Advanced Measurement Techniques in Fluid Mechanics and Heat Transfer
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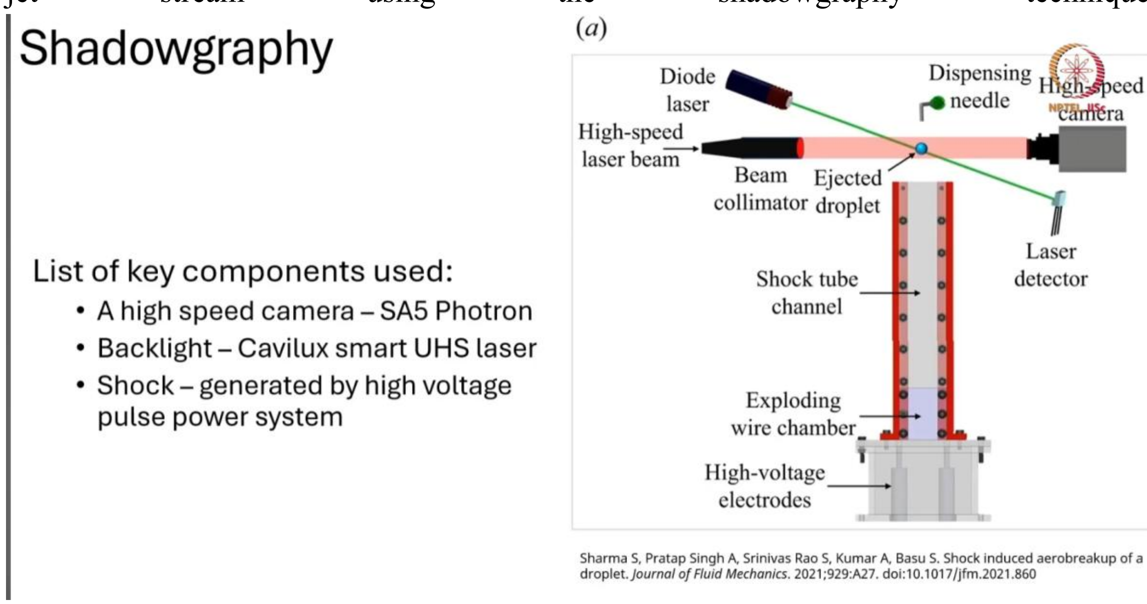
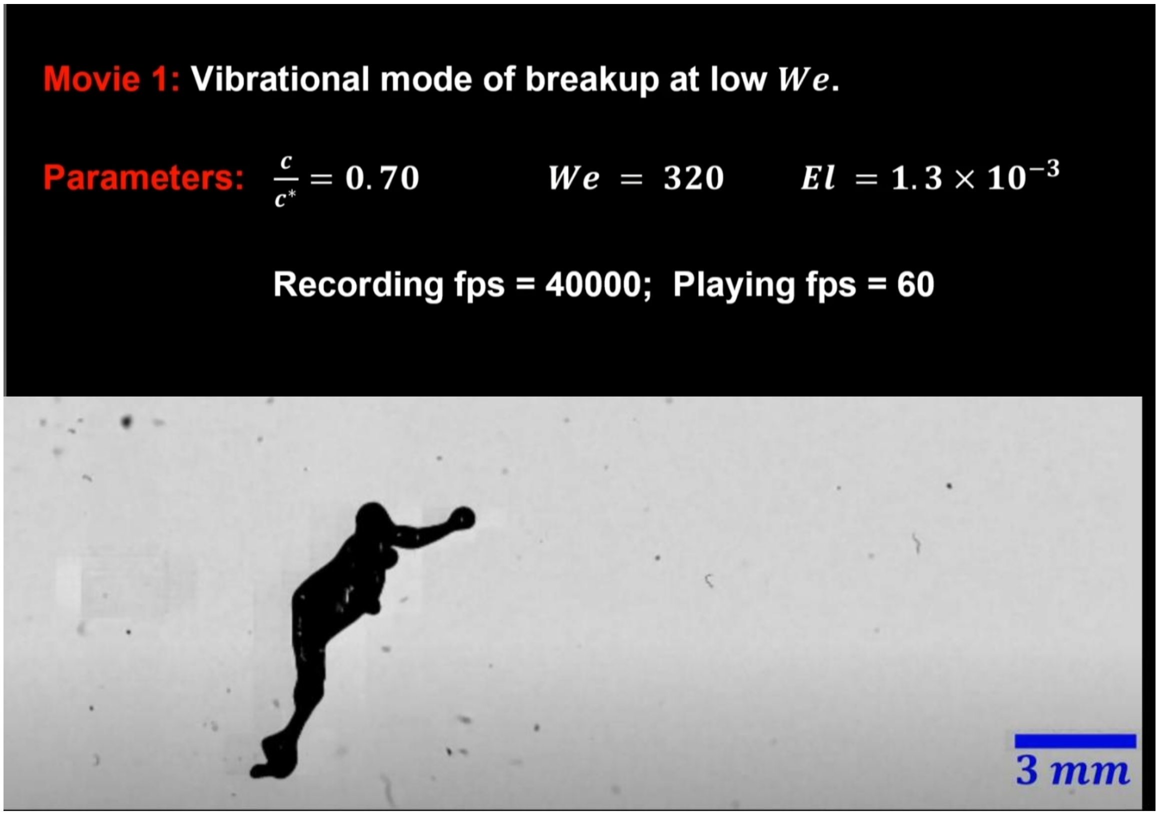
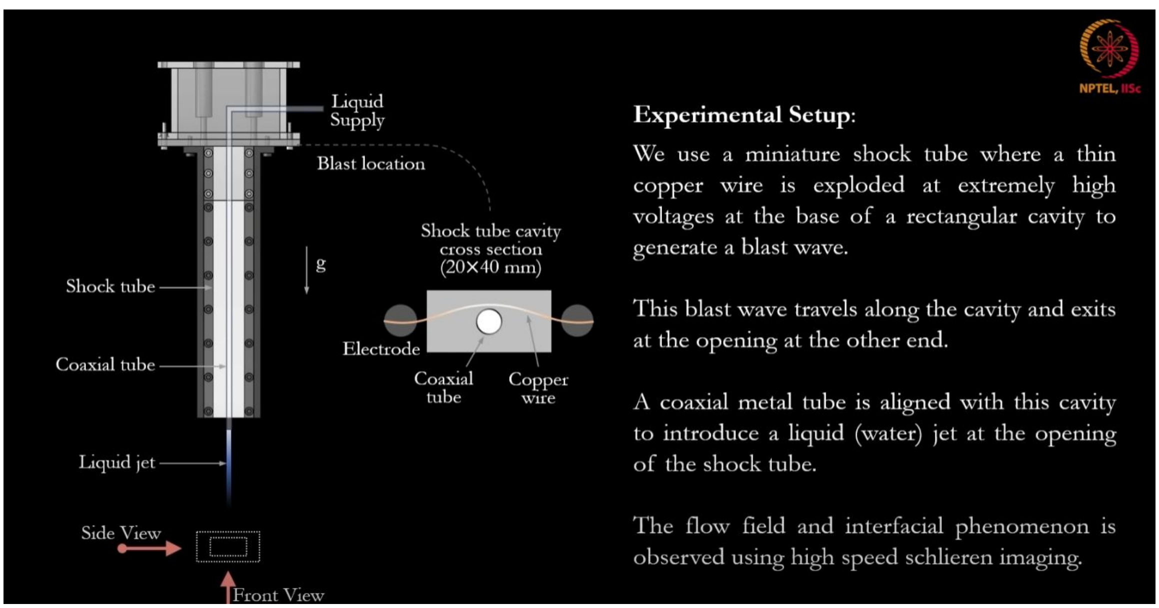
Week – 05
Lecture - 21
Overview of Experimental Techniques – 1

Welcome to this session. Here, we will be showcasing the practical applications of various measurement techniques used across different research areas. By the end of this session, you will gain a deeper understanding of the impact and effectiveness of each technique in specific scenarios as the course progresses. We will introduce and explore several techniques, including shadowgraphy, chemiluminescence imaging, Schillerin imaging, and particle image velocimetry. Additionally, we will provide a detailed look at how the experimental setups for these techniques are arranged and optimized for research purposes. As the first part of our measurement technique visualization, we will be showcasing an experiment that demonstrates shock interaction with a droplet and a liquid jet stream using the shadowgraphy technique.

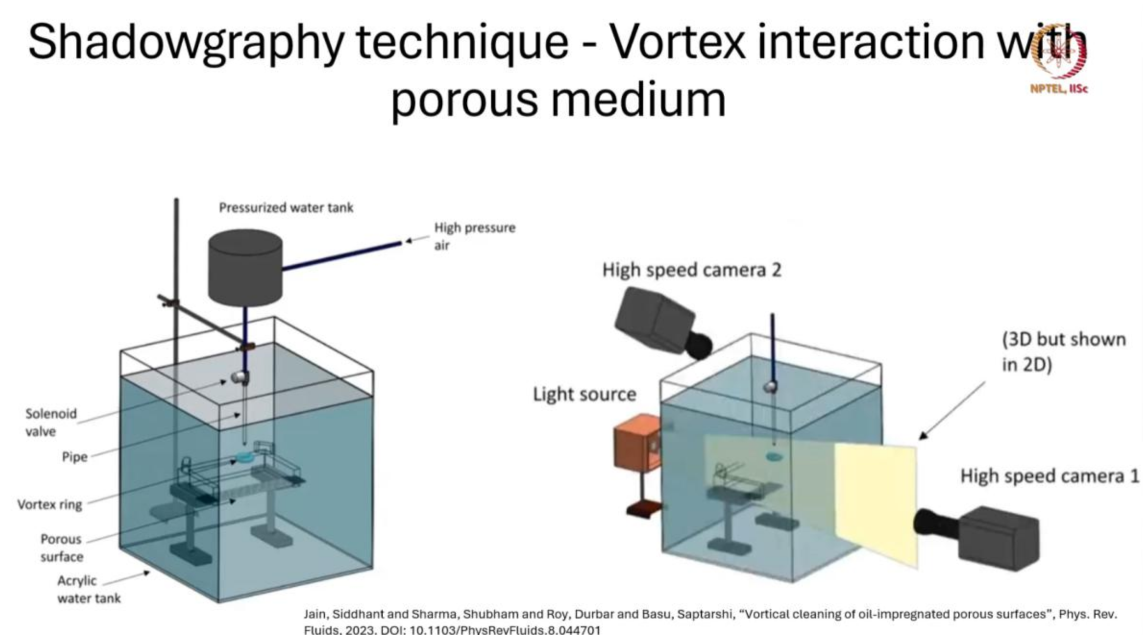


Shadowgraphy is particularly well suited for these types of studies because it provides clear, high-contrast images to visually understand the dynamics behind this experiment. By using this technique, we can capture and analyze the intricate details of how shock waves impact and deform droplets. In general, shadowgraphy experiments mainly need a camera and proper backlighting. Here in this experiment, we have used a high-speed camera, which is a SA-5 Fortron, and a Cavilux Smart UHS laser as a backlight; additionally, we are introducing shock using a high-voltage pulse power system.

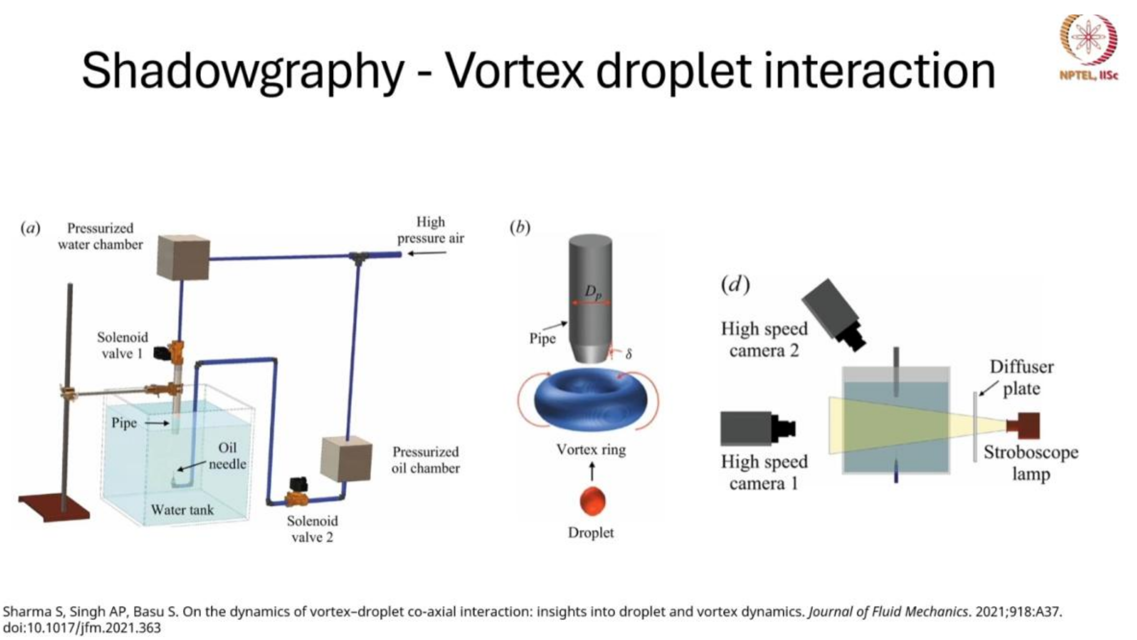




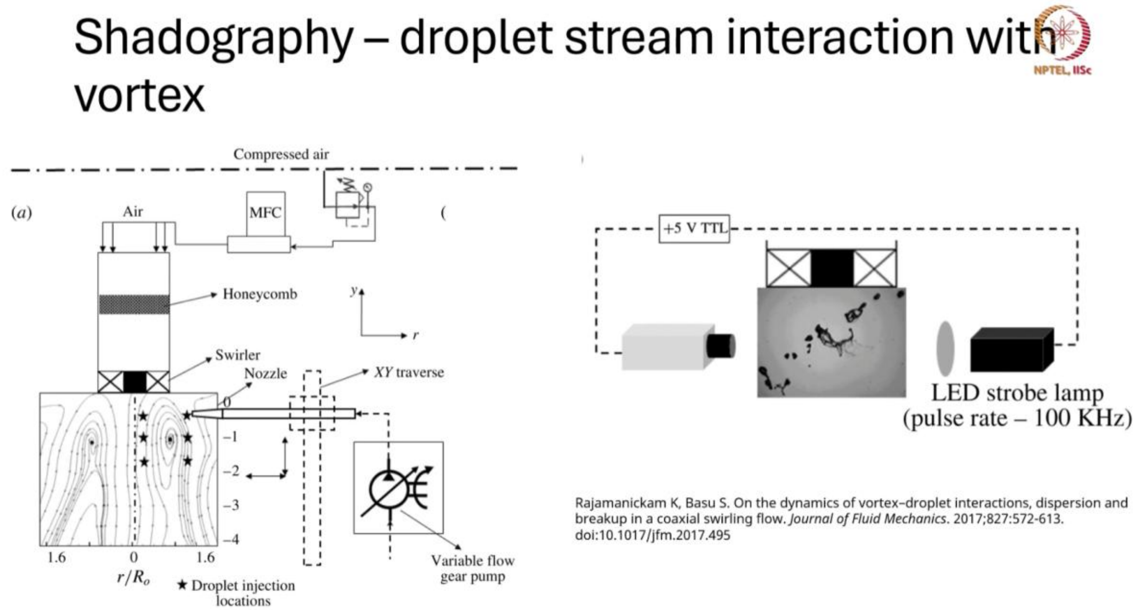
As the next example of the shadowgraphy technique, we will showcase the interaction between a vortex and oil-impregnated porous surfaces. For this experiment, we will utilize a high-speed camera combined with backlighting to perform shadowgraphy. Through this technique, we can clearly observe and analyze the effects of vortex motion on the porous surface and the behavior of the oil film under dynamic conditions. In this example, we will demonstrate how shadowgraphy is utilized to capture the intricate details of the interaction between a vortex and an oil droplet. For this experiment, we employed a high-speed camera paired with a stroboscope for backlighting.



This combination provides the necessary illumination and frame rate to capture the fine-scale dynamics of the interaction between the vortex and the oil droplet.

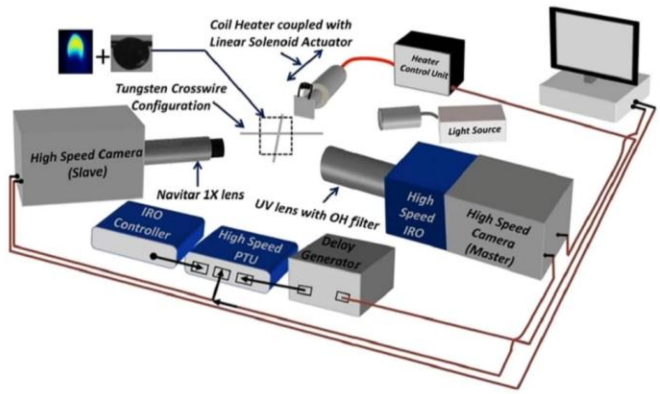


As a final example of the shadowgraphy technique, we will demonstrate the interaction of a droplet stream with a vortex generated in a swirl flow. For this experiment, we have used a high-speed camera along with an LED strobe lamp for backlighting. This setup enables us to clearly visualize how the droplet stream behaves within the flow field. By observing this interaction, we can see how the vortex causes the droplet stream to break up, providing invaluable insights into the dynamics of droplet dispersion and breakup in swirling flows.



In the second part of our measurement techniques, we will showcase the results obtained from a single droplet flame experiment. For this study, we utilized chemiluminescence imaging to focus on the flame's light emission and shadowgraphy imaging to capture the droplet details simultaneously. Combining these two techniques allows us to gain a comprehensive understanding of the droplets' behavior in the flame regime, particularly the boiling dynamics and how they interact with the flame. This powerful combination of methods provides deeper insights into the complex processes occurring during droplet combustion. In addition to shadography equipment, we need a high-speed IRO as an intensifier, a high-speed camera for capturing chemiluminescence images, a PTU for controlling the camera and IRO, a UV lens for allowing both visible and UV range signals, and a bandpass filter for allowing a particular band of wavelengths.

Chemiluminescence – droplet flame



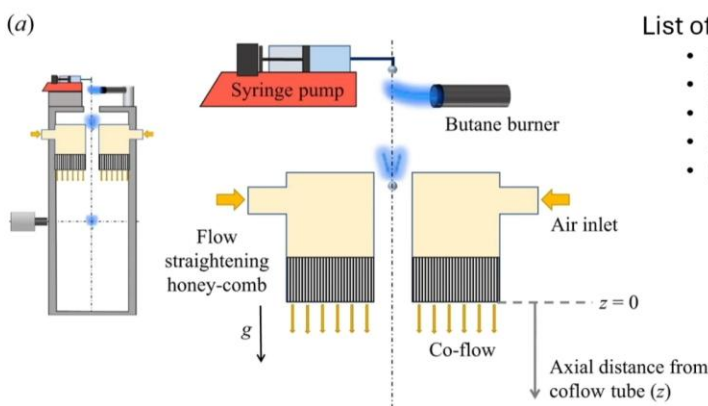
List of key components used:

- High-speed camera
- Backlight – strobe light
- High Speed IRO (Image Intensifier)
- Programmable Timing Unit (PTU)
- UV lens
- Band pass Filter

Khushboo Pandey and Saptarshi Basu, "High vapour pressure nanofuel droplet combustion and heat transfer: Insights into droplet burning time scale, secondary atomisation and coupling of droplet deformations and heat release" Combustion and Flame, 2019. https://doi.org/10.1016/j.combustflame.2019.07.043

As a second example of chemiluminescence imaging, we will showcase the interaction of a falling droplet flame with a co-flow stream. This setup allow us to observe how the flame surrounding the droplet behaves as it moves through the co-flowing air stream. This experiment highlights the intricate interplay between the droplet flame and the surrounding flow fields. Offering a deeper understanding of combustion behavior in dynamic environments.

Chemiluminescence – falling droplet flame



List of key components used:

- High-speed camera
- High Speed IRO (Image Intensifier)
- Programmable Timing Unit (PTU)
- UV lens
- Band pass Filter

dlamudi G, Aravind A, Basu S. Insights into the flame transitions and flame stabilization mechanisms in a freely falling burning droplet encountering a co-flow. *Journal of Fluid* *chanics*. 2023;977:A29. doi:10.1017/jfm.2023.949