Measuring the Thickness of Cryosheet Jets

SLAC NATIONAL ACCELERATOR LABORATORY

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Introduction

What is the experiment?

I have been spending my time working on an experiment dealing with a jet that shoots a tiny sheet of liquid hydrogen, cooled to 19K, into a vacuum. We then recorded images to try and measure the thickness of the stream using thin film interference.

Thin film interference, in short, is a natural phenomenon that results in the bright rainbow you see when looking at bubbles. The reason these colors appear is because the light waves that go into the thin film are reflected at the upper and lower boundaries of the film and, depending on the thickness, can either destroy or amplify the colors that would normally show up. This principle holds true outside of just bubbles and in our experiment we apply it to a thin hydrogen sheet to measure just how thick it is.

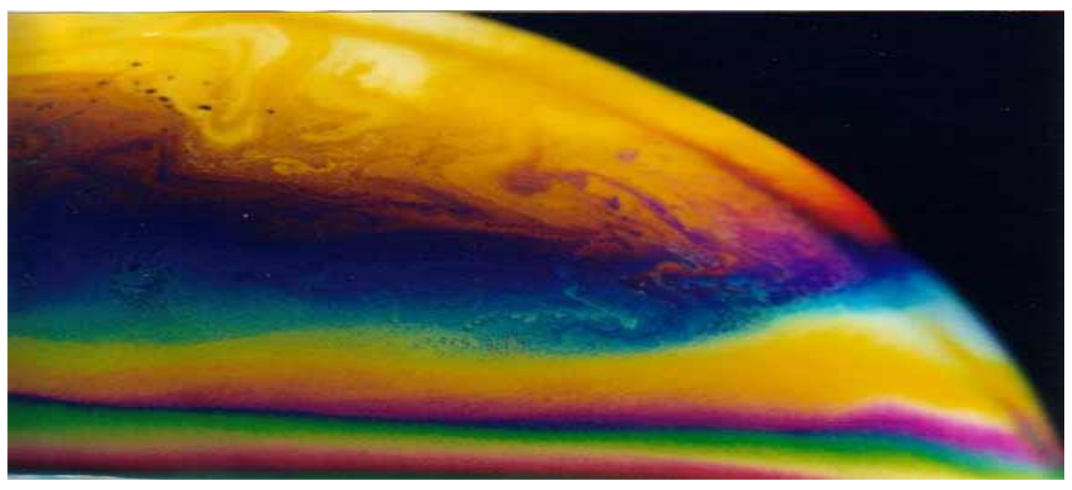


Fig. 1: Image of the colors seen in a soap bubble that showcase the principles of thin film interference.

Research

Why are we doing this?

In short, this experiment will help us in the development of target delivery systems for future projects in our department as well as in many other related subjects.

Why Hydrogen?

First of all, since this experiment is being executed by the High Energy Density (HED) Department, the HED states of Hydrogen are of interest to this group.

Also, Hydrogen has characteristics that make it a good target for this experiment. E.g.:

- Low density in its solid state
- Low proton density

Because it is near critical density, lasers can penetrate the sheet further without being subject to reflection, which helps us measure with less difficulty.

Why a sheet?

In previous experiments on this matter, instead of a jet of water or hydrogen, a foil sheet was used. So to get the best 1:1 comparison we make a sheet with hydrogen. Also, by making a thinner and smaller target, energy deposition is increased, i.e. it gets hotter, so we want our sheet to be as thin as is plausible.

Why measure thickness?

Making calculations with this type of sheet is difficult if we don't know the thickness of the jet. Given that the thickness is not consistent throughout the jet, having a way to accurately measure it precisely at any given point is valuable to us.

Trial:

Without going into too much detail, we followed a certain step of procedures to safely carry out this experiment.

- First, we locked everything down to make sure nothing moved mid procedure and turned on all of the necessary equipment.
- Then, we cooled the hydrogen and the inside of the vacuum to a chilly 19k.
- As those were cooling, we increased the pressure in the hydrogen chamber and sucked everything out of the vacuum chamber until it had the characteristics of a vacuum.
- Once that was achieved, we turned the jet on and aligned our equipment to it and finally recorded our data.

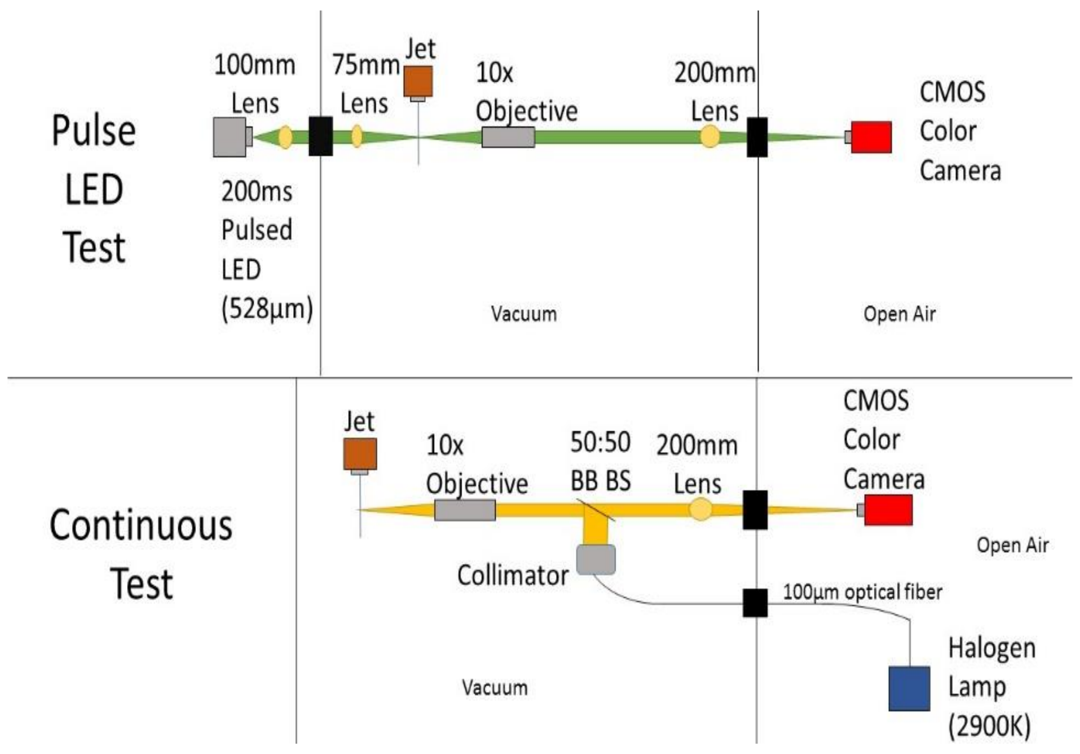
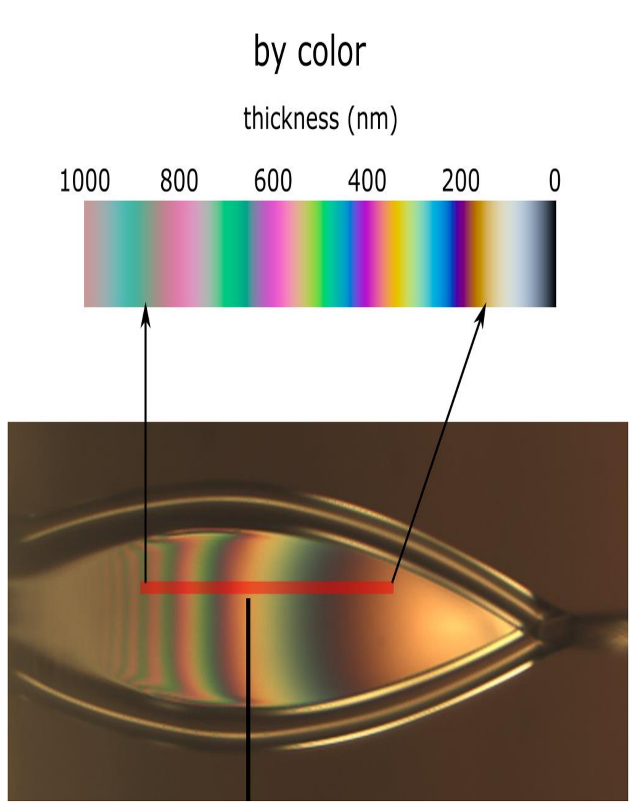


Fig.2: This is a diagram of the two distinct instances of this setup that were ran to record data. The instance on the top had a pulse LED firing light onto the system and the bottom had a halogen lamp shining light through an optical fiber into the system.

Results:

Analysis:

The experiment did not end up how we would have liked. Compared to past experiments like this one, the edges of the sheet are undefined and the reflection image was less than ideal. This made it near impossible to measure the thickness of the sheet. Also, the colors on the image have no meaning when checked by a spectrometer, respectively. They should have looked like colors on the left image: clear, defined, and following a pattern but are instead are mangled and blurry.



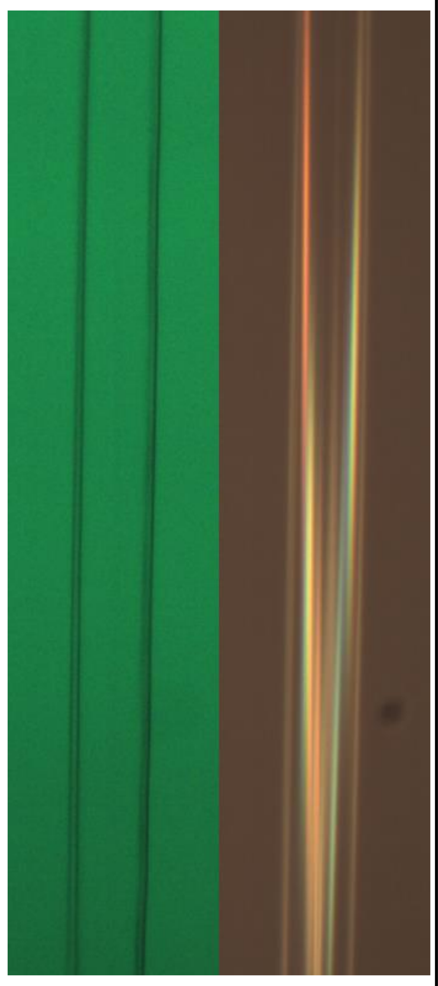


Fig. 3(left): Image of results from past experiment using water instead of hydrogen.

Fig. 4(right): Shows two pictures from our recent experiment, the left being done by the pulse LED and the right being lit by the halogen lamp.

Why did we fail?

There are many reasons our experiment didn't end how we wanted to, but these are the two most likely explanations:

1) Our jet fires a sheet that contains a mix of differing crystal phases and even some liquid phase hydrogen, so when we send a beam that has a uniform index of refraction the light wasn't properly reflected.
2) The crystallites didn't act properly as a flat surface, so when the beam hit the uneven surface, light scattered instead of reflecting into the camera, which would reduce the contrast, and therefore the quality, of our results.

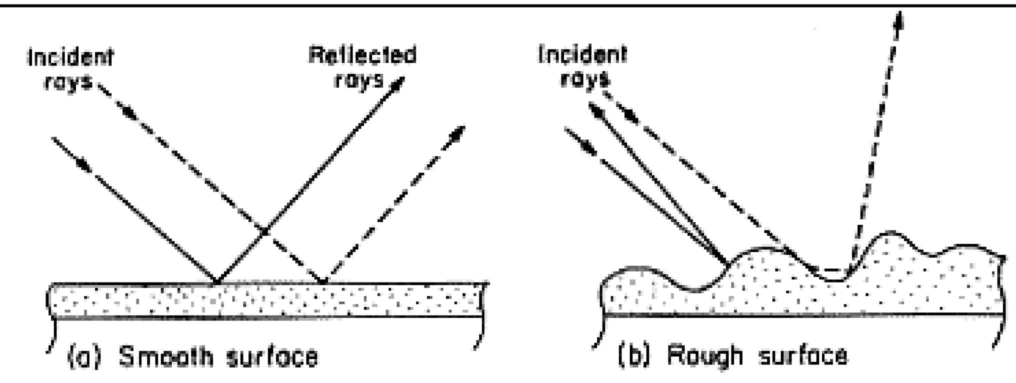


Fig. 5: Diagram of expected reflections on a (a)smooth surface and (b)rough surface.

What did we learn?

Even though the data we recorded is mostly unusable, we were able to take something from this experiment. We now are sure that the technique we used for the sheet is valid and has potential if better refined. In order to make our version better we would have to find a source that is less sensitive to refraction so that the image is more refined.

Conclusions

What I learned:

- I was taught much about the tools and instruments utilized in a lab as well as what the process of completing an experiment is really like.
- I saw, firsthand, the methods experimental scientists go through on a daily basis to get the job done and how much collaboration and communication this line of work involves.
- I should take more time researching the subject of experiments I take part in as well as reaching out to my superiors and try and make more connections.
- I should have asked more questions and not been so afraid of messing things up

Final Thoughts:

This was an amazing experience for me, especially as my first research opportunity, and has definitely aided me in deciding what I really want to do in life. I'm so grateful to everyone involved for giving me this opportunity, especially so, to Jongjin Kim for showing me the ropes and teaching me what it means to be a modern day scientist.

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