Pretest of Rainbow Schlieren Deflectometry for Measurement of Thermal Boundary Layer Thickness

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INTRODUCTION

Motivation

- Based on fast development of computer engineering techniques, the use of **high-precision CFD codes** is increasing.
- In interpreting wall boiling heat transfer using high-precision CFD code, **temperature field information** is a key factor that greatly affects the heat transfer analysis related to the entire process of boiling bubbles.
- Rainbow schlieren deflectometry (RSD) can offer this information in **non-intrusive way** and this is most advantage of it.
- Srivastava et al. [1-5] applied RSD to pool, flow boiling situations and studied single bubble boiling heat transfer phenomena for various variables such as superheating, subcooling, and flow rate.

Object

- In this study, **thermal boundary thickness measurement as a feasibility test** of RSD was performed in simple situations before applying this methodology to various boiling phenomenon.

PRINCIPLES and EXPERIMENT

Principles

Degree of deflection is **proportional** to thermal gradient

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Specially designed color filter visualizes degree of deflection in color

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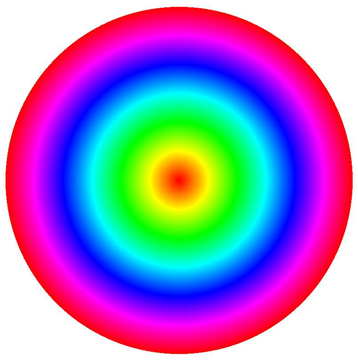
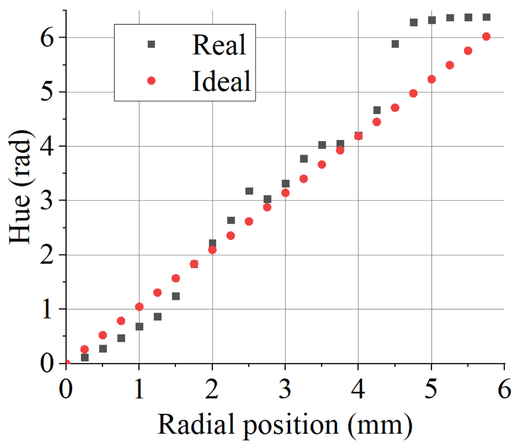
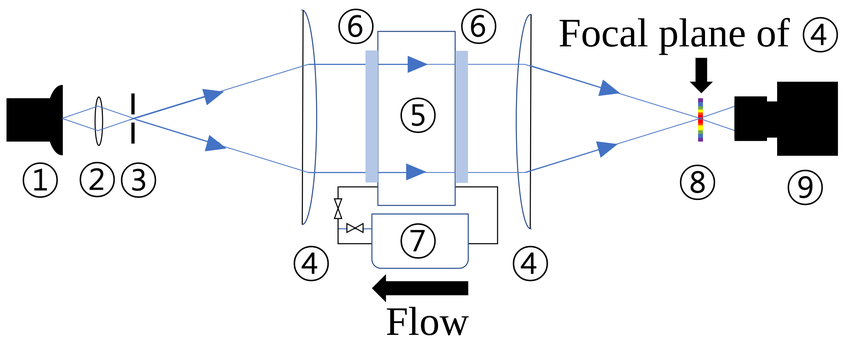
Analyzing color (hue), thermal gradient field and **temperature field can be obtained**


<Ideal color filter>



- **Hue value** of HSV* color system **quantifies** degree of delfection. (* Hue Saturation Value)
- Hue value of manufactured filter in radial position is measured and compared with ideal filter.

Experimental setup and conditions



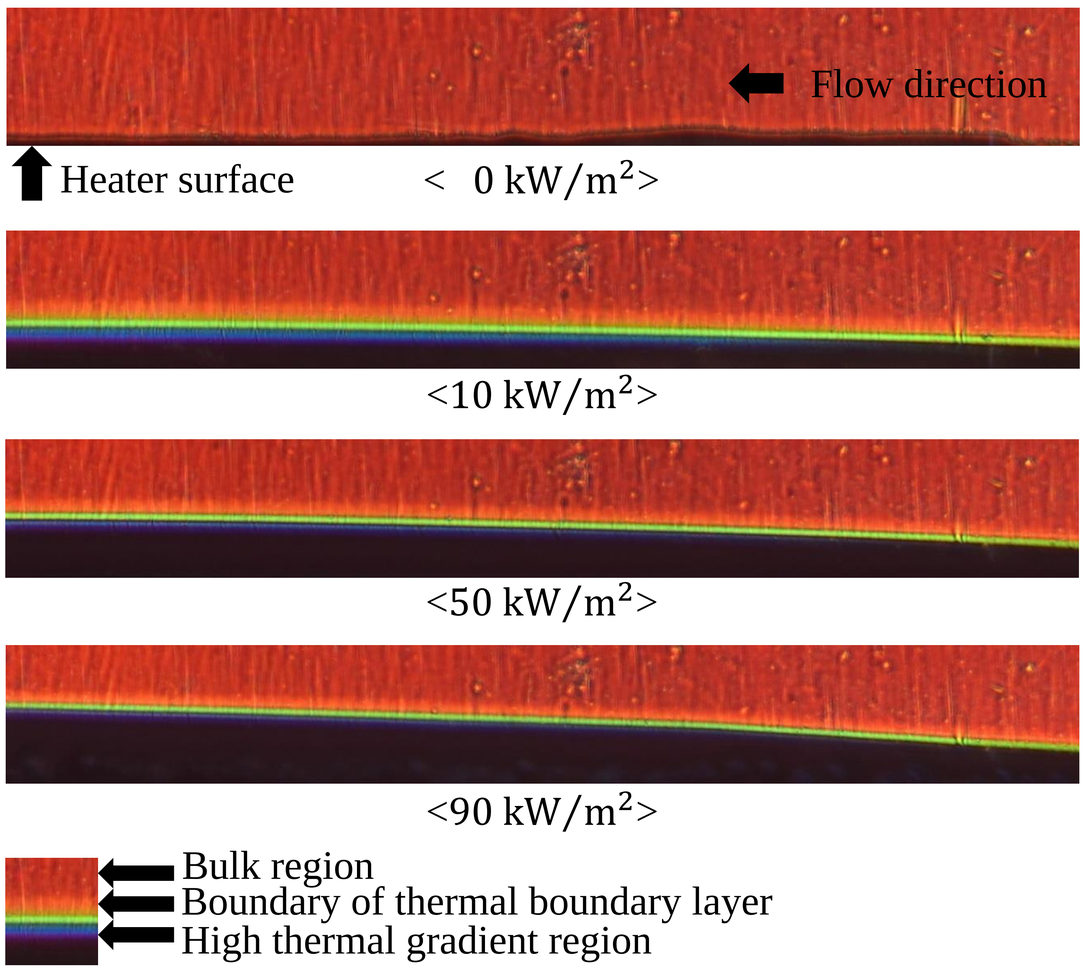
① White light source
② Dual-convex lens
③ Aperture
④ Plano-convex lens
⑤ Test section
⑥ Optical window
⑦ Isothermal circulator
⑧ Color filter
⑨ Camera

- **Silicon wafer heater** at bottom of test section is electrically heated.
- Schlieren images are taken in applied heat flux of $\mathbf{10, 50, 90\ Kw/m^2}$.

Parameter	Value
Pixel size of image	18.857 ± 1.426 μm
Flow rate	0.474 ± 0.028 LPM
Bulk temperature	20 ± 0.5 ℃
Cross-sectional area of flow channel	15 x 10 mm^2

RESULTS and INTERPRETATION

Schlieren images



Calculated thickness

Extract hue value: Hue values are extracted by MATLAB

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Define boundary: A pixel that has moving average in vertical direction which is larger than 0.2 is pointed as a boundary.

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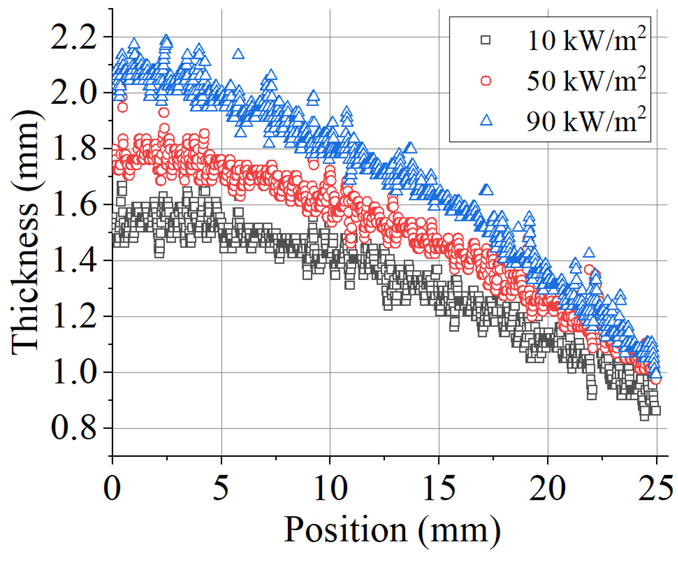
Calculate thickness: The number of pixels from bottom (heater) to boundary is counted and pixel size is multiplied



- **Thickness** of thermal boundary layer is **increase** by applied heat flux.

Heat flux (Kw/m^2)	Thickness at the end of heater (mm)
10	1.536
50	1.780
90	2.080

CONCLUSIONS and FUTURE WORK

Conclusion

- Two dimensional profiles of thin **thermal boundary layer** can be reasonably **visualized and quantitatively measured** using the RSD technique.

Future work

- Geometrical **distortion** of schlieren images due to light refraction
- **Uncertainty** in thermal gradient measurement.
- Conversion to **temperature field**