Photoluminescence of GaAs with varying temperature

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Abstract

The direct bandgap Gallium Arsenide (GaAs) materials and its alloys enables them to be used for both optical and electronic applications. This study is relevant to the applications such as laser emitters, light emitting diodes and solar cells.

A setup was established for the photoluminescence spectroscopy for the optical characterization of bulk GaAs in different temperatures from 317 K to 350 K.

Photoluminescence (PL) of GaAs was obtained using the IHR550 spectrometer in a controlled room. A Diode-pumped Solid State 532 nm green laser was used as excitation source with an energy of 2.34 eV greater than the bandgap of GaAs (E_{GaAs}= 1.42 eV). The PL of the sample was observed under room temperature and was gradually increased its temperature using a soldering iron.

The PL of the GaAs peaked at 890 nm. It showed a peak with a 63 nm Full Width at Half Maximum (FWHM). Also, PL peak intensities of the sample was observed to be decreasing as the temperature was increased, and this peak was observed to be red-shifting. This is an indication of a decreased of the energy of the radiative process when some of the energies were utilized as vibrational energies when the sample was heated. Results showed that varying the temperature of the sample, affects the PL intensities significantly.

Methodology

Growing Gallium Arsenide (GaAs)

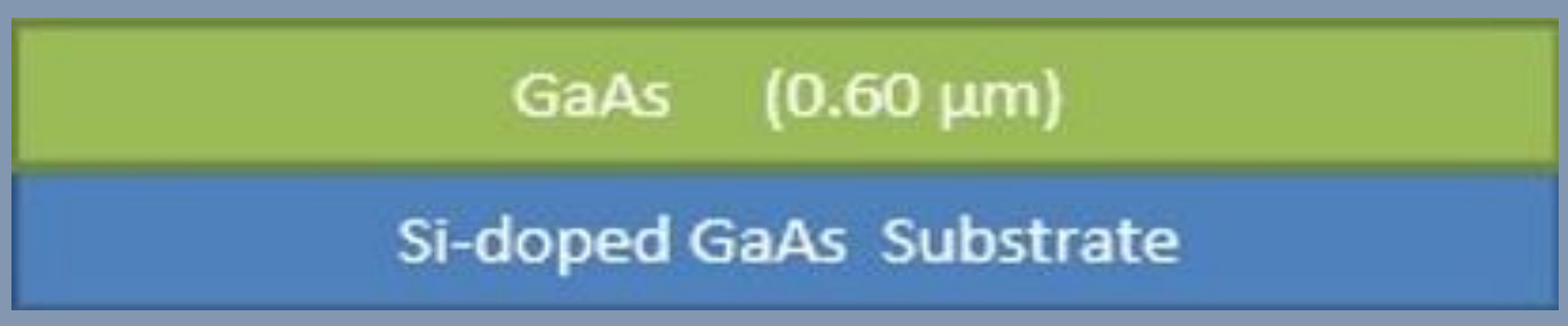

Figure 1. Cross-section of GaAs Sample

The growth of the bulk GaAs is shown in figure 1. It is composed of a silicon doped GaAs substrate followed by the bulk GaAs 0.6 micrometer thick. This is the simplest heterostructure with only one interface. Considered as a bulk material because of its thickness. The sample was grown using the molecular beam epitaxy (MBE) at University of the Philippines Diliman Campus.

Experimental Setup

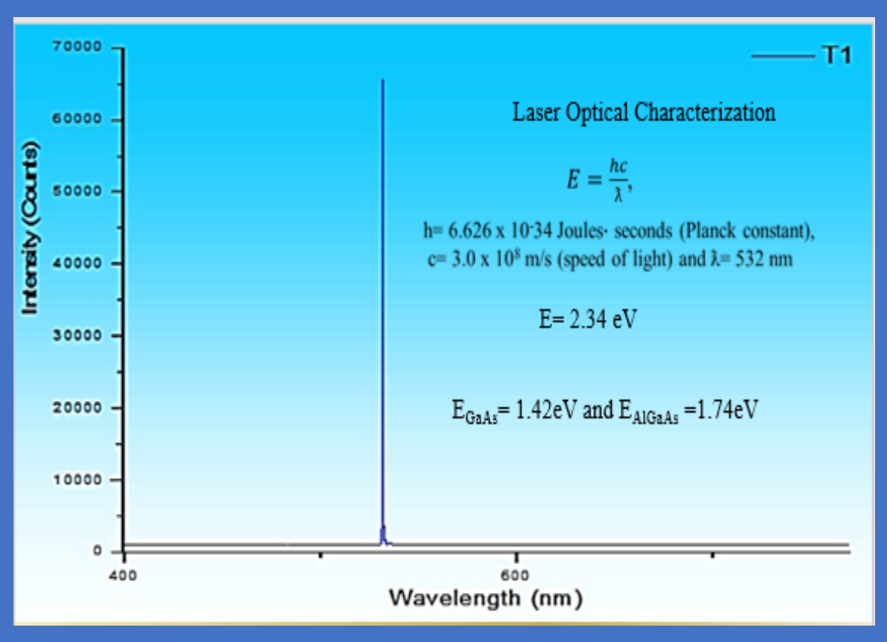

Figure 2. Energy of the 532 nm diode-pumped laser

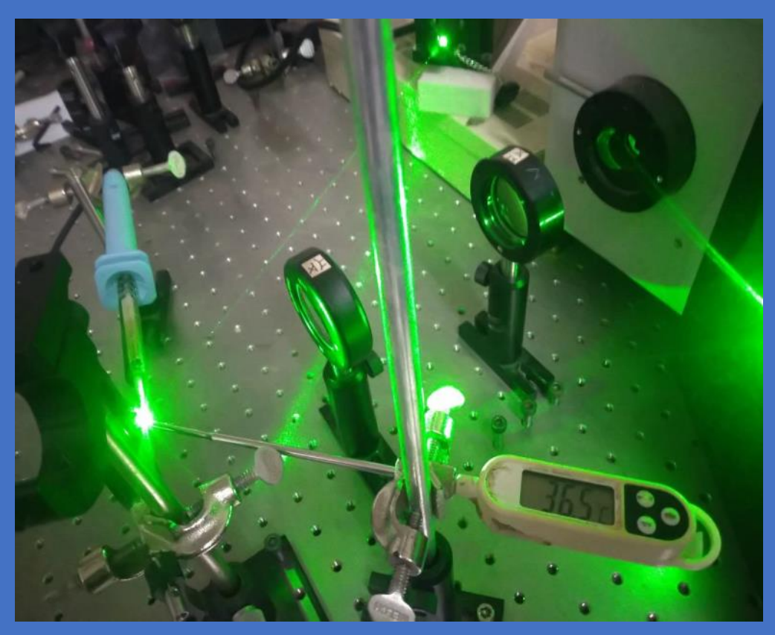

Figure 4. Actual experimental setup

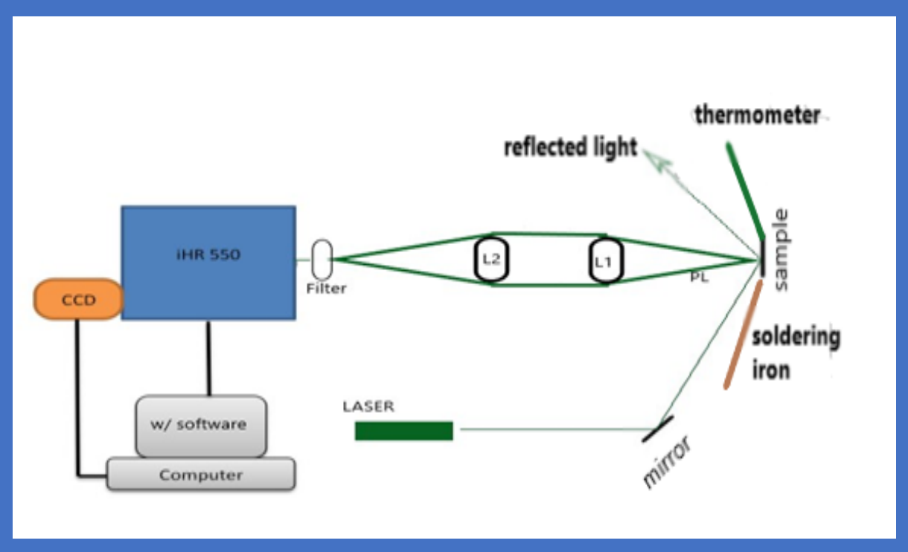

Figure 3. Schematic diagram of the experimental setup

To get the Photoluminescence (PL) of Gallium Arsenide (GaAs), an excitation source that is greater than the bandgap of the sample is needed. Here, we calculated the energy equivalent of the 532 diode-pumped laser that is 2.34 Ev which is greater than the bandgap of GaAs which is 1.42 eV as shown in figure 1. Thus, the laser used is capable of exciting electrons on the sample.

The study looked on the effect of varying temperature on the intensity of the photoluminescence of the sample. The temperature of the sample was varied by the used of soldering iron as it was contacted on it and temperature was monitored using the digital thermometer. As the soldering iron increased the temperature of the sample, the photoluminescence was then detected using the IHR 550 Spectrometer. Using the Yvon Jobin SynerJY data acquisition software, exposure was set on 0.015 s, front slit on 0.6 mm and side slit of 1mm to get the desired graph.

Results and Discussions

Results

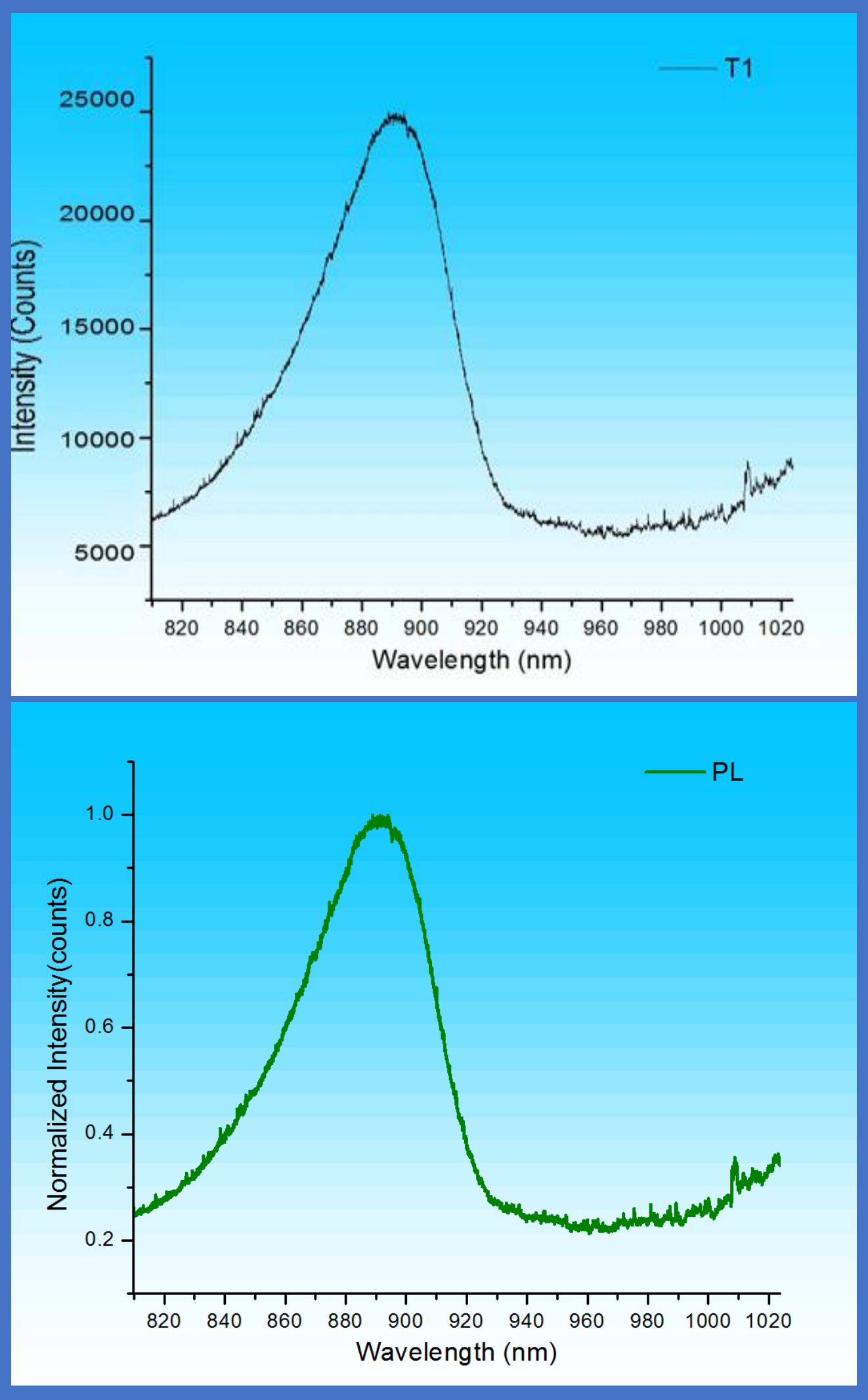

Figure 5. GaAs' PL peaks at 890 nm

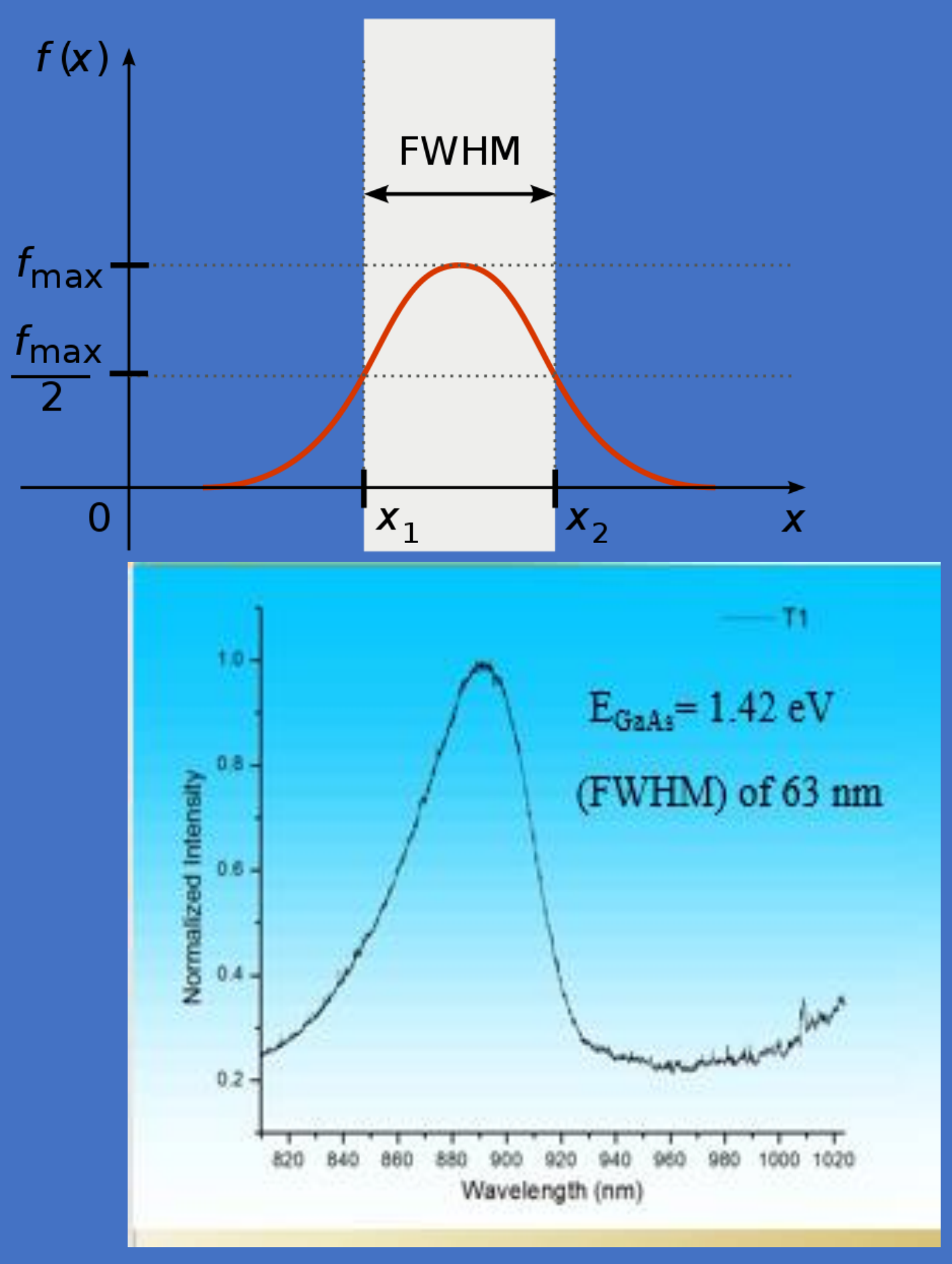

Figure 6. FWHM of GaAs PL

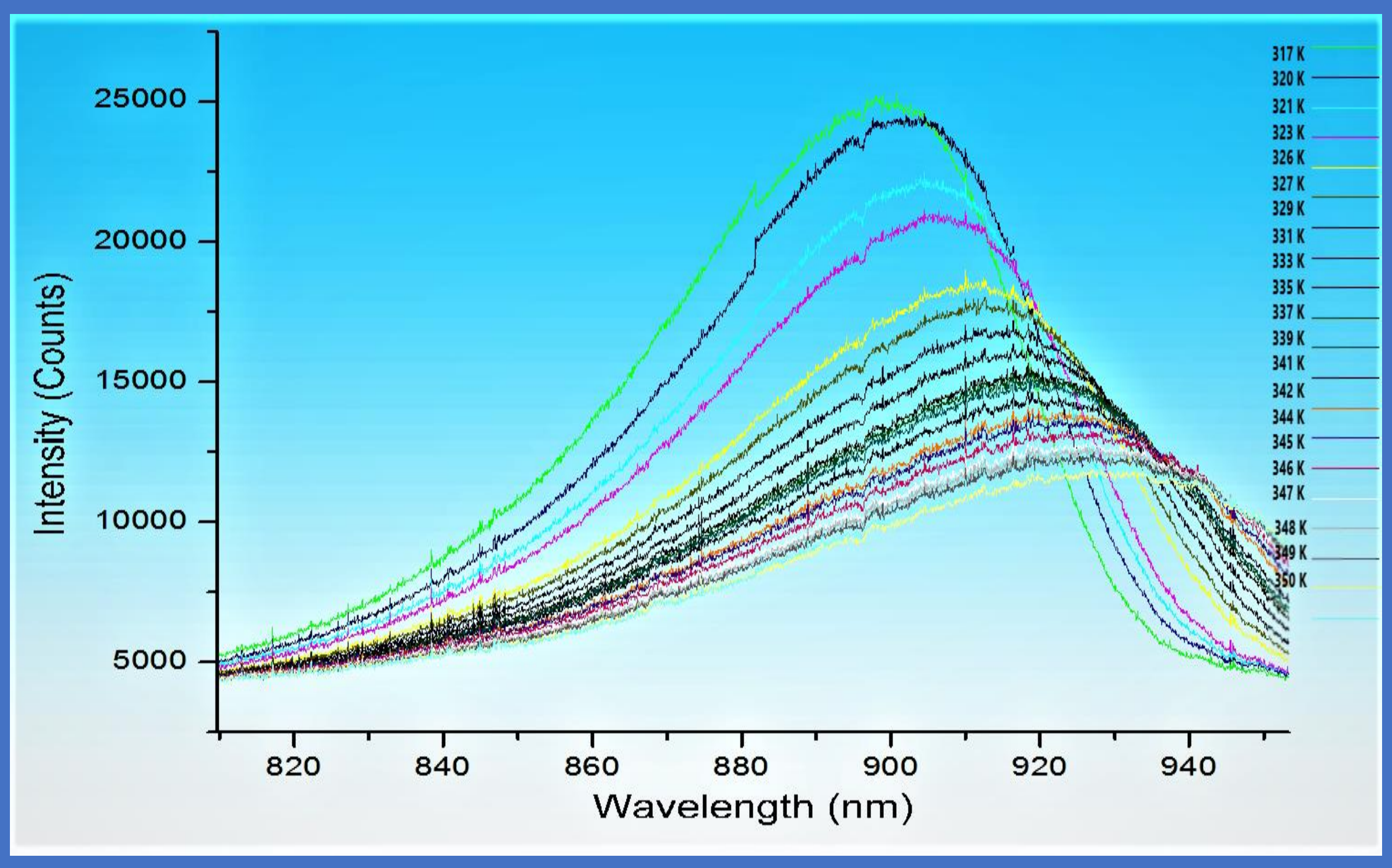

Figure 7. GaAs' PL at different temperature

Discussions

Using the 532 nm diode-pumped laser as excitation source, PL of GaAs was observed to peaked at 890 nm as shown in figure 5.

The GaAs sample was subjected to heat to vary its temperature from room temperature to a higher temperature using the soldering iron that was contacted to it. In this case, we started from 317 K then gradually increased until it reached 350 K. As the temperature was increased, it was observed that the PL intensity peak decreased. In this case, the wavelength peak was also observed to be red shifting at higher temperature as shown in figure 7. The decreased of the PL intensity can be explained by the temperature-dependence of the lattice constant. As temperature increased, the kinetic energy of electrons also increased. The interatomic spacing increased also when amplitude of the atomic vibrations increased due to the increased in thermal energy. Some of the energy was used up during this increased in vibrations, thus lesser energy was produced during photoluminescence. Since energy and wavelength is inversely proportional, we have observed the red-shifting of the PL peaks as energy decreased. This decreased in energy will consequently decreased its PL intensity.

We determined also how broad or resolved is the peak of the PL that was obtained using the FWHM method. Here, we are abled to get 63 nm.

Conclusion

The intensity of the photoluminescence (PL) of GaAs is determined to behave inversely proportional with the temperature. This can be used to predict how the PL of the sample would likely to behave in other certain range of temperatures. This gave us the idea that PL of the sample is greater and efficient at lower temperatures.
Also since the green laser was abled to excite the sample at 2.34 eV, that could be mean also that other higher energy lasers could be used as excitation source to obtain its PL . The Full Width at Half Maximum (FWHM) of GaAs which is 63 nm showed its potential use in electronic applications such as LEDs.

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