Impact of Extreme Temperature Cooling on Semiconductor Wavelength Emission

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INTRODUCTION

- Laser driver built from Arduino board delivers current to laser diode
- The color of the LED is determined by the wavelengths of light that are emitted by the semiconductor of light; when in liquid nitrogen, the temperature of the material drops, causing the band gap to shrink and the emitted photons to have a shorter wavelength

OBJECTIVE

- Investigate the effect of extreme temperature cooling on the semiconductors in lasers and LEDs

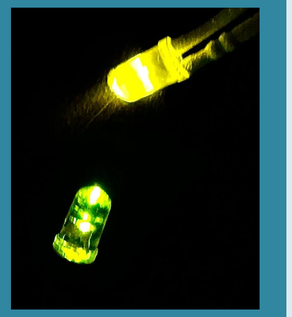
BACKGROUND

- LEDs are specifically built to emit light; they have 2 bands
  - Positive side (anode): contains fewer electrons
  - Negative side (cathode): contains more electrons, which stay in the conduction band
  - Running a current pushes electrons from the positive side to the holes in the negative side.
  - Almost all of the energy of LEDs is given off as light, created when the electrons combine
- The band gap is the energy difference between the top and bottom band; it influences LED color.
  - Electrons falling from the top to the bottom band release energy by emitting photons
- Cooling down semiconductor
  - Changes: When a solid is cooled, atoms get closer
  - Electrostatic potential energy increases → band gap energy increases → photon energy increases → wavelength of emitted light decreases

Fig. 1: Orange LED

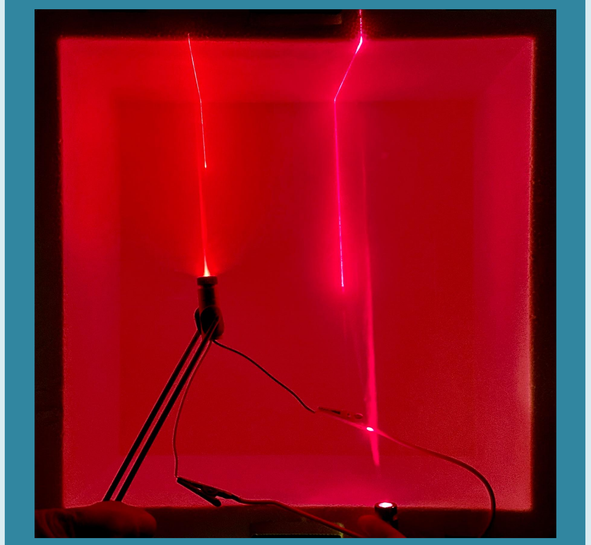
Top: with LN_2
Right: without LN_2

Fig. 2: Chartreuse LED



Top: with LN_2
Right: without LN_2

Fig. 3: Red Laser Diode



Left: with LN_2; Right: without LN_2

Fig. 4: Blue LED, no visible color change

PROCESSES & RESULTS

- We used a red laser and a custom Arduino board driver for a red laser diode and LEDs
- The red laser diode submerged in the liquid nitrogen visibly turned more orange. [Fig. 3]
- LEDs that changed color:
  - Red → Orange
  - Orange → Yellow
  - Warm white → Yellow
  - Chartreuse → Yellow
- However, not all LEDs changed colors. We found that green, blue, purple, UV, and pink all remained unchanged.
- Warm colors such as red, orange, and yellow have a longer wavelength than cool colors like blue and green,
  - The warm colors' change in wavelength is within the visible spectrum, while the cool colors' change in wavelength may be ultraviolet and not visible to the naked eye

FUTURE DIRECTIONS

- Liquid nitrogen only visibly affects warm colors.
- Explore why liquid nitrogen doesn't affect cooler colors. Why are warm colors more visibly susceptible to changes in temperature?

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