Make Your Own Laser Show

People in the music industry in their effort to make music performances more exciting and, visually, more attractive understood that light had to be synchronized with music. In a way, they were looking for a method that will "make light dance" with their music. The most spectacular of all methods has proven to be the laser shows. But, what does make the light dance? Do you want to know? Follow this experiment and by creating your own "laser show device", find out for yourself the answers to these questions.

Degree of Difficulty

Experimental: Difficult
Conceptual: Difficult

Objectives

Completion of the activities should enable you:

- to produce Lissajous (the series of plane curves traced by an object executing two mutually perpendicular harmonic oscillations) figures with a laser beam.
- to understand the relationship between the combination of different frequencies and the Lissajous figures produced.
- to predict the combination of frequencies needed to give a Lissajous figure.

Materials: laser pen (class 2 with power output 1mw), two 3-10 Volt a.c. power supply, 1 signal generator, 1 frequency multiplier/converter, 1 phase converter, a piece of wood (40x40x2 cm), 2 thin aluminum levers (19.5 cm long each), 2 loudspeakers (13cm), 1 mirror (4x4 cm), 1 rubber rod (4x1x1 cm), a piece of wood (4x4x2 cm), 2 pins, table-tennis ball, araldite, silicon rubber, thin wire (about 2 mm in diameter and about 10cm long), 2 pieces of a thin aluminum lever (3 cm long), two wooden dowels 5.5x2x2 cm (make sure the width of these wooden pieces is slightly bigger than the aluminum lever's width), drill, hammer, nails (2.5 cm long), ruler.

Procedure

Constructing the laser show device

1. Put the 40x40x2 cm piece of wood on a table. Find the mid points of two of the longest and opposite sides. Take your ruler and with a pencil draw a line connecting the two points. Repeat the same steps for the other two opposite sides. In this way you

are separating the wooden board into four equal pieces. Name with a different number each quartile (1,2,3,4).

2. Take the two dowels and cement with araldite the first one in the center of the second quartile and the second one in the center of the fourth quartile (cement one of dowel's smallest surfaces).

3. Cut the table tennis ball into two equal pieces. Cement each piece of the ball (convex side out) with araldite in the center of the loudspeakers. Cement a pin at the top of the ball with araldite.

4. Place the 2 loudspeakers in front of the already fixed dowels (step 2). Make sure that the pin lines up with the center of the ball that is positioned upon the loudspeaker, and that it is 8 cm away from the wooden dowel and 10 cm away from the closest side. At this point check whether the top of the pin and the wooden dowel are at the same height. If not, make the necessary adjustments so both are at the same height.
5. Take a piece of wood (4x4x2 cm) and drill a hole (1x1x0.5 cm) in its center. Insert one of the rubber rod's ends into the wooden block (if the rod is loose use araldite). Cement the center of the back of a mirror to the top of the rubber rod.

6. Drill a hole at one of the ends of each of the 2 thin aluminum levers (about 0.5 cm from the lever's end – the diameter of the hole must be much smaller than the width of the lever, but large enough for the wire to go through).

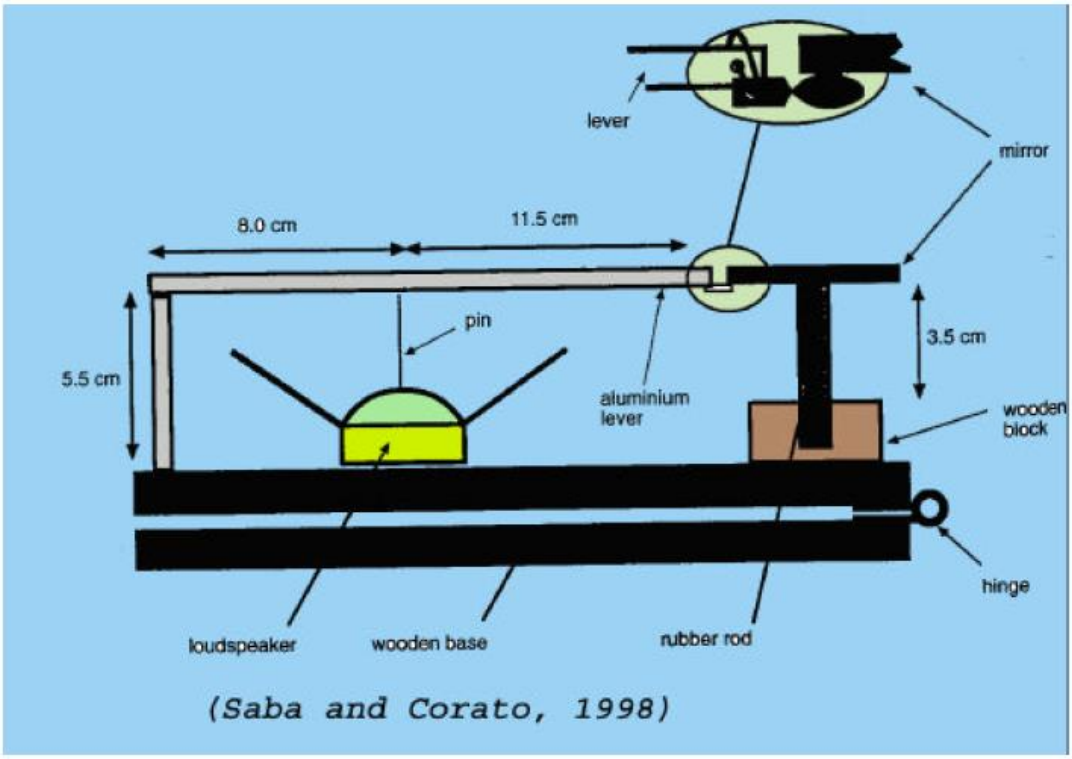
7. Fasten the end (the one without the hole) of each aluminum rod, with silicon rubber (do not use araldite), at the top of the wooden dowels, that were fixed on the wooden board at step 2, and let the levers lie on the top of the pins (see figure 1).

8. Cement the wooden block of step 5 (in the third quartile) in such a way that the mirror at the top of the rubber rod is 1 cm away from the two aluminum levers and at the same height with them (see figure 1).

9. Twist the 3 cm long aluminum levers 180^0. Drill a hole at one of their ends (about 0.5 cm from the lever's end – the diameter of the hole must be much smaller than the width of the lever). Glue to the back of a mirror the end that does not have the hole and connect to each lever by means of a wire that goes through their tiny holes and the holes of the short twisted aluminum pieces (see figure 1).

10. Connect one of the loudspeakers with the 3 V supply and the other one with a signal generator (or functional generator). Make sure that the output impedance of the power supply and the signal generator matches the input impedance of the loudspeakers (in case you have any questions ask your teacher or read the manual of both the loudspeaker and the generator).

Figure 1



11. Set your device at a certain angle and shine a laser beam on the mirror. Make sure that you see the reflected beam on a big white screen or on a white painted wall. If the reflected beam scatters, use a long focusing lens to focus the beam on the screen.

12. Start changing the frequency of the signal generator (start from zero) by small increments. Record your data in the following table:

Table 1

Shape description (Lissajous figures)	Frequency of the generator

What do you observe? Is there a relationship between the shapes and the frequency? Are the shapes stationary or moving? Why?

13. Start changing the amplitude of the signal generator (start from zero) by small increments (the frequency must be kept constant). Record your data in the following table:

Table 2

Shape description	Amplitude of the generator

What do you observe? Explain. Is there a relationship between the shapes and the amplitude?

Activities

1. Repeat steps 1-10. However, this time connect both loudspeakers to the same power supply (can you think of a reason for doing this?). Connect a frequency multiplier in series with the power supply for only one of the loudspeakers. Start changing the frequency (start from zero) by small increments. Record your data in the following table:

Table 3

Shape description	Frequency of the generator

What do you observe? Is there a relationship between the shapes and the frequency? Are the shapes stationary or moving? Why? How is your current setting different from the one you used at step 12? Explain.

2. Repeat steps 1-10. However, this time connect both loudspeakers to the same power supply. Connect a frequency multiplier and a phase converter (if it is difficult to find a phase converter, ask your teacher to make one for you; it is basically a simple RC circuit that delays the phase of the signal) in series with the power supply for only one of the loudspeakers. Start changing the phase by small increments (the frequency

must be kept constant). What do you observe? Is it possible to predict the relationship between the shapes and the phase by just looking at the Lissajous figures? Are the shapes stationary or moving? Why?

3. Explain the reasons of using loudspeakers in your device. Can you think of something else that can replace the loudspeakers and still give Lissajous figures as outcomes?

4. Design and perform experiments to answer the following questions. Your experiment's lab report must include: Title, Purpose, Equipment, Procedure and Data Collection, Data Analysis, Results and Conclusion. The Data Collection is the most critical part of a laboratory experiment. You must follow a *systematic research method* to secure valid answers to your questions. In a systematic research method you define, (a) your independent variable (the variable that is controlled by the researcher and is being changed, increased or decreased, in order to measure any changes regarding the variable we are interested in – It is suggested to change the independent variable by equal increments), (b) your dependent variable (the variable that is under investigation and depends upon the changes of the independent variable), (c) control variables (other variables that you assume that their presence might affect your experiment and therefore, you keep them constant throughout the whole experiment).

    - Can you repeat the results of activity 1 by using a signal generator? Explain.
    - Can you repeat the results of activity 1 by using two signal generators (one for each loudspeaker)? Explain.
    - How can you calibrate a phase converter that is constructed with cooperation with your teacher, by using Lissajous figures?
    - What combinations do you have to make in order to get a rolling ball (hint: use two signal generators)?
    - What combinations do you have to make in order to get a moving figure?
    - What combinations do you have to make in order to get a stationary figure?
    - Which variable(s) relate to the size of the figures?
    - How does the frequency relate with perfect geometrical figures?
    - How does the phase relate with perfect geometrical figures?

Final Project/Report

Write a report summarizing all the experiments and the activities and include information on the applications of your device in everyday life activities (i.e. musical laser shows). Have in mind that your report must be descriptive and understandable by

people that have never conducted a similar experiment. Use of diagrams, tables or pictures is strongly suggested.

References

Saba, M. and Corato, L. (1998). A giant laser show. *School Science Review*, 80 (291), p. 108-109.

Piper, G. and Lawton, P. (1988). The Laser show. *School Science Review*, 70 (250), p. 87.