A Laser, a Transition, and a Counter

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Outline

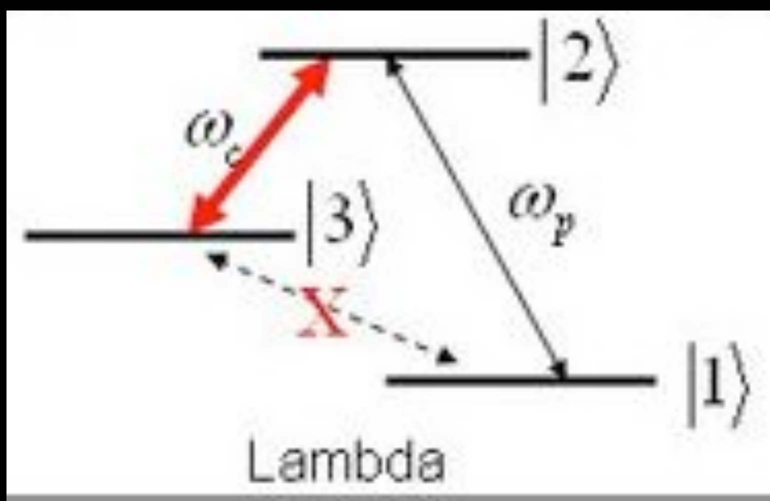
- Overall goal of project
- Background
- The VCSEL
- Rubidium Resonances
- Trouble
- Future Work

Overall Goal of Project

- Create an atomic clock
  - Need: laser, transition, counter, laser frequency lock
  - Have:
    - transition (Rubidium-87 at 780 or 794 nm)
    - counter (piece of equipment that is bought)
  - Working on:
    - laser (VCSEL)
    - laser frequency lock (optical setup)

Background

- Atomic transition in Rubidium-87 is the hyperfine splitting at 780 or 794 nm
- Known as Lambda system



Background continued

- Use electromagnetically induced transparency to measure transmitted light
- The closer to hyperfine splitting resonance, the more transmission
- Counter locked to maximum transmission which corresponds to clock frequency

Background continued

- Lambda system requires two lasers at different frequencies
- Problem: inherent in lasers are small random shifts in frequency around a set frequency (“jumps”)
- Bigger problem: if two lasers are physically separate, the “jumps” are random

Background continued

- Solution: use phase modulation to create two lasers out of one physical laser
- Why? Both lasers “jump” with each other so relative frequency can be set by external generator
- Creates carrier with sideband comb

Background continued

- Three phase modulation formulas

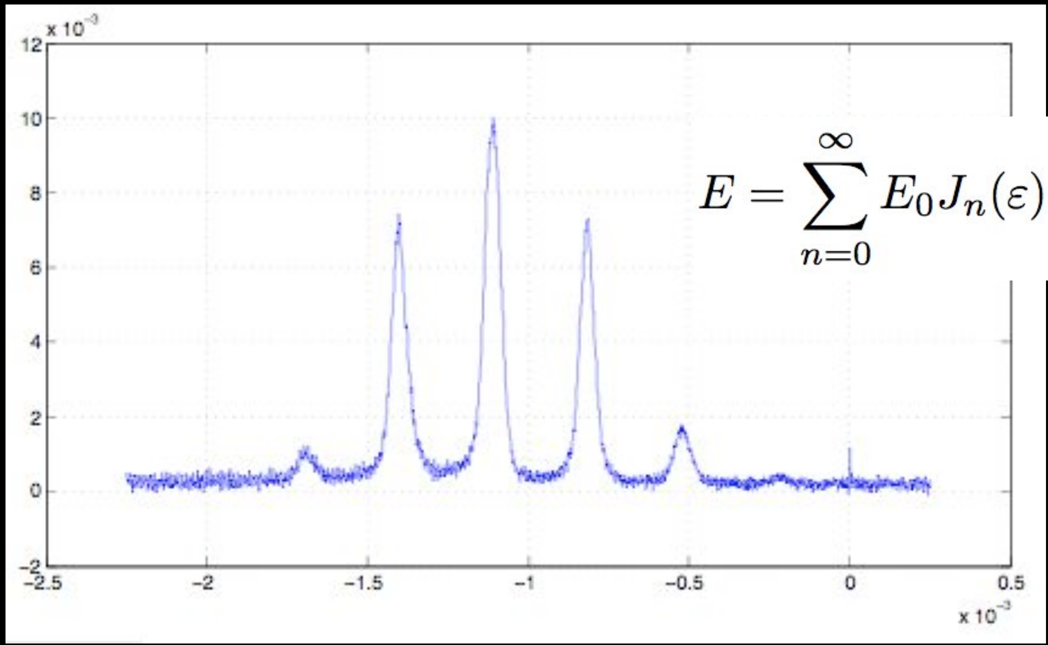
$$E = E_0 e^{ikx - i\omega t + i\varphi(t)}$$

$$\varphi(t) = \varepsilon sin(\omega_m t)$$

$$E = \sum_{n=0}^{\infty} E_0 J_n(\varepsilon) e^{ikx - i(\omega - n\omega_m)t}$$

Background continued

- Carrier to sideband spacing determined by input frequency



$$E = \sum_{n=0}^{\infty} E_0 J_n(\varepsilon) e^{ikx - i(\omega - n\omega_m)t}$$

The VCSEL

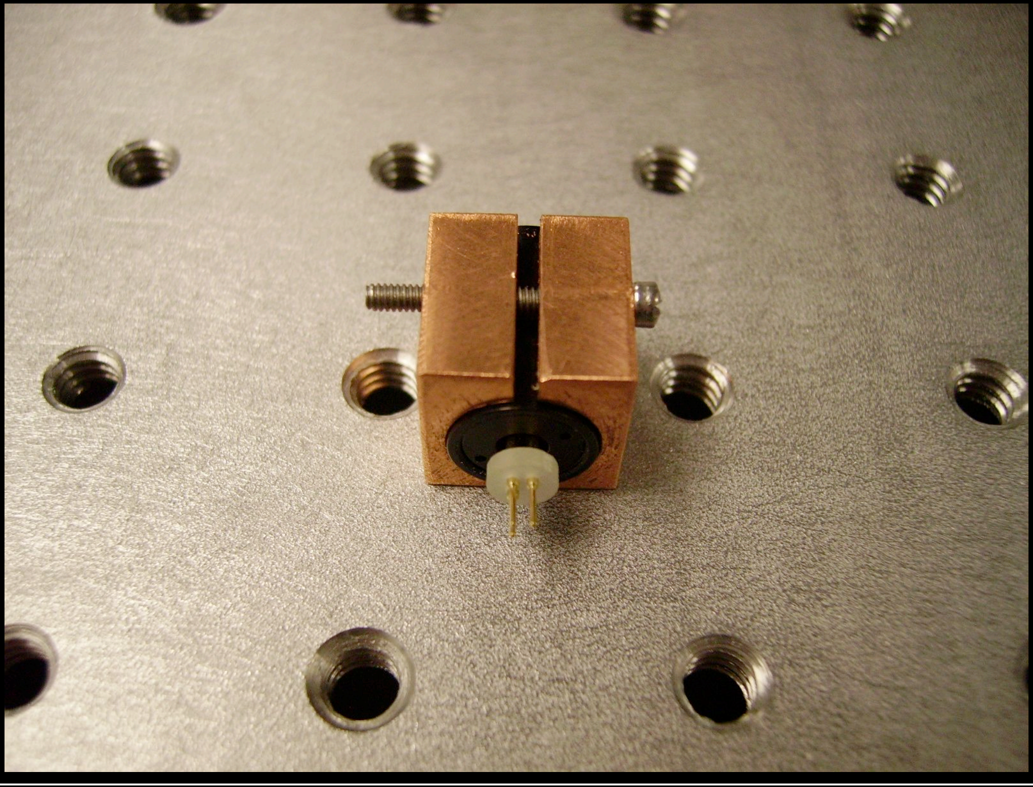
- Vertical-cavity surface-emitting laser
- Why?
  - Low power consumption
  - Easy to modulate current for phase modulation
  - Already in use in miniature atomic clocks

VCSEL continued

- What it looks like…

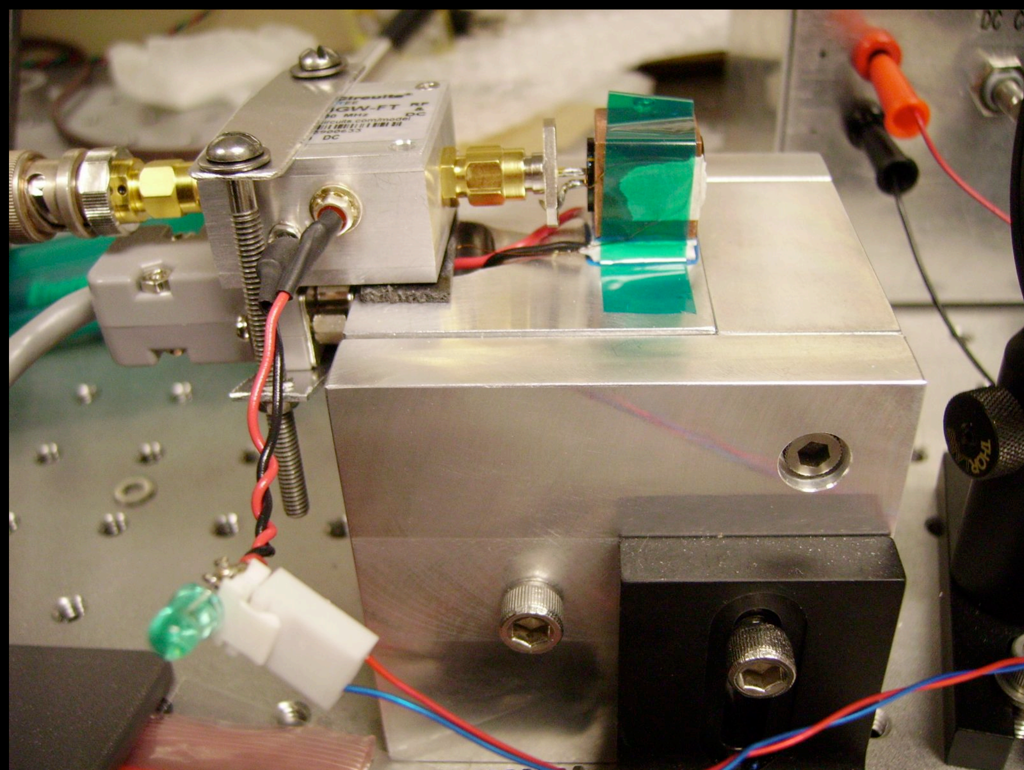
VCSEL continued

- Where it is housed..



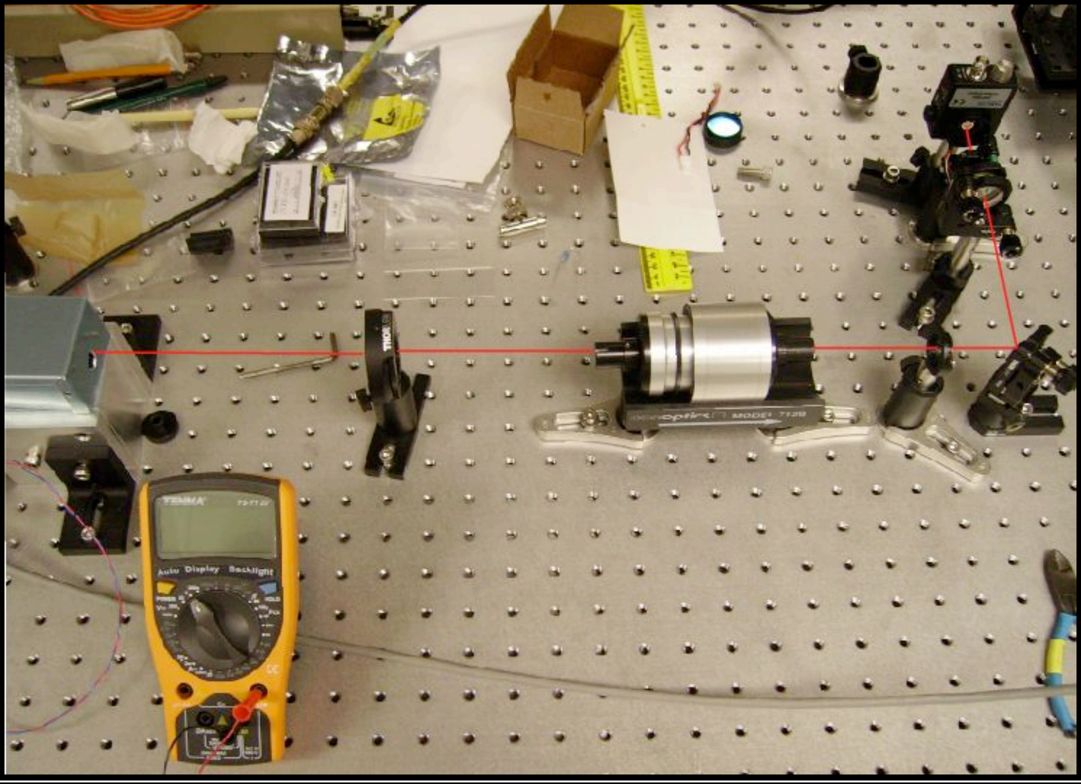
VCSEL continued

- On this heat sink…



VCSEL continued

- In this laser system…

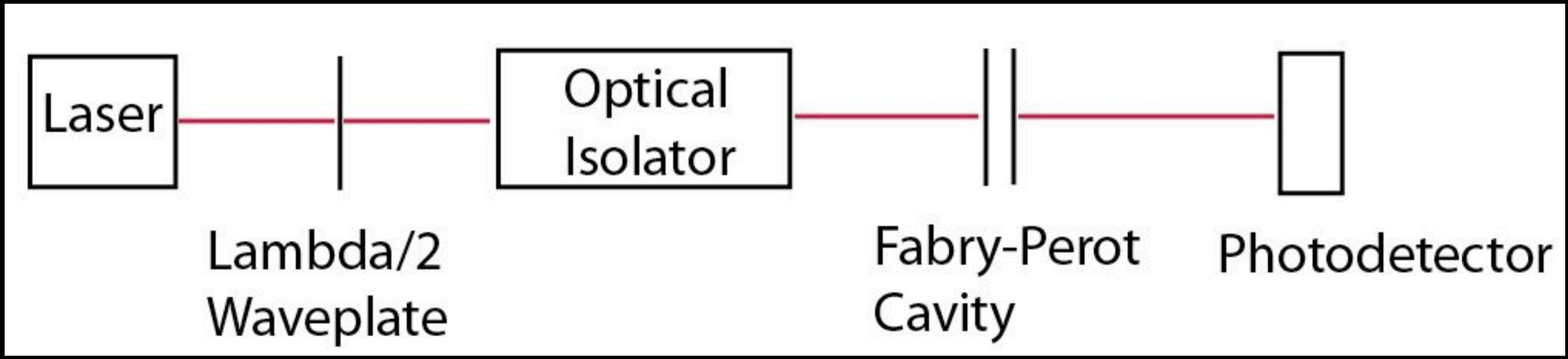


VCSEL continued

- Previous work:
  - Characterization of polarizations and how they interact with changing current
  - Calculating sideband/carrier ratios at different frequencies and modulation powers
  - Seeing resonances in a Rubidium vapor cell

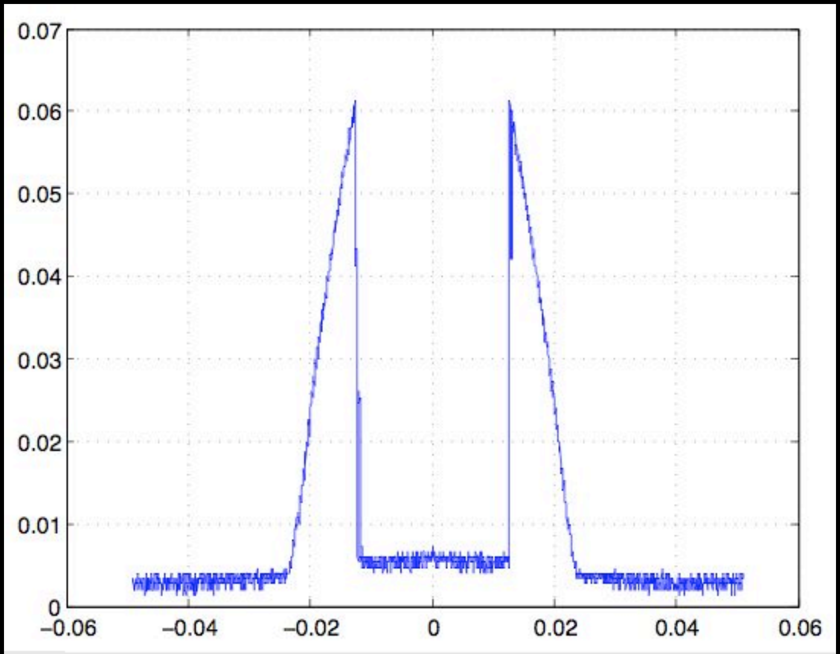
VCSEL continued

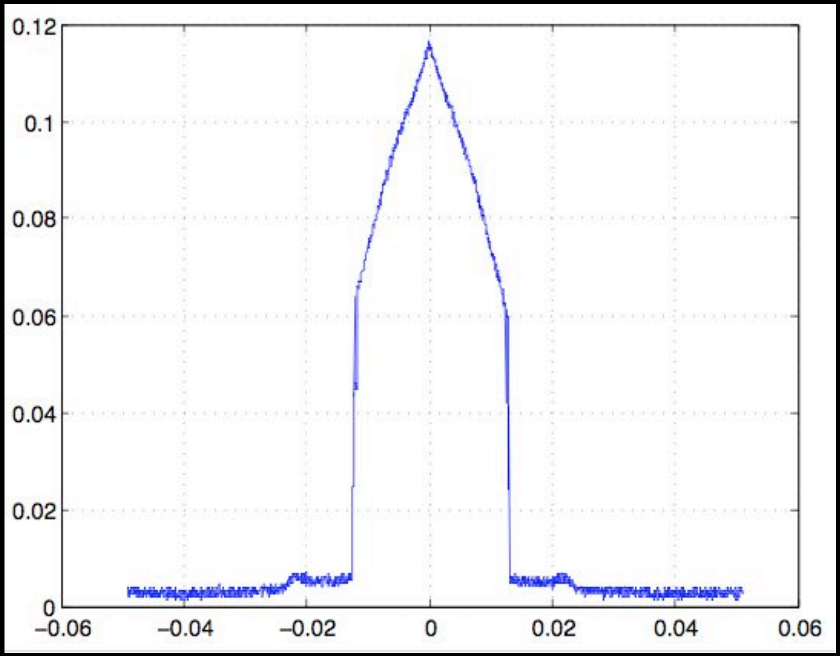
- How we took the polarization and modulation data:



VCSEL continued

- Polarizations with Roithner at 1.35 mA

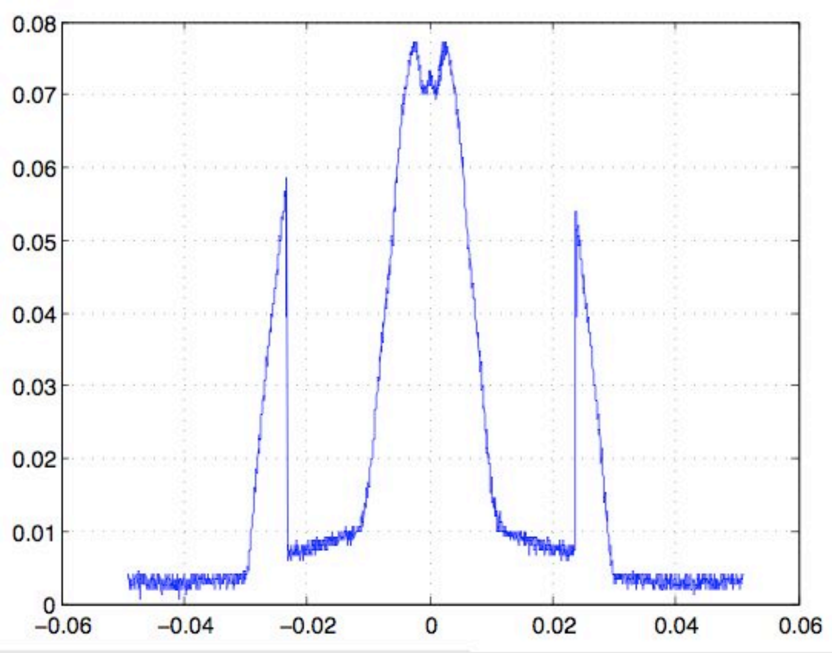


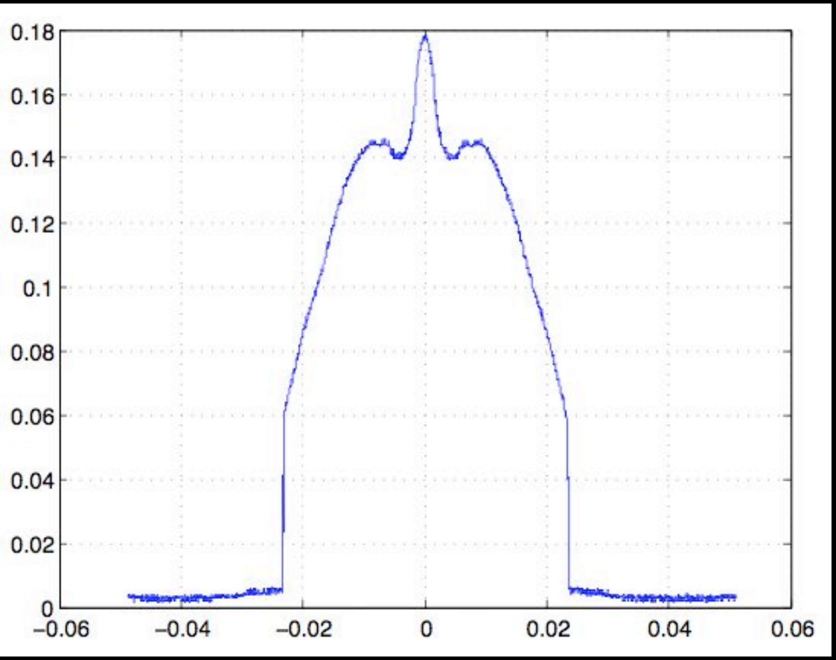


Y-Axis: Amplitude, Arbitrary Units X-Axis: Time, 10 ms scale

VCSEL continued

- Polarizations with Roithner at 2.09 mA

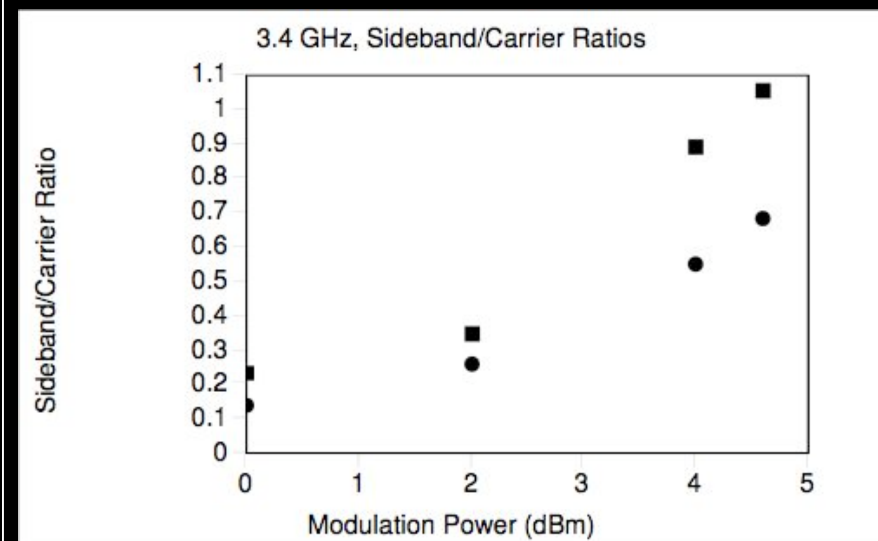


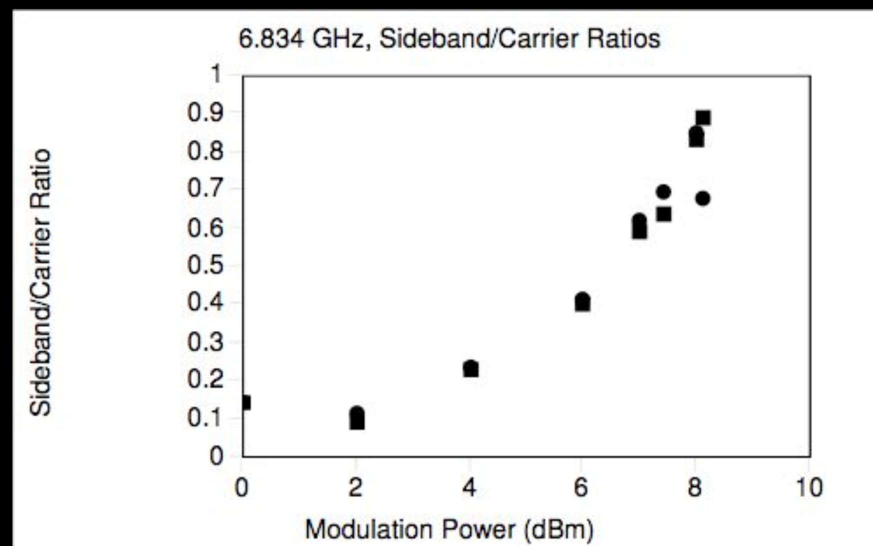


Y-Axis: Amplitude, Arbitrary Units X-Axis: Time, 10 ms scale

VCSEL continued

- Sideband/carrier ratios for 3.4 and 6.8 GHz with Roithner VCSEL



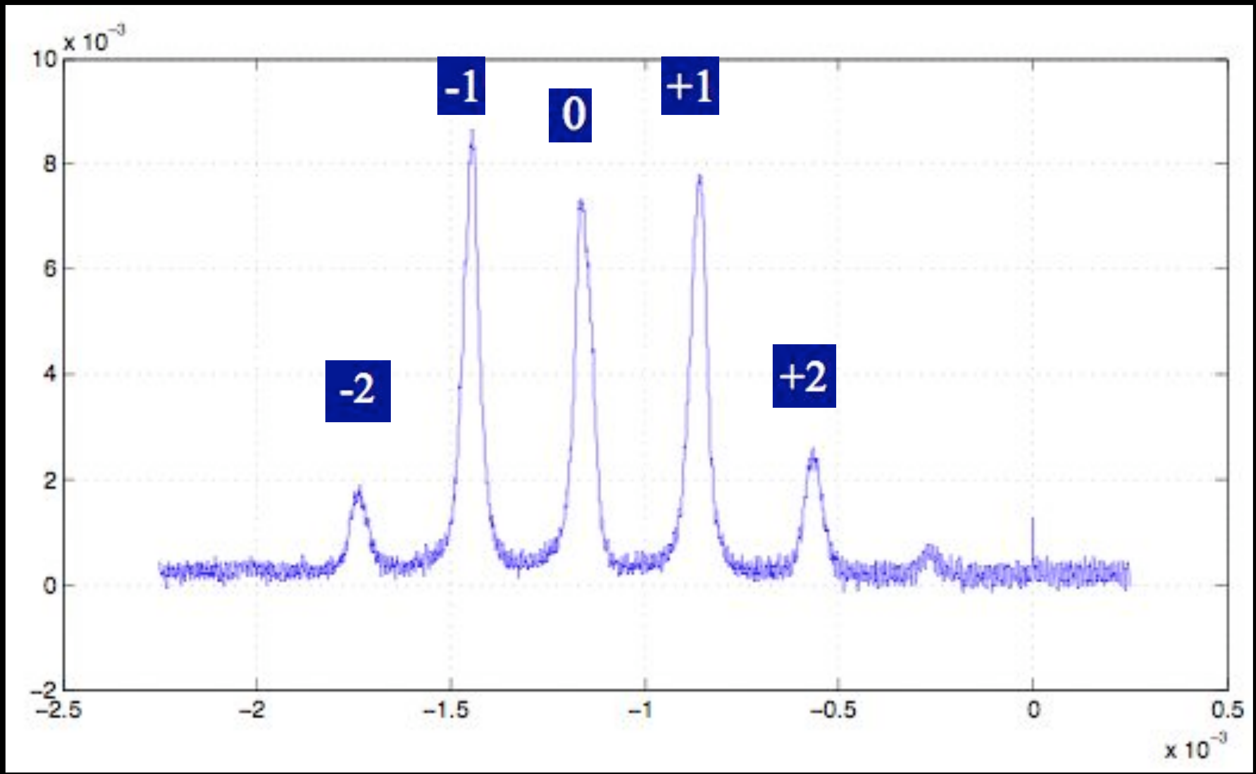


VCSEL continued

- Carrier and sideband combs at 3.4 GHz, -9 dBm, 2.25 mA

Y-Axis:

Amplitude, Arbitrary Units



X-Axis:

Time, 1 ms scale

VCSEL continued

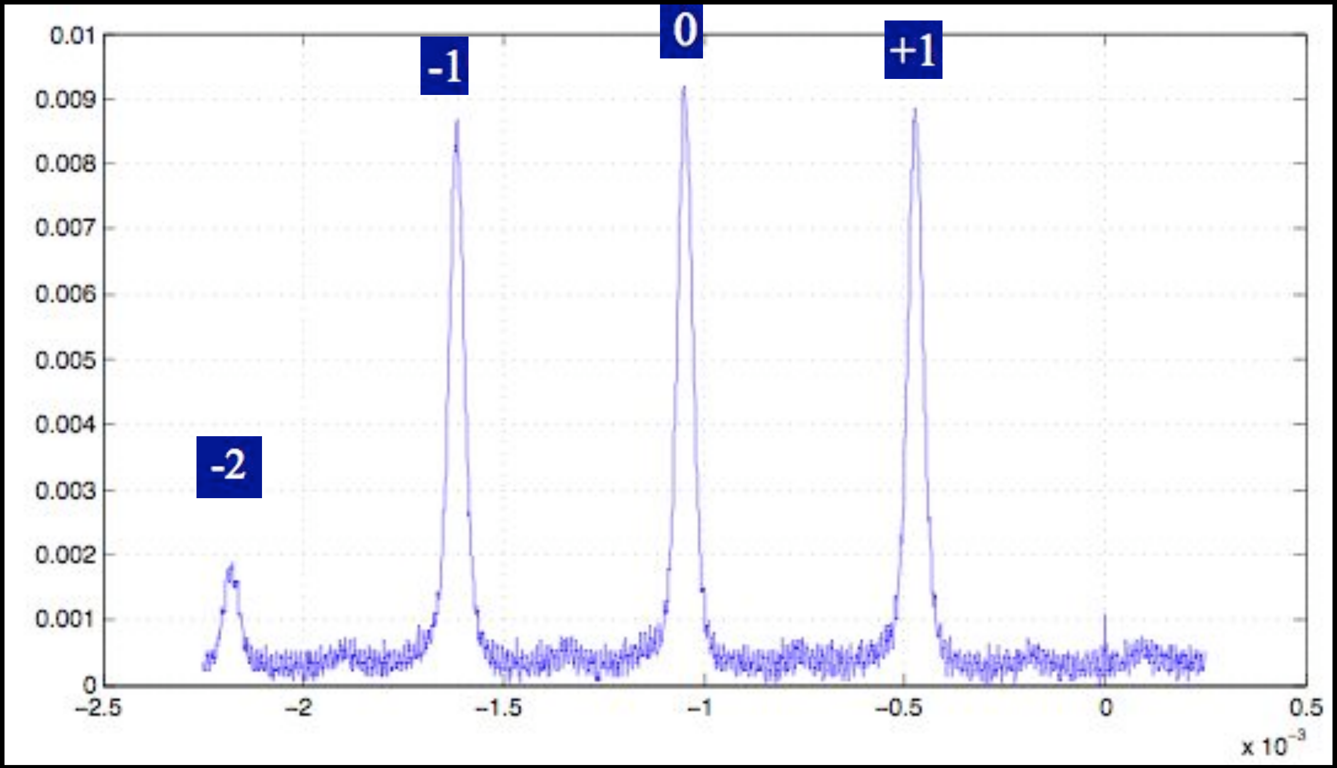
- Carrier and sideband combs at 6.834 GHz, 14 dBm, 2.25 mA

Y-Axis:

Amplitude, Arbitrary Units

X-Axis:

Time, 1ms scale

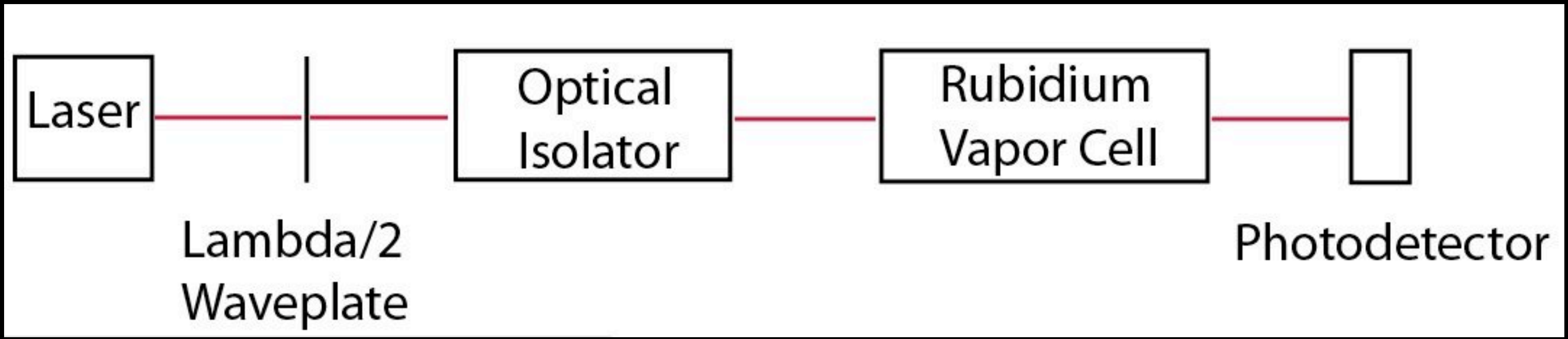


Rubidium Resonances

- Roithner VCSEL not able to get to transition at 780 nm
- 5 nm away, needs to be heated to 80 degrees Celsius
- Can’t get there because of current limits in peltier and temperature controller

Rubidium Resonances continued

- How we measured the resonances:

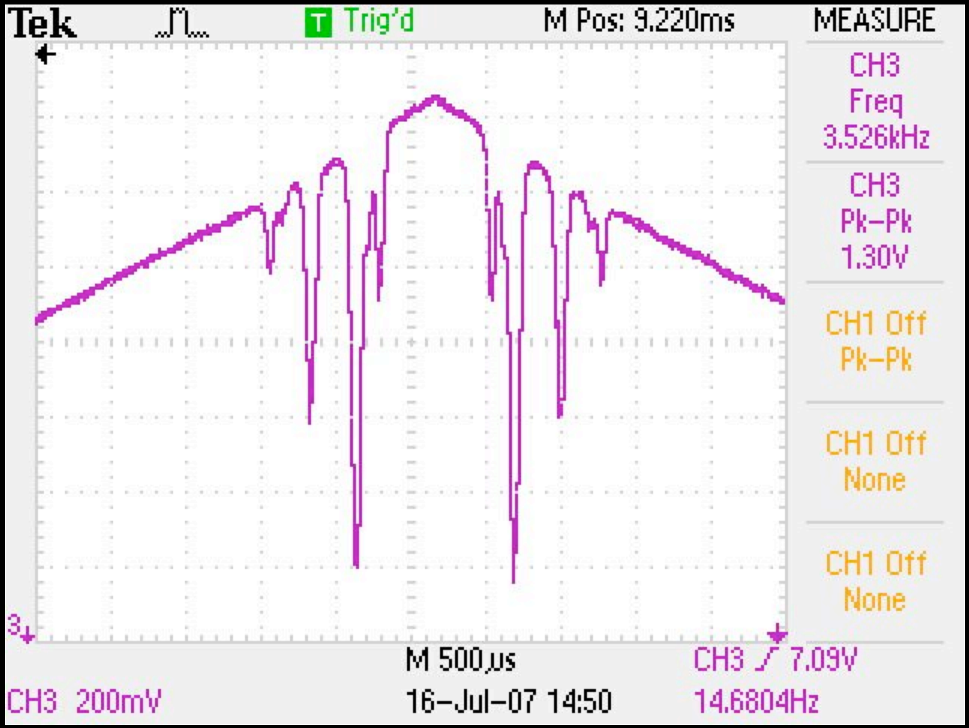


Rubidium Resonances continued

- Switch to Ulm VCSEL #1
- Rated for 795 +/- 1 nm
- Measured at 795 nm
- Need 794.7 nm for resonance

Rubidium Resonance continued

- Resonance with Ulm VCSEL #1

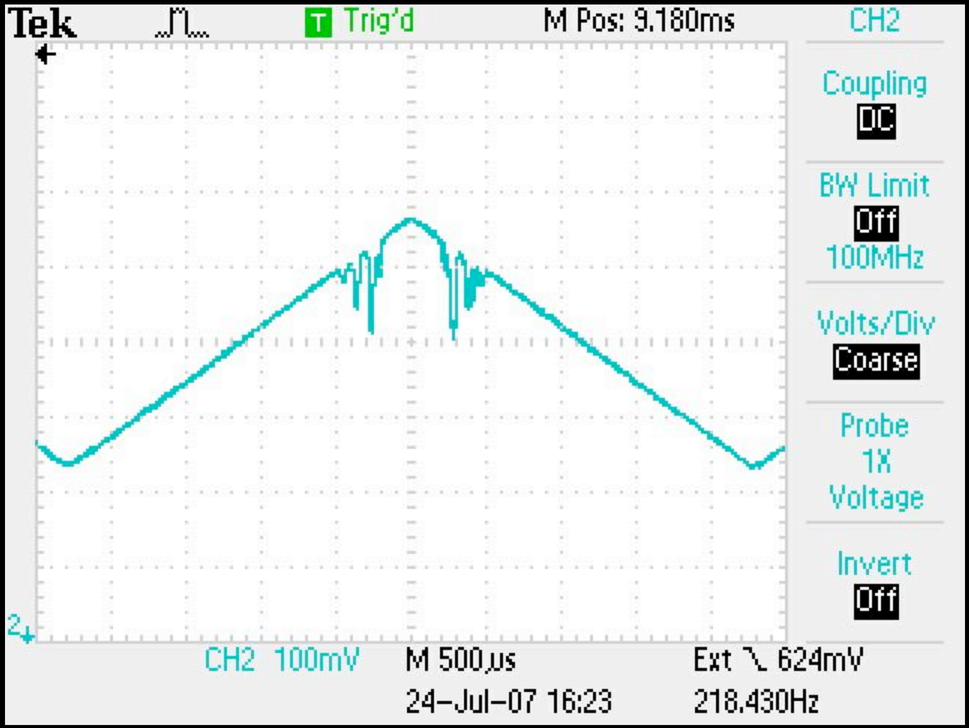


Rubidium Resonance continued

- Ulm VCSEL #2
- Rated for 795 +/- 1 nm
- Measured at 792.9 nm
- Again, need 794.7 nm

Rubidium Resonance continued

- Resonance with Ulm VCSEL #2



Trouble

- Battery-powered constant current source
- Forward current protection with limiting resistor
- No protection from exceeding maximum reverse voltage

Trouble continued

- While looking at resonances, turned amplitude up on function generator too much
- Exceeded maximum reverse voltage
- Destroyed lasing cavity

Trouble continued

- Installed Ulm #2
- Saw resonances
- Used clamp instead of zip tie and double-sided tape to hold Bias-T in place
- Grounded Bias-T to heat sink

Trouble continued

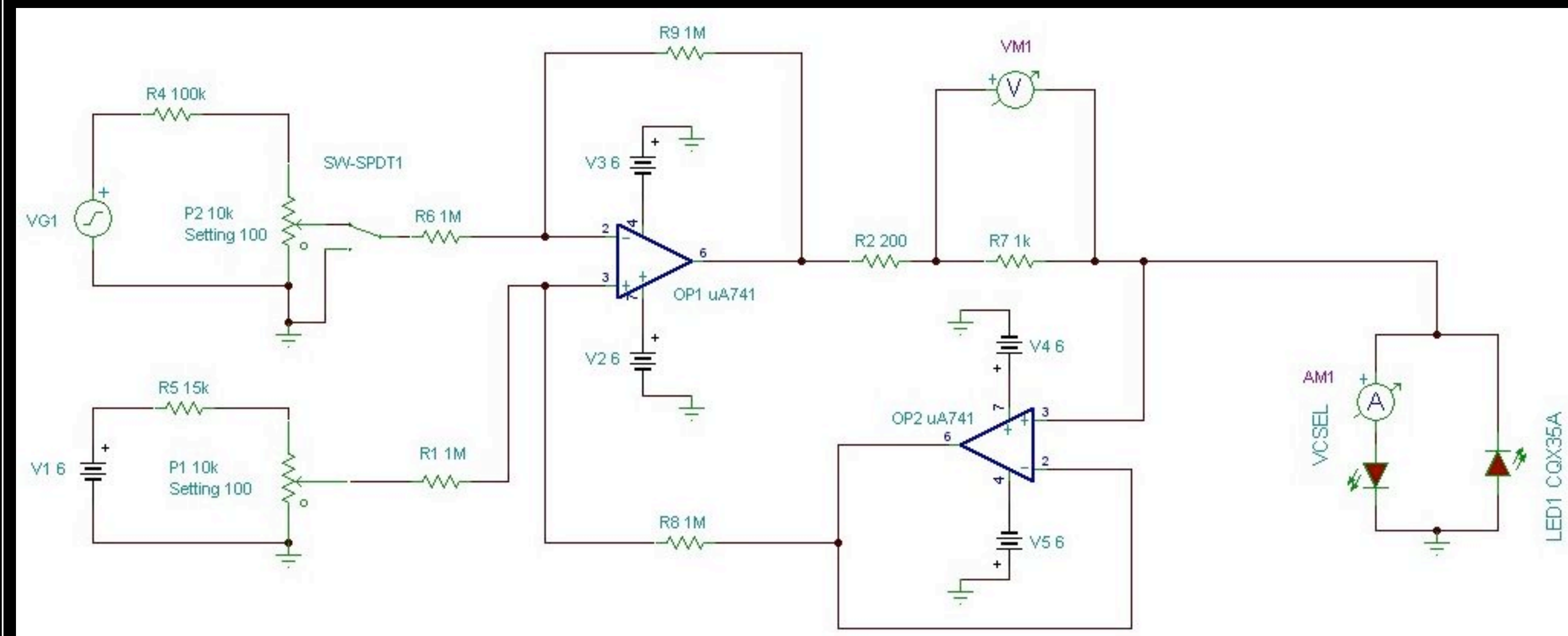
- In circuit design, laser in feedback of operation amplifier
- Current flowing through case of Bias-T
- When shorted, approximately 10 mA of forward current through VCSEL
- Absolute maximum rating: 3 mA

Trouble continued

- Too much forward current through laser
- VCSEL now just fluoresces at some wavelength
- Have to wait for more Ulm VCSELs to arrive

Protection Circuit

- Changed circuit to protect VCSEL



Future Work

- Find resonances with new Ulm VCSEL
- Modulate new Ulm VCSEL
- See electromagnetically induced transparency
- Fabricate box for rf modulator