

# Applying Anti-Reflective Coatings to Laser Diodes

---

David Ludwig

Professor Chad Orzel

Physics Department

# Anti-Reflective Coating

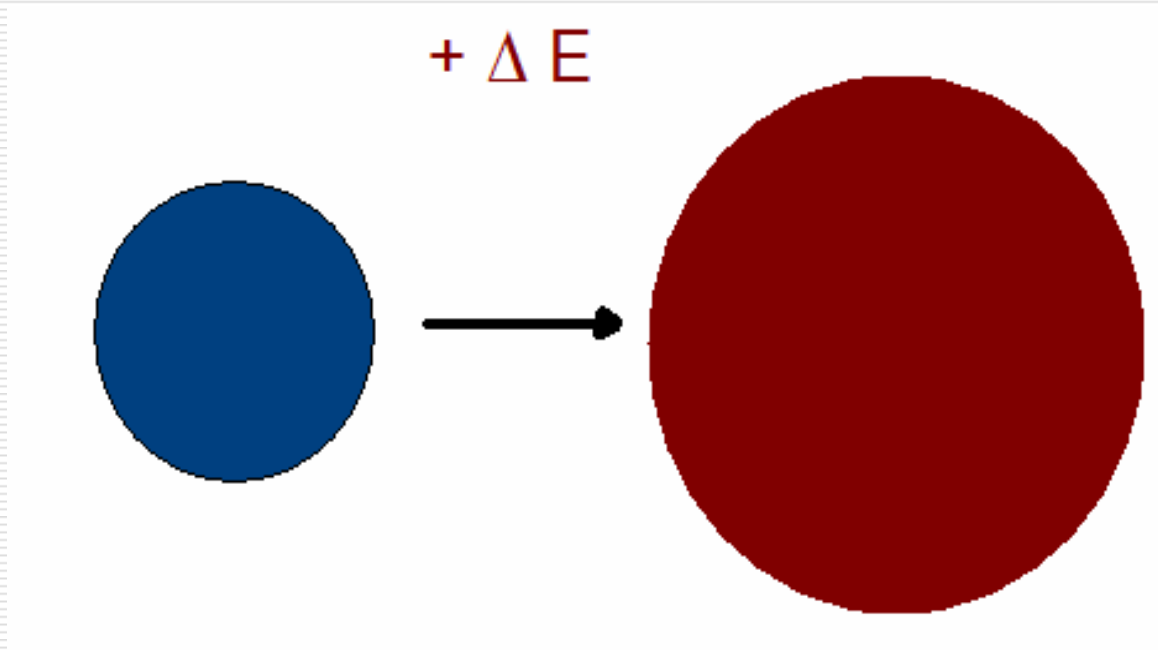
---

- Why anti-reflective coat a laser?
    - Improves injection locking
    - Stabilizes laser
  - How do we do it?
    - Use a vacuum evaporator system
    - Evaporates the coating material onto the laser
-

# Lasers in General

---

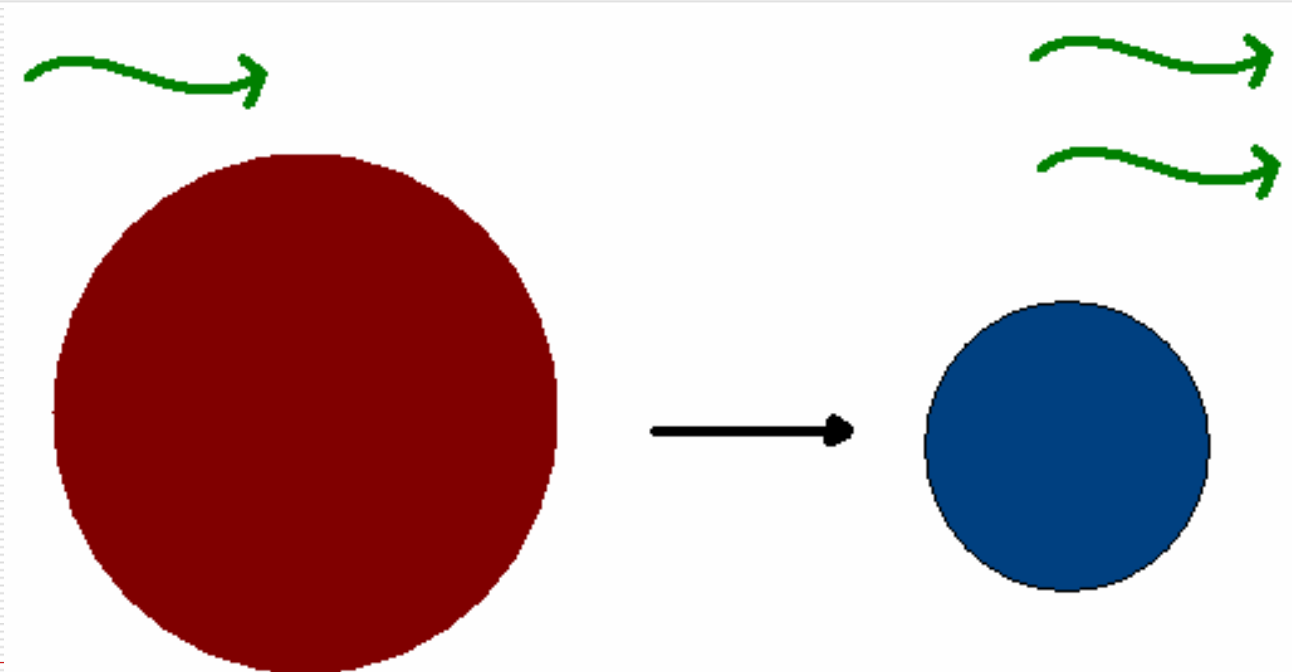
- Inside the laser there is an optical pump that excites the lasing medium into a metastable state



# Lasers in General

---

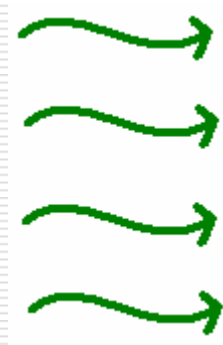
- When a photon encounters an atom in the metastable state, the excited atom releases a duplicate photon in sync with the original



# Lasers in General

---

- As photons move through the lasing medium, many in-phase identical photons form
- This produces a beam of collimated light



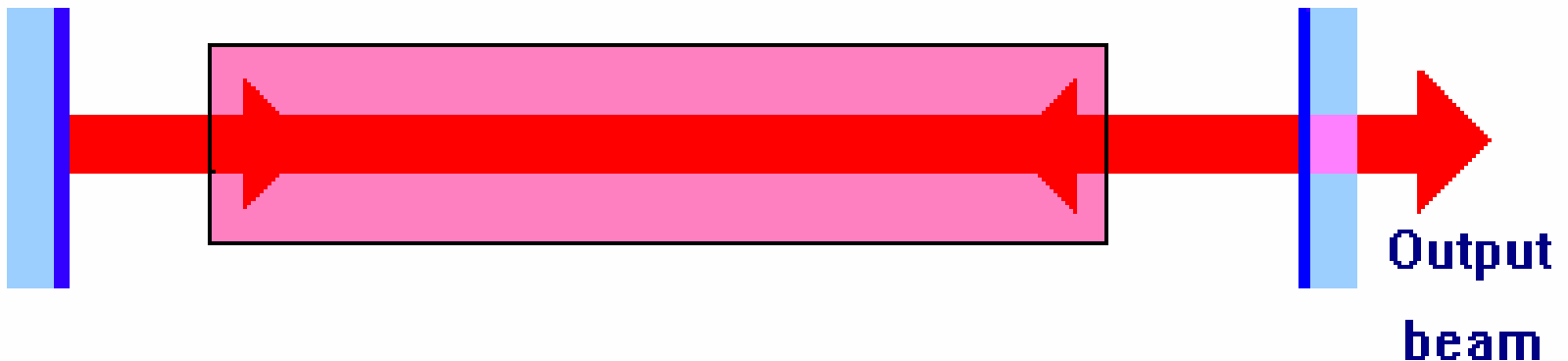
# Lasers in General

---

- Each end of the laser is a mirror that reflects the photons back and forth, amplifying the light intensity
- One end is only partially reflective, which allows some light to escape

**Total  
reflector**

**Partial  
reflector**



# Injection Locking

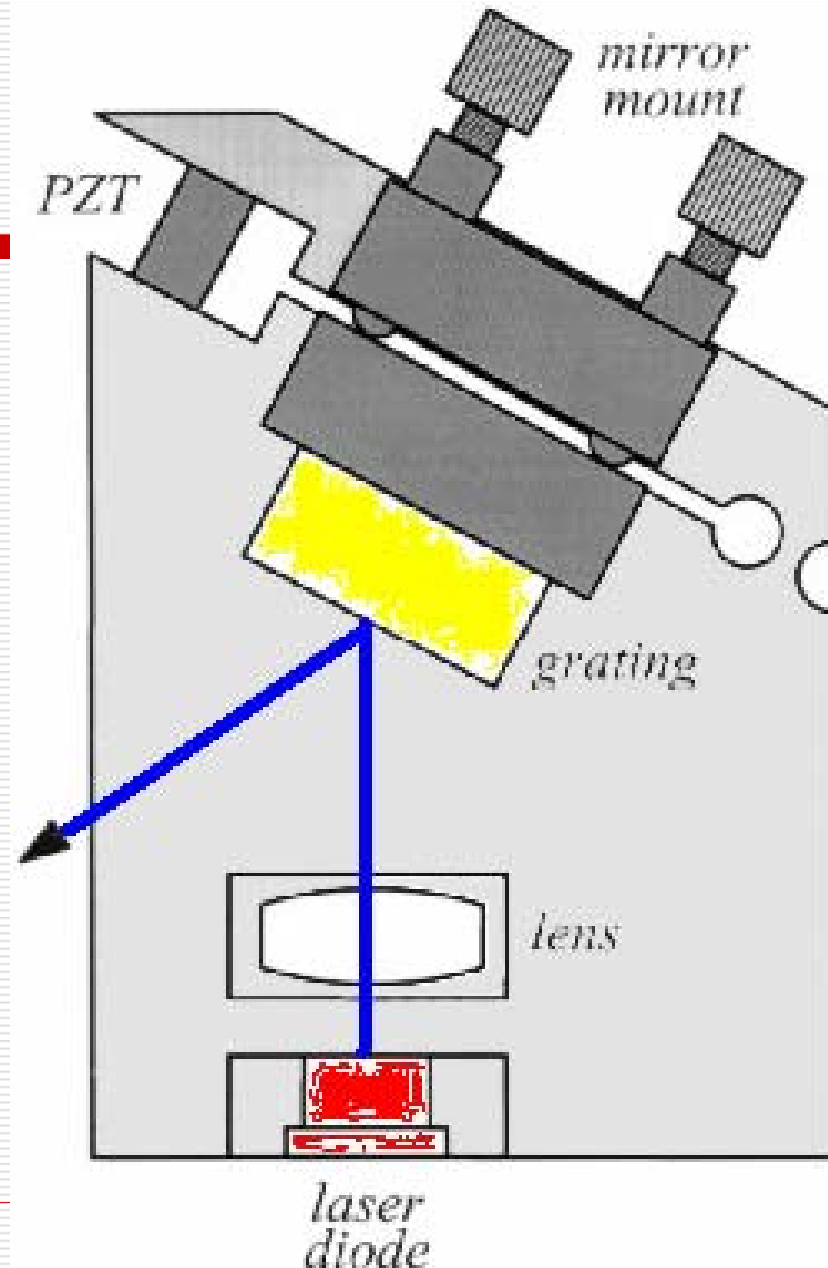
---

- Improves laser stability by shining a second laser (master laser) of the correct wavelength into the face of the main laser (slave laser)
  - In our lab we use a diffraction grating to reflect part of the laser back into itself to self-stabilize
-

# Injection Locking

---

- By doing this we reduce “noise”
- Noise is unwanted light frequencies emitted by the laser
- Ben Miles’ project was exclusively this element



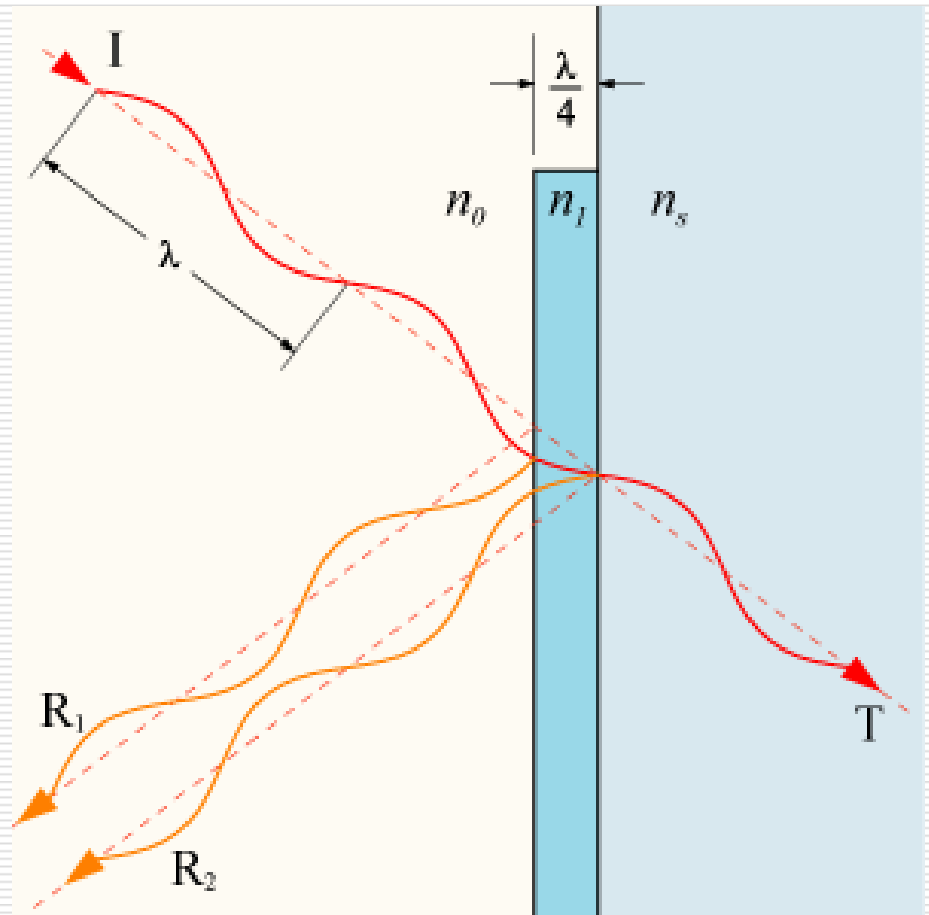
# Injection Locking

---

- However, there is a problem!
  - Since the laser face is highly reflective, it reflects away most of the injected light before it can get inside the laser to stabilize it
  - This reduces the effectiveness of the injection locking
-

# How Anti-Reflective Coating Solves the Problem

- By adding a thin layer of silicon dioxide (quartz) to the tip of a laser, we cause incoming waves to partially reflect at two points
- $n_1 = \sqrt{n_s}$



# How Anti-Reflective Coating Solves the Problem

---

- If the thickness of the layer of silicon dioxide is  $\frac{1}{4}\lambda$ , then the reflected waves from the two tiers will destructively interfere
  - If the reflected waves all destructively interfere, then in actuality there are no reflected waves!
  - Hence all injected light must be transmitted into the laser
  - Injection locking then becomes much more effective
-

# Coating the Laser

---

- In order for the coat to work, it must be extremely even, smooth, and precise in thickness
  - In order to apply such a coat, we must use a vacuum evaporator
-

# The Vacuum Evaporator

---

- The vacuum evaporator applies thin coats to objects by melting a small amount of the coating material in a vacuum directly beneath the object being coated
  - The evaporated particles then condense on the object, forming a smooth, even film
-



# The Vacuum Evaporator

---

- 2 pump vacuum system
  - Pressures at  $\sim 10\mu\text{torr}$
-

# The Vacuum Evaporator

- Mechanical Pump  
(not visible)
- Diffusion Pump
- Liquid Nitrogen  
Cold Trap for  
Diffusion Pump
- Removable Bell Jar
- Copper Strips for  
High Current

# The Vacuum Evaporator

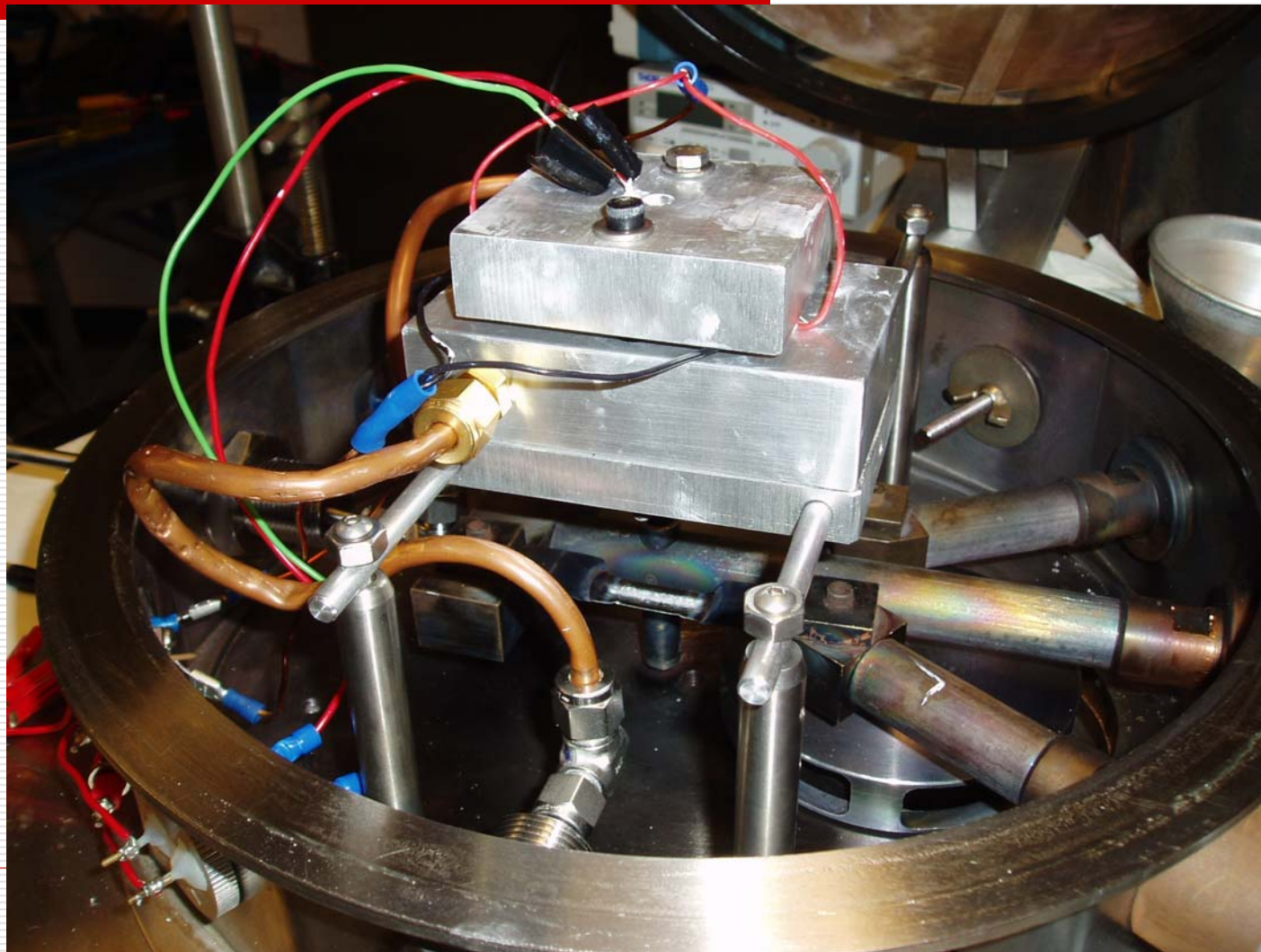
---

- ❑ We place silicon dioxide in a small molybdenum tray
- ❑ Run approximately 120A through it
- ❑ Heat the silicon dioxide up to over 1640°C



# The Vacuum Evaporator

---



# Cooling the Laser

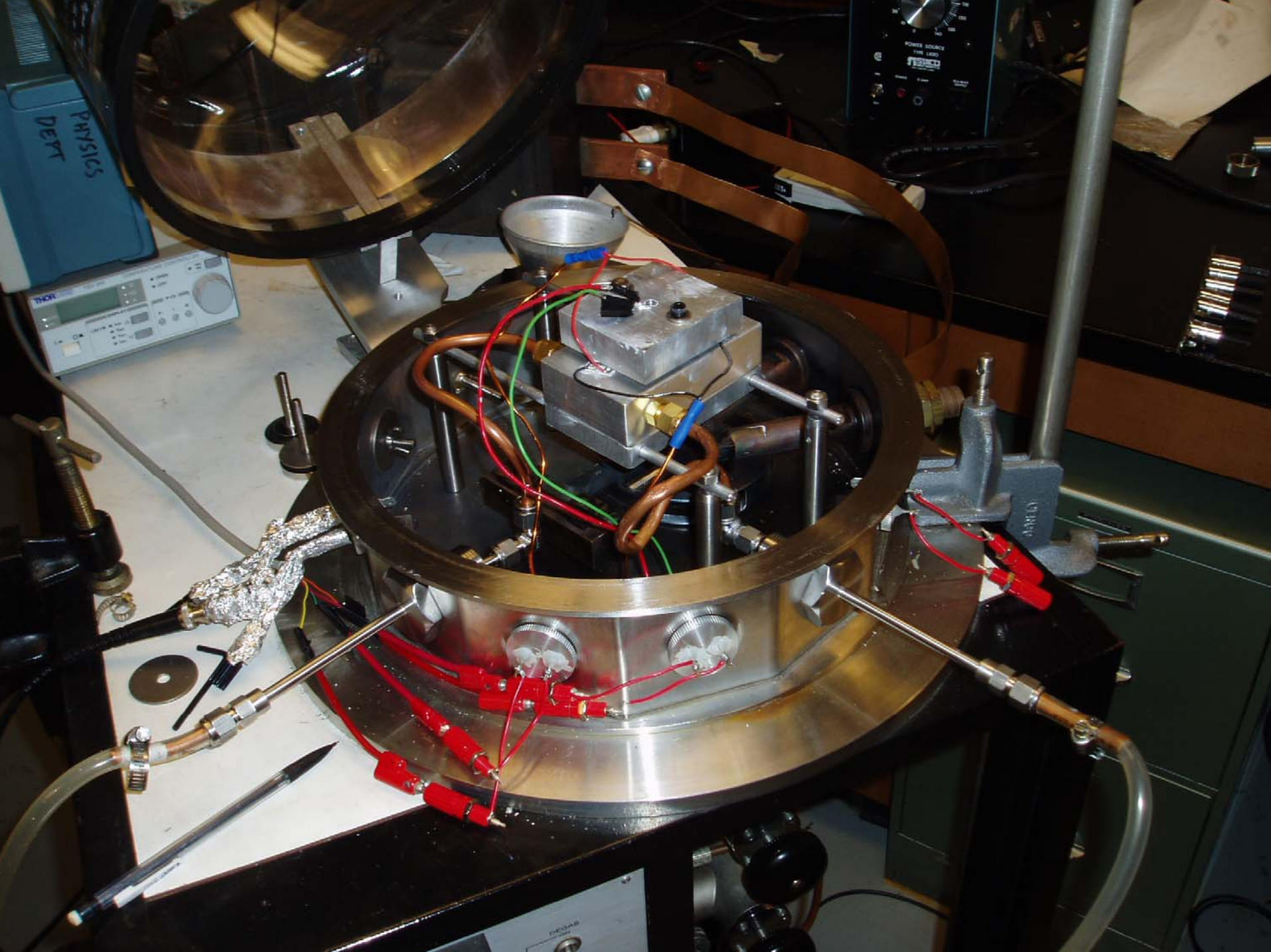
---

- ❑ The laser is temperature sensitive
  - ❑ We need the laser to be on in order to know when the coat is the right thickness
  - ❑ We needed to create a system for cooling the laser during the procedure
  - ❑ Accomplished this through the use of thermal-electric coolers and running cool water through the laser platform
-

# Cooling the Laser

---

- By adding a water cooler, we could flush heat away as quickly as it was absorbed from the heated tray
  - Then the TECs could successfully keep the laser at a constant cool temperature during the coating procedure
-



# Applying the Correct Thickness

---

- Although we have not yet coated any lasers, we are close!
  - Each laser diode has an output sensor
  - As we coat a laser, it's output power will oscillate
  - We can use this to know when to stop coating the lasers for maximum effect
-

# Acknowledgements

---

- Thanks to:
  - Professor Chad Orzel
  - Ben Miles
  - John Sheehan
-

# Accomplishments

---

- ❑ Successfully restored an old vacuum evaporator
  - ❑ Coated non-laser objects with silicon dioxide
  - ❑ Installed an adequate cooling and temperature stabilizing system
-