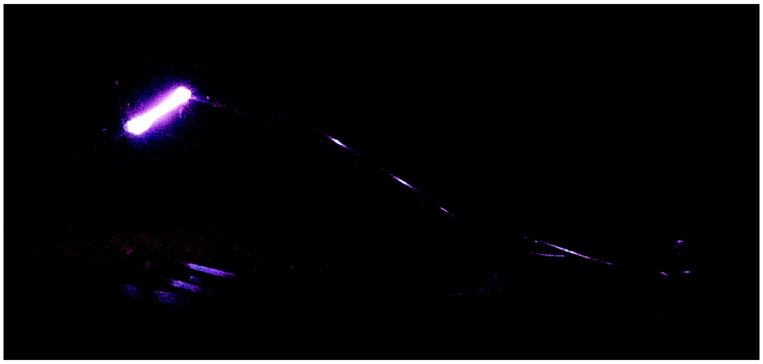
Group Project 2



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Flow Visualization Group Assignment 2

April 5, 2010

My intention for this assignment was to explore the visualization of electron flow. Our group could not match our schedules in time to work together, so I did this project individually. I wanted to produce an image showing a flow of electrons arcing through the air. I am pleased with the image I produced and the flow physics apparent in it.

The phenomena seen in my image is that of an electric current flowing between two objects of greatly different charge. A large voltage was stored in a capacitor, and then was discharged to ground, as seen in Figure 0.1. The spark seen is due to the dielectric breakdown of the air in between the two charged objects[2]. When the electric field is strong enough across air, the molecules begin to ionize and break down, allowing them to conduct current[1]. This is the same mechanism seen in lightning strikes. The dielectric breakdown of the air occurs when the electric potential exceeds the dielectric strength of the air, which is 3×10^6 V/m[6]. The spark seen in my image is about 3 mm long, which indicates that the charge between the objects was about 9000 V.

$$3,000,000(V/m) \cdot .003(m) = 9000(V)$$

The visualization of this flow is purely by emittance. The electrons are emitting the light that is seen in the image, which is the only light in the photograph. When the air breaks down due to the voltage across it, it becomes a plasma, which readily releases energy in the form of photons[4]. The electron flow is visible in my image because the electrons lose energy as they arc through the air, and that energy is converted to and emitted as photons, which were then captured by the camera.

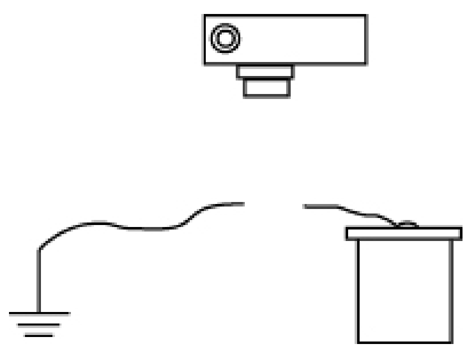

Figure 0.1: Sketch of flow apparatus.

To charge the capacitor, I rubbed rabbit fur against a PVC tube. This works because of the triboelectric effect. When certain materials come into contact, they form small surface bonds, and when they are again separated, an electrical charge is left on the surface of the materials[7]. These two materials have very different surface properties which cause them to generate an electrostatic charge when rubbed together[7]. The PVC pipe was also rubbed against the wire leads on the capacitor, thereby charging it as the PVC pipe was moved against the rabbit fur, as seen in Figure 0.2.

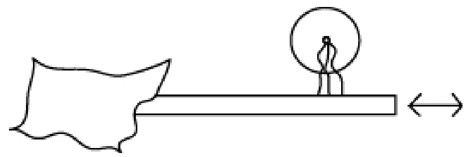

Figure 0.2: Sketch of charge apparatus.

The capacitor that I used was a home-made Leyden jar. This consisted of a plastic container with a layer of tin foil around the outside and inside. These thin layers held opposite charges, with the plastic in between the acting as the dielectric insulator[3]. The container was then filled with salt water to increase the charge capacity and to conduct the charge to the lid, in which there was a screw. On the outside of the lid, the screw was attached to some wires, which allowed the capacitor to be charged and discharged.

The photographic technique that I used was somewhat tricky. I charged up the capacitor with PVC and rabbit fur. I then grounded myself, set up the camera as quickly as I could, and set a timer on the camera. I set the shutter to about a second and the room was completely dark. Then when the timer ended, the shutter opened, so I had one second to ground the capacitor and make the spark, which was the only light that the camera saw. It was difficult to work quickly enough so that the capacitor did not lose much charge, and to time the discharge with the shutter. The arc in the photograph moved the distance between the capacitor and ground at a speed of at least 1×10^5 m/s[8]. This means that the time scale of movement in my image is on the order of 30 nano seconds, and my image is not time resolved.

The size of the field of view of the original image was approximately 30 cm^2. The distance from the lens to the object was approximately 10 cm, and the focal length was 4.0 mm. The type of camera that I used was a 10 MP digital camera, Panasonic DMC-FX500. The original image file was 3648 x 2736 pixels, and the final image is 1428 x 671 pixels. The exposure specifications were shutter speed of 1.6 seconds, ISO 400, and F number 2.8. I processed the image slightly in Photoshop, cropping the image and then increasing contrast, brightness, and blue hue.

This image reveals the flow physics of electrons arcing through the air. I am very pleased with the phenomena seen; I intended to capture an image showing electron

flow. I am not very pleased with the quality of the photograph, I had a very hard time getting the image in focus, and getting a clear picture of what was going on. I had a hard time getting the right exposure, and am disappointed that the image looks so grainy when cropped to size. In the future, I would like to improve my photographic technique, and try to reduce sensor noise. Overall, I am pleased that I produced an original flow with some interesting qualities.

Bibliography

[1] "Electrical Breakdown" Wikipedia, the Free Encyclopedia. Web. 30 Mar. 2010. <http://en.wikipedia.org/wiki/Dielectric_breakdown>.

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