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Lasers: Childhood Toy, Adult Passion

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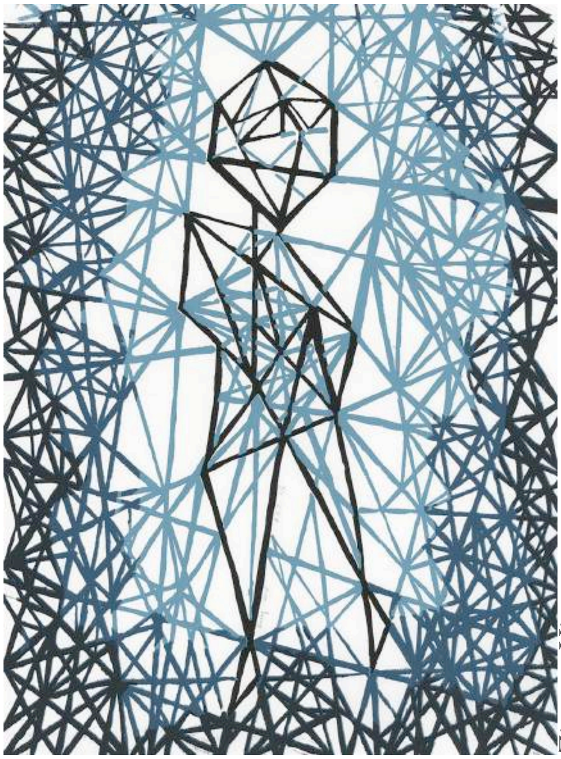

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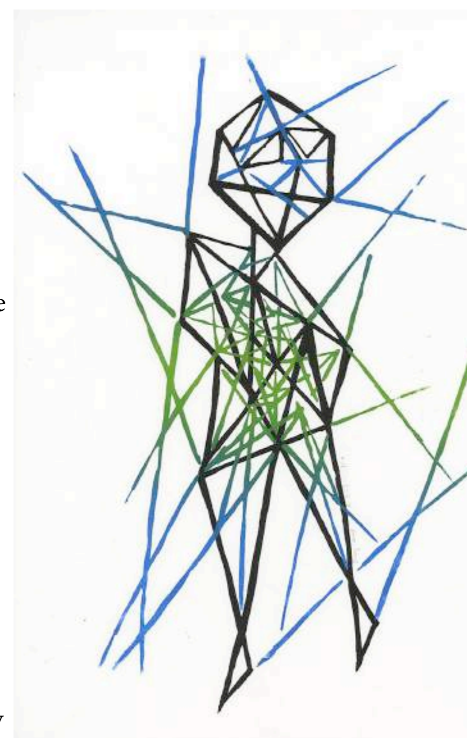
One of the best presents I ever received was a board game involving placing mirrors to bounce a laser into the other person's goal. I remember when I first got the present; I was so excited to play with these strange things. They were like light from a light bulb but so much more fascinating. Being my spoiled self, I was a little disappointed in the rather flimsy nature of the game. The lasers often didn't work and the mirrors had a tendency to fall over, but perhaps the biggest let down was how low powered the lasers were. They were designed for a kid's toy so you could barely see them in broad daylight. So, when I learned about an internship with the Richard Russo group at Lawrence Berkeley National Laboratory that worked with extremely high-powered lasers to determine the chemical makeup of a sample, I jumped at the opportunity.

The desire to learn what everything around us is composed of has been on our minds since early humans first marveled at fire. As science has progressed, we have developed more and more accurate techniques for determining what something is; now, we can determine the makeup of almost anything to a huge degree of accuracy. However, many of these methods involve large-scale machines or require complicated manipulation of the sample to get it in a state that the process can work with. This posed a problem to those who wanted to calculate the chemical makeup of anything outside of the lab, for example studying samples on the Mars Rover, doing soil analysis in the field, or working to identify a coffee bean's origins. Laser Induced Mass Spectroscopy is the first step to having a solution for these problems. It can be performed in a relatively small machine and requires no sample preparation. As a result, it has found uses in many aspects of scientific research today. For example, the technology is used to determine the age of things such as coins.

During my two summers at the lab, I learned a lot about how the process of laser induced mass spectroscopy works and why it is a useful tool in both industry and academia. Essentially, it works on the principle that different atoms and molecules give off different frequencies of light when they are excited or have a lot of energy. When energy is put into the molecule or atom the electrons gain more energy and are moved into a higher energy state. Then, when they lose the energy they "fall" back down to the lower energy levels and release that energy. The key is that the electrons can only have very particular energies which are inherent to the nature of the molecule or atom. As a result, all atoms and molecules give off very specific wavelengths of electromagnetic radiation. In other words, there is a distinct set of wavelengths of light that each atom or molecule will give off when it is excited.

This is where the laser comes in. It fires a pulse of light that is emitted over the course of a few femtoseconds (one femtosecond is one quadrillionth of a second—or the time it takes for light to travel across the tip of a pencil). This pulse of light is so powerful that it turns a small part of the sample into plasma—a state of matter when all of the electrons are excited—which in turn allows the emission of electromagnetic radiation. This wavelength is then measured by the spectrometer in order to determine the makeup of a sample. This is just the basic concept behind the process; there are many nuances that have to be considered and can have some very interesting implications. When you look at molecules with this technique, you have to consider not only the position of the electrons, but also how the molecule is rotating and vibrating in space. In addition, when you try to use this analysis to determine what amount of different isotopes are in a sample, it can be very difficult as the wavelengths of light given off are quite similar between isotopes. You have to find ways to increase the sensitivity of the measurements. This is extremely important and useful as determining the amount of a certain isotope in a sample can be used for radioactive dating. This and similar techniques are how much of the fossil record was dated.

Lasers are one of the most amazing inventions of the 20th century. They have revolutionized many aspects of society, from children's play toys to Hollywood blockbusters to cutting edge science research. In my mind, the process of forming light into a laser beam described the almost magical nature of my summers at the Russo Lab. When I arrived and was shown around, I realized that the lab was a scaled up, industrial version of the old board game I used to play, or at least it looked like that to my naïve eyes. There were lots of little mirrors, lenses, and countless other exciting objects designed to manipulate lasers screwed into a big metal table. At one end of the path of mirrors, there was a laser that weighed at least 300 pounds and was the size of a small ping pong table, and at the other end could go a sample of any solid or liquid. I was struck by the playfulness of the lab environment—not to say that the scientists there weren't serious about their work—but everyone genuinely enjoyed what they were doing. Dr. Russo would always say that these lasers were just "really expensive toys for adults," and it was true.



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