

## **Lab Exercise: LASER (Light Amplification by Stimulated Emission of Radiation)**

### **Objectives**

- Describe the difference between spontaneous and stimulated emission.
- Describe the way a laser produces light.
- Ability to explain how lamp intensity and wavelength, lifetimes, and mirror reflectivity affect lasers.

### **Part One: Review Light Interactions with Atoms**

- **Q1: What happens when a photon interacts with an atom? Think in terms of electron energy levels.**
- **Q2: Define the following terms: spontaneous emission, stimulated emission, absorption.**

### **Part Two: One Atom (Absorption and Emission)**

Open your computer's internet browser and navigate to the Laser Simulation Java Applet (<http://phet.colorado.edu/en/simulation/lasers>). Start the applet by clicking on Run Now! This simulation uses optical pumping, or stimulation by photons, as an energy source for the laser. Most conventional lasers use "electrical pumping", or stimulation by energetic electrons, to excite the atoms.

Go to the *One Atom (Absorption and Emission)* tab. This set-up will give you a general idea of the electron energy levels of an atom. Increase the intensity of the lamp using the Lamp Control slide button. Vary the light wavelength to a color that has a low energy and then to a color with a high energy.

- **Q3: When does absorption occur? How does the energy of the incident photons compare to the energy levels of the atom?**

Press "Reset All." Set the lamp back to a very low intensity level so that the electron has enough time to return to its ground state.

- **Q4: What do you notice about the direction of the emissions?**

Now increase the lamp intensity to a higher level, so that photons hit the atom while it is already excited.

- **Q5: What do you notice about the direction of the emissions now?**

The *lifetime* represents the amount of time before an excited electron will undergo spontaneous emission and return to its ground state. With the light intensity at a medium level, change the lifetime of the atom.

- **Q6: What do you notice as you increase the lifetime? What do you notice as you decrease the lifetime?**
- **Q7: Putting all the observations and concepts together, choose the correct conditions in order to increase the likelihood that the excited atom will undergo stimulated emission:**
  - a. (Increase/Decrease) the lifetime of the excited state.
  - b. (Increase/Decrease) the lamp intensity.
  - c. Use the lamp light with the wavelength that is (higher than/lower than/the same as) the energy separation between the lower and upper energy levels of the atom.

Now change the settings from *Two* energy levels to *Three* energy levels.

- **Q8: What effect does the light from the second lamp have? Can the second lamp stimulate the atom to emit photons at the same energy level as the first lamp?**

Turn off the first lamp so that only the second lamp (set to its initial blue light setting) is on.

- **Q9: Observe the absorption and emission process and briefly describe the difference between two and three energy levels.**
- **Q10: With both lamps on, describe how the simulated emission is produced and its direction.**

### **Part Three: Multiple Atoms (Lasing)**

A single atom is insufficient to create a laser, because it produces a relatively low number of emitted photons. Multiple atoms are required to cause a landslide of excited photons and stimulated emissions. Select the *Multiple Atoms (Lasing)* tab with three energy levels. Start ‘pumping’ photons to the atoms by increasing the intensity of the lamps.

- **Q11: What do you observe in terms of stimulated photons?**

Notice the *Lasing* tab only has one light source, whereas the *One Atom* setting had two.

- **Q12: What is acting as the second light source in this simulation?**

In order to produce a consistent stable laser, the internal power must be within the green “lasing” range.

- **Q13: What do you observe as a problem for why the current set-up is NOT ideal for producing a consistent laser?**
- **Q14: To produce more frequent stimulated emissions than spontaneous emissions, how do you need to alter the lifetime of each energy level? (Note that you may not be able to verify this by adjusting the lifetime settings yet, but you should be able to answer the question using the information we have gained so far.)**

By pumping energy into the system, we can achieve “population inversion”, which is when there are more excited atoms than atoms in the ground state.

- **Q15: Can you achieve the population inversion at the current setting? Why or why not?**

Add a mirror by clicking ‘enable mirrors’. Set reflectivity at 100% and then try to increase the power of the laser using your answer to Q15.

- **Q16: What happens? What is the purpose of the mirror?**
- **Q17: In order for lasing to occur, what do you need to do to the reflectivity of one of the mirrors?**

Change the view of the Lower Transition into Wave view.

- **Q18: What do you notice about the amplitude of the wave? Explain the difference inside and outside the mirrors.**
- **Q19: Summarize the settings you used to achieve a stable laser?**