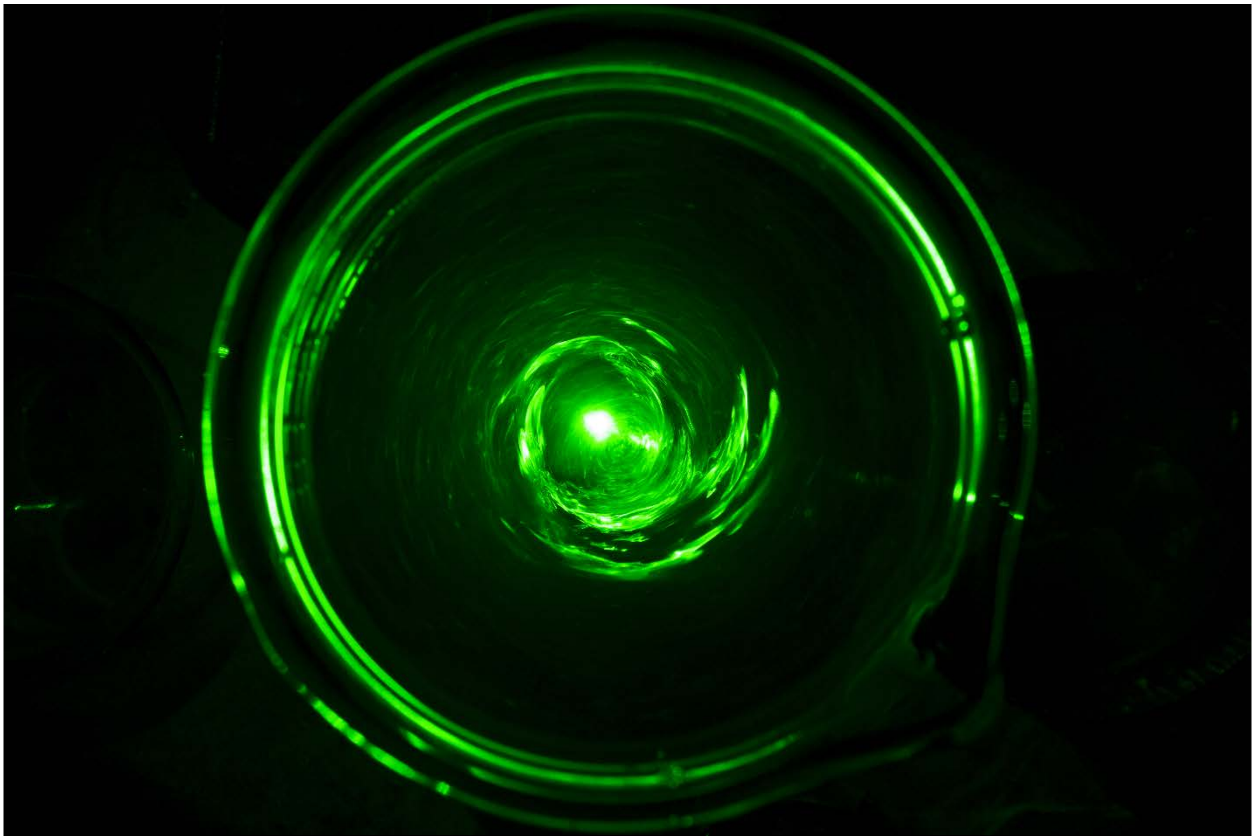
Rasputin



By: Kenny Wine

My image was inspired by vortices and light! This is an image of water in a beaker being stirred by a stirring bar. The stirring bar has many different speeds and has the ability to create beautiful vortices'. Suspended in the water are Aluminum flakes taken from a machine shop floor. They were small enough to be in suspension and not affect the other flakes in the water. The green light appearing in two rings is the light of a green laser beam. It was a 25 mW laser that emits a beam with a wavelength of 532 nm which appears in the green spectrum of visible light.

The lighting and camera setup was very simple. The group turned off all the lights and let the laser be the single source of light. The camera was held 12" above the rim of the 500 mL beaker as centered and square with the beaker as possible. Upon playing around with the laser the group noticed very interesting effect that the water had on the beam of light. Some of the light bent towards the middle of the vortex while the rest of the light seemed to hang around the rim of the beaker. The light bending into the vortex is caused by the surface boundary of the air and water which in turn form a basis for the analysis of Snell's Law.

Snell's Law is the description of the way light bends in accordance with the materials index of refraction and the angle at which the light entered the boundary layer. The mathematical description of this phenomena is represented with:

$$n_! sin\theta_1 = n_2 \sin\theta_2$$

An important concept critical to the analysis of concentrations of light is the idea of a critical angle. The critical angle is the angle at which the light coming from the first medium enters the second medium creating reflection angle of 90 degrees normal to the surface. This concept is used in fiber optic cables that use the orientation materials that enable this phenomena to transfer light efficiently. The conical surface of the water is caused by the stirring bar and this surface submits itself to an interesting interaction with the laser. The index of refraction for air and water is $n_1 = 1$ and $n_2 = 1.33$ respectivly. Since the angle of the laser beam from horizontal is very shallow as noted in Figure 1. The light hits the critical angle and is now bending with the water vortex. The streaks in the center of the image are from the aluminum flacks added to the water. The flakes reflect the light directly back into the lens creating over exposed sections of this image. Lastly, the light also hits the rim of the beaker creating a Cyclops look to the image. The physics of this is related to Snell's Law which is called the Brewster's angle. The Brewster's angle is the angle at which light passing through the boundary is polarized and perfectly transmitted through the medium. This is the reason why the photo is so ominous. The light passes through some portions of the beaker getting reflected and while other bits of light just transfer through the different mediums without being visible to the observer.

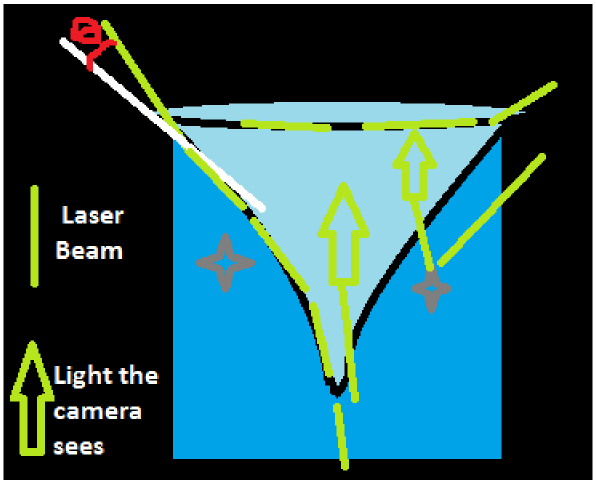


Figure 1

Another aspect of the physics invoked by this image is what's the Reynolds number associated with the rotating vortex? Since the vortex is induced by stirring it will be useful to analyze the Reynolds number of this particular flow. Through further investigation and research the Reynolds number associated with this phenomena is: $Re = \frac{\rho N D^2}{\mu}$

Where,

ρ Is the density of the water

N is the rotational speed RPM

D is the diameter of the agitator which is the stirring bar in this case

μ is the dynamic viscosity of the water

To determine the rotational speed RPM I decided to analyze motion blur in the image. With a shutter speed of $\frac{1}{40}\,seconds$ all that needs to be done is to determine the arc length of the blurred lines. Using figure 2 the angle was measured and $\theta = 105\,°$, knowing this and the fact that it took $\frac{1}{40}\,seconds$ to move that far it was determined:

$$N = \frac{100°}{\left(\frac{1}{40}\right)s} = 4000\frac{degree}{second} = 666\ RPM$$

With this the Reynolds number can be determined and comes out to be:

$$Re = 66{,}533$$

It is known for this type of stirred induced flow a Reynolds number about 10,000 is considered to be turbulent flow. The flow has now been classified as turbulent and this is expected because the function of the stirring bar is to mix. If the flow was laminar whatever is in the beaker will not mix very well because no layers of the flow mix. The conclusion is in order to have good mixing one would want as turbulent a flow as possible or as necessary.

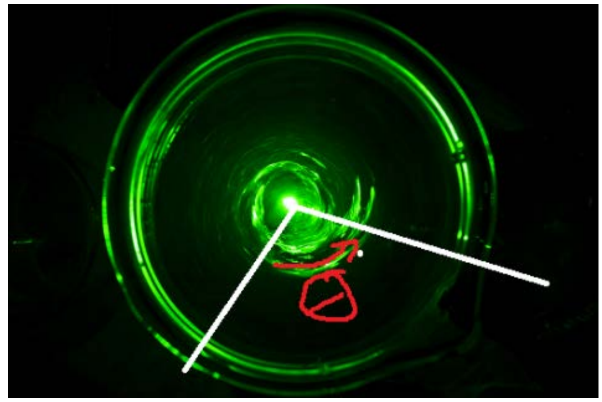


Figure 2

The type of camera used was a Canon EOS Rebel T31 and the lens on the camera was a 18-55mm lens. The focal length the camera was set up at was 31mm it was hard to get a really crisp focus on the beaker for the light was very deceiving. Next, I dialed in the shutter speed. Although there wasn't very much light involved in this image the shutter didn't need to be too slow to reveal the extreme intensity of the green laser. Also, since there was only one color of light involved in the image setting the camera setting for the type of lighting to auto did a nice job. The aperture was fairly close with f/8 which didn't give a wonderful depth of field but the main issue was the motion blur associated with the shutter speed. Lastly, the ISO was set to 400 attempting to really bring out the bright green.

I decided to use this particular image because it looked like it was straight out of a SYFY movie. The motion blur was very provoking in the image because it almost looks like light spiraling into a black hole. Some thing that could improve the image would be spending more time on the camera set up along with using a different method of seeding the fluid with some substance smaller than aluminum flakes.

Works Cited

"Brewster's Angle." *Princeton.edu*. Princeton University, n.d. Web. 23 Apr. 2014.

"Dimensionless Numbers." *Dimensionless Numbers*. Rensselaer Polytechnic Institute, 1996. Web. 23 Apr. 2014.

"Water - Dynamic and Kinematic Viscosity." *Water - Dynamic and Kinematic Viscosity*. N.p., n.d. Web. 23 Apr. 2014. <http://www.engineeringtoolbox.com/water-dynamic-kinematic-viscosity d_596.html>.