Simulating Attosecond Experiments with Arduino-controlled LEDs

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INTRODUCTION

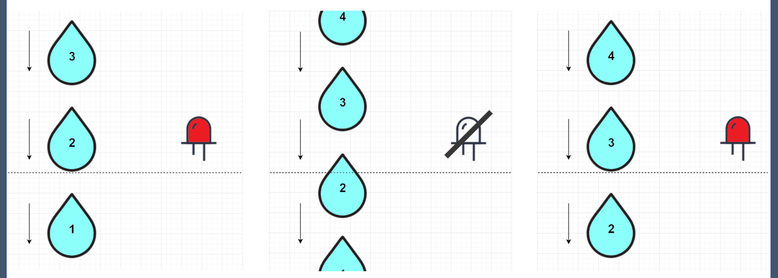
In the Attosecond Condensed Matter Experiments Laboratory at the University of Windsor, we are developing ultrafast lasers that produce light pulses that last only a few hundreds of attoseconds (1 as = 10^{-18} s) to femtoseconds (1 fs = 10^{-15} s). With these incredibly fast pulses, we can strobe matter to temporally resolve the motion of electrons in atoms, molecules, and crystals.

For my undergraduate project, we have created a Time Fountain – a water fountain that uses the stroboscopic effect to appear as though water is levitating (shown on the right) – as a pedagogical introduction to attosecond science. We substitute water droplets for electronic wave packets and Arduino-controlled LEDs for ultrafast laser pulses. By matching the frequency of LED flashes to the frequency of the water droplets, we can easily observe motion and the evolution of the droplets as they fall from a spout.

The Time Fountain

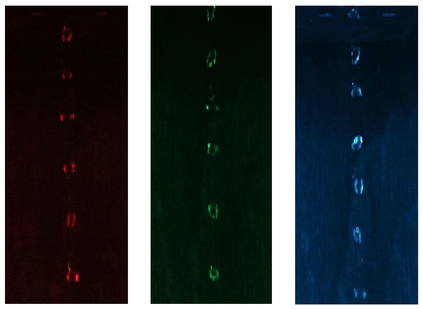
SETUP

We constructed a portable demonstration containing everything the system needs, such as the LED light strips, water reservoir, water pump, tubing, power source, and an Arduino-controller.

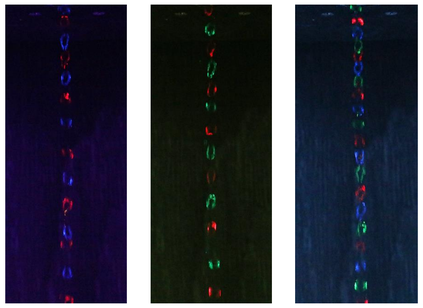


The fountain works by the stroboscopic effect (shown above), a visual phenomenon caused by aliasing when continuous motion is represented by a series of short or instantaneous samples. The Time Fountain, also known as a strobe fountain, illuminates the water droplets so they appear to be suspended in mid-air if the strobe frequency matches the water droplet rate. We can also make the droplets appear to slowly travel upwards (which gives the sensation of defying gravity), or downwards, if we slightly offset the strobe frequency of the lights.

Examples of the Time Fountain operating in single-colour modes.



Examples of the double and triple colour modes. Multiple colours can simultaneously be seen, but in reality the LEDs are set to cycle through the colours, which are out of phase.

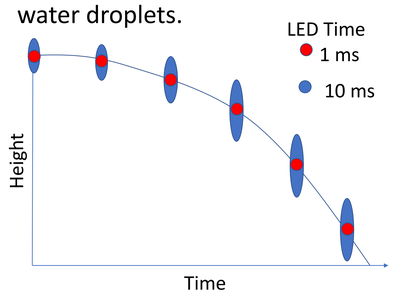


We can see that since the frequency of the light pulses has been doubled (tripled), there are twice (three times) as many droplets in a given length with half (one third) the spacing between them.

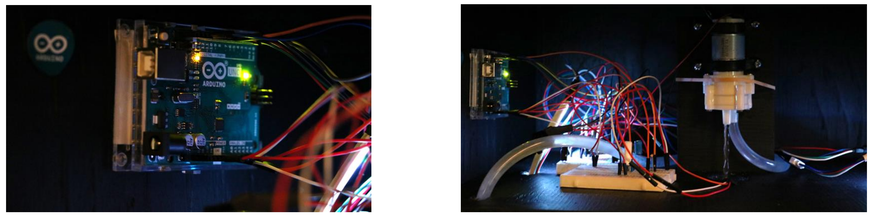
DISCUSSION

We chose a diaphragm pump for the water pump and located it directly above the water's trajectory to produce stable droplets.

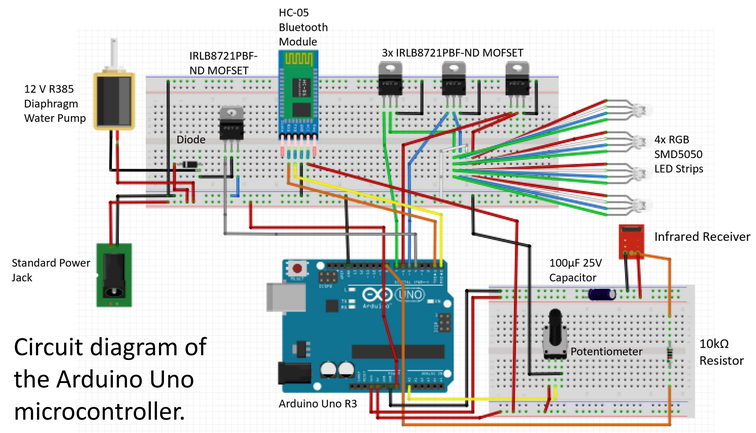
The requirements of the LEDs were that they needed to be controlled through the Arduino, and that we needed to be able to strobe them within 3 ms to resolve the water droplets.



The resolution of the droplets depends on the LED strobe time. As the droplets fall and accelerate, they become blurred if the strobe time is greater than a few ms.



The Arduino and circuitry inside the fountain.



Circuit diagram of the Arduino Uno microcontroller.

CONCLUSIONS

The Time Fountain is a stimulating and engaging demonstration for ultrafast physics experiments.

Incorporating Arduinos to control the LEDs and pump introduced us to programming microcontrollers, useful in experimental physics groups.

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