

Study of He II boiling flow field around a heater

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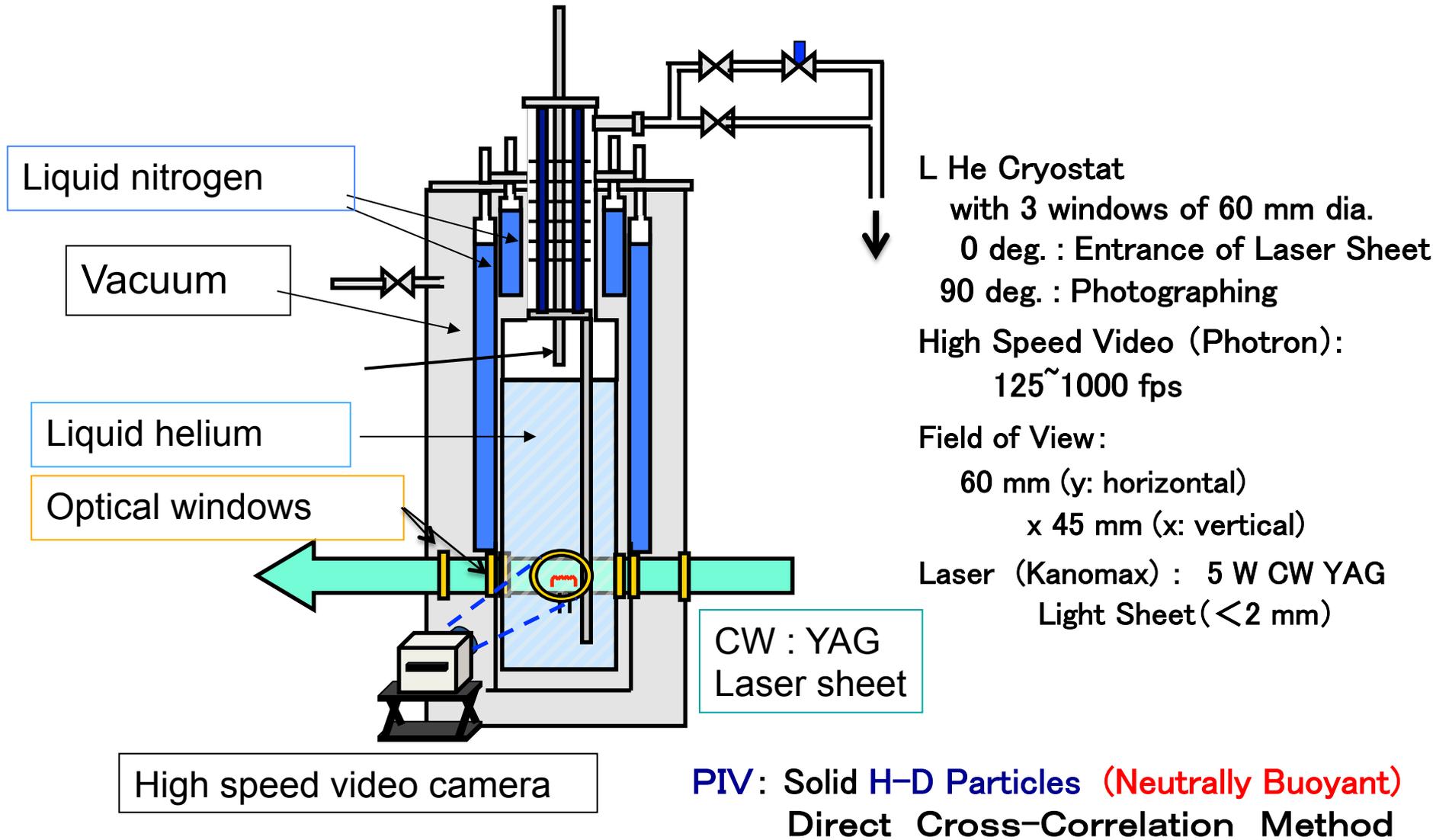
Transient Record of PIV Velocity $U_{PIV}(t)$

Time-Averaged Flow Velocity $\langle U_{PIV} \rangle$:

Velocity Contour, Velocity-q, Velocity-T

Velocity Fluctuation ΔU_{PIV}

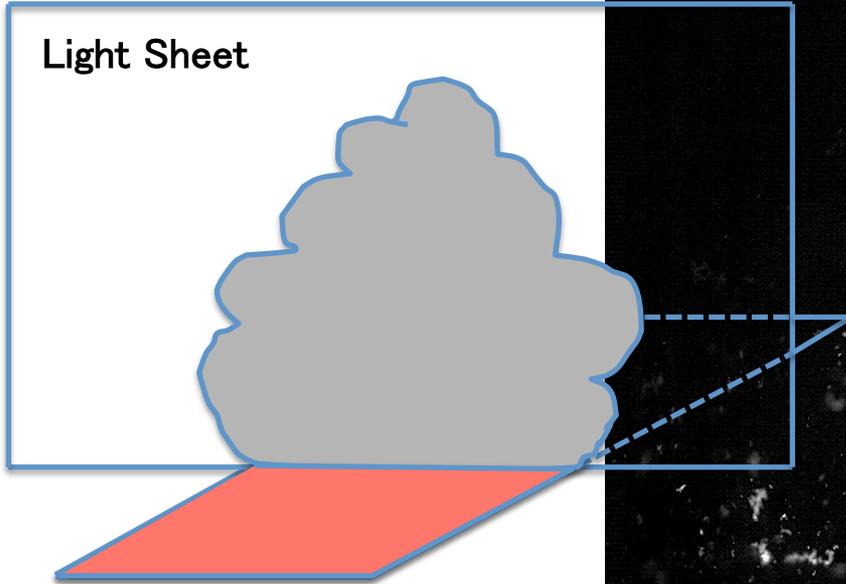
Cryostat and PIV Experiment



Significant improvement in **Accuracy of calculating the the Average**
as compared to the Previous results

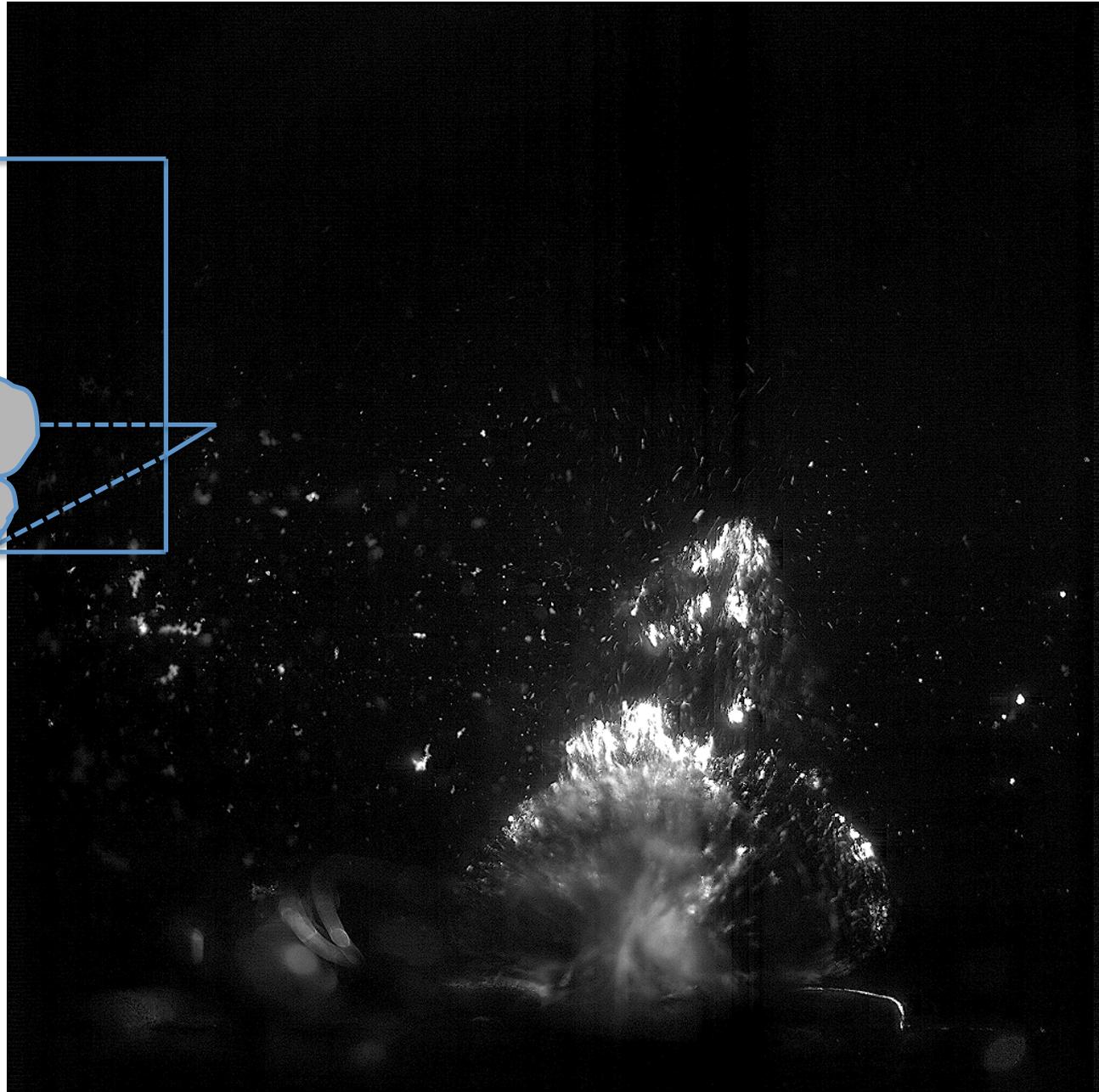
Visualisation of Vapour Bubble + Tracer Particles

Noisy Boiling Planar Heater



Heater (Horizontal)
10 mm (w) x 39 mm (depth)

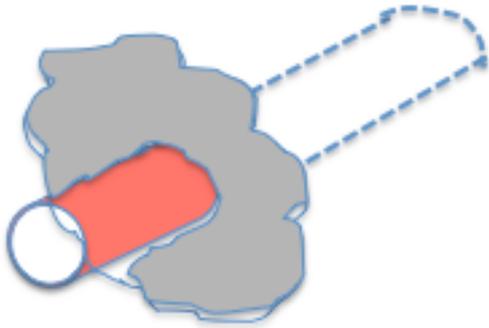
Photographing time = 0.2 s
Temp. = 1.96 K
 $q = 6.64E4 \text{ W/m}^2$



Visualisation of Vapour Bubble + Tracer Particles

Noisy Boiling
Cylindrical Heater

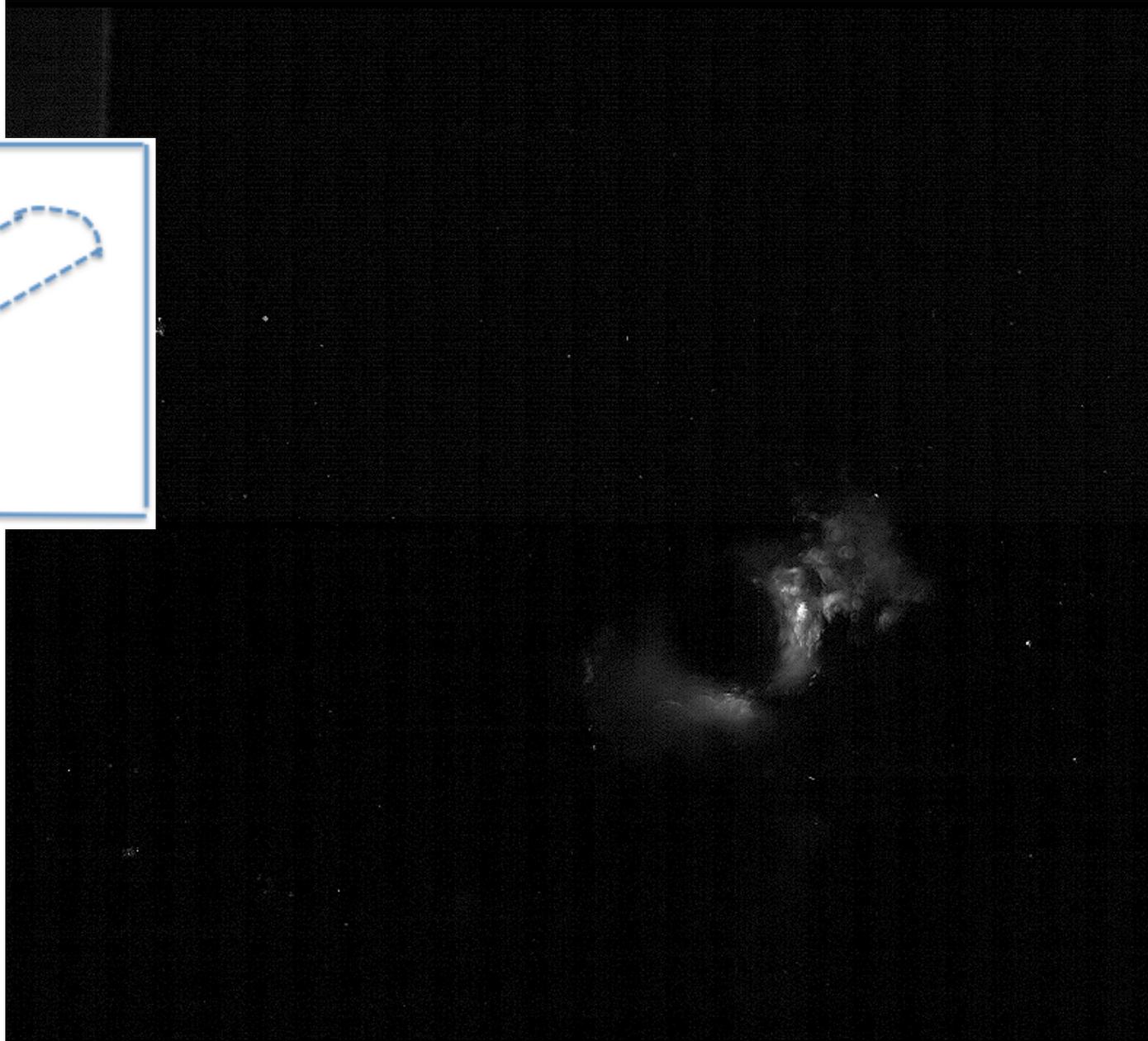
Light Sheet



Heater (Horizontal)
5 mm (d) x 50 mm (Length)

Photographing time
= 0.1 s

Temp. = 1.95 K
 $q = 2.04E4 \text{ W/m}^2$



Visualisation of Tracer Particles

Non-Boiling

No Vapour Film

Cylindrical Heater

Imaging time = 0.5 s

Temp. = 1.90 K

$q = 1.03E4 \text{ W/m}^2$

Photron FASTCAM SA4 model 500K-M1

1/125 sec

frame : 0

Time : 15:18

Photron

125 fps

Start

Date : 2013/10/25

960 x 720

+0 ms

FASTCAM SA4 model ... Partition : 001

1/125 sec

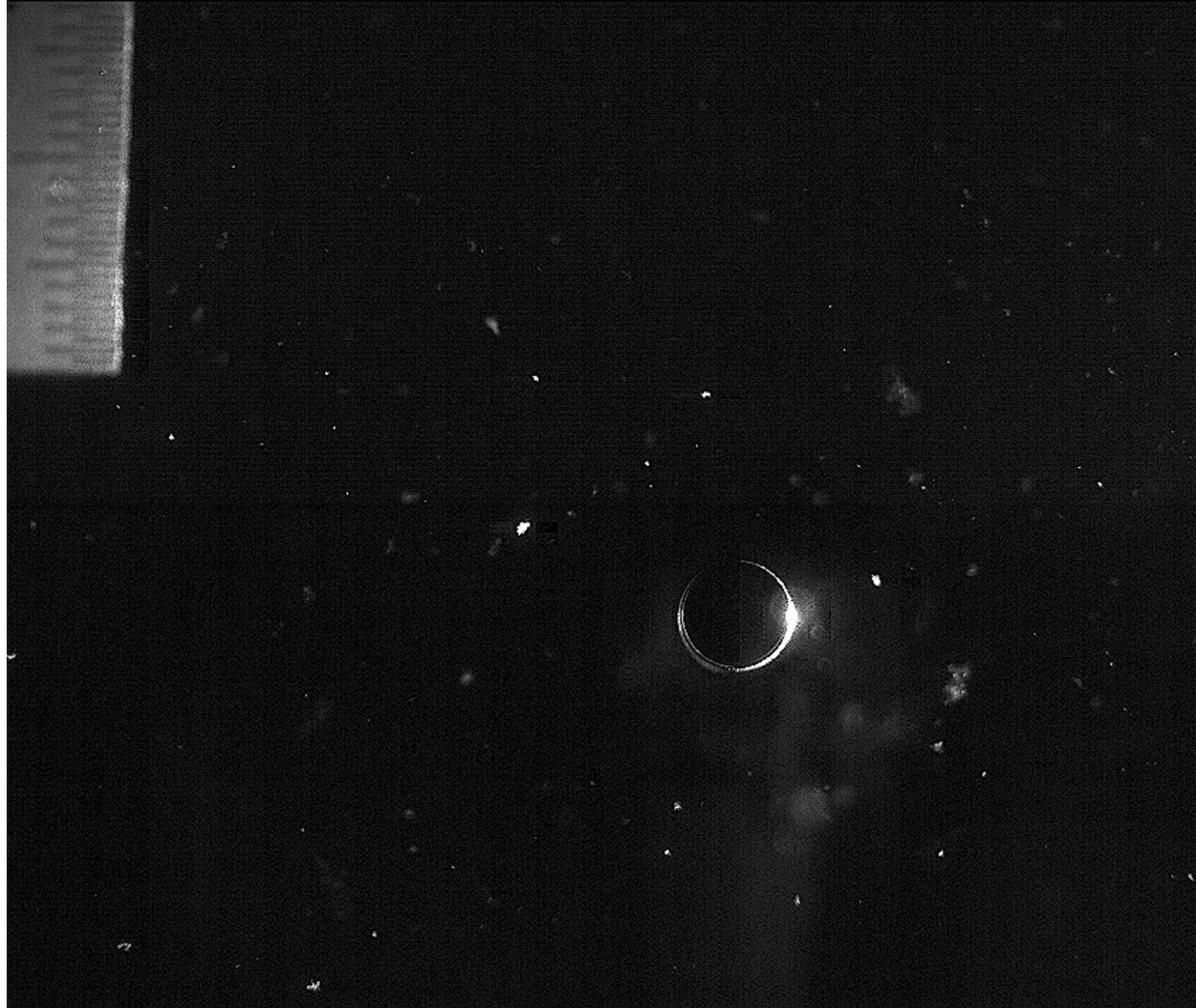
frame : 0

Time : 15:18

125 fps

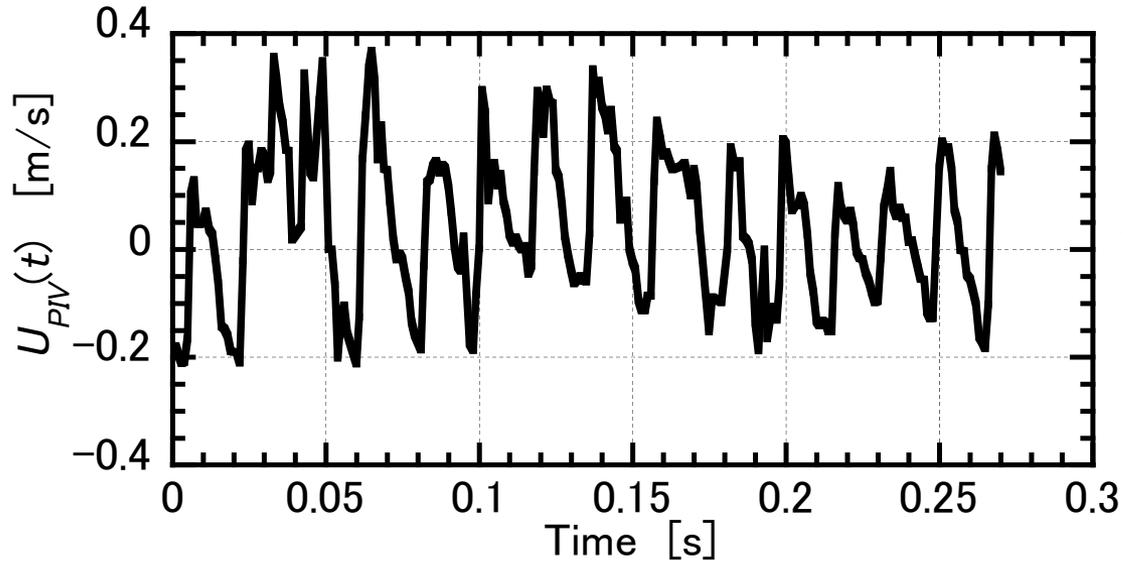
Start

Date : 2013/10/25



Transient Velocity Record $U_{PIV}(t)$, Fluctuation Component

Transient Velocity Record



← $\langle U_{PIV} \rangle$

at $x = 25.3$ mm, $y = 0.0$ mm
(Outside the Vapour Area)

Noisy Film Boiling
Planar Heater

$T = 2.00$ K, $q = 4.4e4$ W/m²

$\langle U_{PIV} \rangle = 0.045$ m/s, RMS = 0.147 m/s

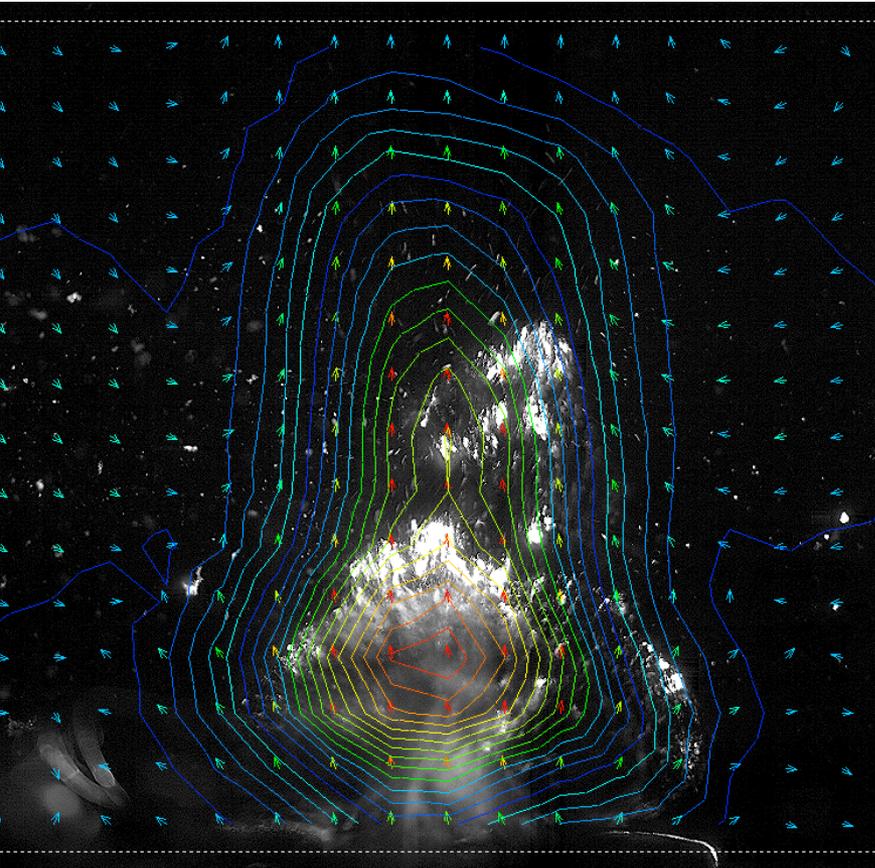
Jumping up Period : Bubble Expansion
Gradual Decrease : Bubble Collapse

Fluctuation Component

Boiling Mode	Noisy	Silent	He I	Non-Boiling
$\Delta U_{PIV} / \langle U_{PIV} \rangle$ (%)	>100	≤ 40	≤ 30	≤ 25

Noisy Boiling : Extremely large

Time-Averaged Velocity $\langle U_{PIV} \rangle$: Velocity Vectors and Contour



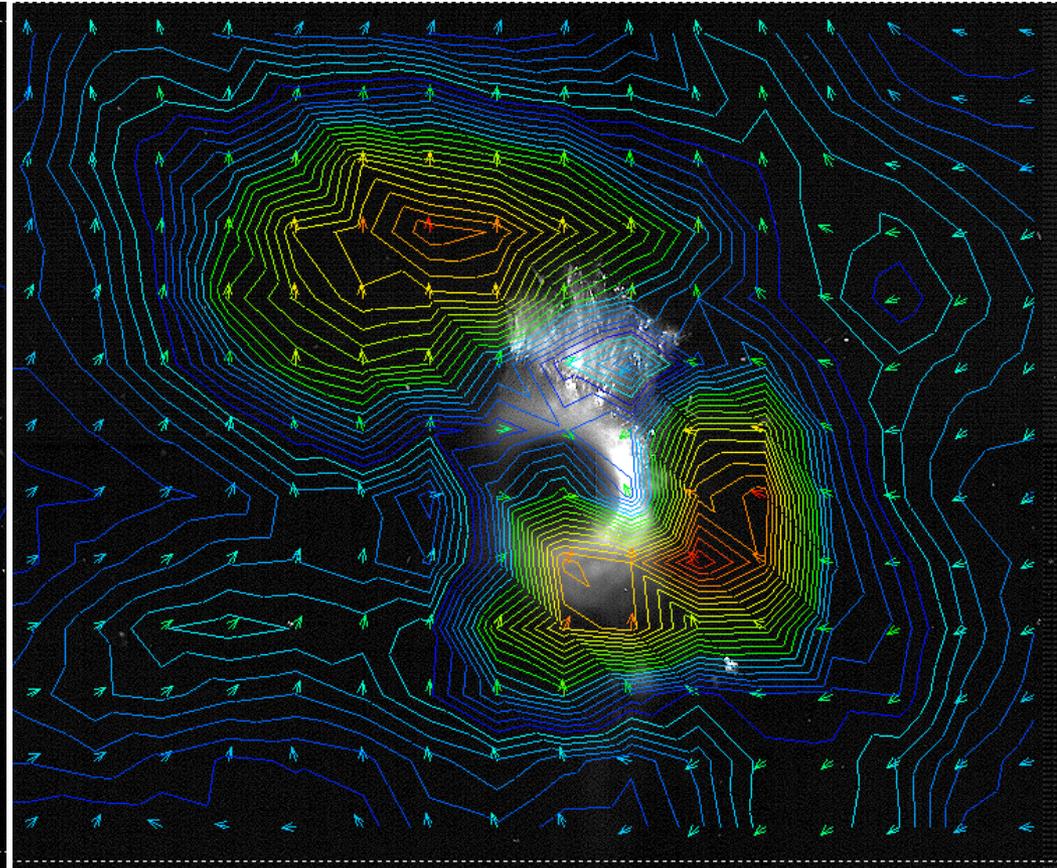
Noisy Boiling (Planar Heater)

Max Velocity = 0.19 m/s

Averaging Time = 2.73 s

Temp. = 1.96 K

$q = 6.64E4 \text{ W/m}^2$



Noisy Boiling (Cylindrical Heater)

Max Velocity = 0.019 m/s

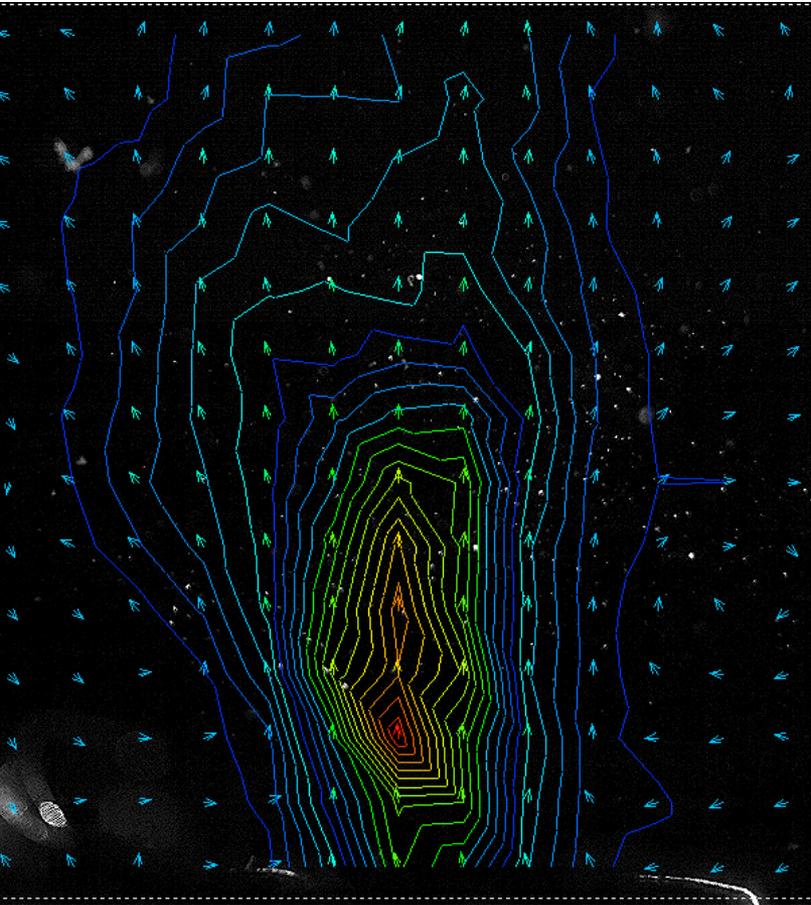
Averaging Time = 5.07 s

Temp. = 1.78 K

$q = 1.23E4 \text{ W/m}^2$

Reverse Flow : at the lower right of the heater

Time-Averaged Velocity $\langle U_{PIV} \rangle$: Velocity Vectors and Contour



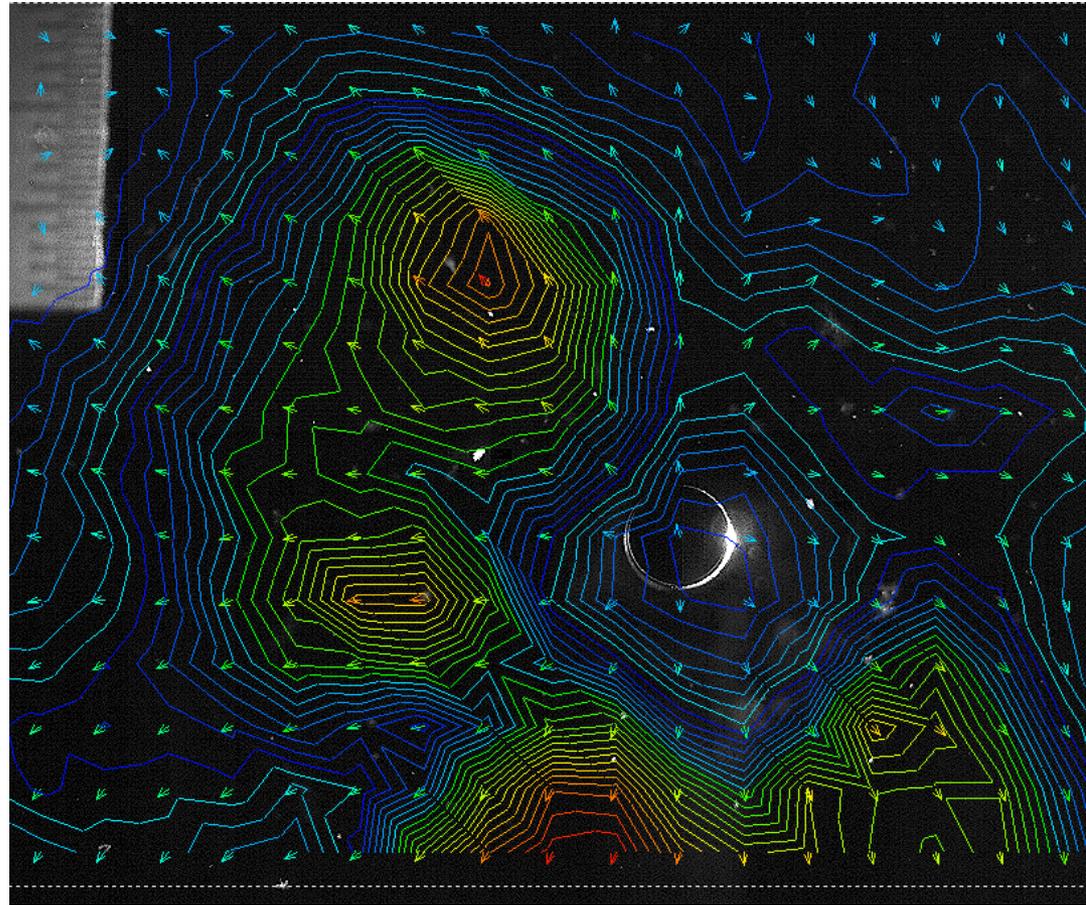
Silent Boiling (Planar Heater)

Max Velocity = 0.052 m/s

Averaging Time = 2.73 s

Temp. = 1.96 K

$q = 6.64E4$ W/m²



Non-Boiling (Cylindrical Heater)

Max Velocity = 0.0081 m/s

Averaging Time = 11.0 s

Temp. = 1.90 K

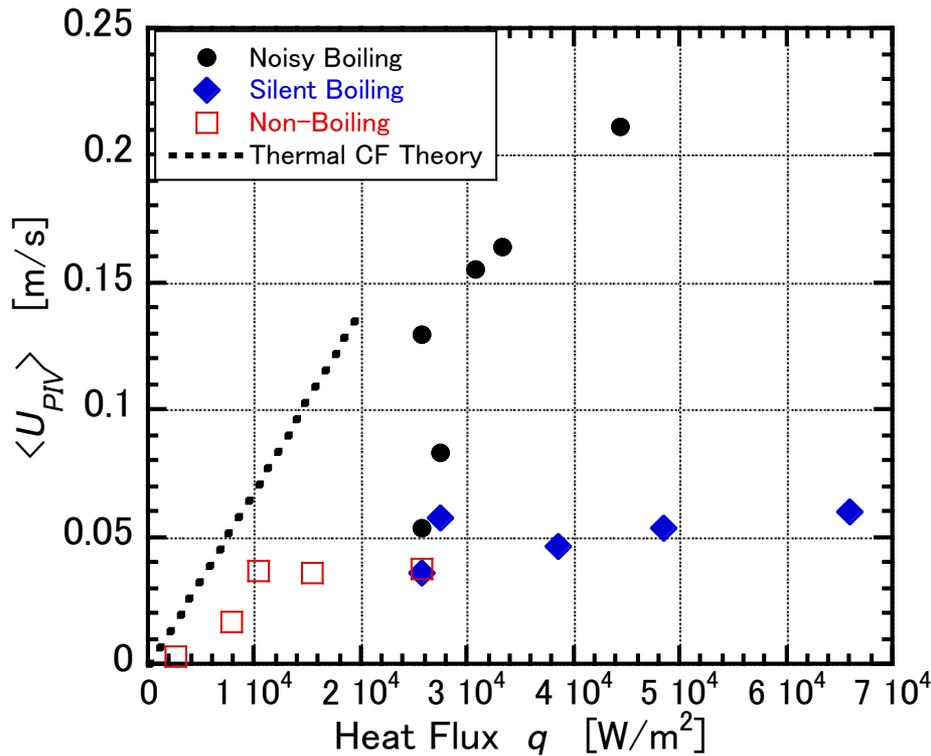
$q = 1.03E4$ W/m²

Time-Averaged Velocity $\langle U_{PIV} \rangle$ vs. Heat Flux q

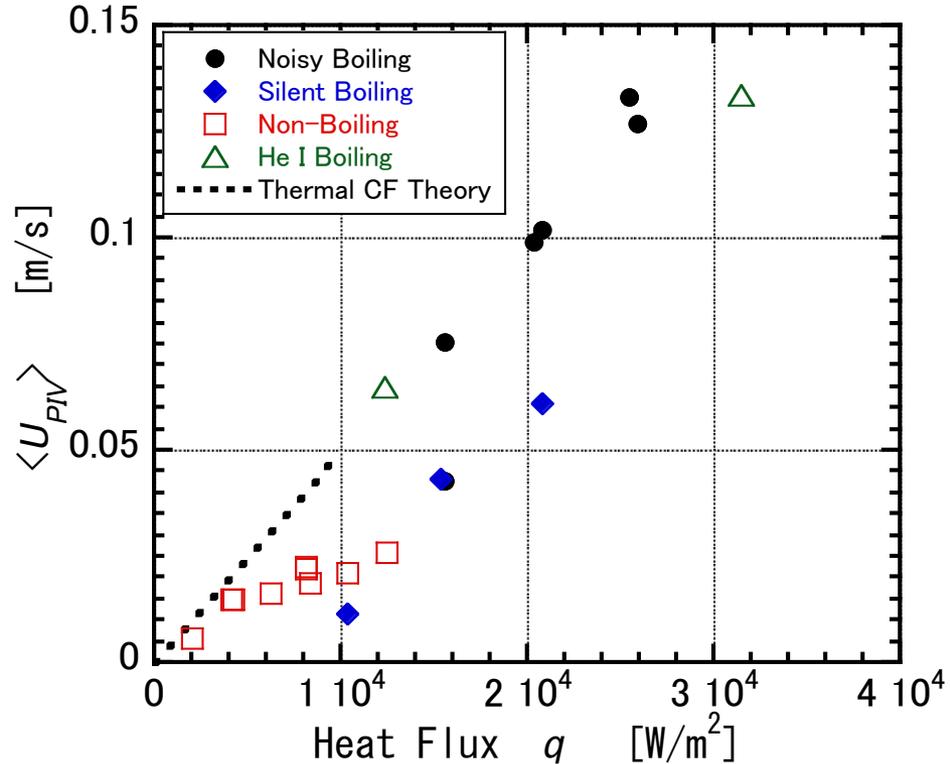
$\langle U_{PIV} \rangle$: Measured at Immediate Outside of Vapour Bubble Region

Thermal CF Theory : $U_{n,theo} = q/(\rho ST)$

Planar Heater $\sim 1.8K$



Cylindrical Heater $\sim 1.9K$

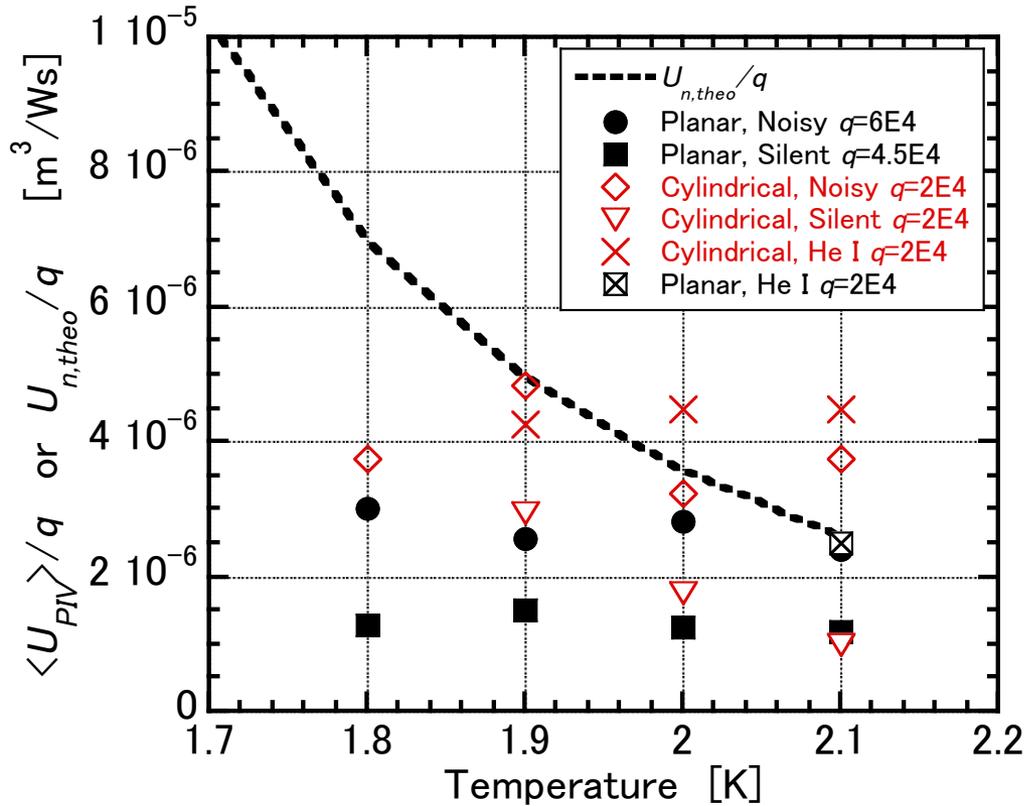


Non-Boiling : $\langle U_{PIV} \rangle \propto q$, and $\langle U_{n,theo} \rangle \leftarrow$ Interaction with Q Vortices

Noisy : Rapidly Rising Plume induced by Buoyant Bubble ($>$ Silent)

Magnitude of $\langle U_{PIV} \rangle$: **Noisy** $>$ **He I** $>$ **Silent** $>$ **Non-Boiling**

Temperature Dependence of PIV Velocity : $\langle U_{PIV} \rangle / q$



Noisy Boiling : $\langle U_{PIV} \rangle \approx$ Thermal Counterflow Theory near T_λ
induced by Asymmetry of bubble expansion and collapse

Silent Boiling : $\langle U_{PIV} \rangle <$ Thermal Counterflow Theory
Effect of Quantized vortices is predominant

He I Boiling : Nothing to do with Superfluidity, Temperature Independent

Conclusion

- Flow field around He II boiling
 - : composed of thermal **counterflow** (DC background)
 - + **alternating flow** of Total He II **induced by boiling**.
 - alternating flow component generated in the **whole He II** (**Noisy**)
 - only **near heater** (**Silent**)
- Noisy Boiling
 - : Bubble motion induced **Fluctuating Flow** Component is far larger than the **Average velocity**.
 - : DC component resulting from the asymmetric bubble motion is as large as the theoretical thermal counterflow velocity
- Silent Boiling : Quantized Vortices Dominant PIV Flow Field
- Non-Boiling : nearly **axisymmetric**, **no gravity** effect ,.
- He I Boiling : rapidly rising buoyancy convective **Plume of He I**.