Online laboratory assignment 13 – The laser

Purpose: to qualitatively study spontaneous and stimulated emission.

Introduction

The laser is a light source that produces a beam of highly coherent and very nearly monochromatic light as a result of cooperative emission from many atoms. The name "laser" is an acronym for "light amplification by stimulated emission of radiation." Two concepts are necessary to understand the basic ideas behind a laser; (1) population inversion and (2) stimulated emission.

A single molecule can absors a photon with energy equal to the energy difference of between the molecule's ground state and an excited state. The excited state has a lifetime before relaxing back to the ground state. When this process happens naturally without external influence and the relaxation results in a single photon being released, then it is called *spontaneous emission*.

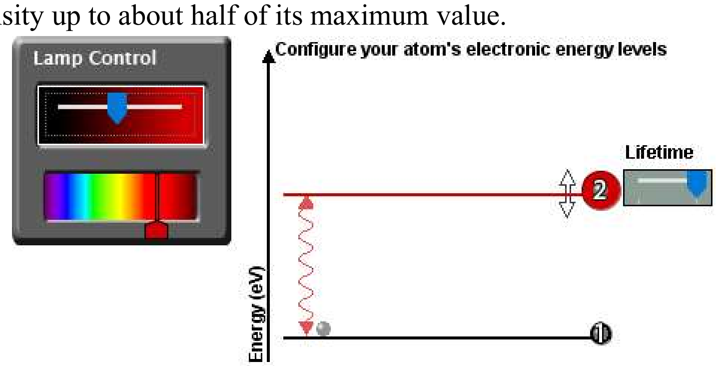
In stimulated emission, a kind of resonance effect induces each molecule to emit a photon with the same frequency, direction, phase, and polarization as other photons passing by the molecule. Because the photons have the same phase, they emerge together as coherent radiation. The laser makes use of stimulated emission to produce a beam consisting of a large number of such coherent photons.

We need to create a nonequilibrium situation in which the number of atoms in a higher-energy state is greater than the number in a lower-energy state. Such a situation is called a population inversion. Then the rate of energy radiation by stimulated emission can exceed the rate of absorption, and the system will act as a net source of radiation. We must use at least three energy states to achieve a population inversion, where the ground state is "pumped" to the second excited state and relaxes to a long-lived first excited state. Thus, the population of the first excited state exceeds that of the ground state.

Laboratory assignment

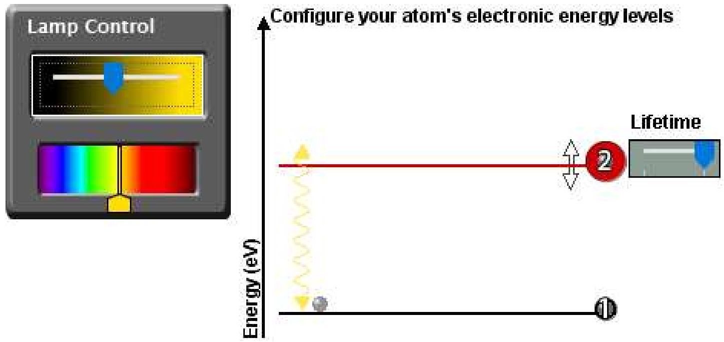
Part 1: spontaneous emission

1. Run the "Lasers" PhET simulation. Because this simulation is complex, **downloading the Java app and running on your computer is much better** than running the simulation online.
2. Select the "One atom" tab. One Atom (Absorption and Emission)
3. Keep the lamp emission frequency tuned to the ground state to first excited state resonance. Turn the lamp intensity up to about half of its maximum value.



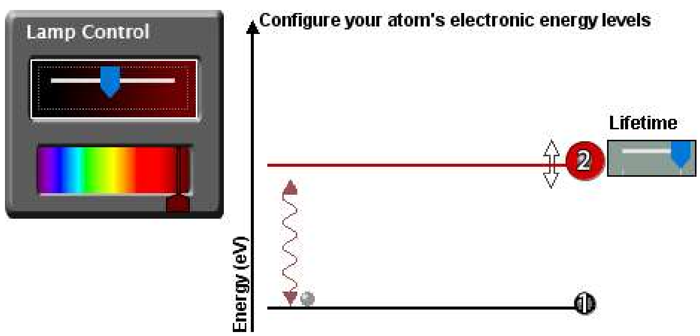
4. Describe what happens.

5. Tune the lamp emission frequency to the yellow so that it is higher than the atom's resonant frequency.



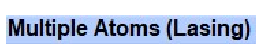
6. Describe what happens.

7. Tune the lamp emission frequency to the near infrared so that it is lower than the atom's resonant frequency.



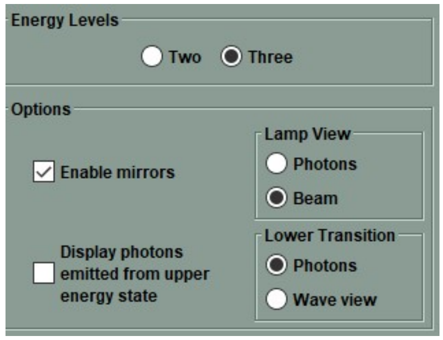
8. Describe what happens.

Part 2: stimulated emission

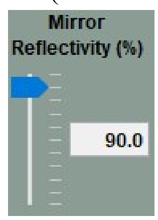
9. Select the "Multiple atoms" tab. 

10. Select the pause button.

11. Check the boxes and radio buttons as shown below.

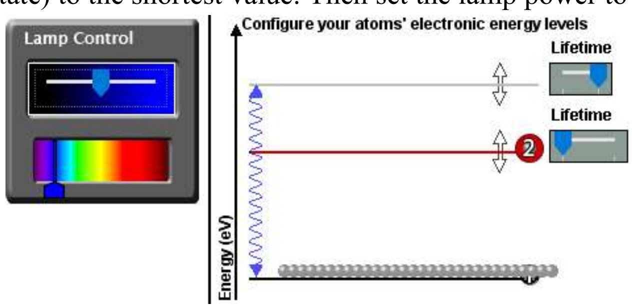


12. Change the reflectivity of the right mirror (called the output coupler) to 90%.



13. Note the meter measures the power inside the laser as well as the power leaving the laser.

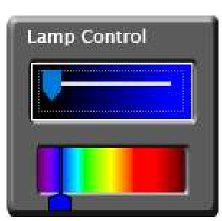
14. Set the lifetime of the 3rd state (2nd excited state) to the longest value and the lifetime of the 2nd state (1st excited state) to the shortest value. Then set the lamp power to approximately 50%.



15. Press the play button and wait a couple of minutes.

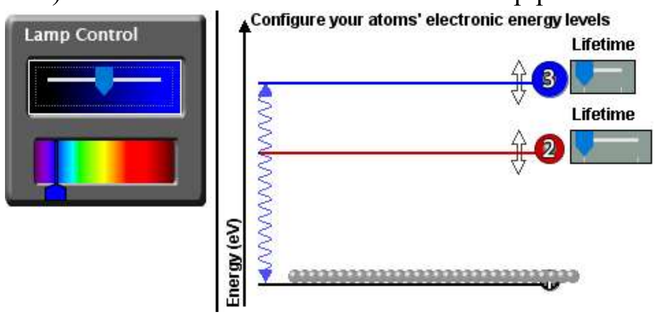
16. Does the system produce laser light (yes/no)? _____________

17. Reduce the lamp power to zero and wait until all the atoms are in their ground state and all photons have left the system.



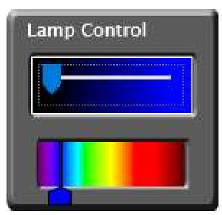
18. Select the pause button.

19. Set the lifetime of the 3rd state (2nd excited state) to the shortest value and the lifetime of the 2nd state (1st excited state) to the shortest value. Then set the lamp power to approximately 50%.



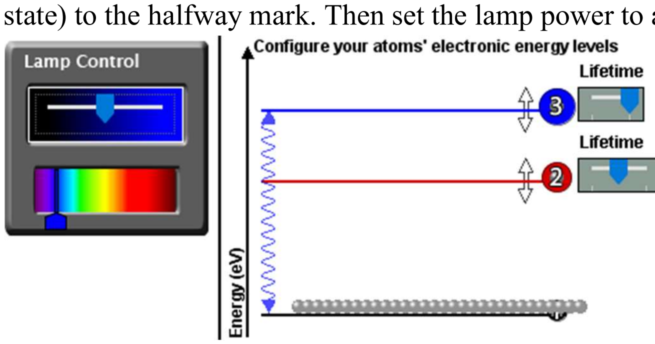
20. Press the play button and wait a couple of minutes.

21. Does the system produce laser light (yes/no)? ______________
22. Reduce the lamp power to zero and wait until all the atoms are in their ground state and all photons have left the system.



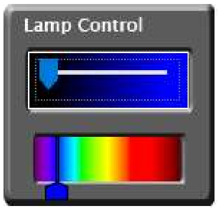
23. Select the pause button.

24. Set the lifetime of the 3rd state (2nd excited state) to the longest value and the lifetime of the 2nd state (1st excited state) to the halfway mark. Then set the lamp power to approximately 50%.



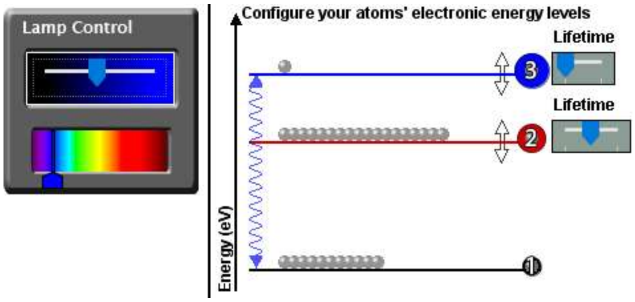
25. Press the play button and wait a couple of minutes.

26. Does the system produce laser light (yes/no)? ______________
27. Reduce the lamp power to zero and wait until all the atoms are in their ground state and all photons have left the system.



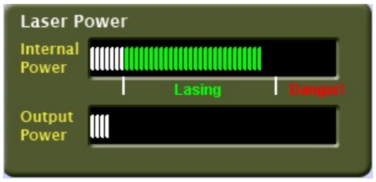
28. Select the pause button.

29. Set the lifetime of the 3rd state (2nd excited state) to the shortest value and the lifetime of the 2nd state (1st excited state) to the halfway mark. Then set the lamp power to approximately 50%.



30. Press the play button and wait a couple of minutes.

31. Does the system produce laser light (yes/no)? ______________
32. Using the current settings, wait until the internal power is nearing the "danger" level.



33. When the power is just below the "danger" level, quickly reduce the mirror reflectivity to 0%.
34. Describe what happens to the output power.

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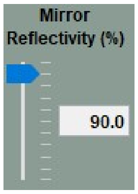
35. Move the reflectivity back to 90%.



36. Wait a while for the power to build up past the "danger" level.
37. Describe what happens to the laser.

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38. Using the information from your experiment, explain why high-power lasers are often pulsed lasers rather than continuous-wave (CW) lasers.

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39. Write a brief conclusion to this laboratory.

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