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Coupled Analysis of High-Resolution Localized Temperature Measurement Using an Optical Fiber Sensor and Bubble Dynamics in Pool Boiling

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Introductions

Measurement Technique

- **Conventional measurement methods have limitations in accuracy and spatial resolution.**
- **Optical Fiber Sensor (OFS) can measure variations in temperature distribution along the sensing path with high spatial resolution.**
- **OFS uses Rayleigh scattering for continuous temperature sensing, enabling precise monitoring of localized temperature changes.**

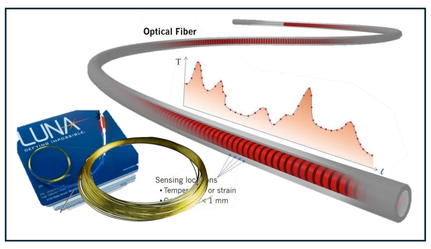

Fig. 1 Schematic of OFS for distributed temperature sensing.

Application: Pool boiling and Bubble Dynamics

- **Data obtained from pool boiling can be used to design efficient heat transfer and cooling systems.**
- **The characteristics of surface bubbles and surrounding temperature can be analyzed.**
- **Through surface local temperature measurements, it is possible to study bubble dynamics such as dry spot and microlayer formation.**

Experimental Method

AI-Based Bubble Detection

- **The AI model preprocesses high-speed camera images and detects bubbles in each frame.**
- **A YOLO (You Only Look Once)-based AI model is used for object detection.**

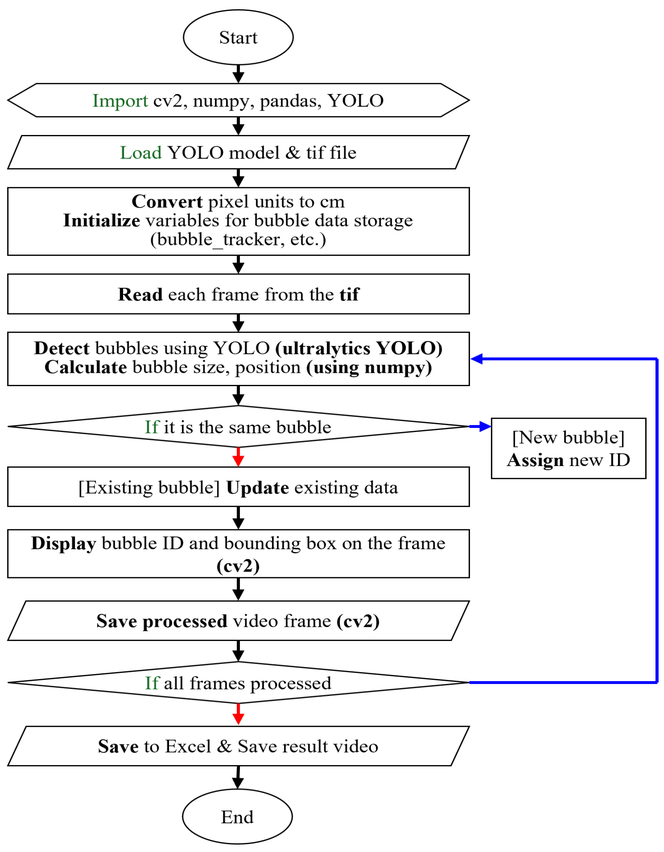

Fig. 4 Flowchart of the AI-based Bubble Detection Processing Using YOLO

Experiment Setup

- **A cartridge heater is used to establish saturated boiling conditions.**
- **An OFS is inserted into an STS tube, which is heated by joule heating, to measure surface temperature.**
- **The OFS features a gauge pitch of 0.65 mm and a measurement rate of 31.25 Hz.**
- **The high-speed camera records at a frame rate of 125Hz, and with speed setting of 10, it captures at 1250 fps.**
- **A TTL trigger powered by a 5V power supply is used to synchronize the camera and Luna sensor measurements.**

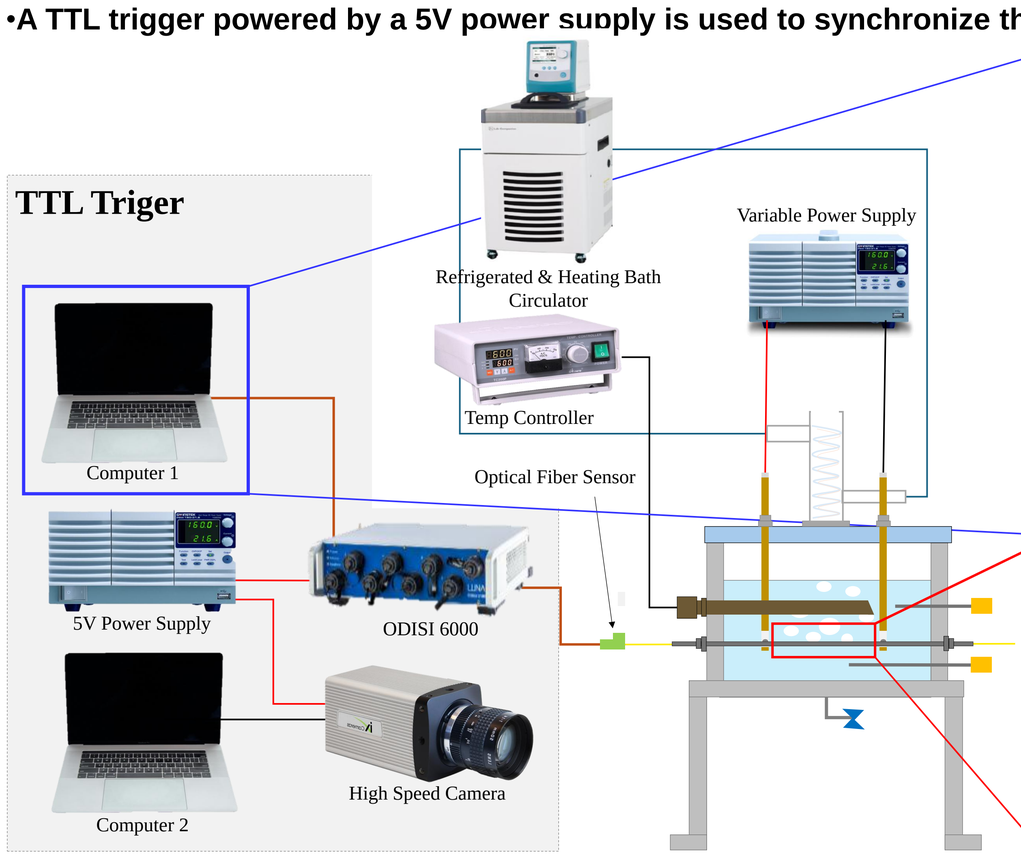

Fig. 2 Schematic of pool boiling experiment

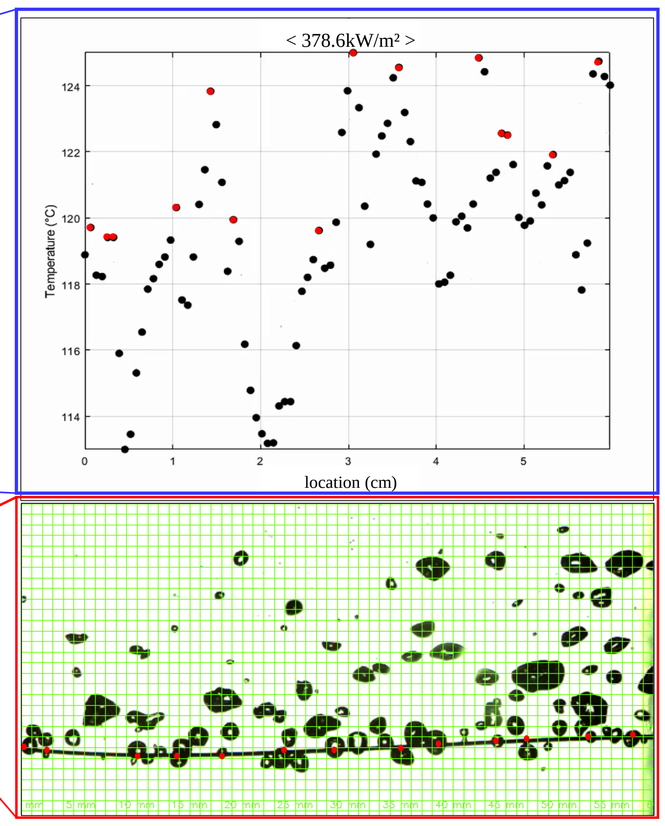

Fig. 3 Comparison of Bubble Dynamics and Temperature Distribution with position at 315.71kW/m² Heat Flux

Results and Discussion

1. Pool Boiling Experiment Results

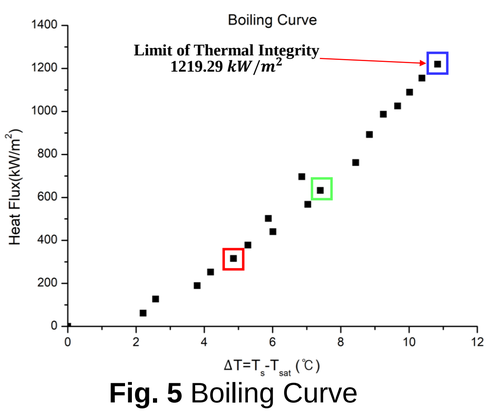

Fig. 5 Boiling Curve

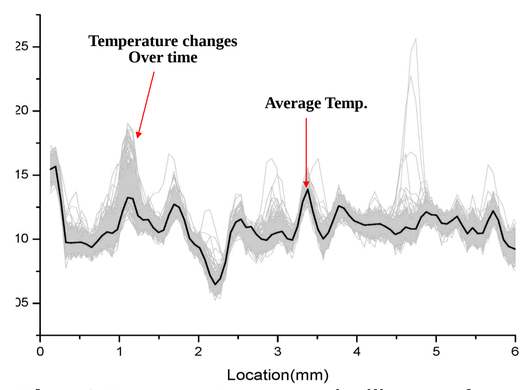

Fig. 6 Temperature on a boiling surface at 1219 kW/m^2

- **The boiling curve represents heat flux with surface superheat.**
- **The observed trend is consistent with nucleate boiling behavior.**
- **Greater deviations indicate intensified local boiling activity.**

2. AI-Based Bubble Detection Results

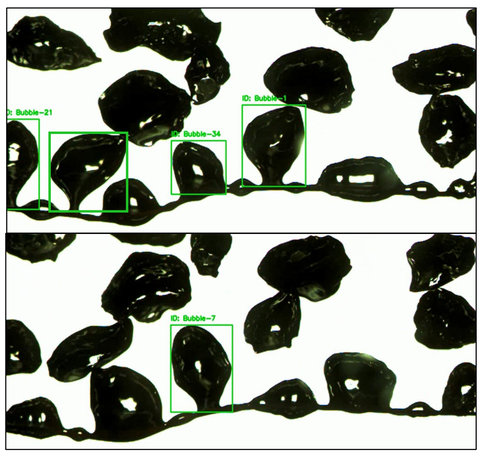

Fig. 7 Visualization of AI-Based Bubble Object Detection of Bubbles in the 1219.29 kW/m^2 Experiment

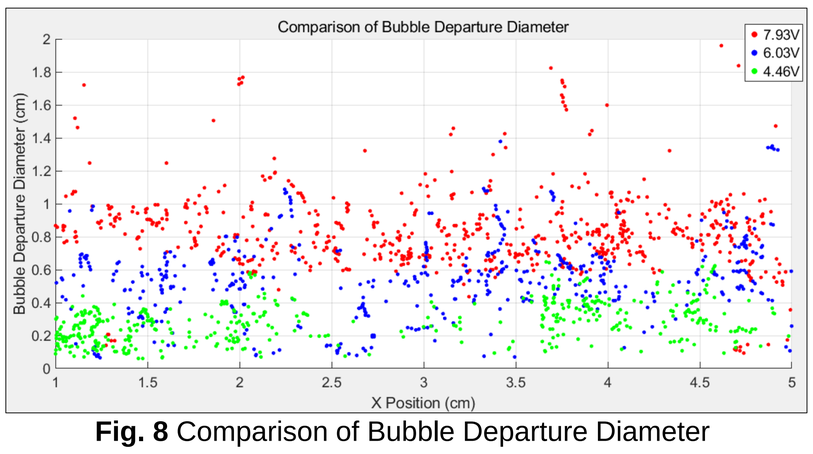

Fig. 8 Comparison of Bubble Departure Diameter

- **Bubble departure diameter varied along the longitudinal direction under difference heat flux levels.**
- **Increasing heat flux intensifies phase change, evidenced by larger bubble dimensions.**

Conclusions

- **Pool boiling experiments were conducted using an OFS to obtain high-resolution temperature data.**
- **Local temperature measurements enabled the analysis of the maximum and minimum temperature differences, as well as the construction of a boiling curve.**
- **An AI-based model was applied to extract bubble departure diameters from high-speed image data.**
- **Further analysis will focus on parameters such as bubble growth time, frequency, and other characteristics related to boiling behavior.**

Acknowledgements

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