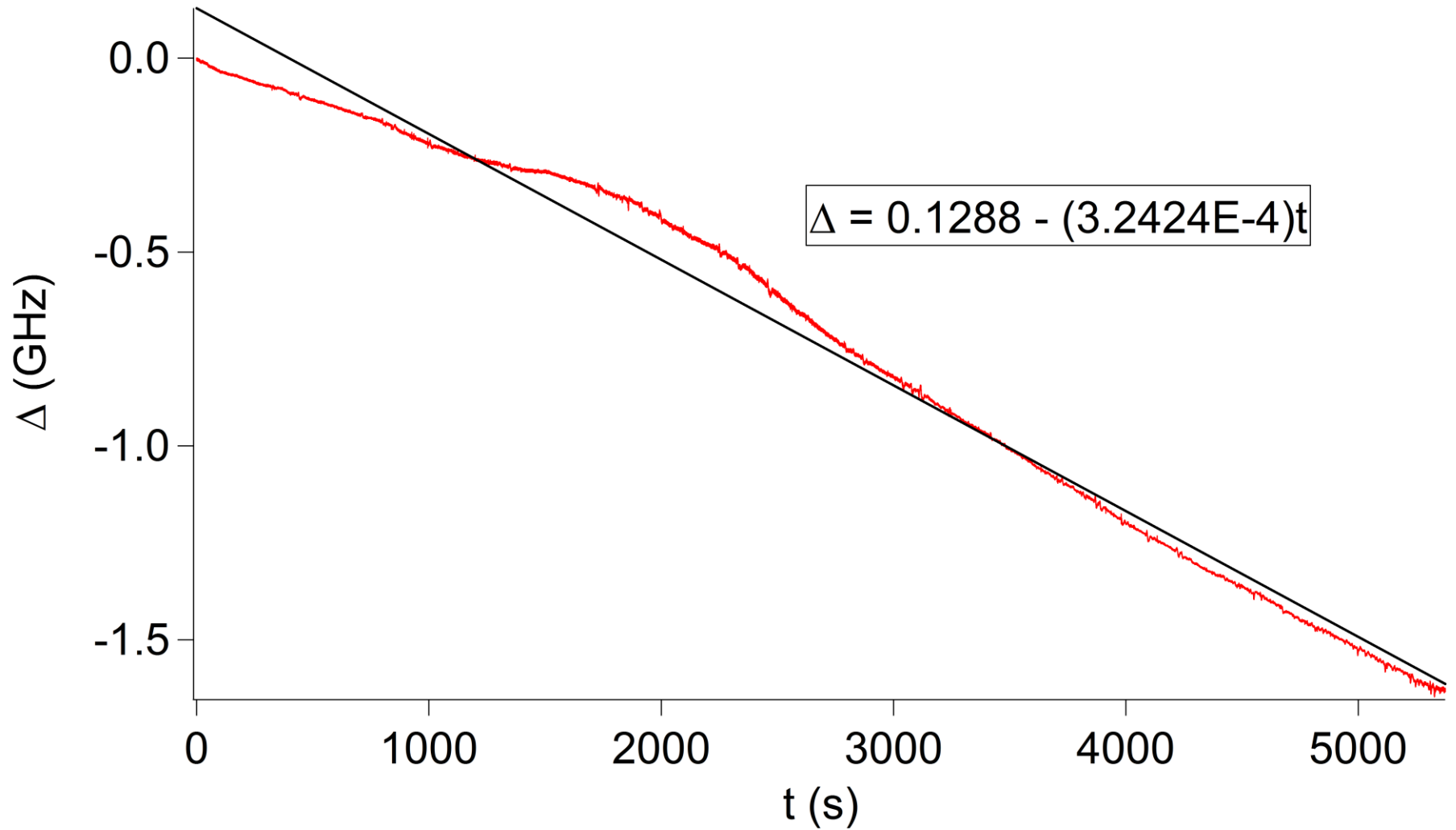


Deviation of 60 MHz

Rings for  $\sim .25$ s



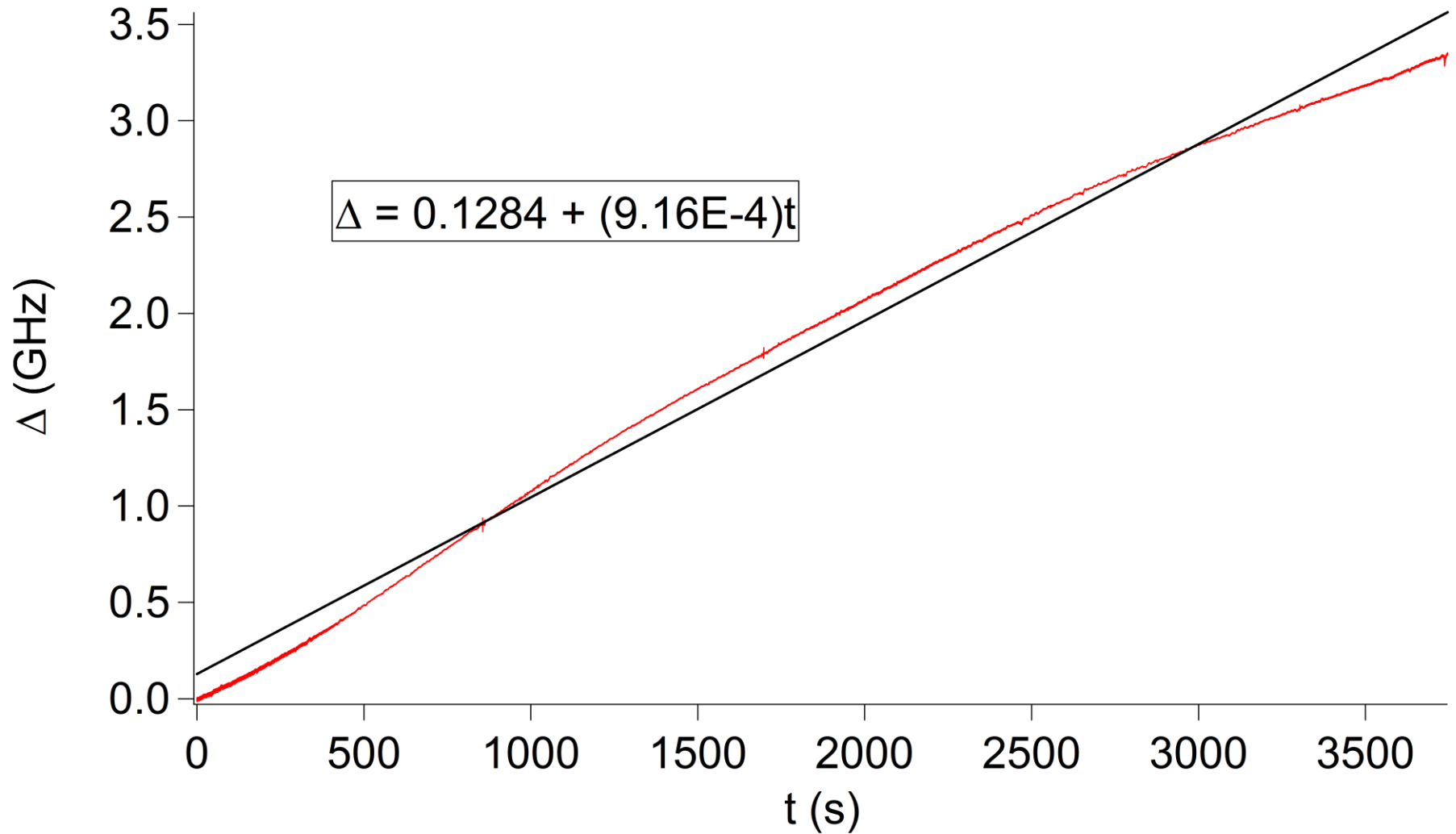
# Old ECDL – Long-term Drift



Data taken in morning

~0.3 MHz/s change

# Old ECDL – Long-term Drift



Data taken in afternoon

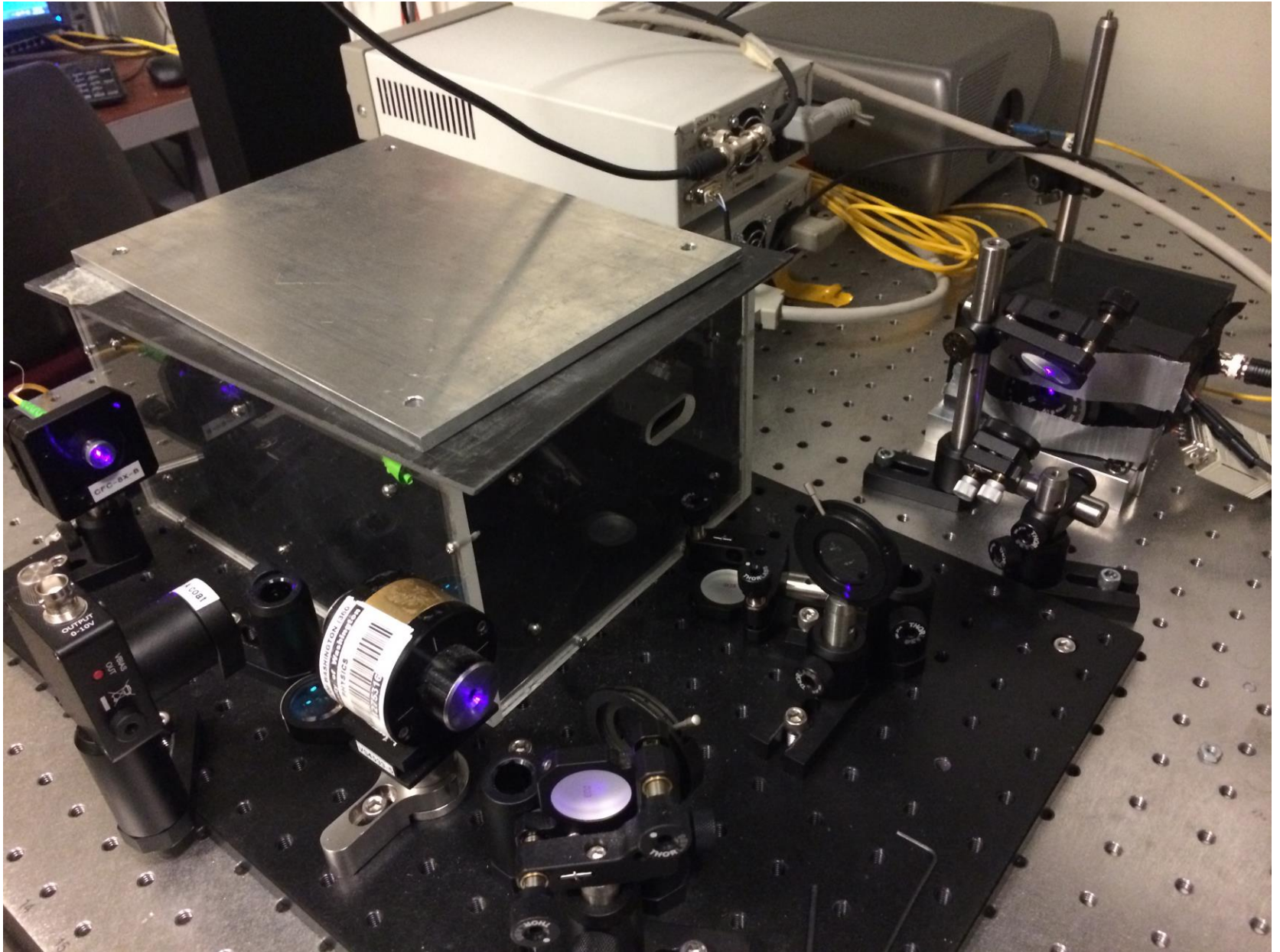
~1 MHz/s change

# Old vs New

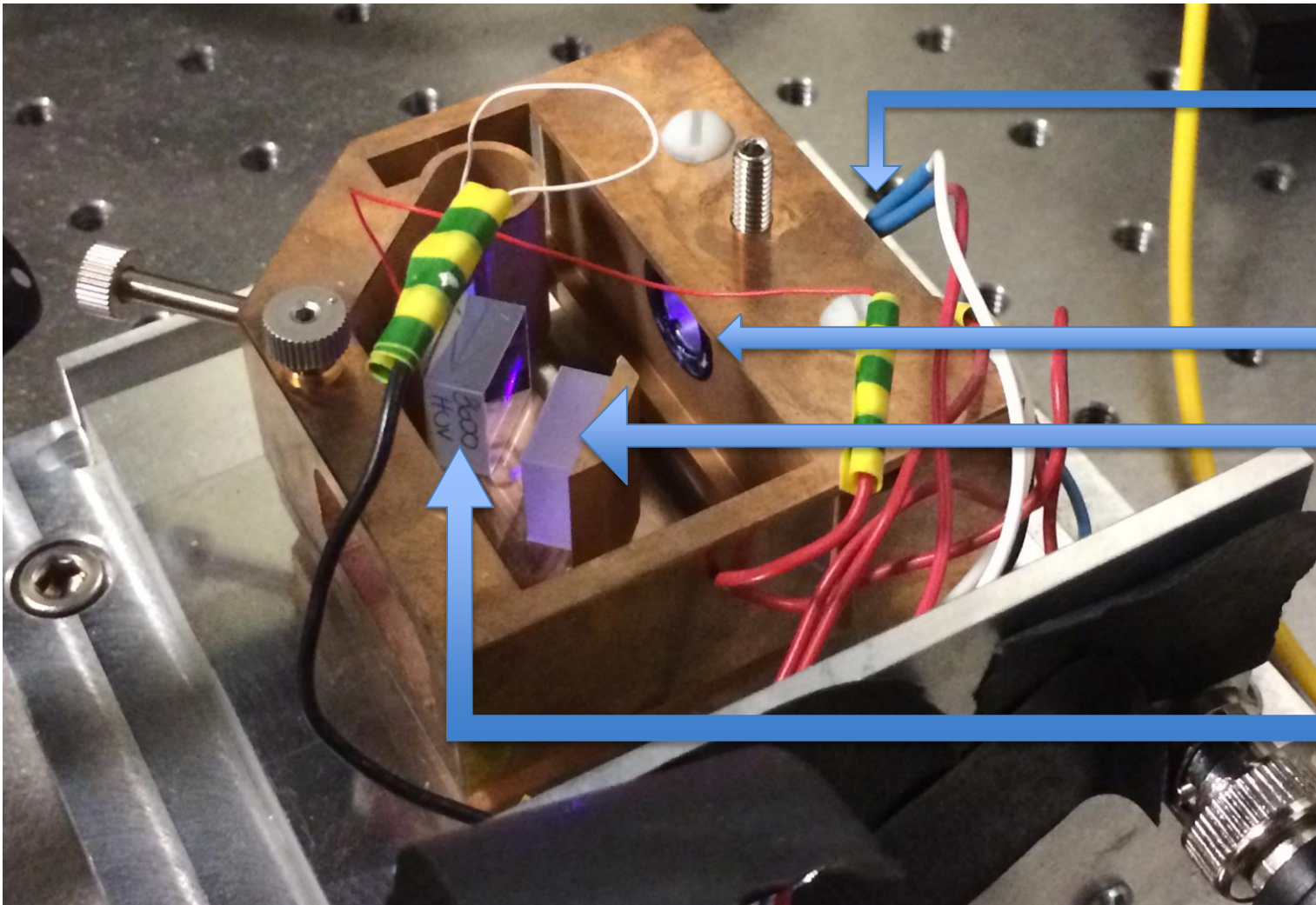
- Difficult to adjust position of grating
- Open cavity
- Thermistor far from diode
- Susceptible to air currents
- Uses gravity to hold itself down

- Easier to seed
- Thermally isolated
- Close off from the environment
- Monolithic
- Phosphor Bronze
  - High thermal conductivity

# New ECDL



# New ECDL



Thermistor & TEC

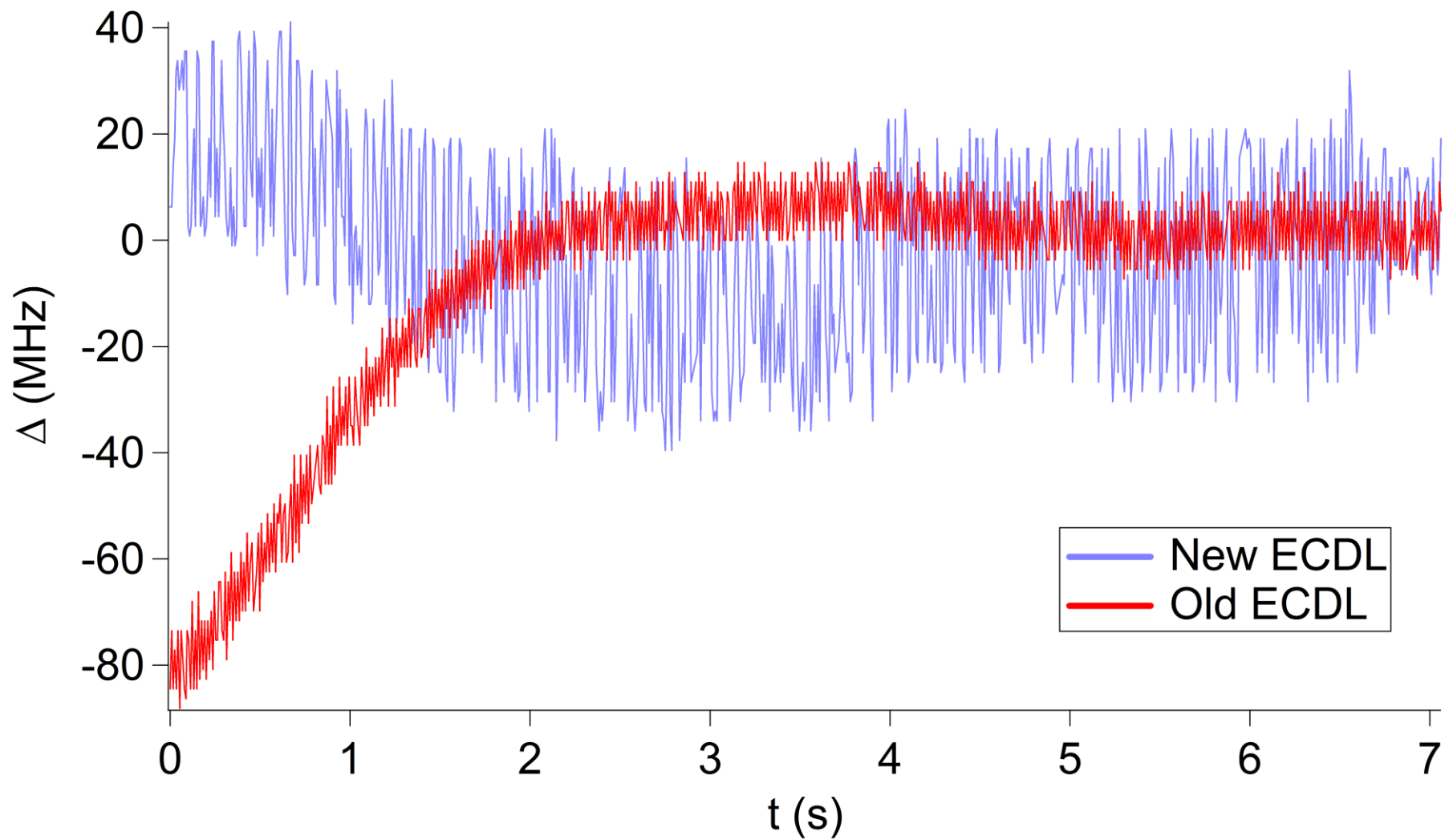
Diode

Mirror

Grating

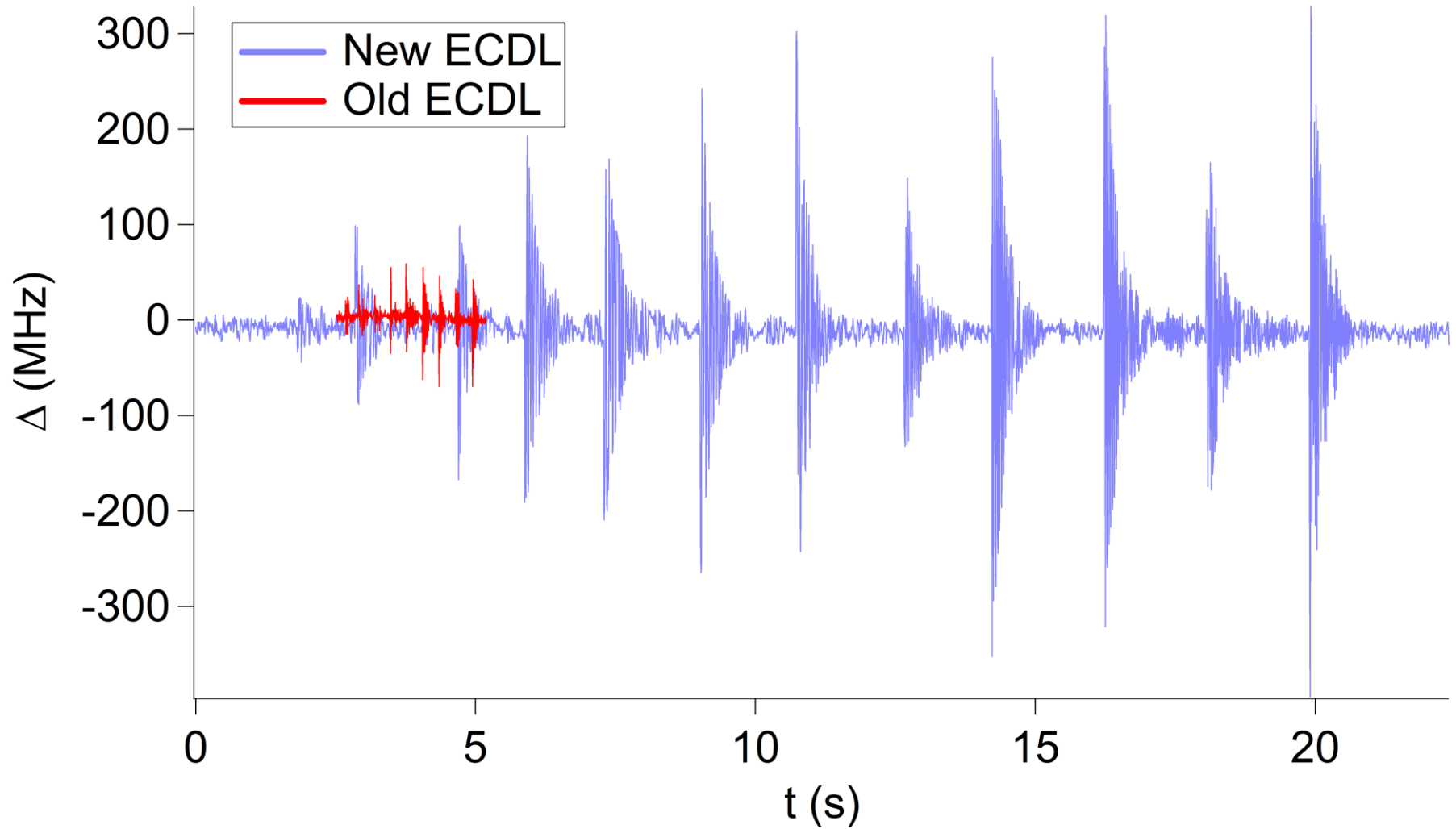


# New ECDL – Air Currents



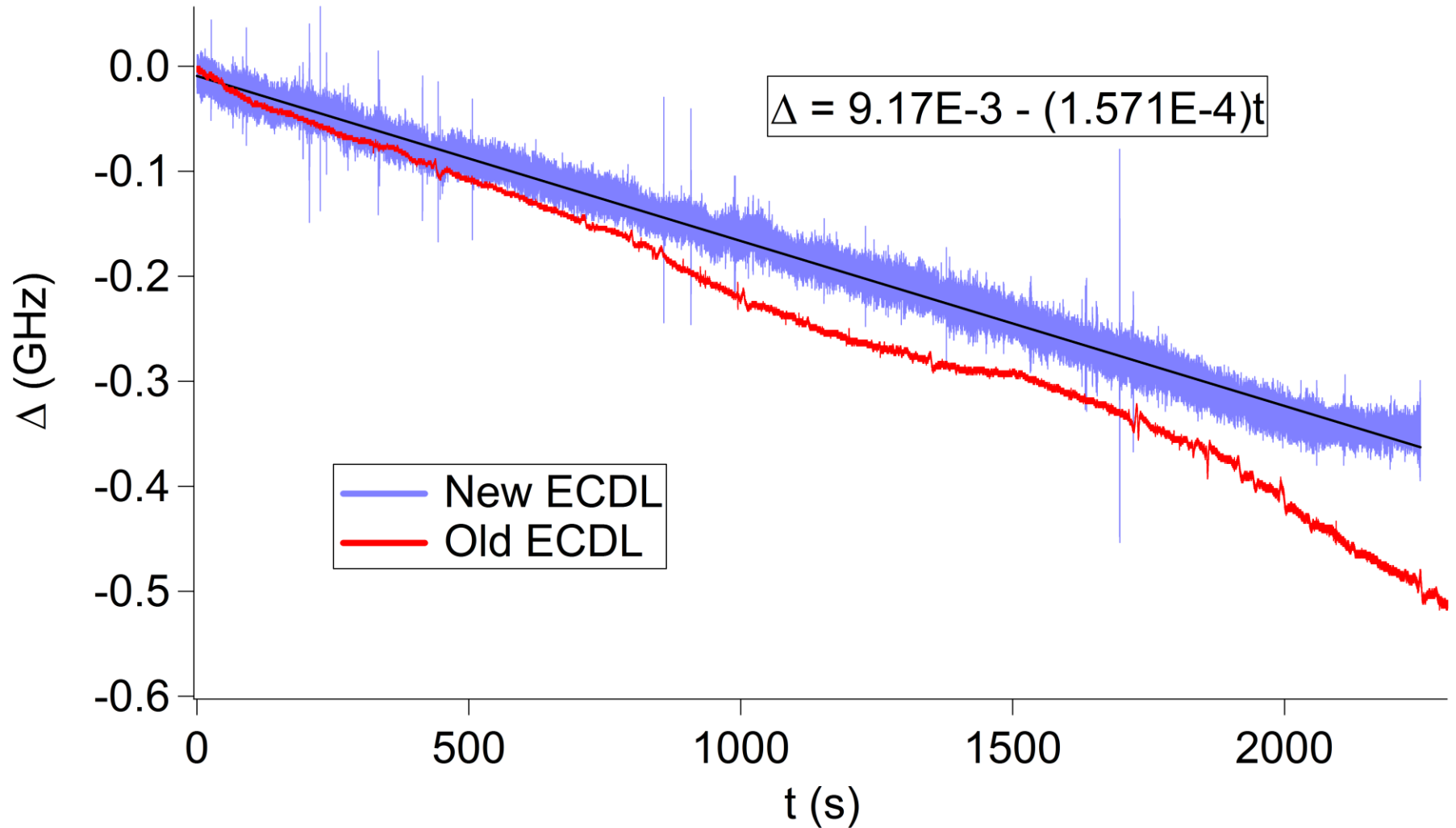
Roughly ~2s to equalize

# New ECDL – Vibrations



Larger disturbance in wavelength (could be due to instability in mode)

# New ECDL – Long-term Drift

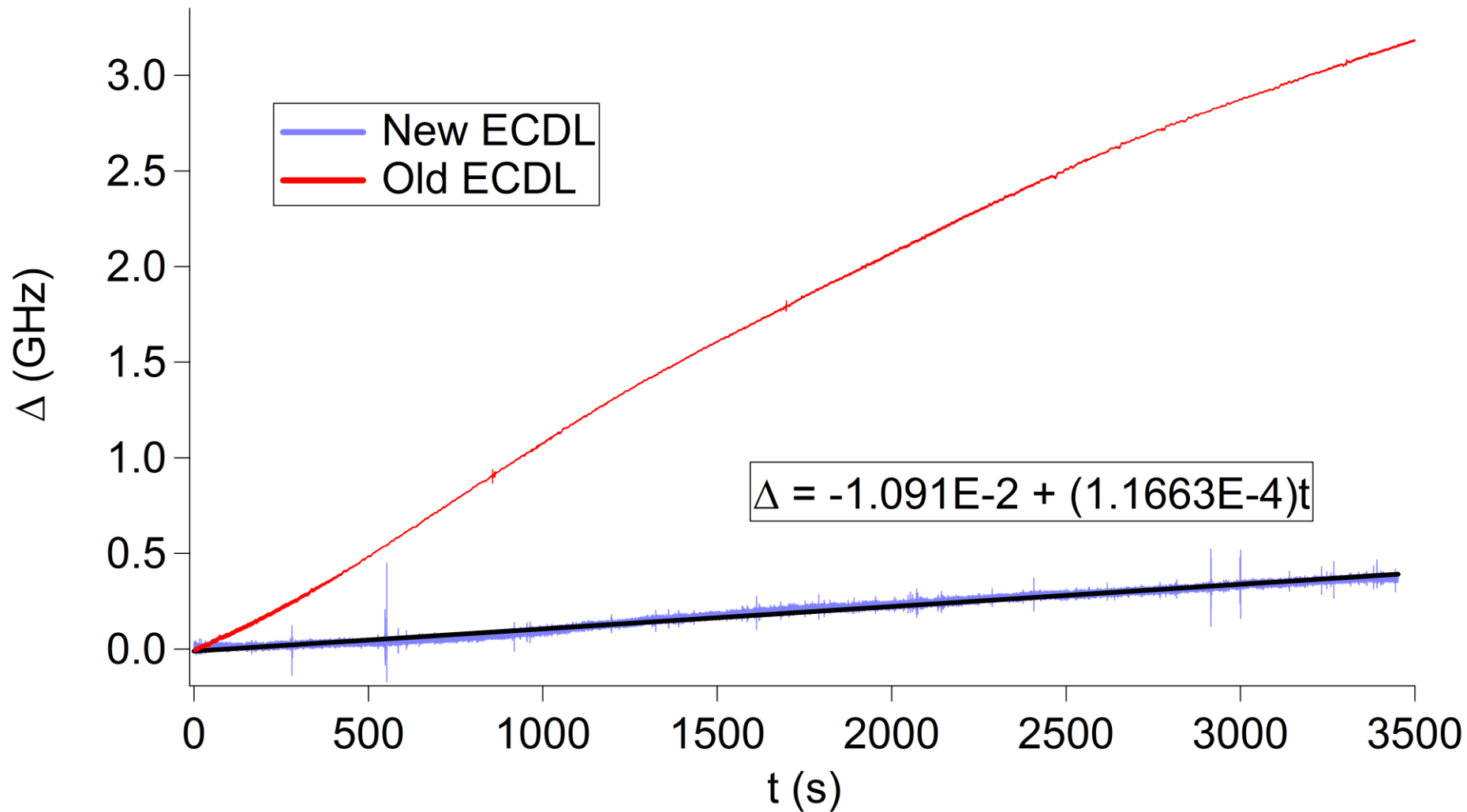


Data taken in morning

$\sim 0.2$  MHz/s change



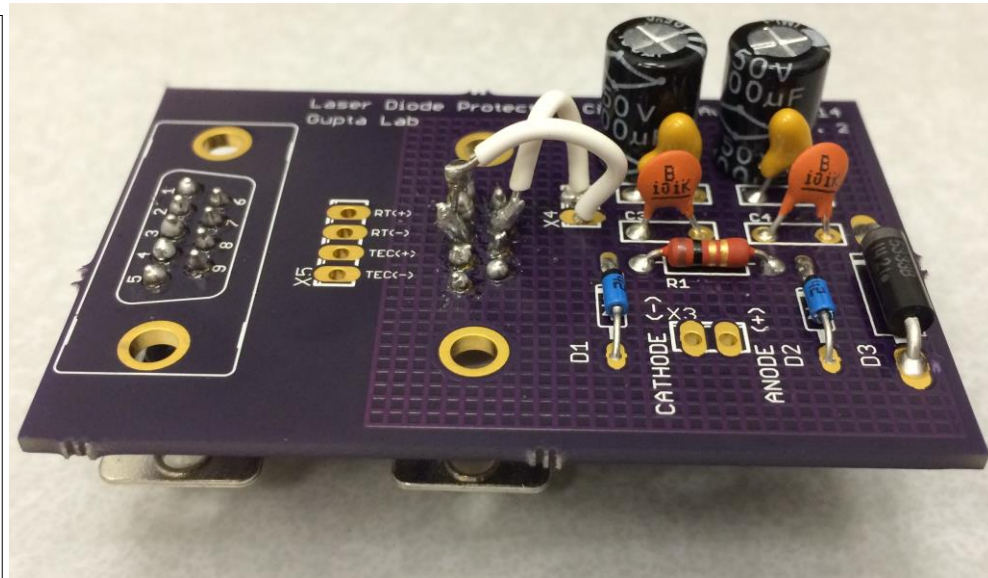
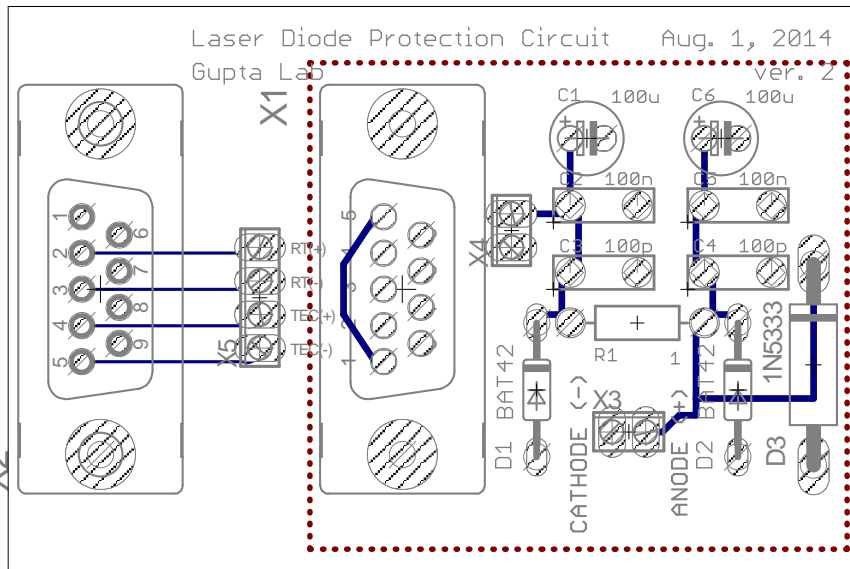
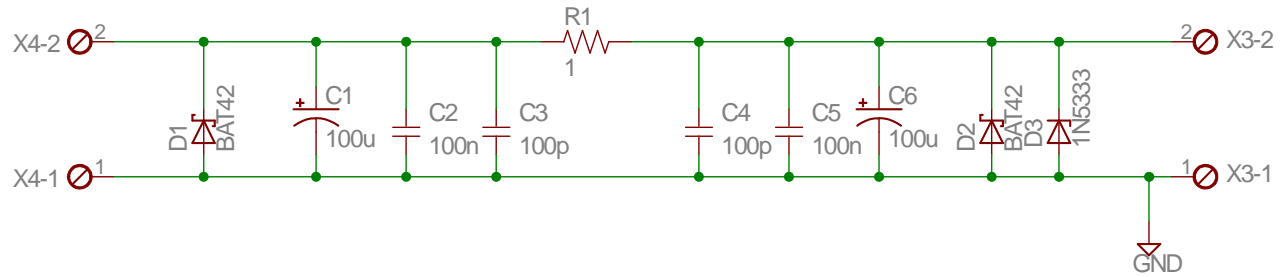
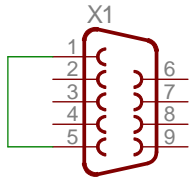
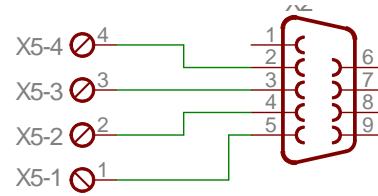
# New ECDL – Long-term Drift



Data taken in afternoon

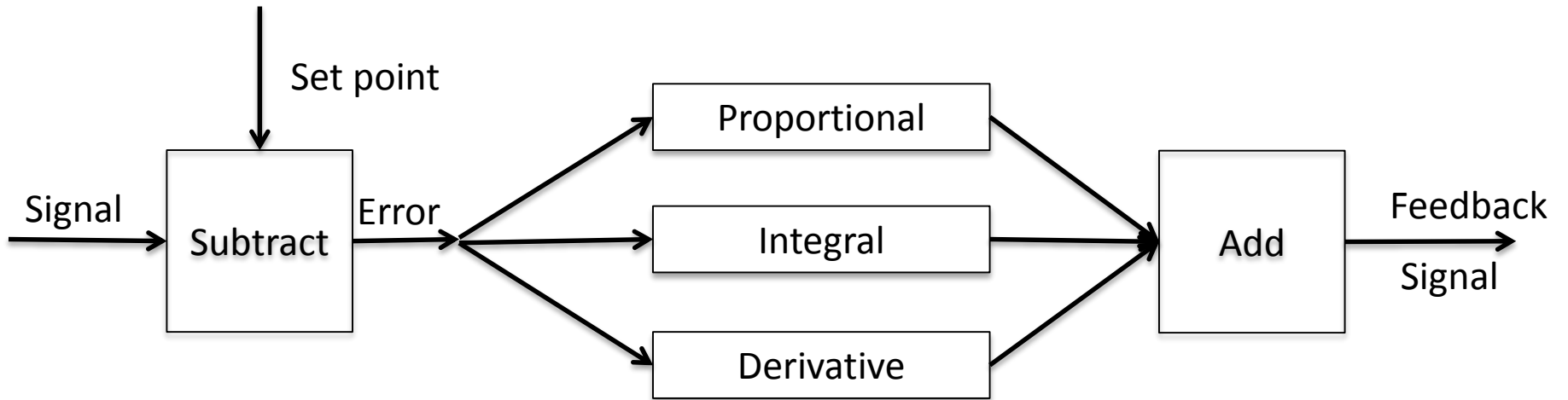
$\sim 0.1$  MHz/s change

# Protection Circuit



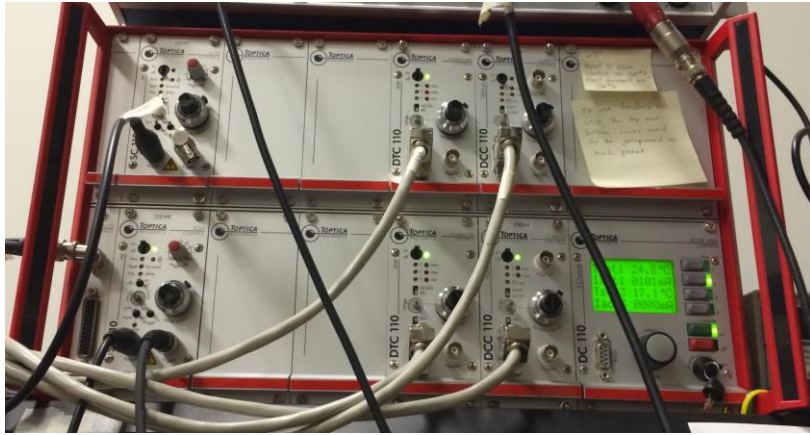
# Locking Software

## PID Controller

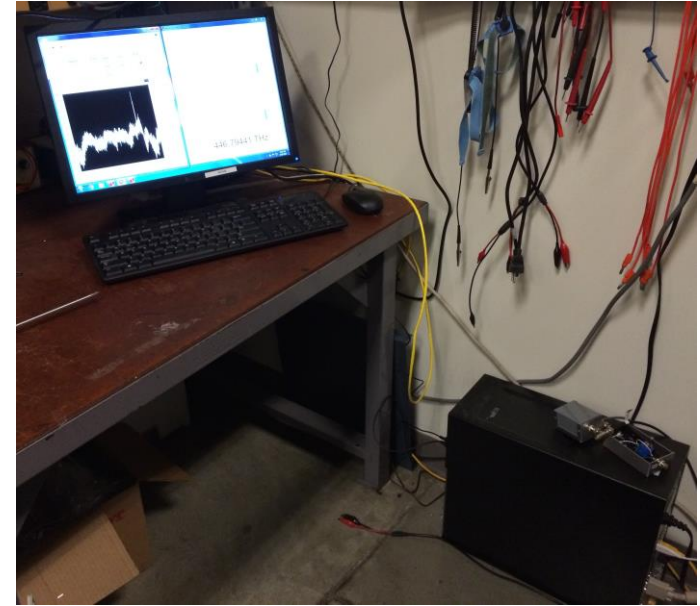


Set/control frequency of diode and stabilize output

# Locking Software



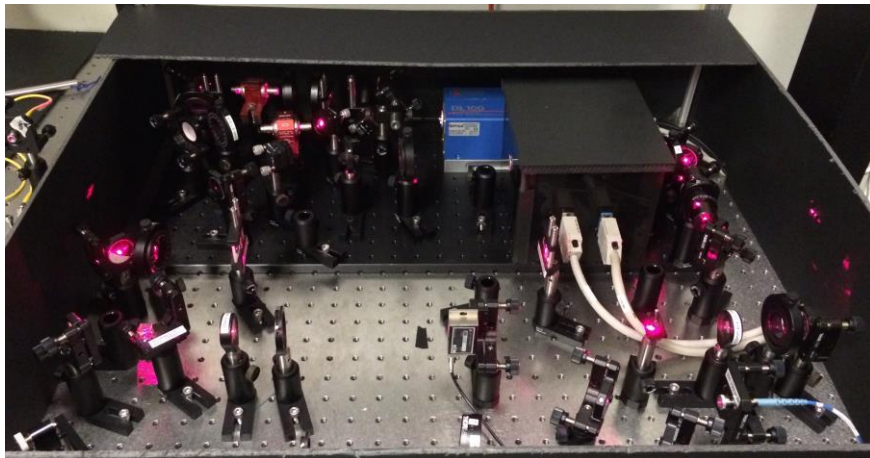
Signal to  
correct any  
deviation



Data sent to computer



Send current  
Drives piezo



Measure  
 $\lambda$



# Future Enhancements

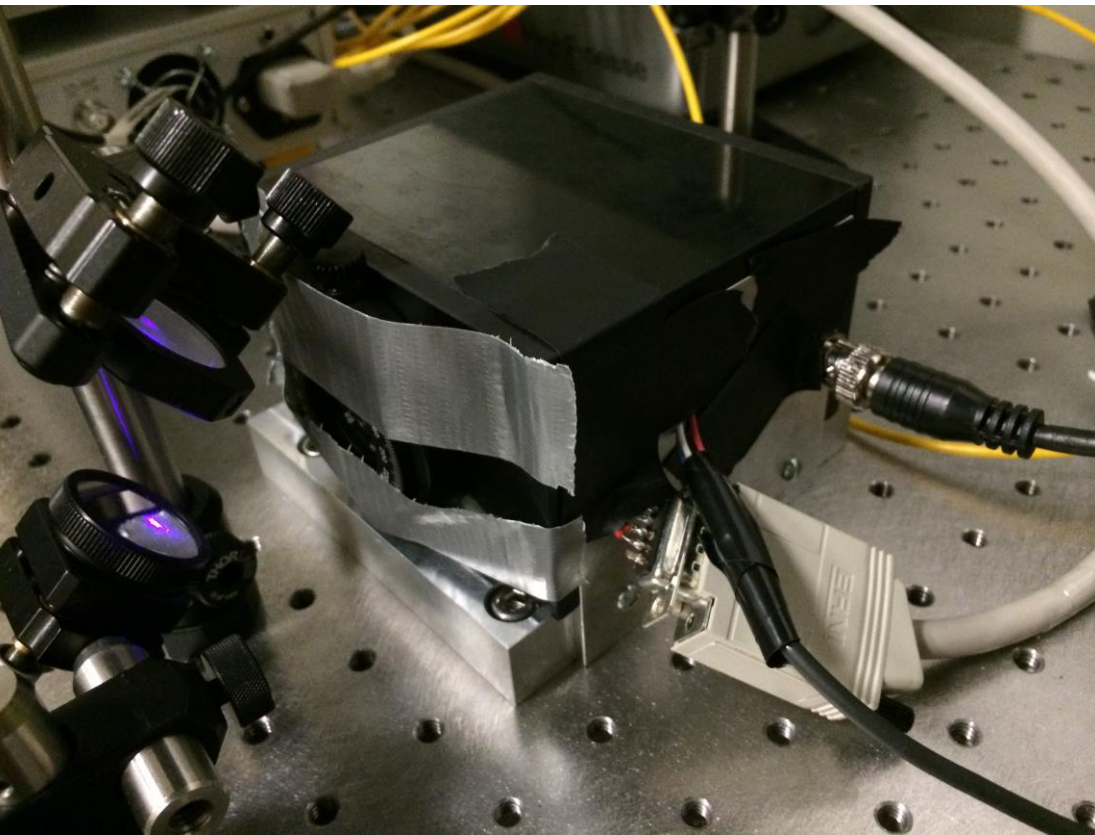
Install circuit boards and finish construction of ECDL

Jury-rig old ECDL housing to hold the 2<sup>nd</sup> gen ECDLs

Run similar stability tests

Find the right conditions for the desired mode

Install in experiment and hope it does the job





# Acknowledgements

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- Ricky Roy, Raj Shrestha, Alaina Green, Will Dowd
- Ron Musgrave
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