Heat Transfer Characteristics on Several Film Boiling Modes in Superfluid Helium

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Murakami Lab. in Univ. of Tsukuba

the Saclay-KEK cooperation program Feb. 15th at KEK

Contents

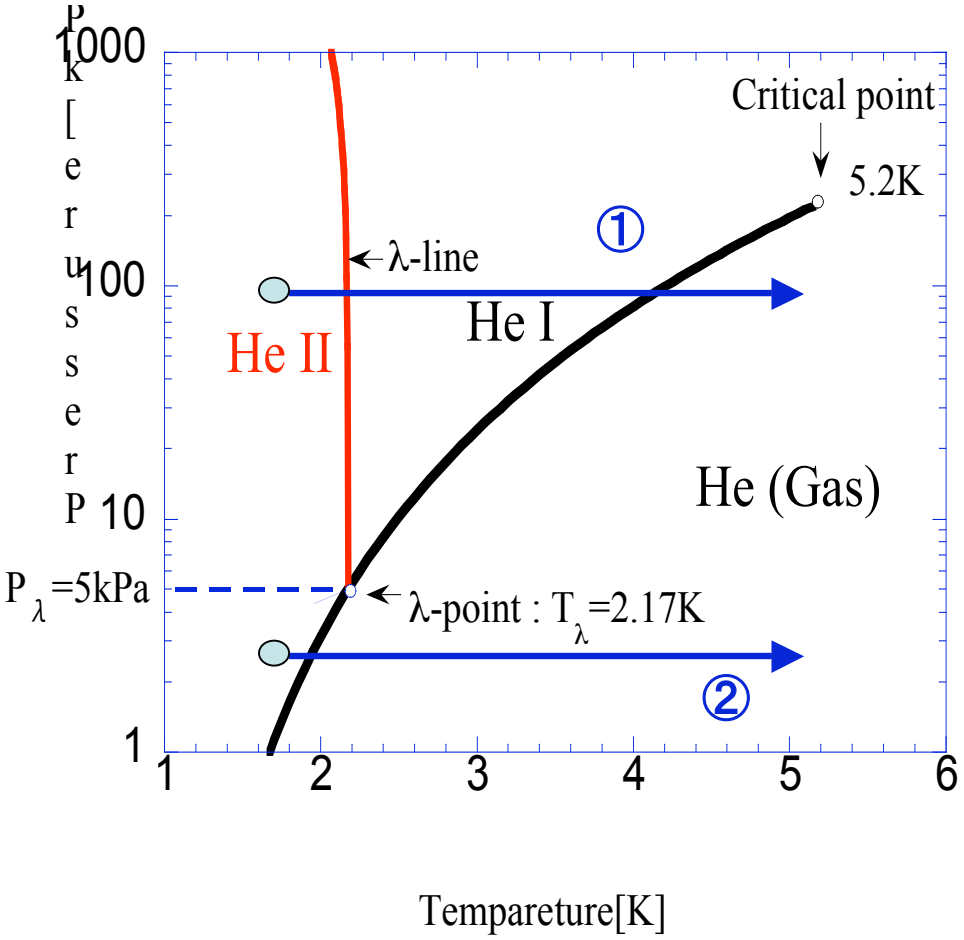
1. Background

2. Difference of the heat transfer coefficient among film boiling modes

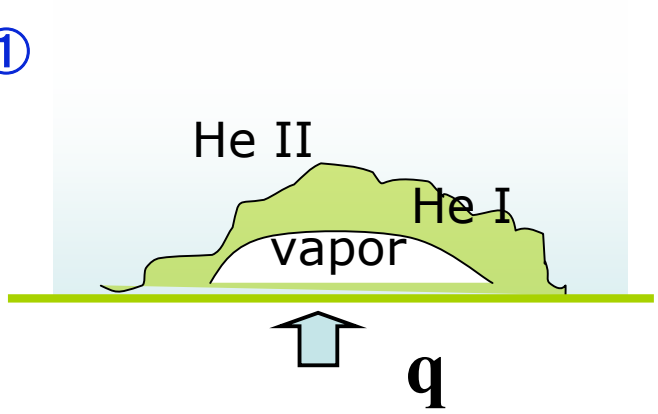
3. Effect of Heat Capacity of Heater on Several Film Boiling Modes in He II

4. Visualization study of Film Boiling In Narrow Two Dimensional Channel

Background

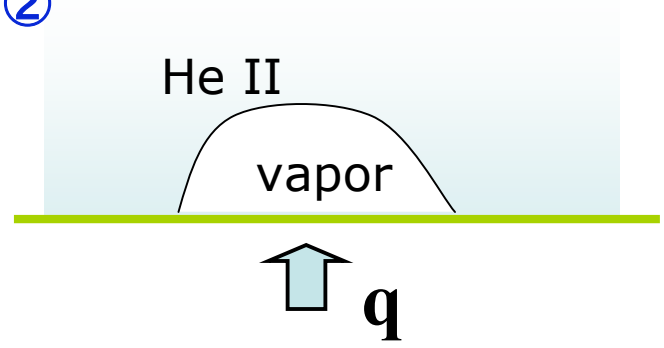


①



He Vapor →He I →He II （P＞ P_λ ）

②



He Vapor →He II （P＜ P_λ ）

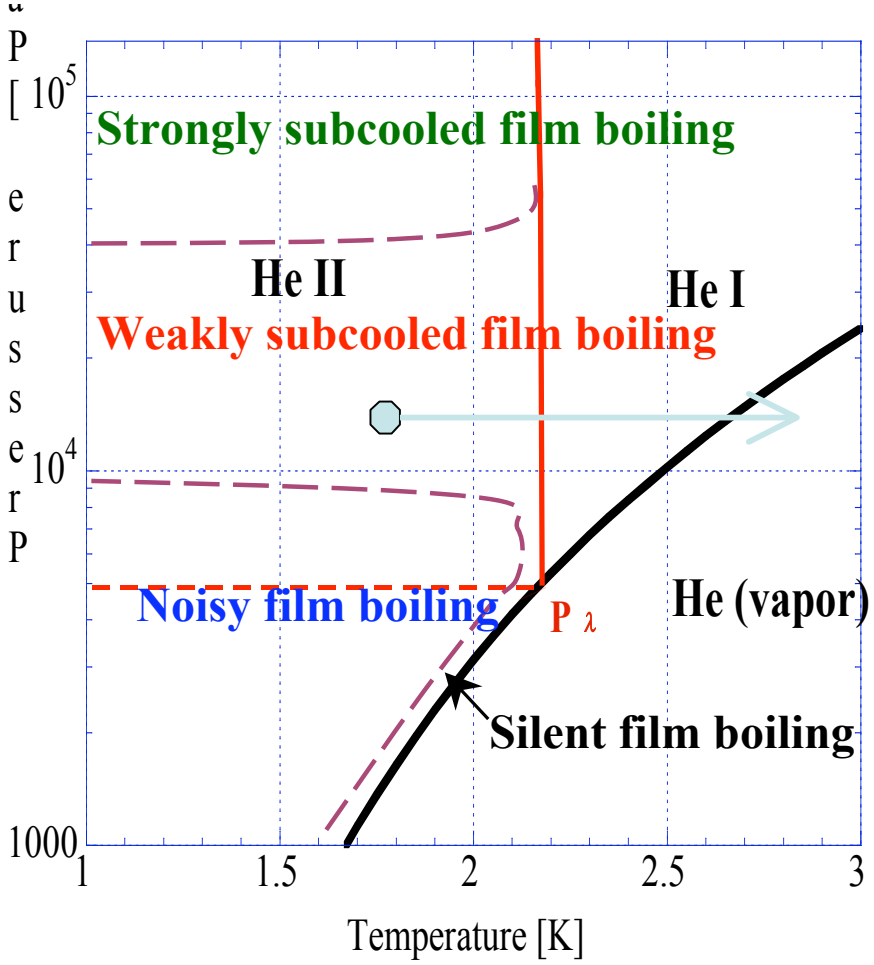
Four film boiling modes in He II

Strongly Subcooled Film Boiling ;
Stable vapor layer

Weakly Subcooled Film Boiling ;
Weakly turbulent vapor layer,
audible noise of several kHz

Noisy Film Boiling;
Large scale bubble repeat
generation and collapse

Silent Film Boiling;
Stable vapor layer

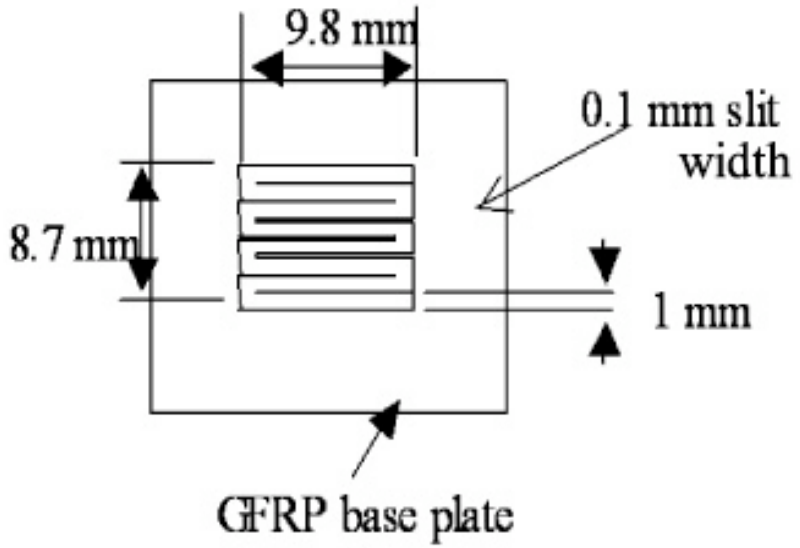


Focusing on Heat transfer characteristics

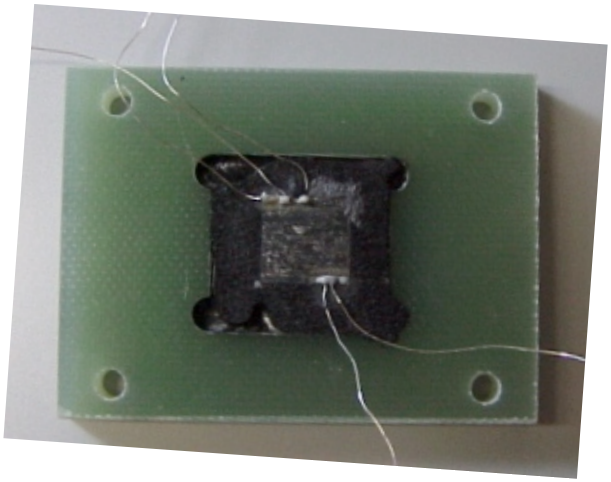
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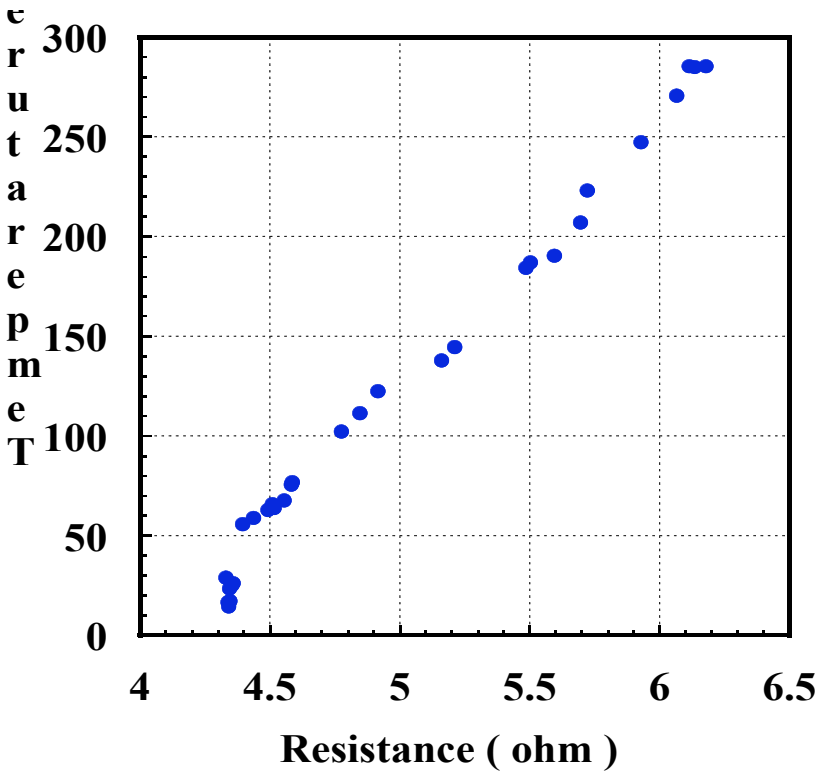
Difference in the heat transfer coefficient among several film boiling modes in He II

*Stainless Steel Foil Heater

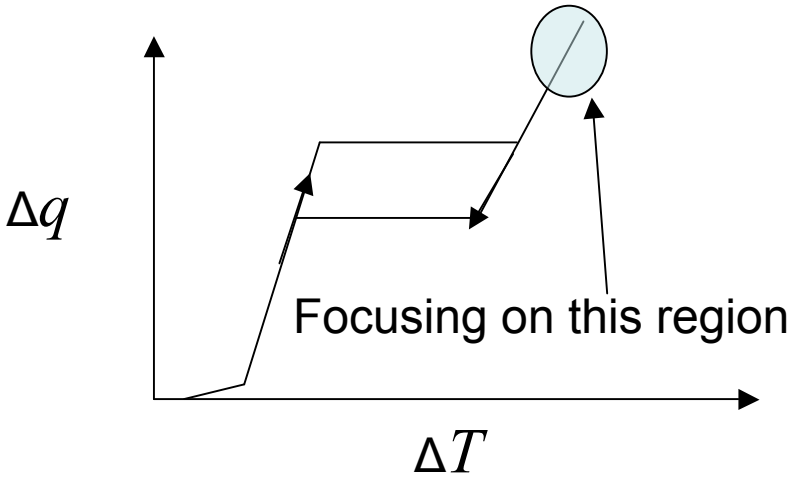


Thickness 8 μm

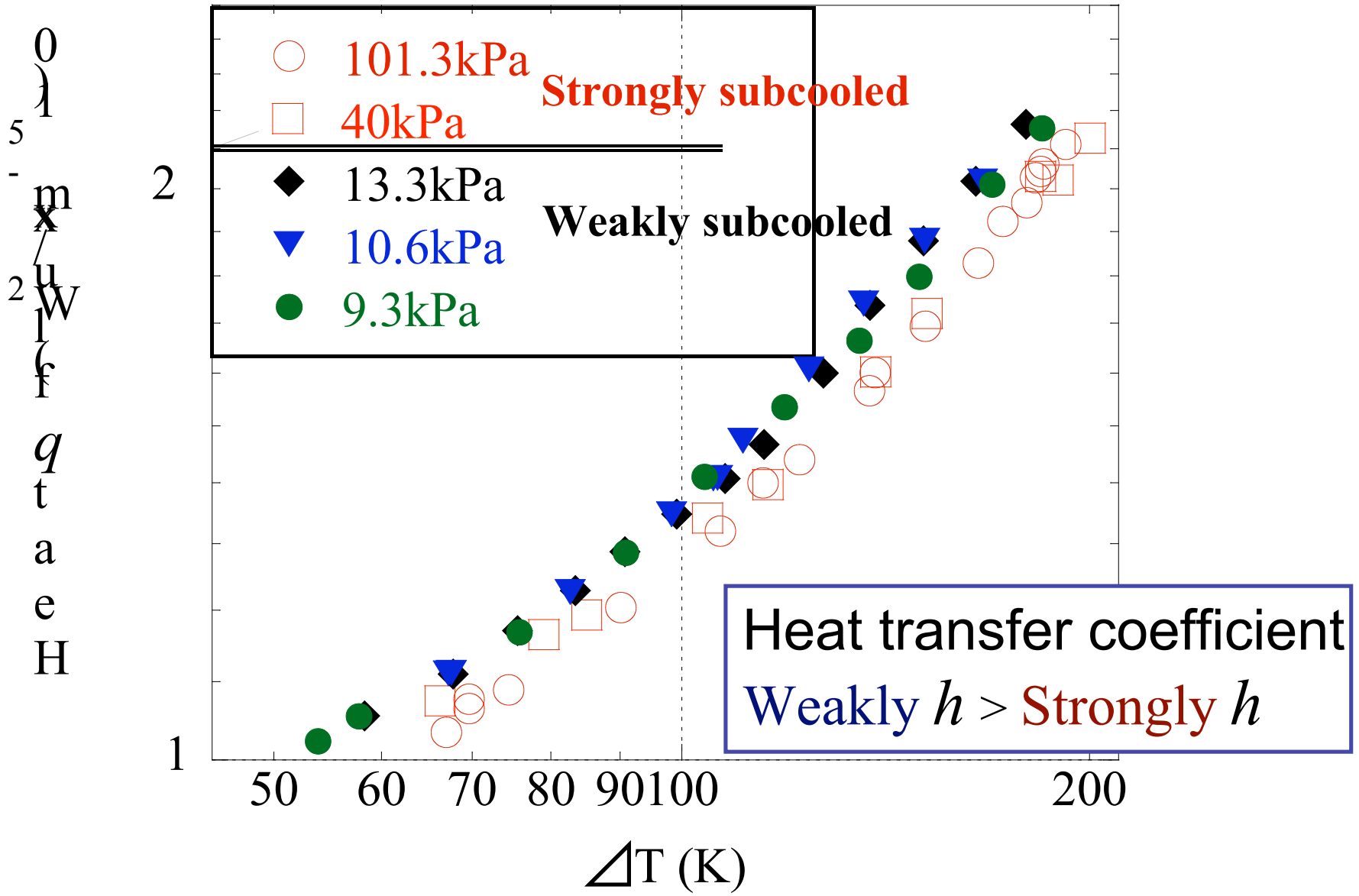




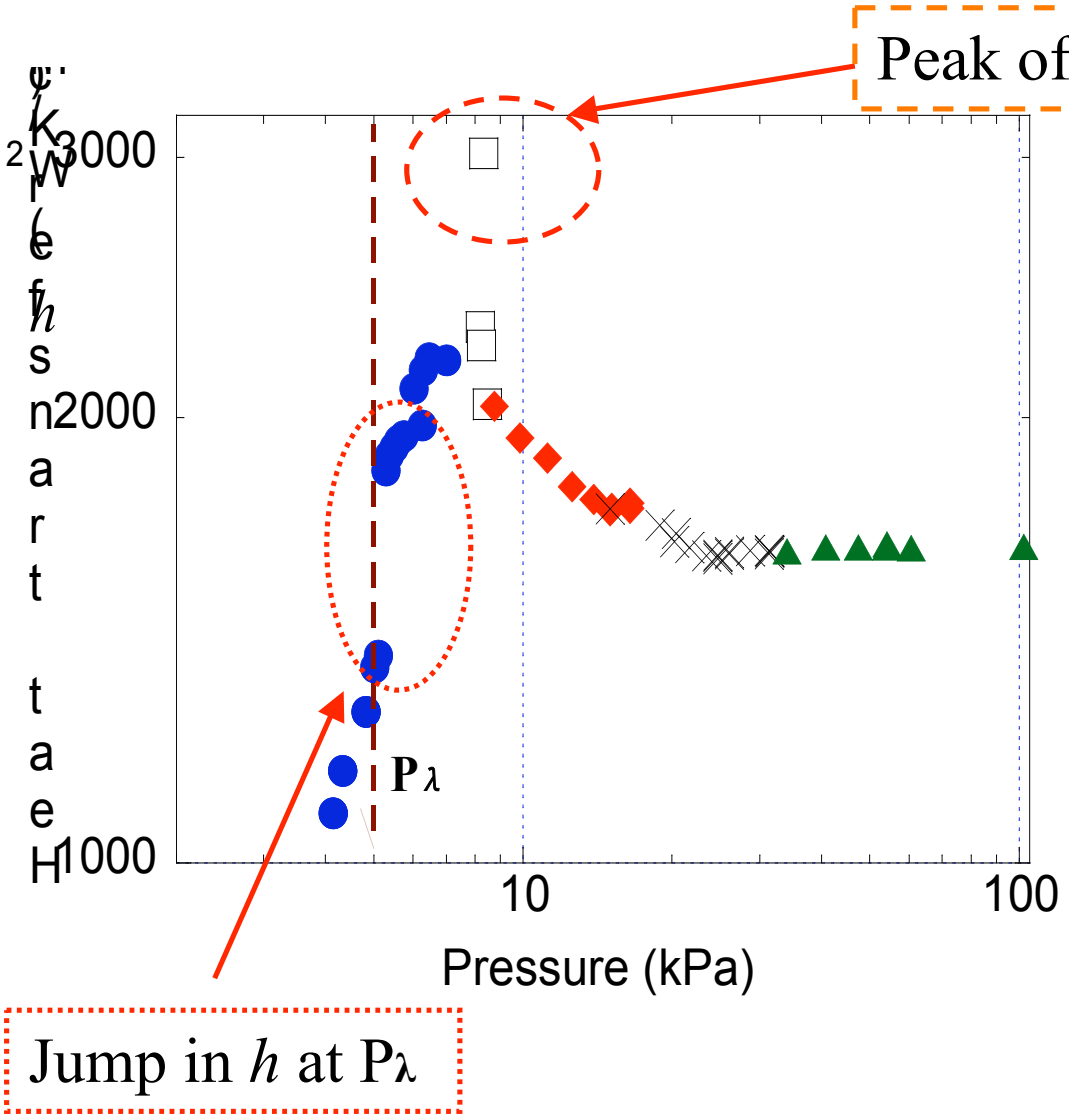
Calibration Curve of the Heater



Boiling curves



Unique Dependence of Heat Transfer Coefficient on Pressure



▲Strongly Subcooled;
(Independent)

×Transient [S-W]

◆Weakly Subcooled;
(Weak negative gradient)

□Transient [W-N]

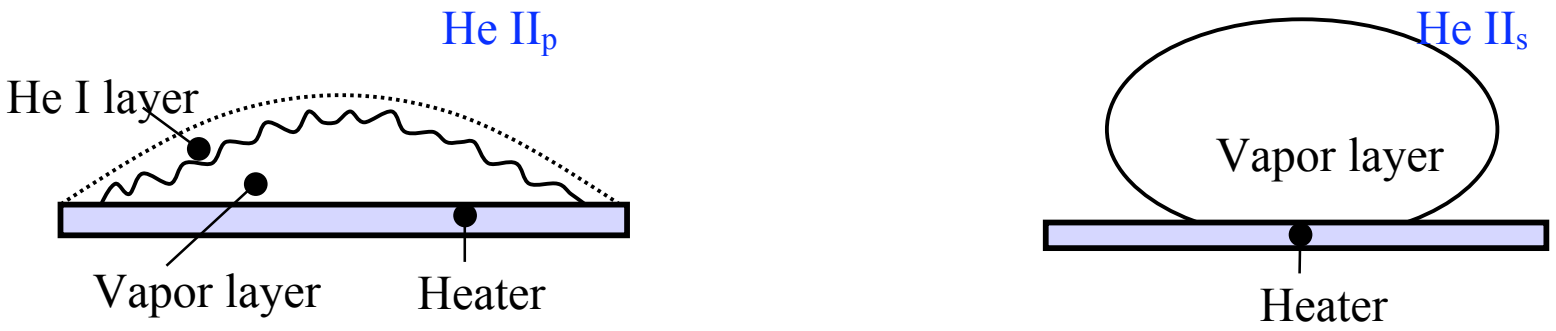
●Noisy;
(Strong positive gradient)

q = 11.2 x 10^4 W/m^2 at 1.9 K

3.

Effect of Heat Capacity of Heater on Several Film Boiling Modes in He II

Two Unstable Film Boiling Modes



Weakly subcooled film boiling; Nearly constant heater temperature

Noisy film boiling;

Heater temperature oscillation responding vapor dynamics

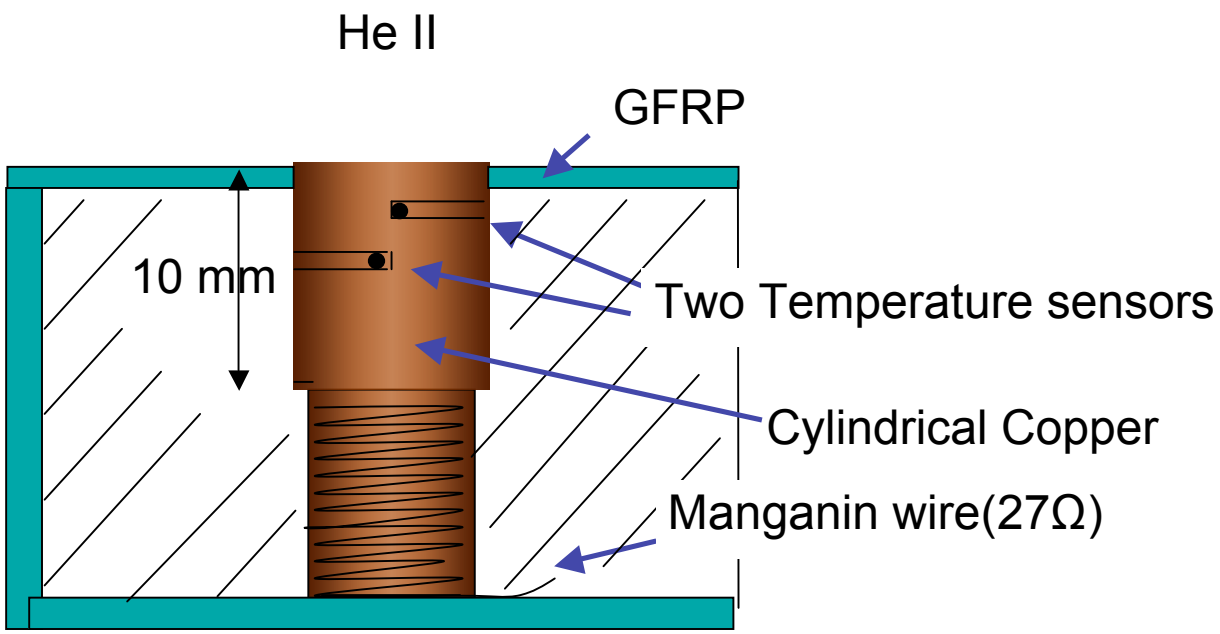
Noisy film boiling ; Noise induced instability

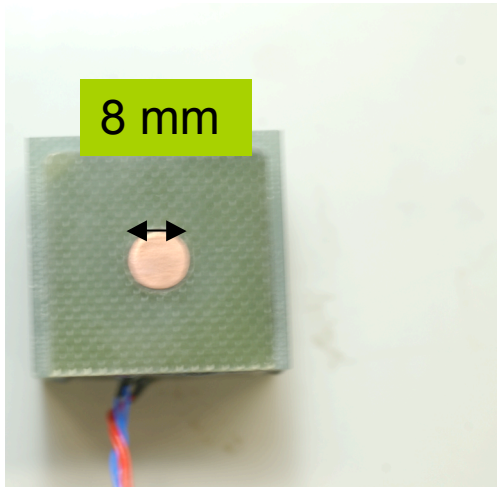
Feed back mechanism;
Vapor film dynamics and Heater Temperature oscillation

Heat capacity ↑ ⇒ Does Noisy film boiling Occur?

∗Previous experiments;　thin film heater(～10μm)

⇒ Copper cylinder of 10mm thickness
about 10^4 times larger heat capacity

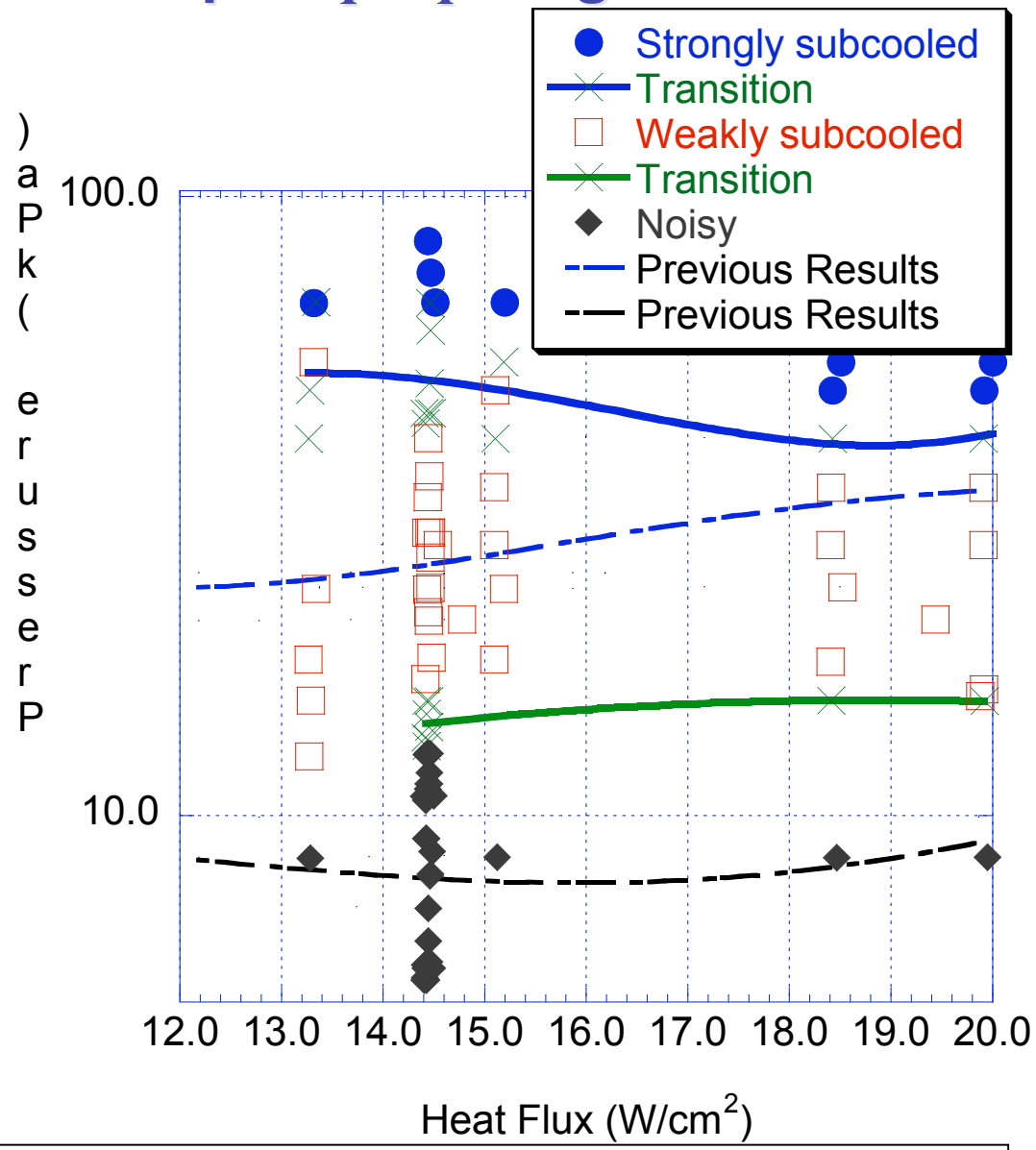




Top view of this heater

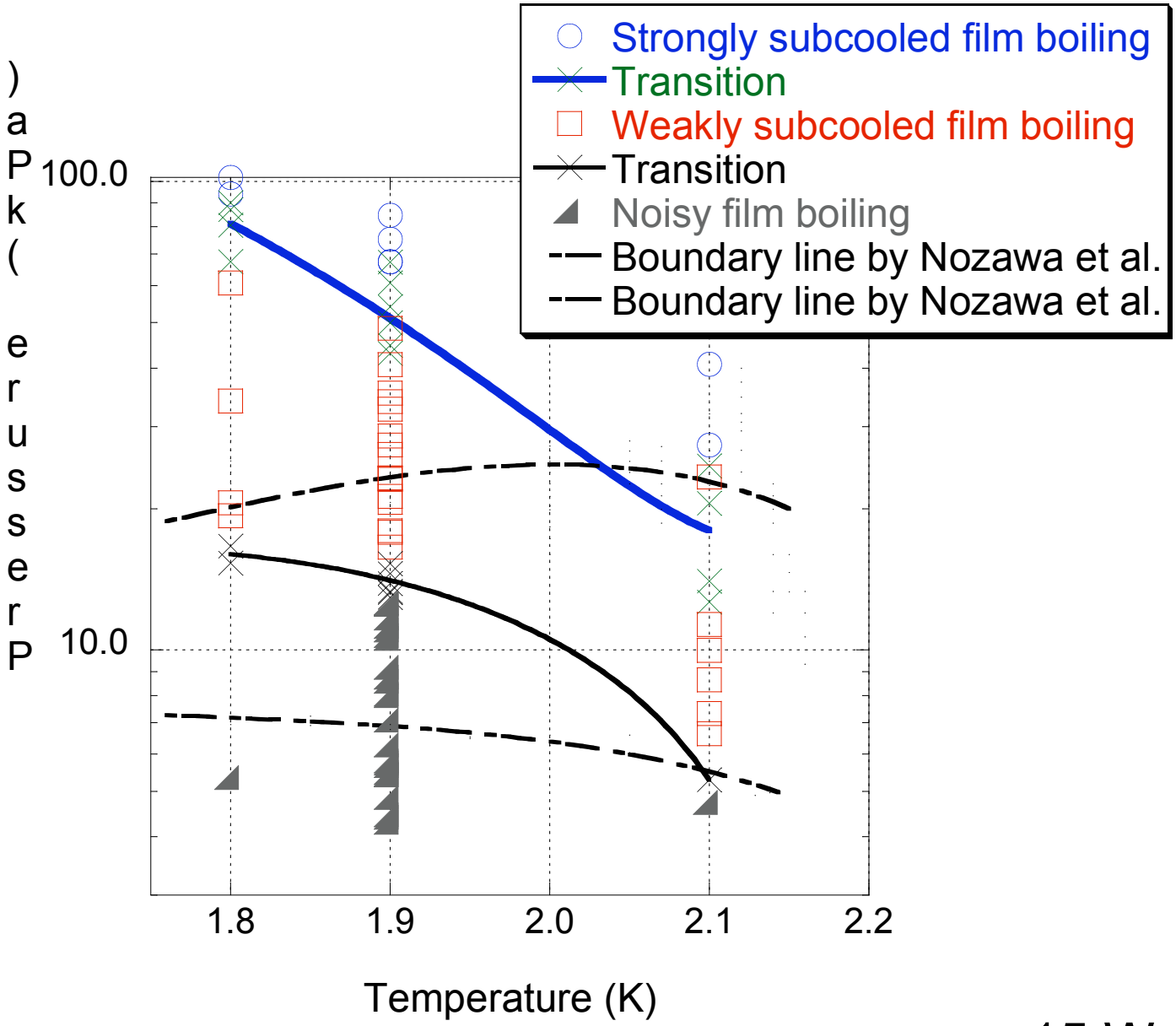
Hatched area are filled by Staycast

Boiling Mode Map on p - q Diagram at 1.9 K



Boundaries shift toward Higher pressure side

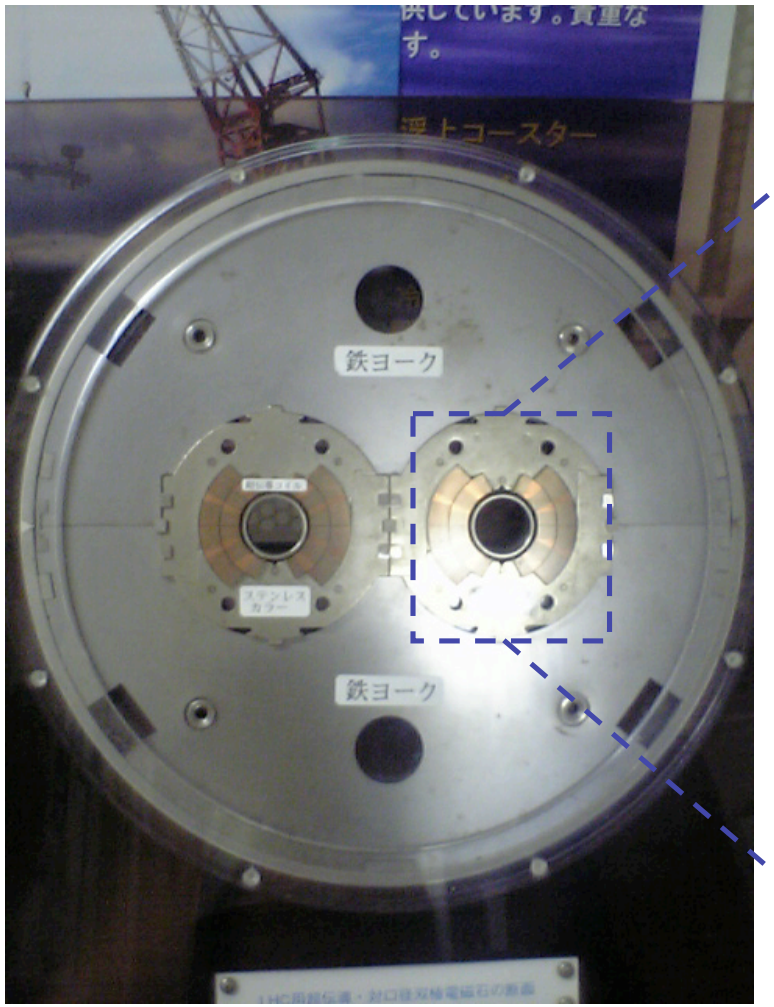
Boiling Mode Map on p - T Diagram



q = 15 W /cm^2

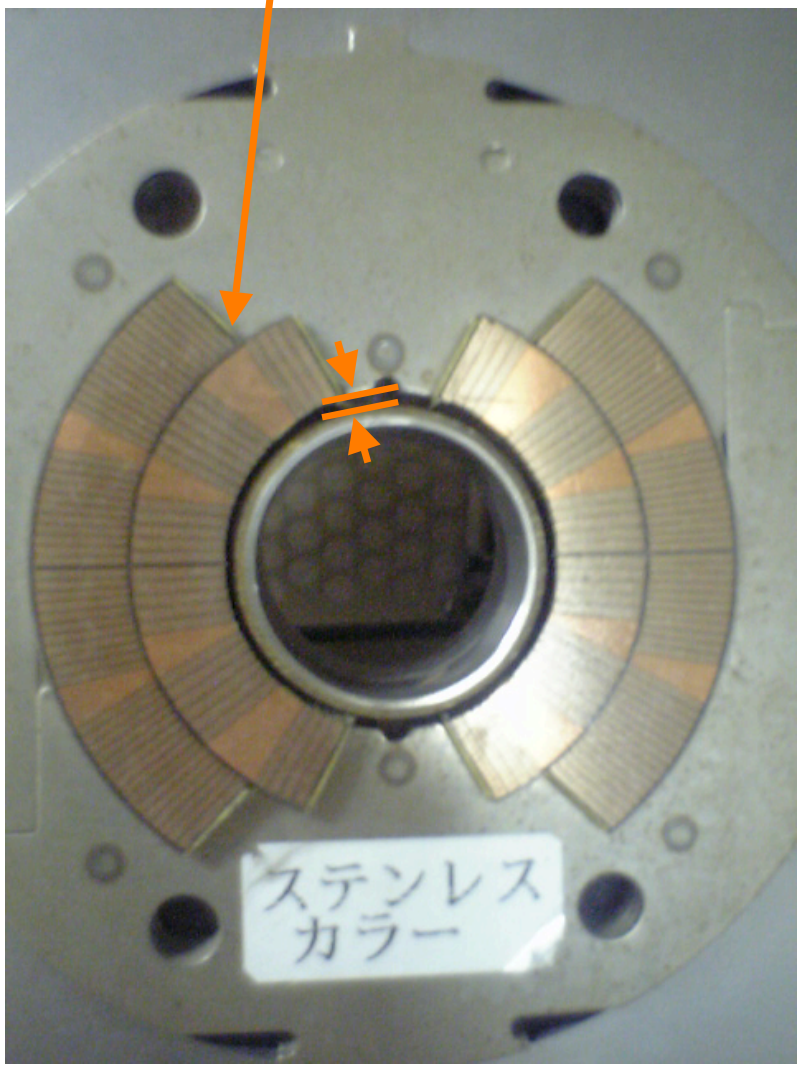
4.
Visualization Study of Film Boiling In Narrow Two Dimensional Channel

Application of He II in narrow channel



Superconducting Magnet for LHC

Confined He II (1 atm)
In Narrow channel（<100μm）



Experimental apparatus

Narrow Two-Dimensional Channel : formed between Transparent heater (Indium Oxide) and Cover Glass Plate

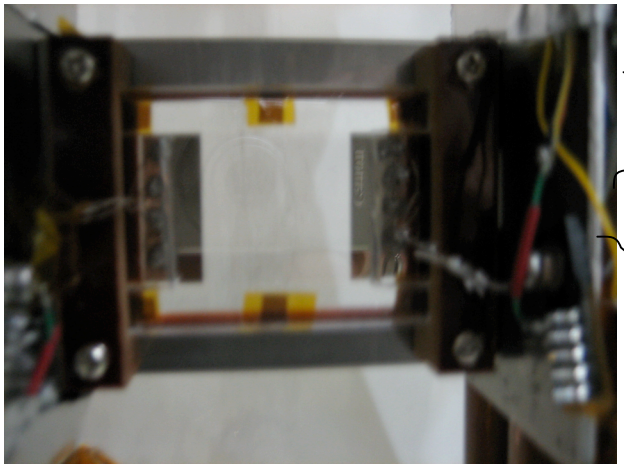
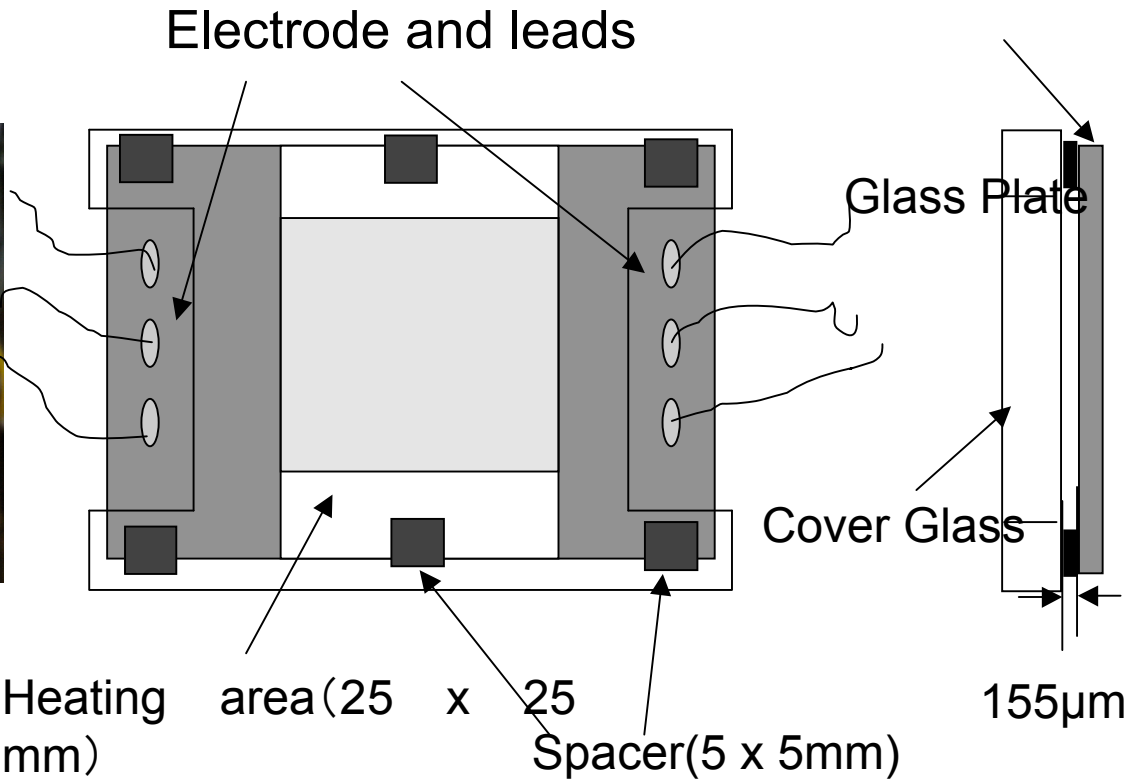
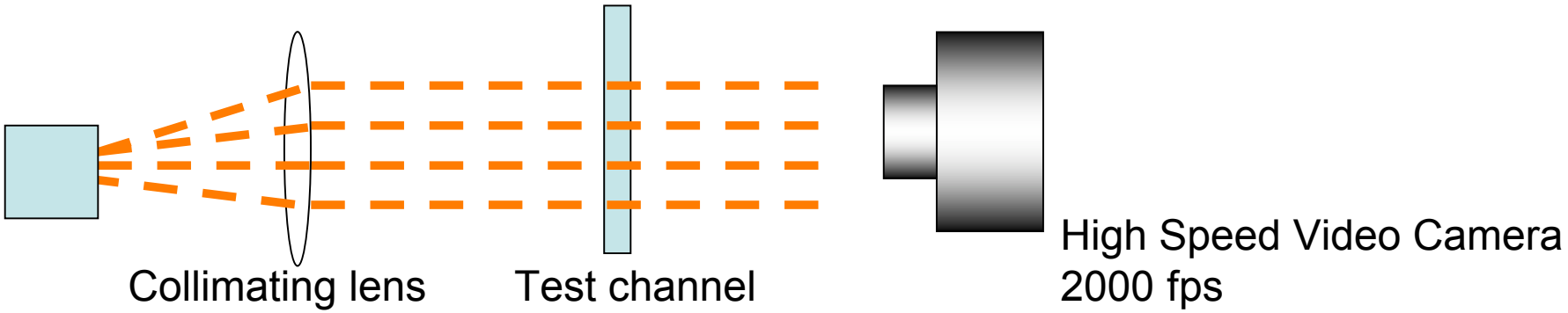


Photo of heater assembly





Gap 155μm

Bond number small

→ Gravity effect is negligible

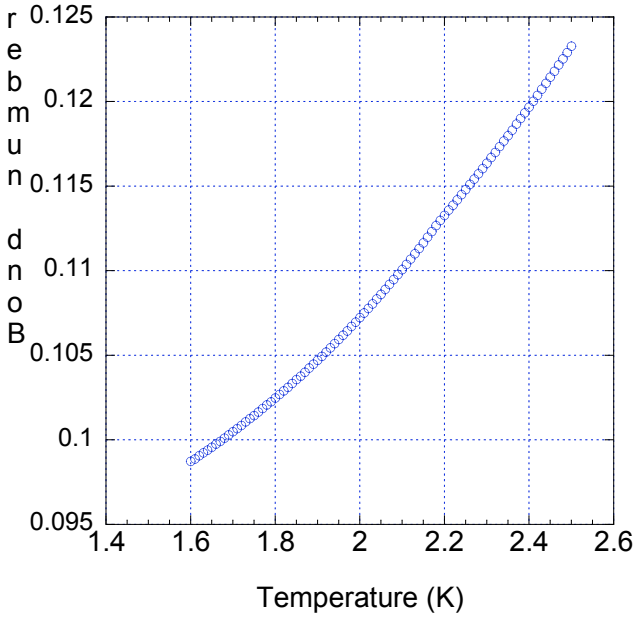
$$Bo = \frac{g\rho D^2}{\sigma}$$

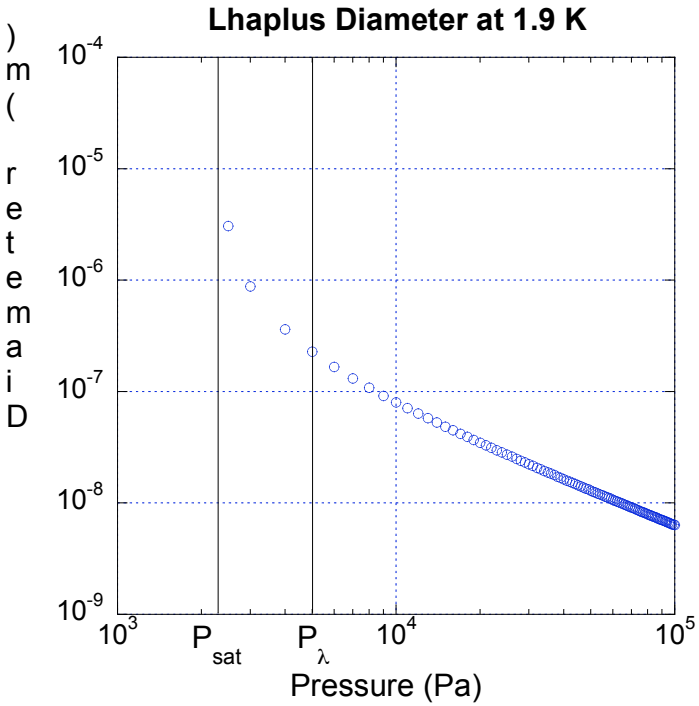
Laplace Diameter

$$\mathrm{Re} = \frac{2\sigma}{p_{sat} - p}$$

$\sigma : surface_tension$

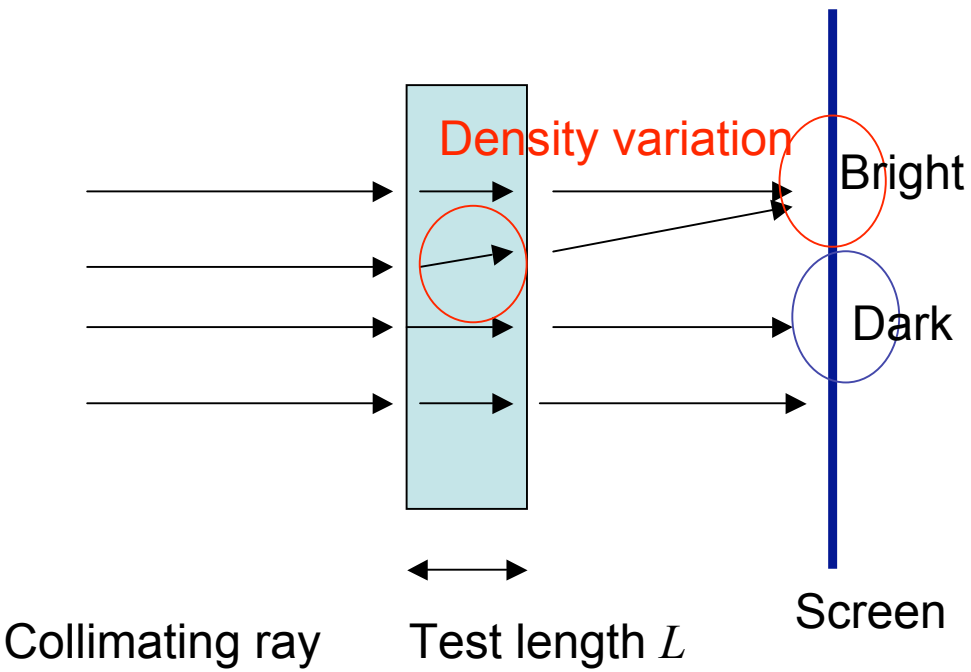
$D : Gap_thickness$

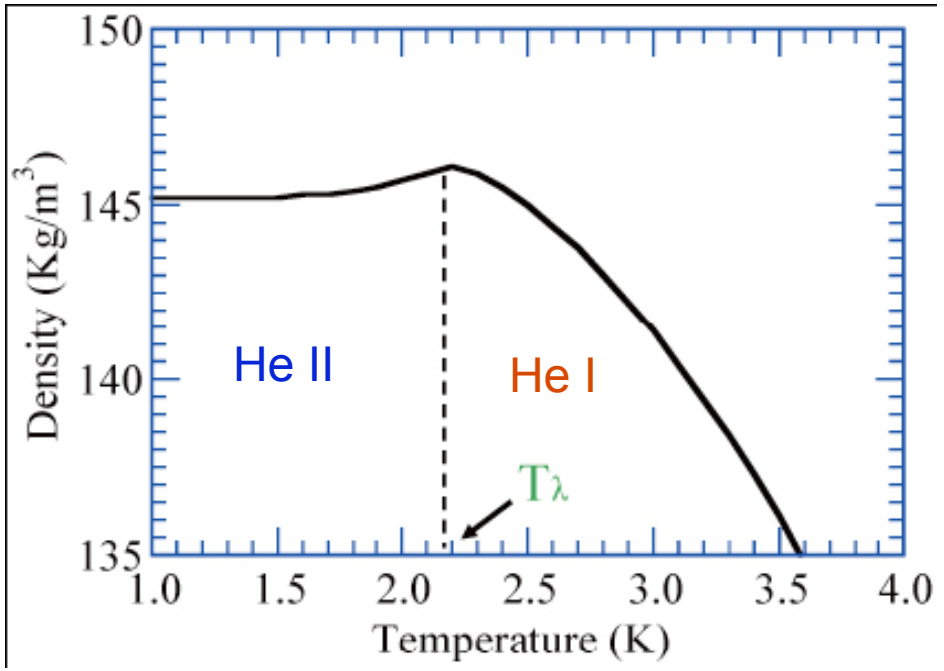




Visualization method

Shadowgraph Method

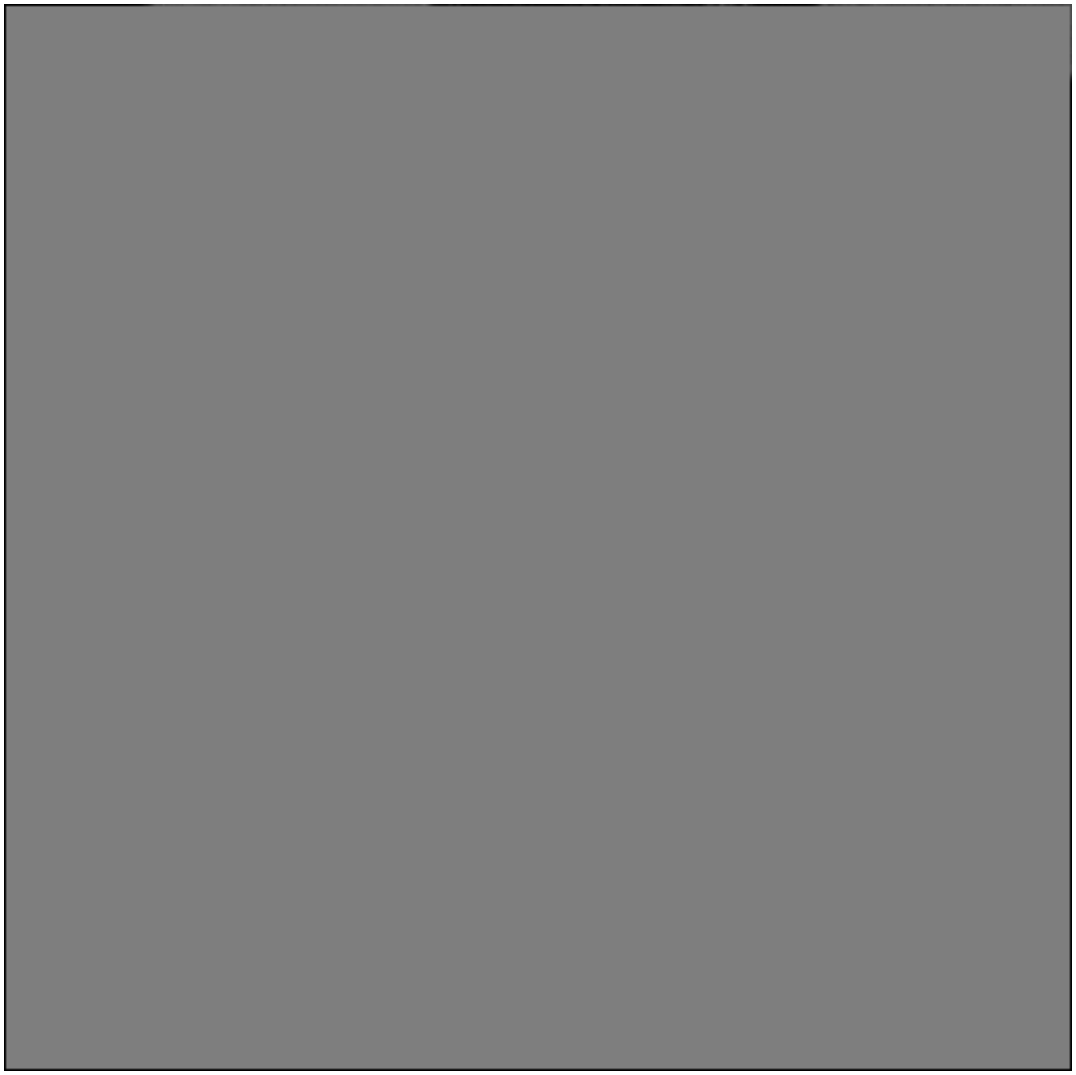


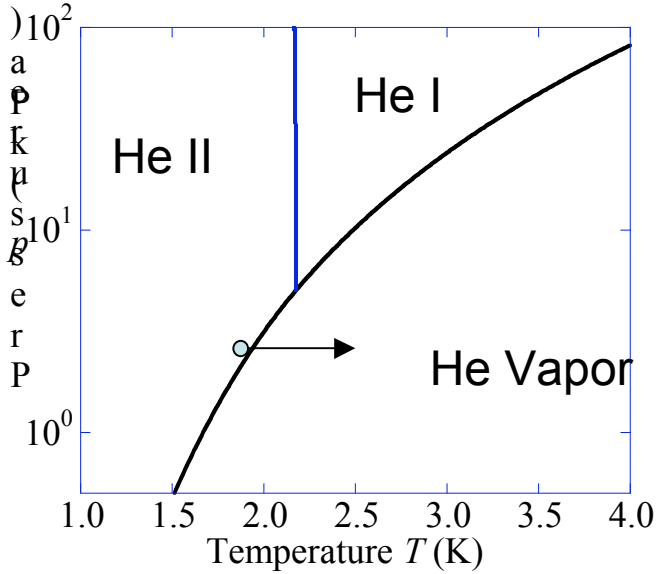


In He II

He I-He II interface and temperature distribution of He I can be detected

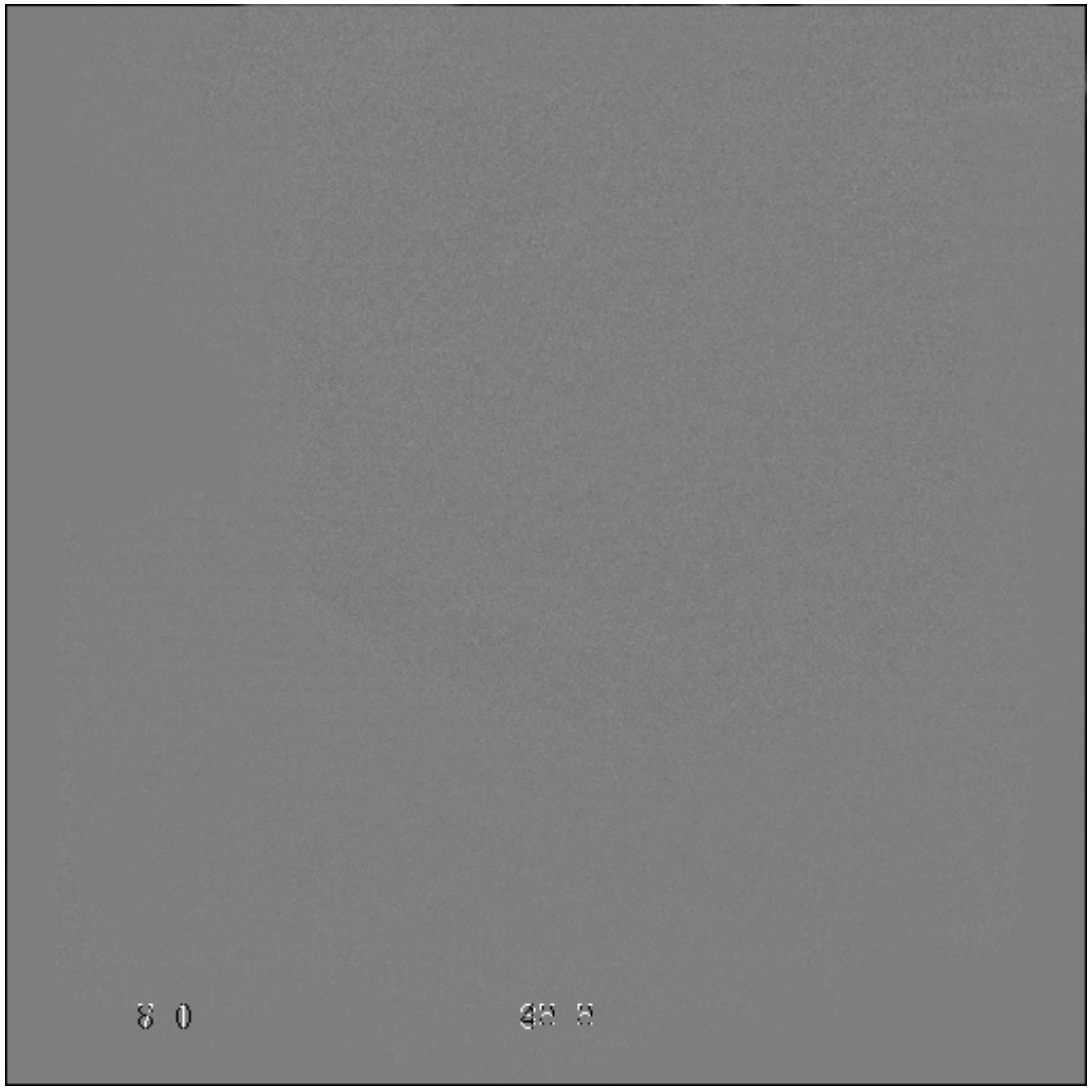
Result of visualization

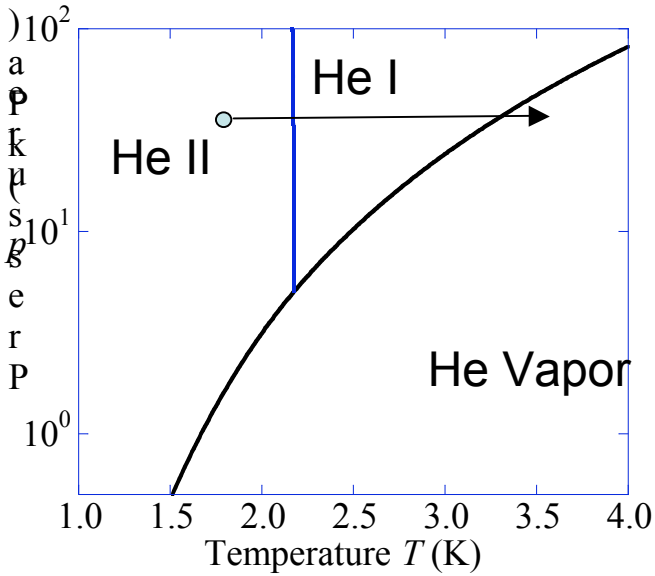




Film Boiling in saturated He II
In Narrow channel

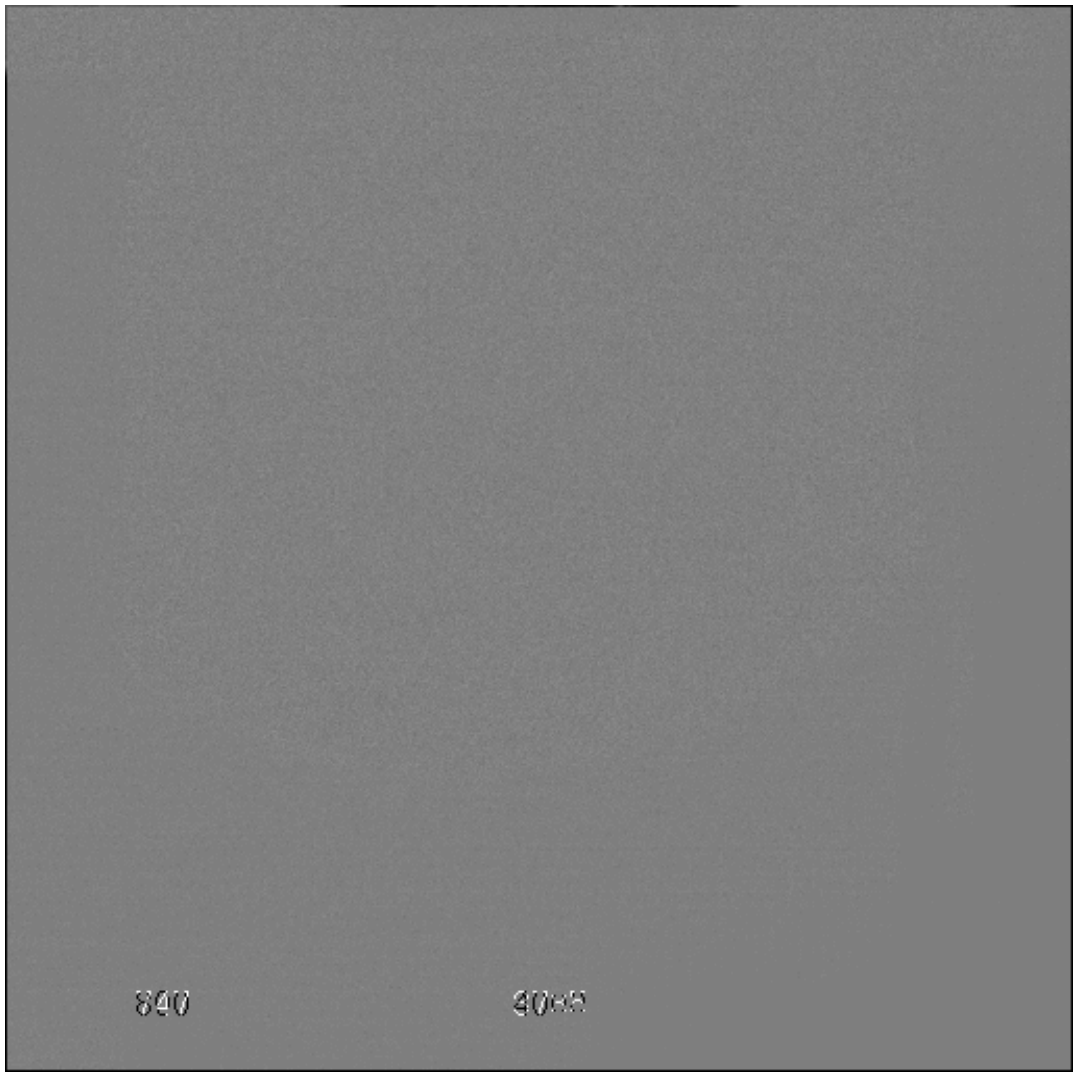
Result of visualization

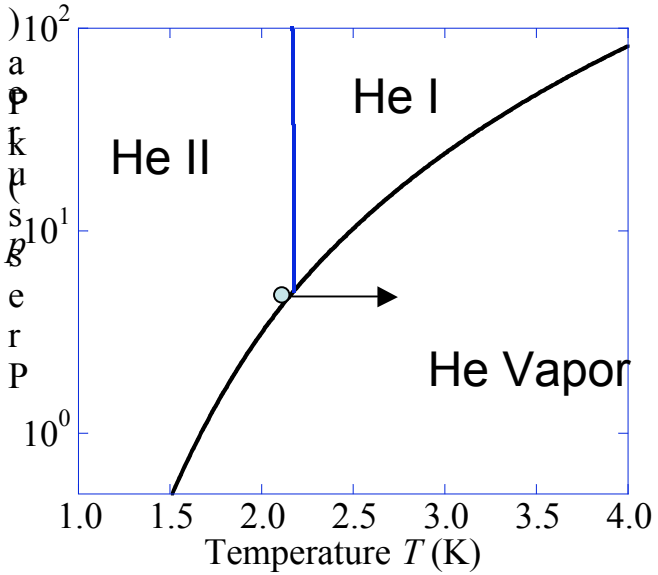




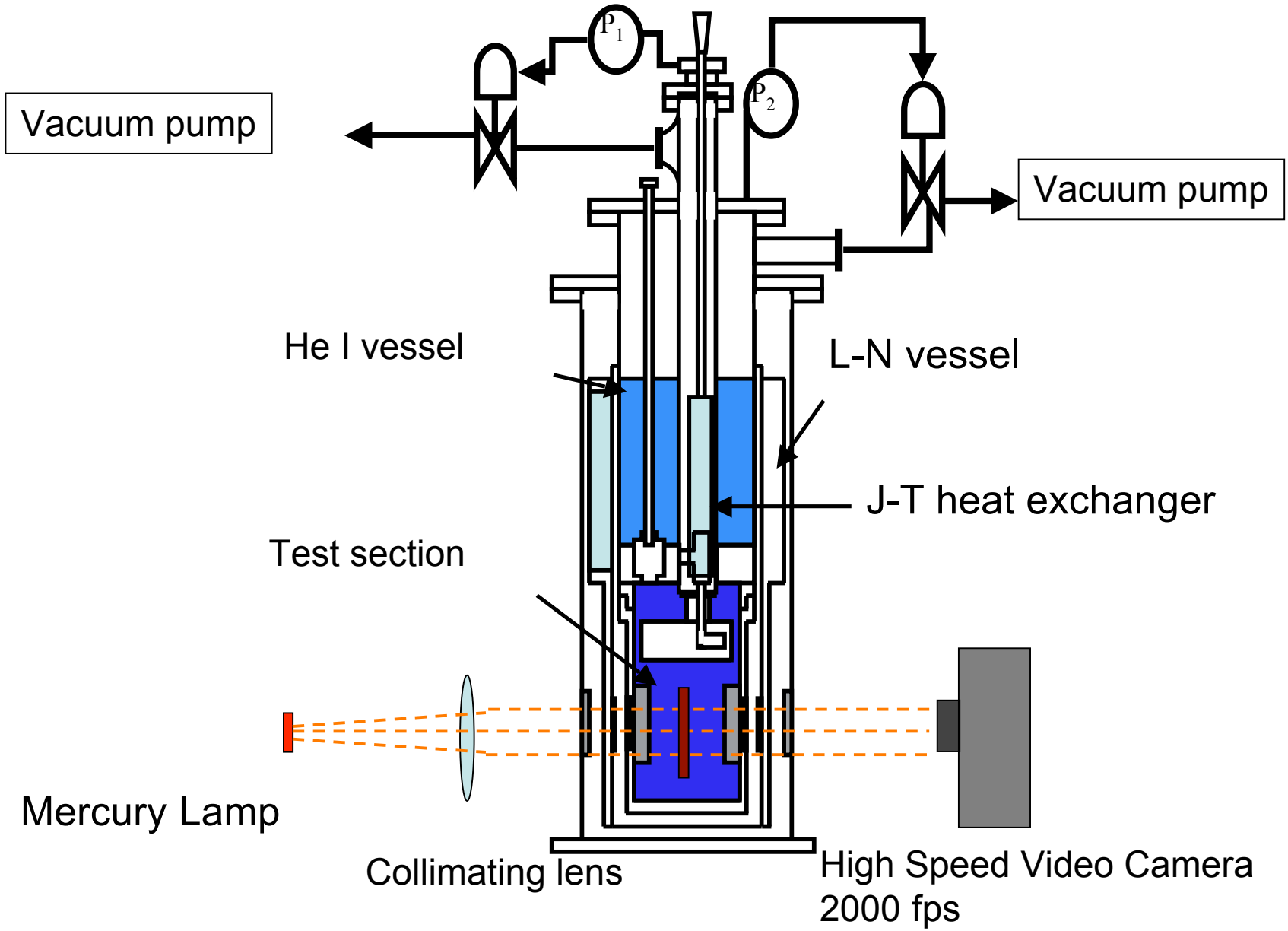
Film Boiling in Pressurized He II
In Narrow channel

Very near T_λ just below P_λ

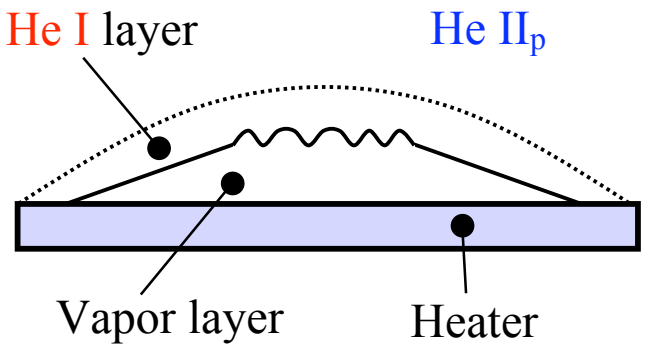




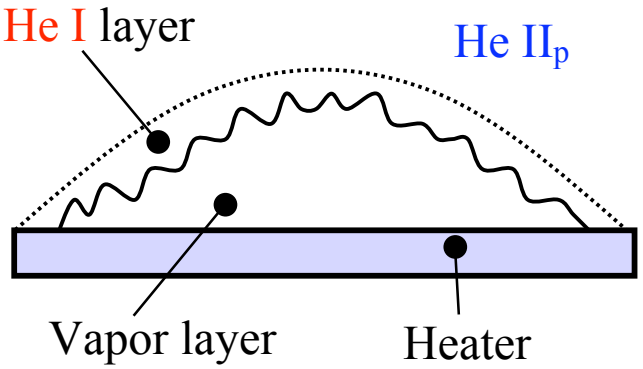
2.15 K Immersion depth 18 cm (P_λ = 22.3 cm)


Vacuum pump
P1
P2
Vacuum pump
He I vessel
L-N vessel
J-T heat exchanger
Test section
Mercury Lamp
Collimating lens
High Speed Video Camera
2000 fps

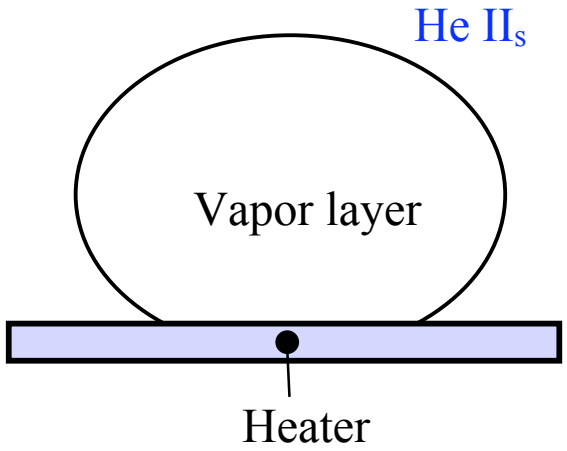
Schematic Illustration of Vapor Layer



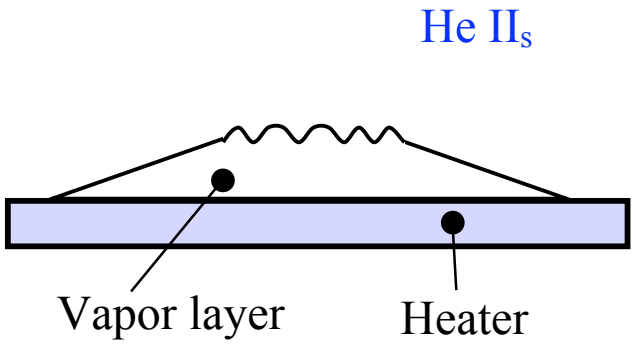
[Strongly Subcooled]



[Weakly Subcooled]

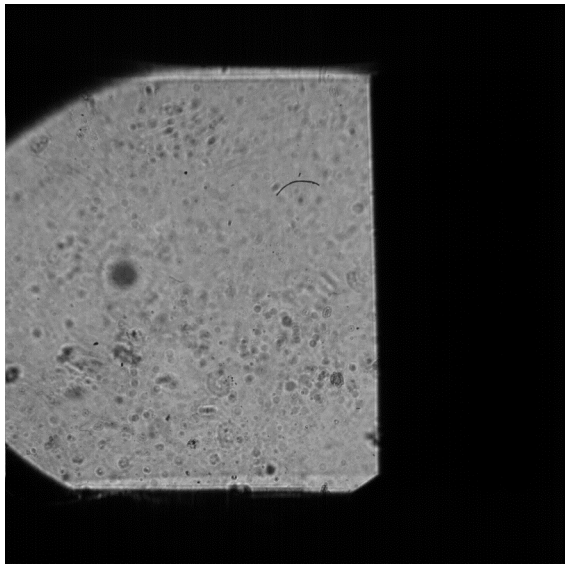


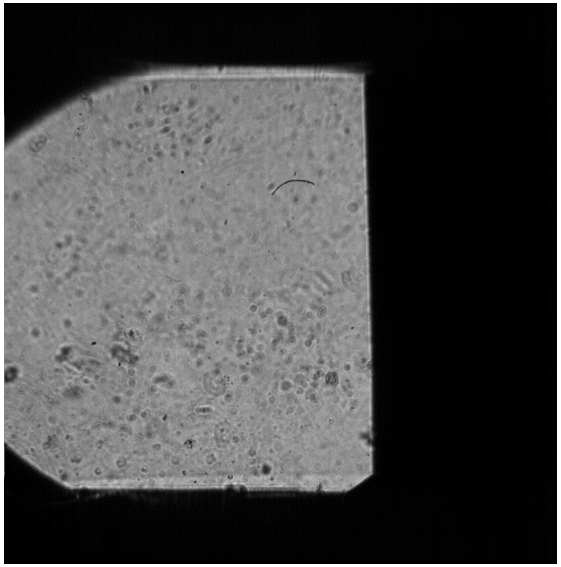
[Noisy Film Boiling (Saturated)]

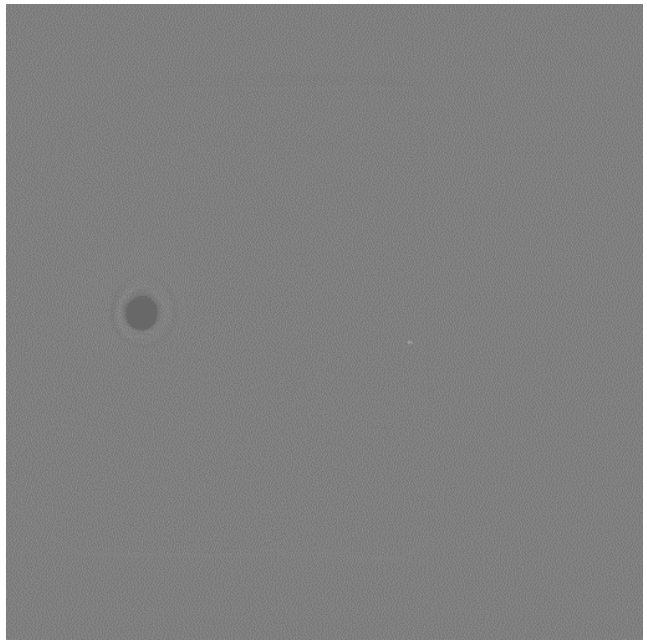


[Silent Film Boiling]

Image processing Eliminating of Background Noise

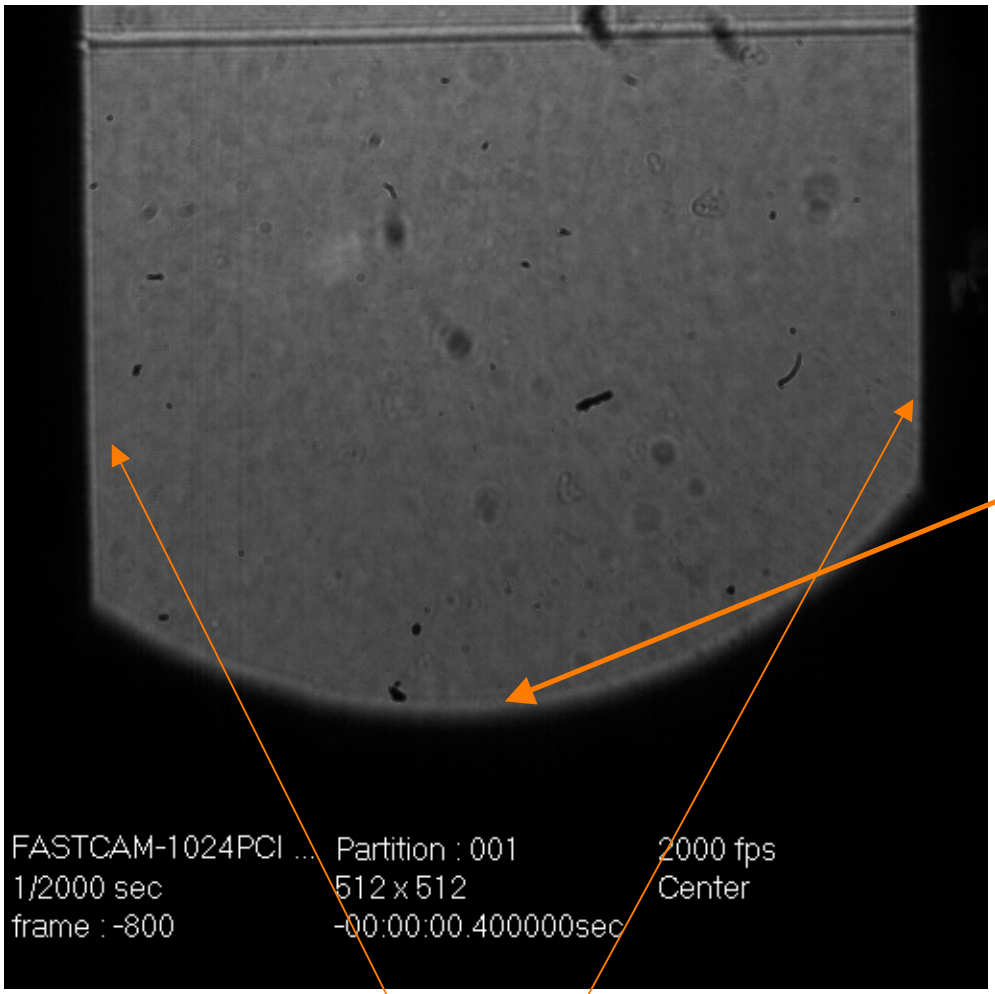




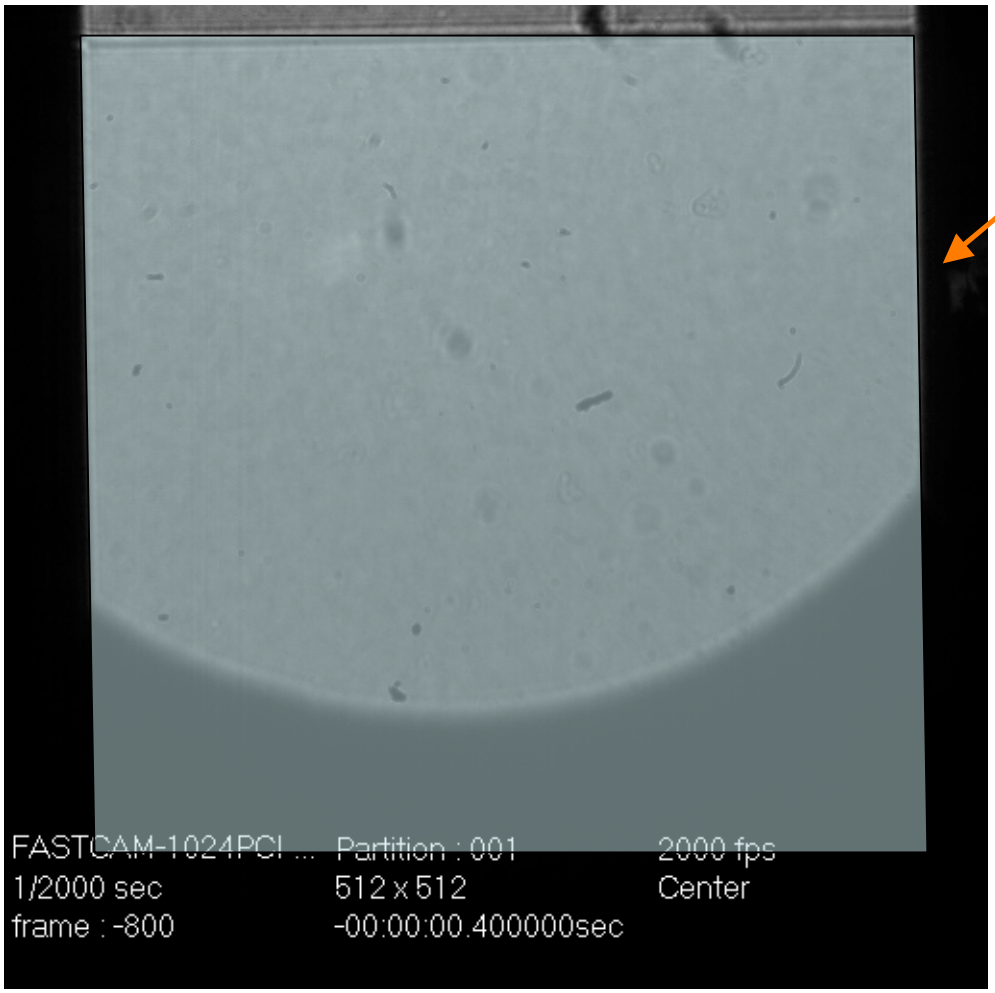


Signal enhanced image

He II 膜沸騰の撮影例



He II 膜沸騰の撮影例



開放系：1.9 K 飽和He II

Superheated He II, Superheated He I

Many researchers find the role of Superheated He II and He I In the Specific Channels

: **Narrow Long Tube, Low Vibrating Cell Connected Capillary and Two Dimensional Channel**

