Cross Sectional View of Fog Falling through Air

Brock Derby

Flow Visualization

University of Colorado at Boulder

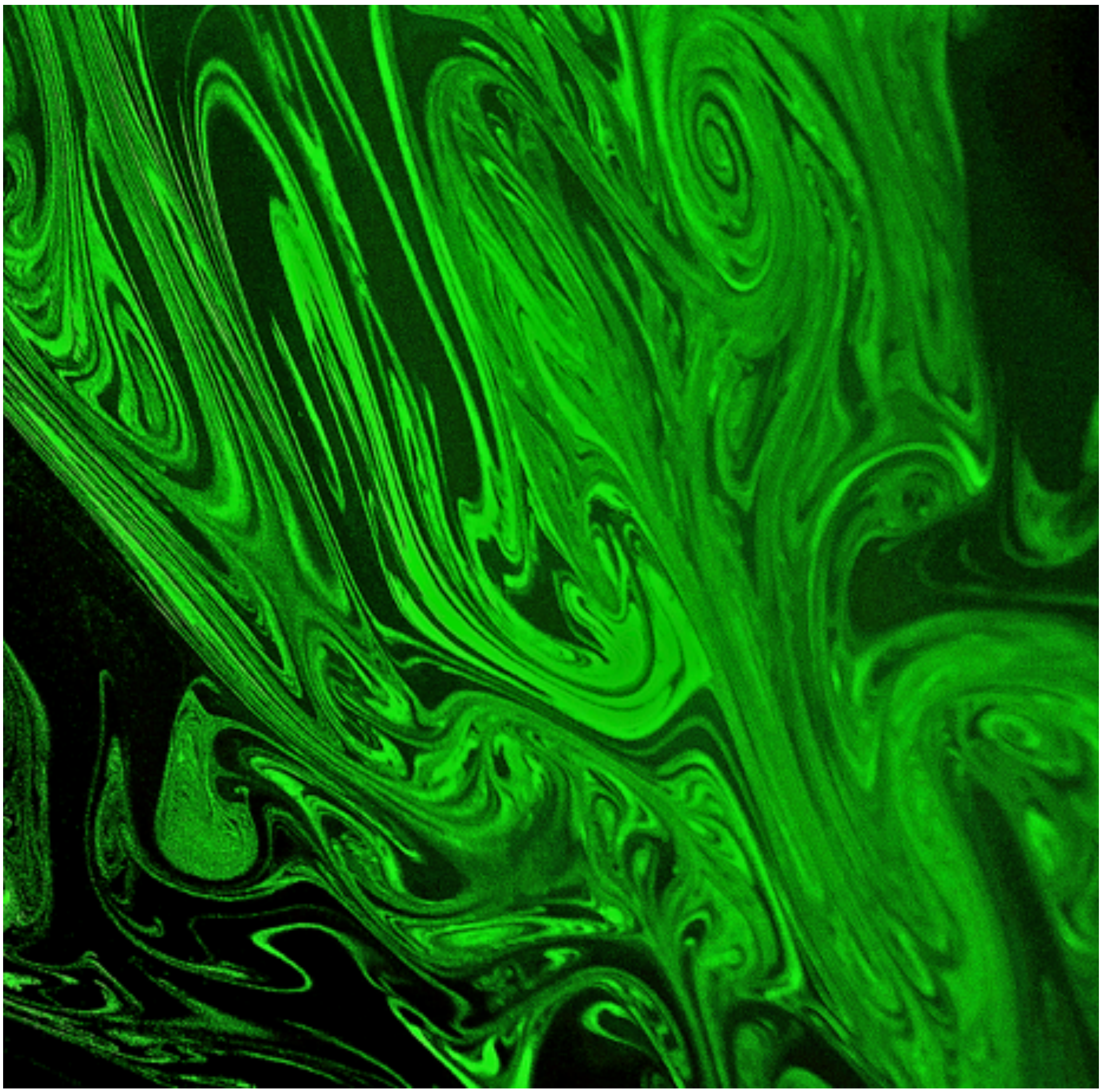
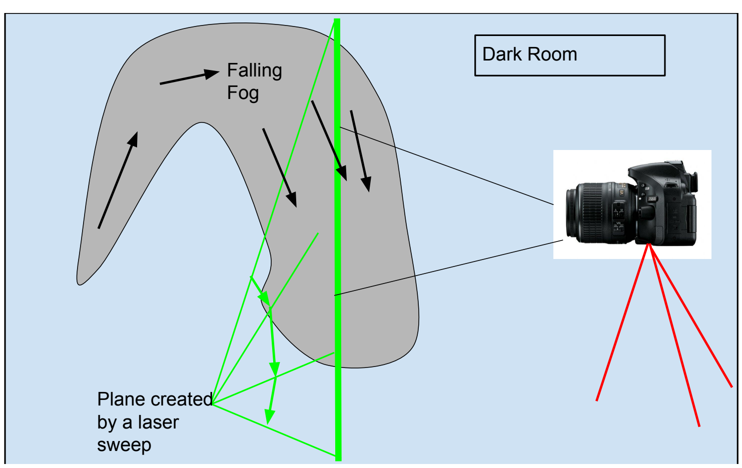


Figure A: Final image edited image

When watching fog flow through air it can be difficult to spot all of the small intricacies taking place. From a standard perspective a cloud of fog injected into air just appears as a white cloud with a turbulent outer layer churning with the air. However, if the flow is shown in a single 2D plane within this cloud, many of the elegant curves formed by the mixing are revealed. This image was taken to show just how beautiful and complex this mixing can be. Using a laser the non-diffusive mixing patterns of fog mixing with air are revealed and show countless laters of air and fog swirling and folding together.

The mechanisms used to take this picture consist of a green laser, electronic cigarette utilizing vegetable glycerin fog, a Nikon D5200 on a tripod and a very dark room. The shot acquired can be visualized without a camera simply by quickly shaking the laser in the same plane within a cloud of fog. However since the fog is dynamic, if the laser was to pass over the same plane twice, within one exposure it would result in two or more exposures and what appears to be motion blur. In order to get a clear shot of the plane of fog the camera was manually focused three feet away from the lens with a slow shutter speed of two seconds. The fog was blown above the focal point and as it fell through the field of view, the shot was taken and the laser was swung through the fog. This experimental set up is depicted below.



Since the laser was only passed through the fog a single time there was no double exposure or motion blur issues. Coincidentally, since the laser was swung through by hand and the focus was at a set distance, the timing and location of the laser path became difficult. If the laser beam swung to far or to close to the camera it would be out of focus. If it swung to early or too late, either the camera would not capture it or the fog cloud was not in the correct place. For the final shot, the laser beam was swept through the fog at roughly 2 feet per second right as the cloud fell through the focal point of the lens capturing the fog tumbling and swirling with the surrounding air.

The flow patterns seen here are the result of three key factors; buoyancy, shear forces, and non-diffusive mixing. First, the vegetable glycerin fog which is denser than air causes it to fall through the air. This falling creates shear forces between the stagnant surrounding air and the falling glycerin vapor, resulting in swirling along the boundary layer of fog and air. The swirling motion caused by the falling of a dense fluit falls through a less dense fund is known as a Rayleigh Taylor instability. The swirls tend to hold together better with a low reynolds number at the boundary layer of the two gasses [Jim'enez]. Finally, the glycerin fog is not yet exhibiting non-diffusive properties, allowing thin shear layers of air and fog become visible and easily seen through a laser plane. With time, these shear layers thin further, allowing diffusive effects to become dominant in the mixing. Without the different forces acting on the falling fog it would become far less interesting and mesmerizing.

In order to visualize this effect a vegetable glycerin fog was generated in a electronic cigarette. This vegetable glycerin is commonly used as stage fog and is not associated with any serious health concerns associated with inhalation [Varughese]. The only lighting used was a single 500 mW green laser shone through the smoke within a dark room. This caused a single plane of light going through the cameras focal point. The plane of laser light was created with a single swing of the arm traveling across the field of view at the focal point from top to bottom over roughly one second. The laser was moved at a near constant speed to ensure equal exposure across the image. Finally, it was found that a single pass of the laser produced a crisper image than a rapidly rotating laser beam which resulted in visible motion blur in the dynamic fog. Despite the constant image exposure, diffracted light would illuminate surrounding fog decreasing contrast inevitably requiring post processing.

To remove blurred areas and remove the foggy contrast from scattered light shown in Figure B, the following items were edited in Pixelmatr 3.4. The image taken with a Nikon D5200 with a Nikon DX AF-S Nikkor 18-55mm The image was first cropped from 4496 × 3000 to 3030X3000 pixels, removing the negative and blurry space. The contrast was increased between shear layers by altering the RGB color balance and sharpness increased. The RGB curves were shifted, decreasing the red values and increasing the blue and green values. To smooth the shear layer lines, the image sharpness was increased by 50%. Finally, to obtain enough exposure after one swipe of the laser the ISO was set to 800 in a dark room with an aperture of 4.8 and F Stop of 5.3. A two second shutter speed allowed sufficient time to pass the laser across the focal point, manually set at 1.5 ft away from the lens.

Despite my appreciation of this turn out, there are several aspects of this experiment which I would alter in the future. To reduce scattered light, I would create a black backdrop and attempt to remove any residual diffused fog in the room. Finally, The laser's path through the focal point should be well marked to ensure the shot is in focus. Over all, this was a fun and simple experiment which results in phenomenal visuals.

References

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2. Varughese, Sunil, Kay Teschke, Michael Brauer, Yat Chow, Chris van Netten, and Susan M. Kennedy. “Effects of Theatrical Smoke s and Fogs on Respiratory Health in the Entertainment Industry.” American Journal of Industrial Medicine 47, no. 5 (2005): 411–18. doi:10.1002/ajim.20151.