Flashing Lasers on Fog

Leo Steinbarth
MCEN 4151 - 001
Team Third Project Report
12/6/23

Introduction:

For our latest project, my team wanted to redeem ourselves for not capturing the full mesmerizing nature of the captivating Rayleigh-Bénard convection phenomenon. For our third team project, armed with a laser pointer, a glass dowel, and a fog machine in a dark bedroom, we sought to visualize the intricate dance between the laser and fog against a cylindrical plane. Our experimental setup involved directing the laser beam into the glass dowel, where fog from the machine filled the space, creating an ethereal atmosphere. With each click of the camera capturing the moment, we observed the laser's journey through the fog, unveiling a symphony of patterns reminiscent of the captivating chaotic turbulent flow of the fog and the unstable bright red laser. While our attempts did not fully encapsulate the turbulent flow of the fog, the improvisation of our team provided an engaging experience filled with potential for refinement. The interplay between the laser and fog unfolded as a captivating art form, with the fog responding dynamically to the laser's path, generating intricate patterns that offered glimpses into the enchanting world of light and fluid interaction. The main fluid dynamic observed in this experiment was Reynold’s number. Although my camera did not capture the turbulent fog as much as I hoped, the dynamic shape of the laser made by pointing into the glass dowel makes up for it. I extend my gratitude to my team—Greg Kornguth, Stella Meillon, and Austin Sommars—for their collaborative efforts, turning this experiment into a success that refined our skills in capturing the subtle beauty of fluid dynamics.

Fog with Lasers & Reynold's Number Explained:

For the experimental setup of this project, we used a red laser pointer with a wavelength of 635-660 nm, a fog machine, a glass cylindrical dowel, and a couple of boxes to rest the fog machine and glass dowel on. As you can see in the photo below, we had the fog machine at about 45° relative to the drywall. The camera was set up about 1 and a half feet away from the wall mirroring the 45° angle of the fog machine. Lastly, the glass dowel was pinned with a clothespin to keep it standing upright to ease the process of shining the laser off of it. The laser pointer used in this experiment lies right next to the dowel. The teammate who was shining the laser pointer at the glass dowel must point the laser at an acute angle relative to the glass dowel. In addition, to achieve the circular glow from the dowel, the line of the laser must have been pointed slightly offset to the center of the dowel to create the vibrant red circular shape projected on the wall. Although I tried taking photos with my Canon EOS Rebel T6 camera, my chosen photo was taken with my iPhone 13 mini.

Figure 1: Photo showcasing the experimental setup

In regards to fluid dynamics, I will explain Reynold’s number, focusing on the interplay between the laser and fog’s fluid motion. Reynold’s number is a dimensionless parameter, that plays a crucial role in characterizing the movement of a fluid, distinguishing between laminar and turbulent flows, each exhibiting very distinct characteristics. Its essence lies in establishing a relationship between inertial forces and viscous forces within a fluid system. When the Reynolds number surpasses 2100, it signifies turbulent flow, while values equal to or below 2100 designate laminar flow. The equation below provides the formula for determining this significant value:

$$Re = \frac{\rho u D}{\mu}$$

In the equation, ρ is the density of the fluid ($\frac{kg}{m^3}$), u is the velocity of the fluid ($\frac{m}{s}$), D is the diameter of passage (m), and μ is the dynamic viscosity of the fluid ($\frac{kg}{m-s}$). Based on Figure

1, we can estimate the diameter of the fog machine's exhaust was about 0.05 meters. To ease calculation, the fog slowly exiting out of its exhaust could be estimated at 1 $\frac{m}{s}$ and the density of the "air" (assuming the fluid is air and not fog) would be estimated at 1.292 $\frac{kg}{m^3}$. Lastly, the dynamic viscosity of the "air" would be 1.81E-5 $\frac{kg}{m-s}$ (assuming the room temperature was 15°C) [1]. Substituting these values into the Reynold's number formula gets us:

$$Re = \frac{1.292\times1\times0.05}{1.81E-5} = 3569.06 > 2100$$

Based on the calculation above, we can confirm that the flow coming out of the fog was indeed turbulent.

Visualization Technique:

For the experimental setup for the project, I encountered challenges with the initial approach, primarily related to the fog not appearing on my camera. We took photos of this phenomenon in a bedroom with the laser projecting up against an egg-white drywall. In addition to not having a completely black background to focus on the fog & laser, the laser itself was not bright. If we had a brighter laser, the turbulent fog would have been more visible to the camera. When I was capturing my photo on my camera, the darkness of the room would engulf the not-bright enough laser. However, when I improvised and switched to using my iPhone camera, the night mode of the phone illuminated the laser and fog interaction. To reiterate, the equipment used in this lab was a laser pointer, a glass cylindrical dowel, a fog machine, and a couple of boxes to mount both the fog machine and the glass dowel.

Photographic Technique:

As mentioned before, although I initially planned on using my Canon EOS Rebel T6 camera, the laser was not bright enough for the camera to capture a good-looking photo. The camera and the iPhone were situated about one and a half feet away from the projection on the drywall mirroring the 45° angle of the fog machine. This angle with my wide camera captured the big projection on the drywall. The table below shows the image properties of the photo I took including an exposure time of 1 s, an ISO 10000 setting, a pixel dimension of 3024 x 4032, and an f-stop of 1.6.

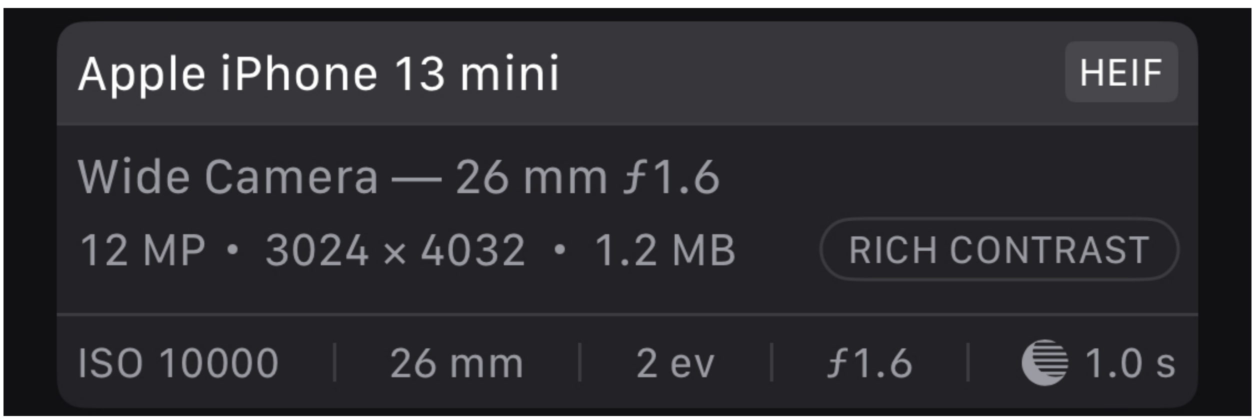

Table 1: Properties of the final photo presented

After finding the ideal angle and the best camera to use, I uploaded the HEIF file into Photoshop to boost the exposure, lighting, shadow, contrast, blackpoint, and saturation slightly, I transformed my dull-looking original photo into a poster-quality image as shown respectively below.

Figure 2: Original image taken on my camera

Figure 3: Final image edited using photoshop

Conclusion:

Overall, I find this image to offer intriguing insights into the dynamic behavior of turbulence as the flow of the fog expands and its interactions with the red laser. Initially, the fog appears transparent and lacks the “misty” feature around the laser shown in the final image. Over time, distinctive features such as vortices emerge, further highlighting the characteristic traits of turbulent flow. The final image exhibits a vibrant red circle with a beautiful crack of red lightning going through the middle of it. This image was enhanced using Photoshop to intensify the red laser hues, “mistify” the fog around the laser and darken the background. However, a minor drawback is the subtle showing of the turbulent fog flow. I believe that even though I could not fully showcase the turbulent flow, I captured the beauty of the red laser interacting with the fog in a unique geometric way.

In hindsight, if I were to replicate this experiment, I would purchase a brighter laser as that would have helped me capture the laser using my regular camera instead of my iPhone. This adjustment would contribute to an overall enhanced image. Additionally, I would explore the use of different colored lasers, like blue or green. Despite these considerations, I deem this experiment a success. The mesmerizing laser projected on the way with the fog creating some kind of aurora around the laser contributes to the experiment's overall success.

Source:

[1] Edge, E. (2023). *Viscosity of air, dynamic and Kinematic*. Engineers Edge - Engineering, Design and Manufacturing Solutions. https://www.engineersedge.com/physics/viscosity_of_air_dynamic_and_kinematic_14483.htm

: