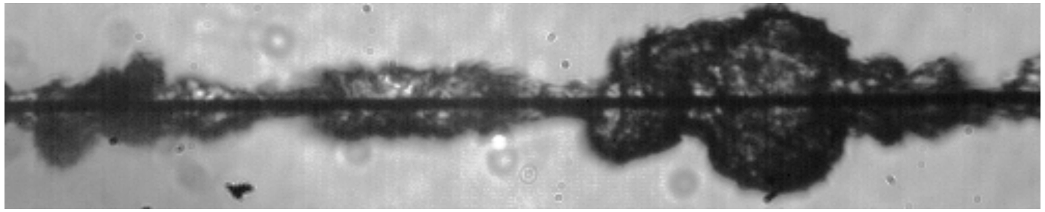
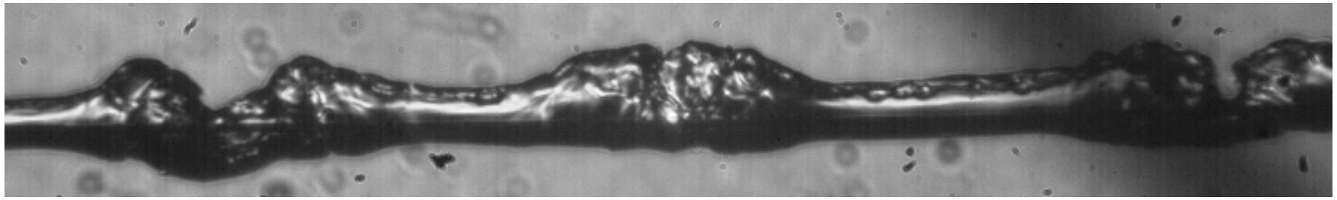
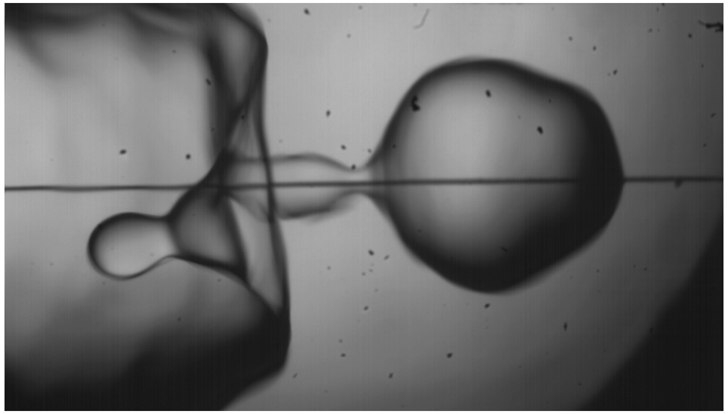


The hydrodynamic and heat transfer characteristics of film boiling modes in He II





Suguru TAKADA (University of Tsukuba)

Collaborators:
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Nobuhiro KIMURA (KEK)
Naoya YOKOTA (Univ. of TSukuba)
Masakazu NOZAWA (Tohoku Univ.)

A workshop for the Saclay-KEK cooperation program 2009, March 24

background

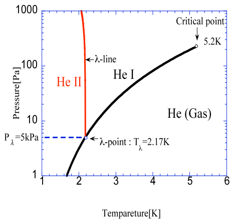
- This study have been investigated to understand He II film boiling inclusively

ILC
Saturated He II, 2.0 K

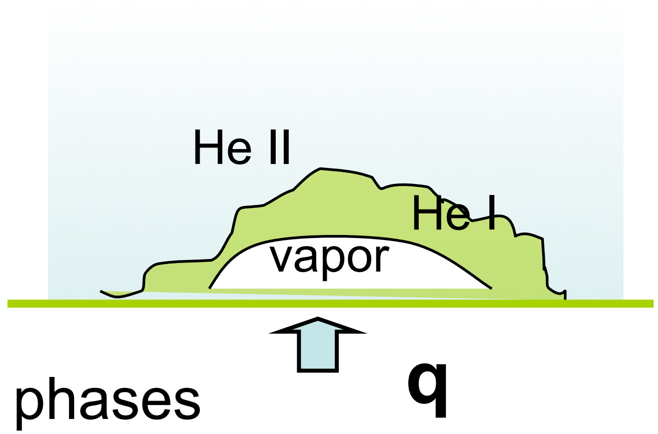
LHC
Pressurized He II, 1.8 K

AMS-02 (Alpha Magnetic Spectrometer on ISS)
Saturated He II **in *space*** *(microgravity)*
1.8 K

Pressure effect of film boiling in He II



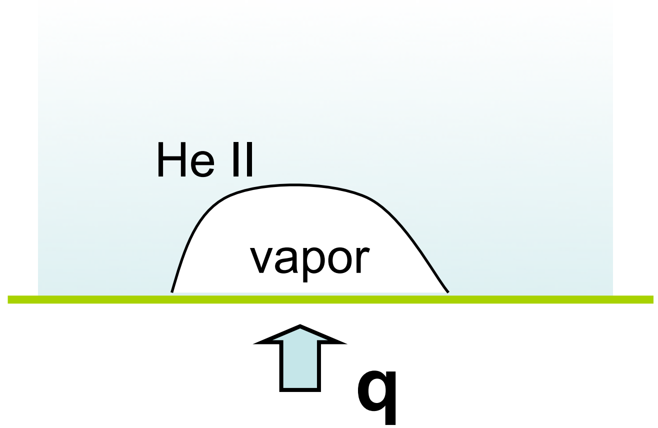
①



3 phases

He Vapor →He I →He II （P＞ P_λ ）

②



2 phases

He Vapor →He II （P＜ P_λ ）

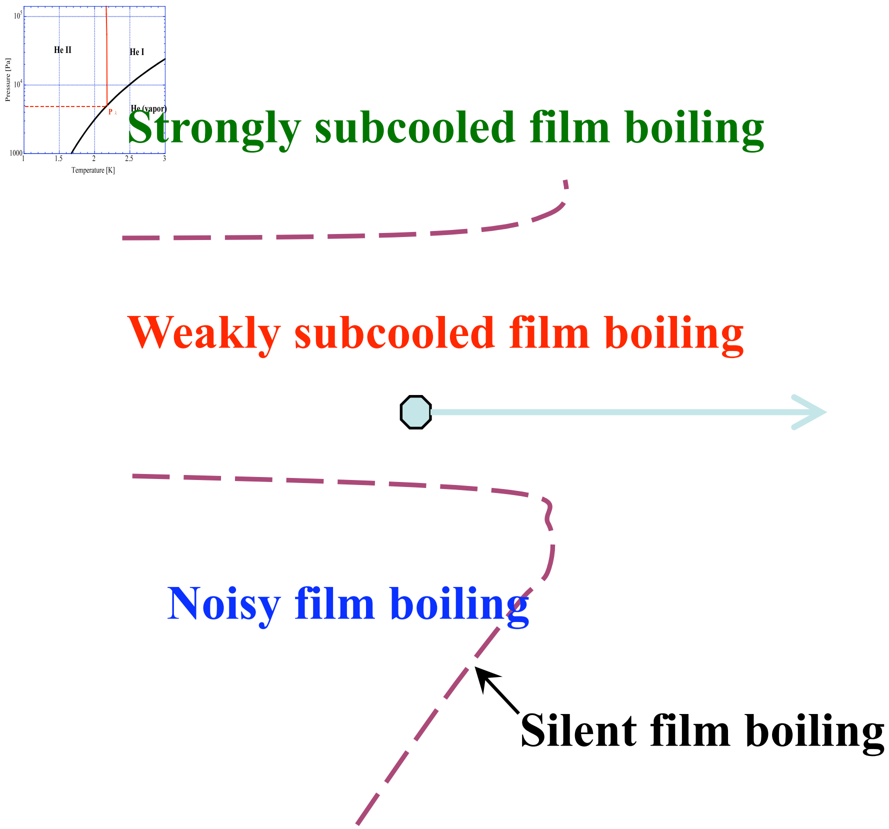
Four film boiling modes in He II on a flat plate

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



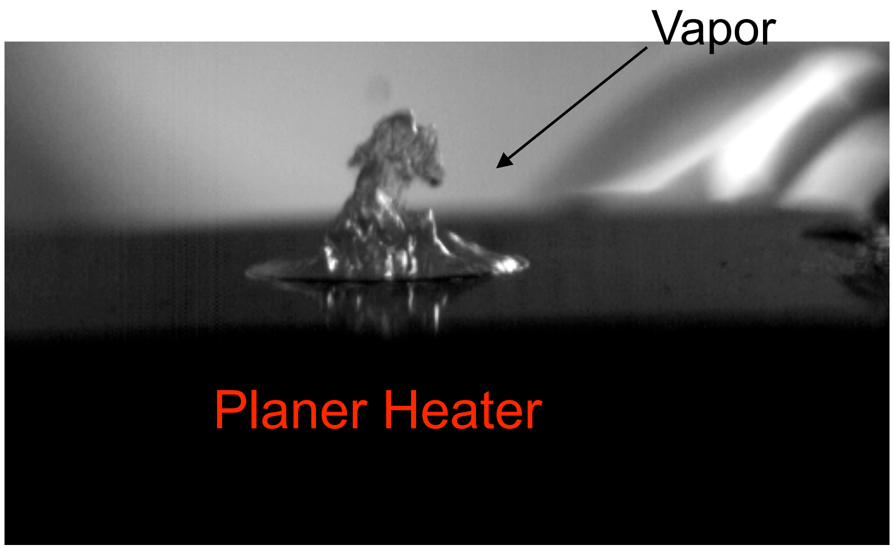
Visualization of Vapor behavior during film boiling

On flat plate, it is too hard to observe the vapor shape

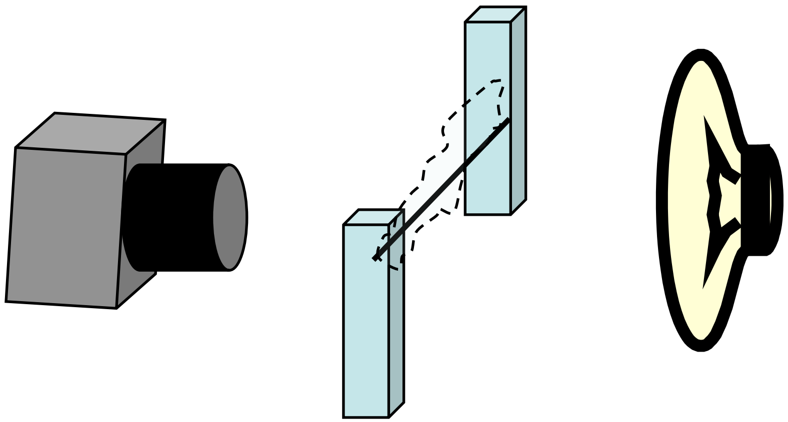
Lack of information of vapor film thickness and wave shape in detail

→ Wire Heater Experiment

We also aim to know the effect of heater geometry for film boiling modes

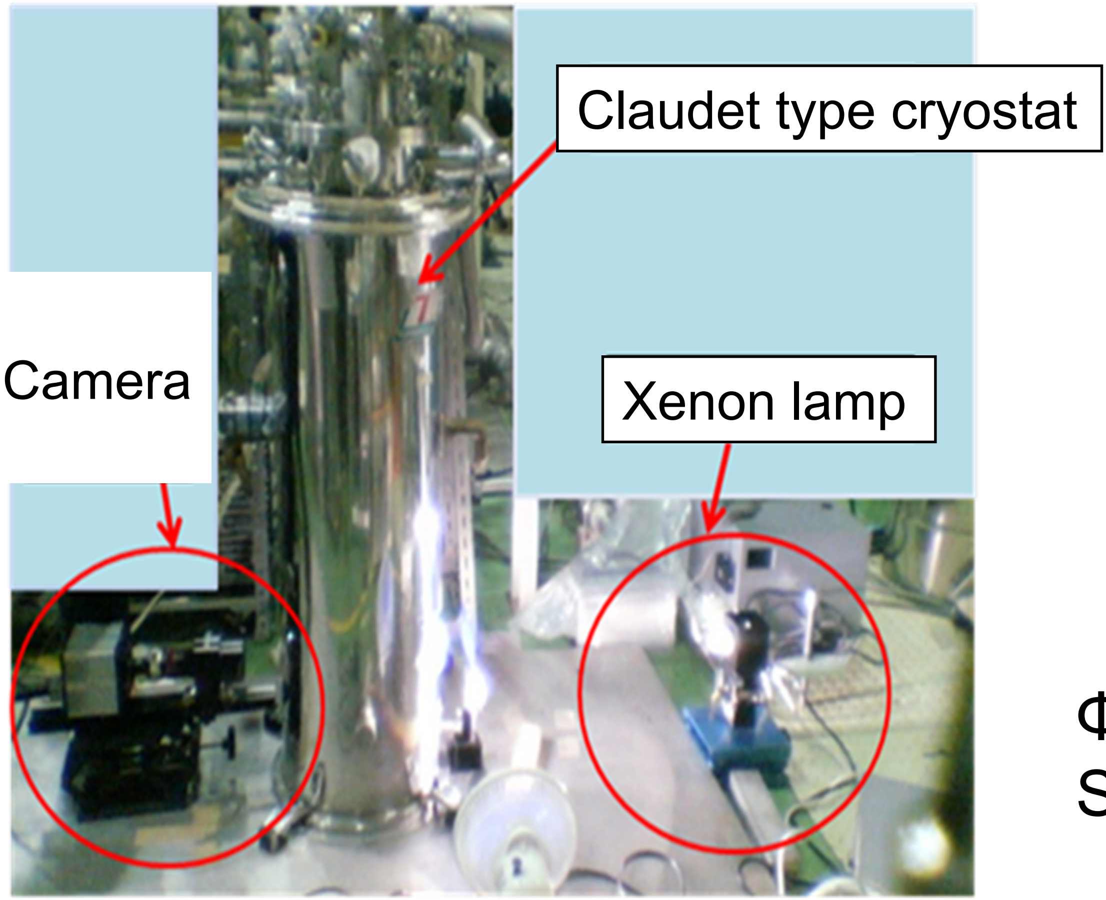


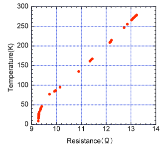
Film boiling in He II on a flat plate



Simple setup

Set up



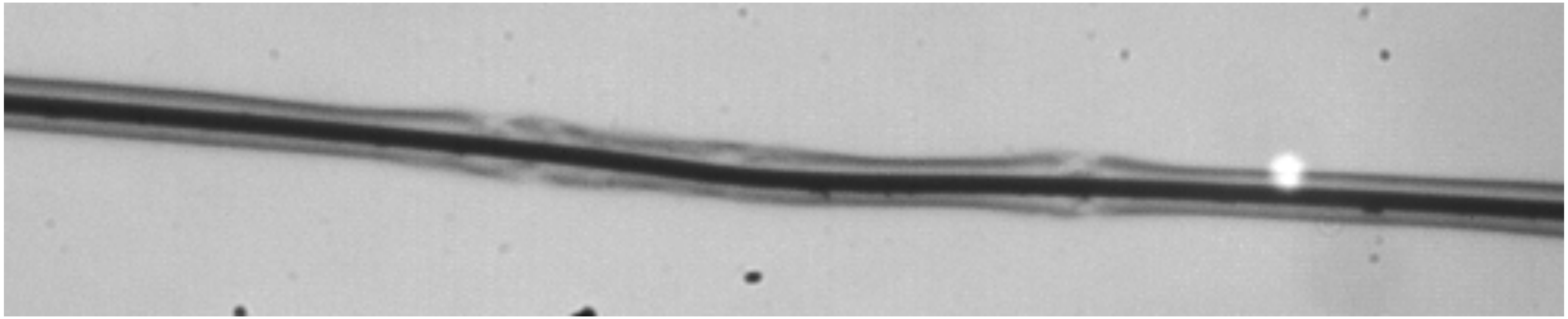


Φ 50 μm
Stain steel wire (SUS304)

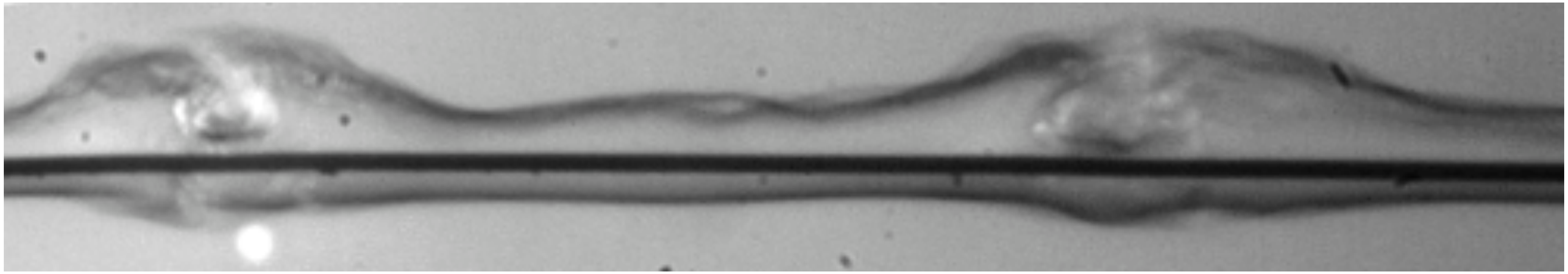
Stainless steel wire is used as a heater and as a thermometer

Visualization Result

T = 2.1 K



q =21.7 W/cm^2



q =42.1 W/cm^2

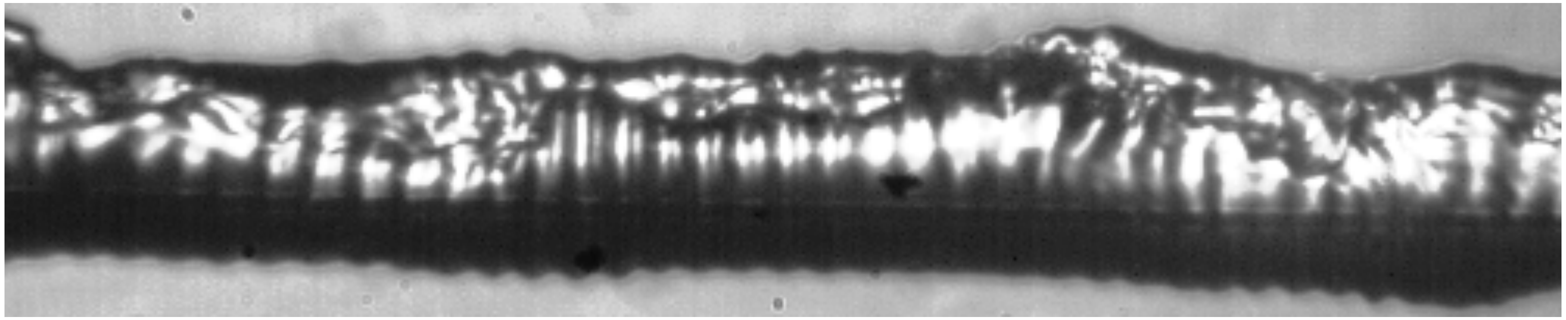
Rayleigh -Taylor instability pattern was seen when large heat flux applied.

Strongly subcooled film boiling 101.3 ～25 kPa

Weakly subcooled film boiling mode

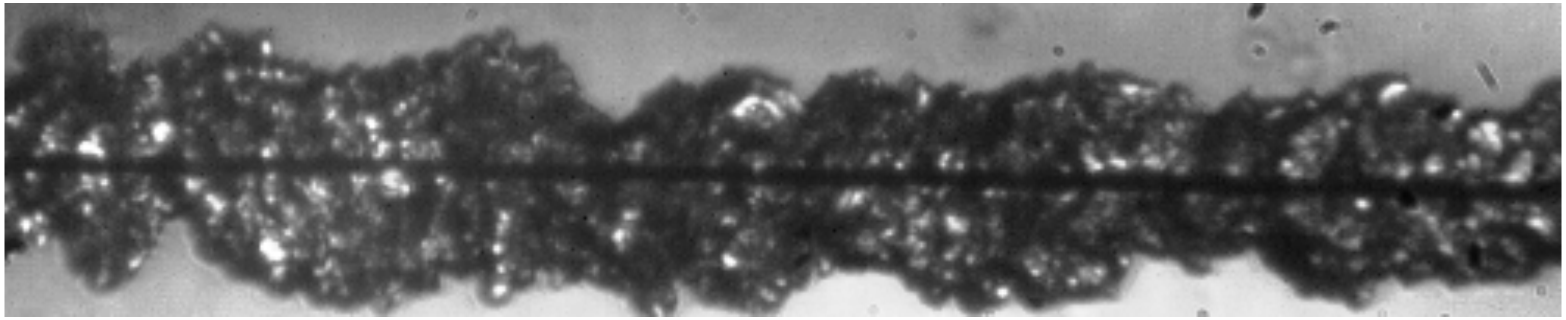
25 ～10 kPa

About 0.1 mm wave length, corrugated tube shape



P = 16 kPa, q =60.1 W/cm^2

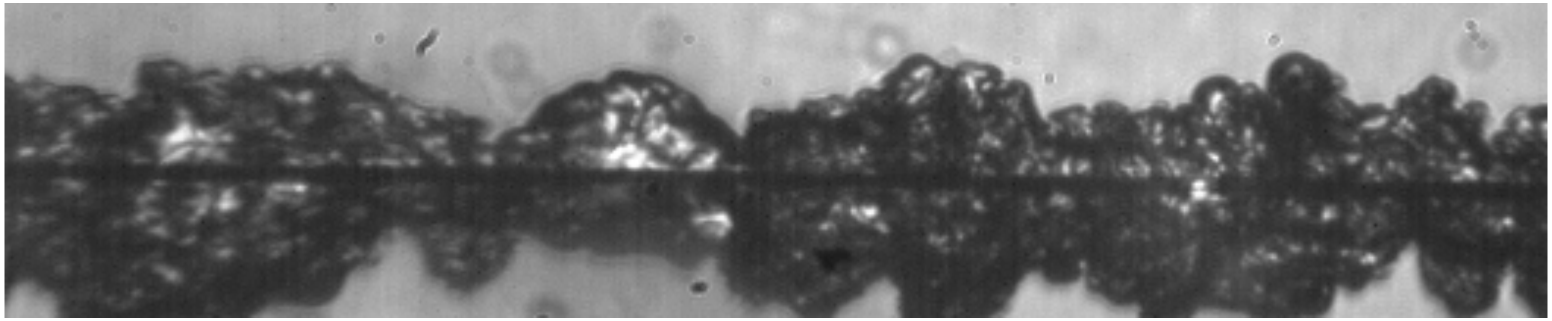
Pressure ↓



P= 13.3 kPa, q =57.9 W/cm^2

Accompanying loud keen noise of high frequency

The bifurcation of Film boiling mode exist in He II independently heater geometry

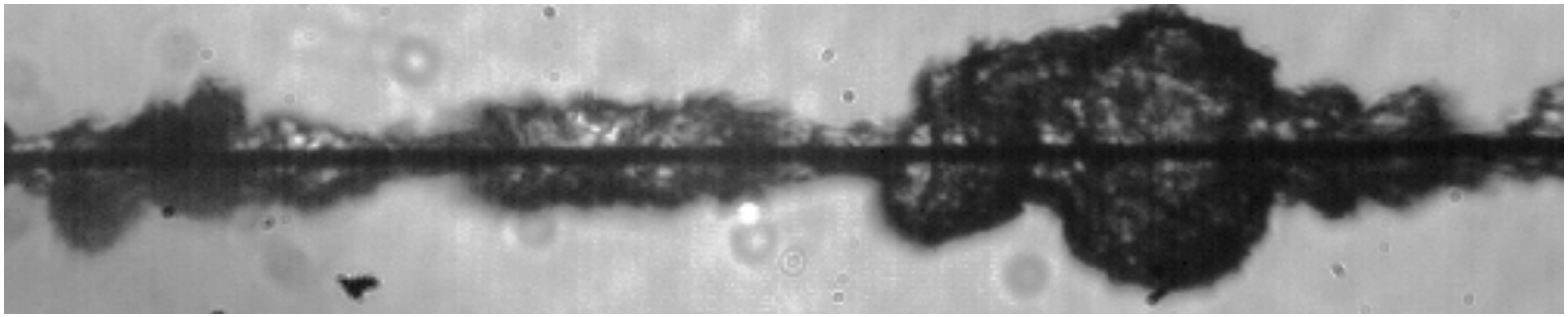


Weakly subcooled film boiling mode

P= 10.1 kPa ,q =42.2 W/cm^2

Transition

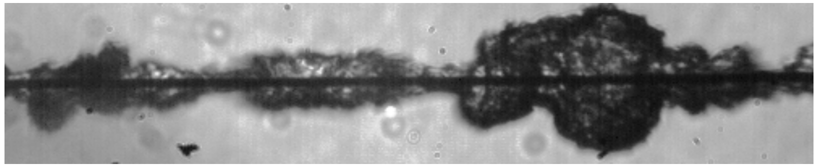
Weakly subcooled to Noisy film boiling mode

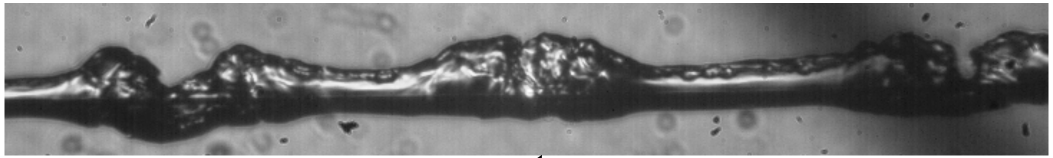


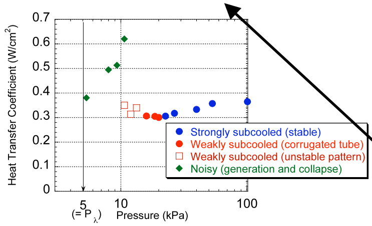
Noisy film boiling mode

P= 5.3 kPa, q =37.3 W/cm^2

Heat transfer coefficient and vapor behavior

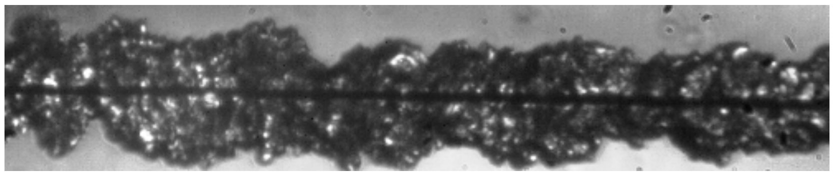


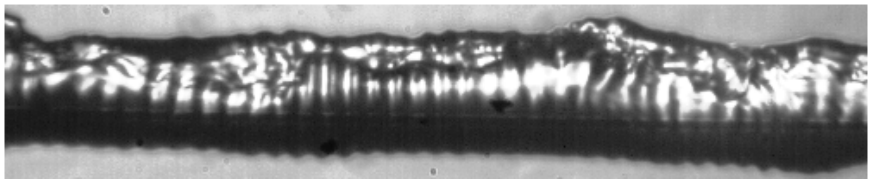




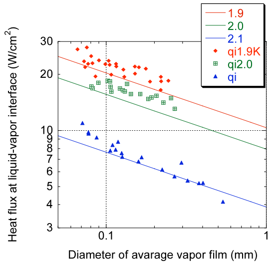
T = 2.1 K

q = 30 W/cm^2





Relation btw film thickness and heat flux



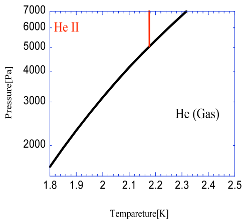
m=3.4

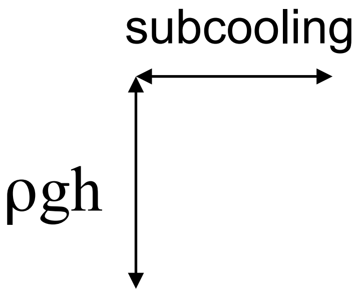
$$q_i = \left[\frac{(m-1)}{r} \int_{T_b}^{T_\lambda} \frac{dT}{f(T)} \right]^{\frac{1}{m}}$$

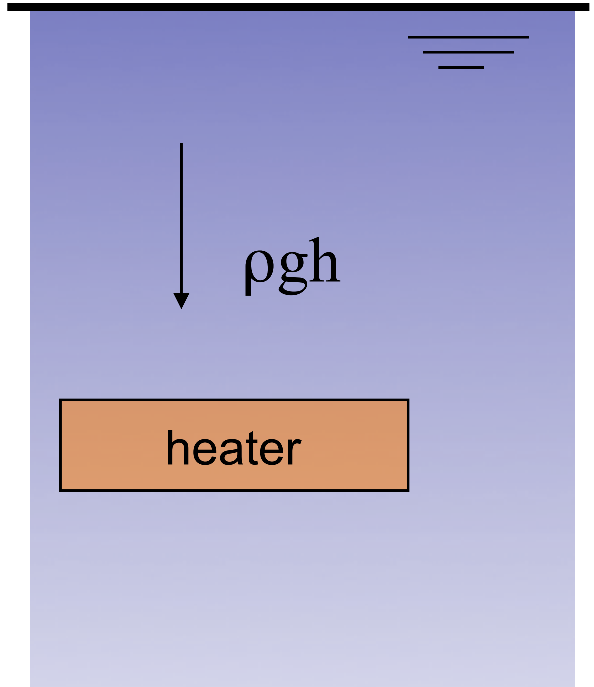
$$q_i D_i = q_w D_w$$

Di : diameter of vapor film
Dw: diameter of wire

Microgravity Experiment of He II







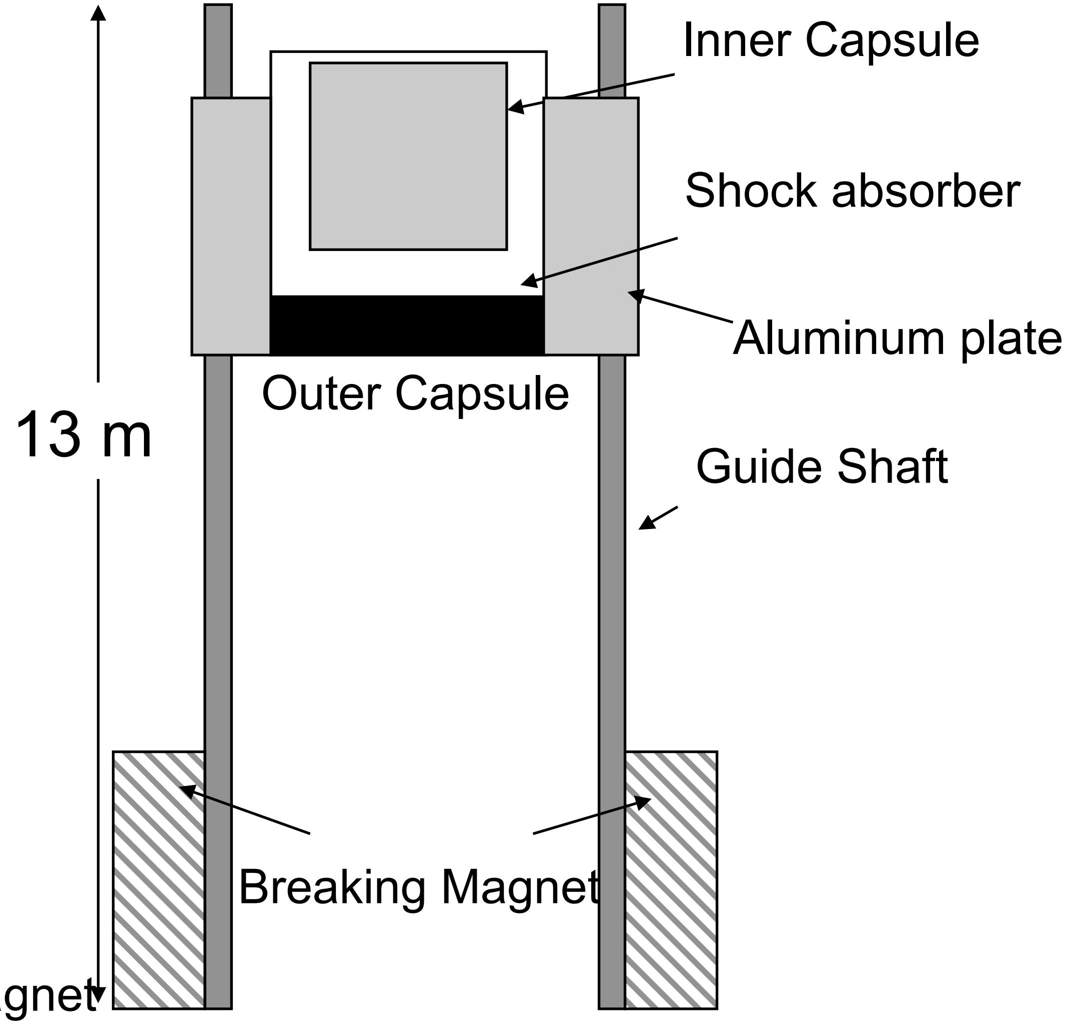
Additional pressure:
h=1 cm
ρgh = 14.28 Pa (1.9 K)

Under micro gravity, temperature difference of subcooling become zero.

Free Fall Tower in Open Space

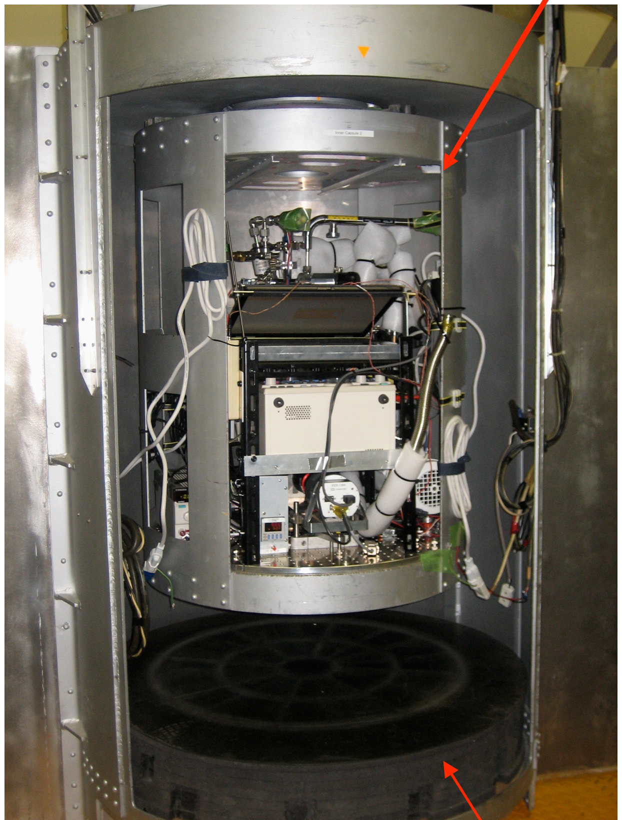
located in AIST Hokkaido center

The picture of guide shaft and beak magnet
taken from downstairs



Double Capsules system
< 1 mG, 1.27 sec

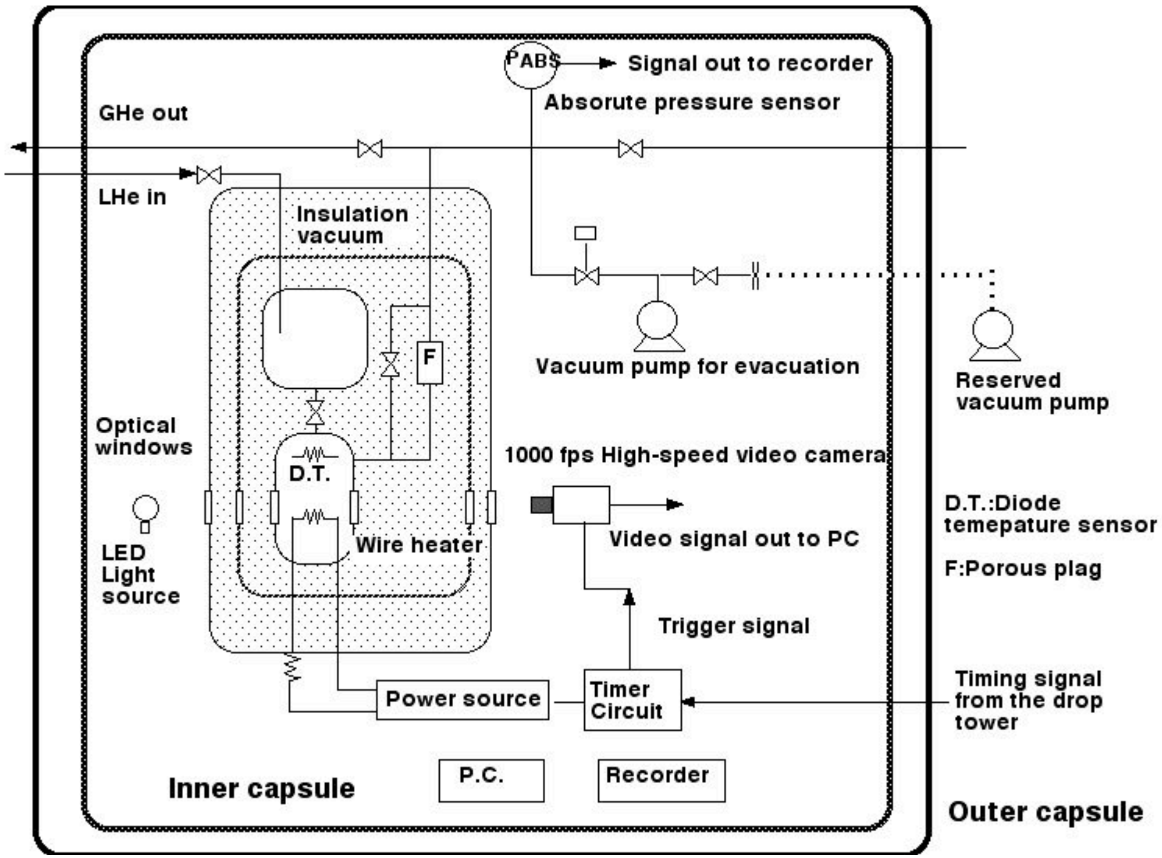
φ720 x 820、60 kg (+ capsule 90 kg)

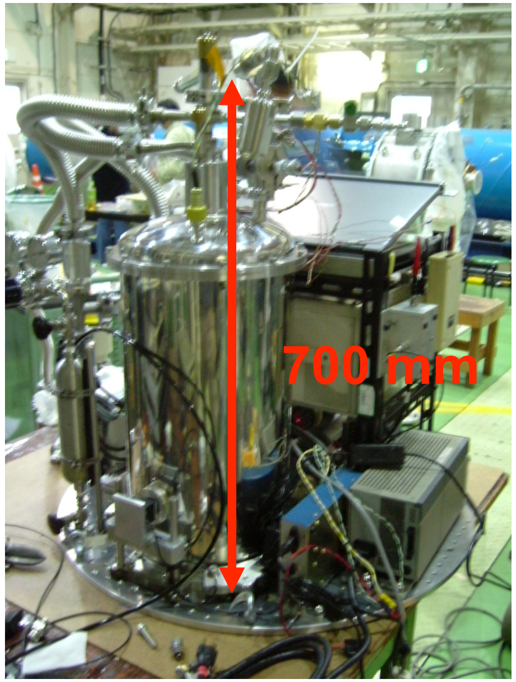


Inside the outer capsule

Shock absorber

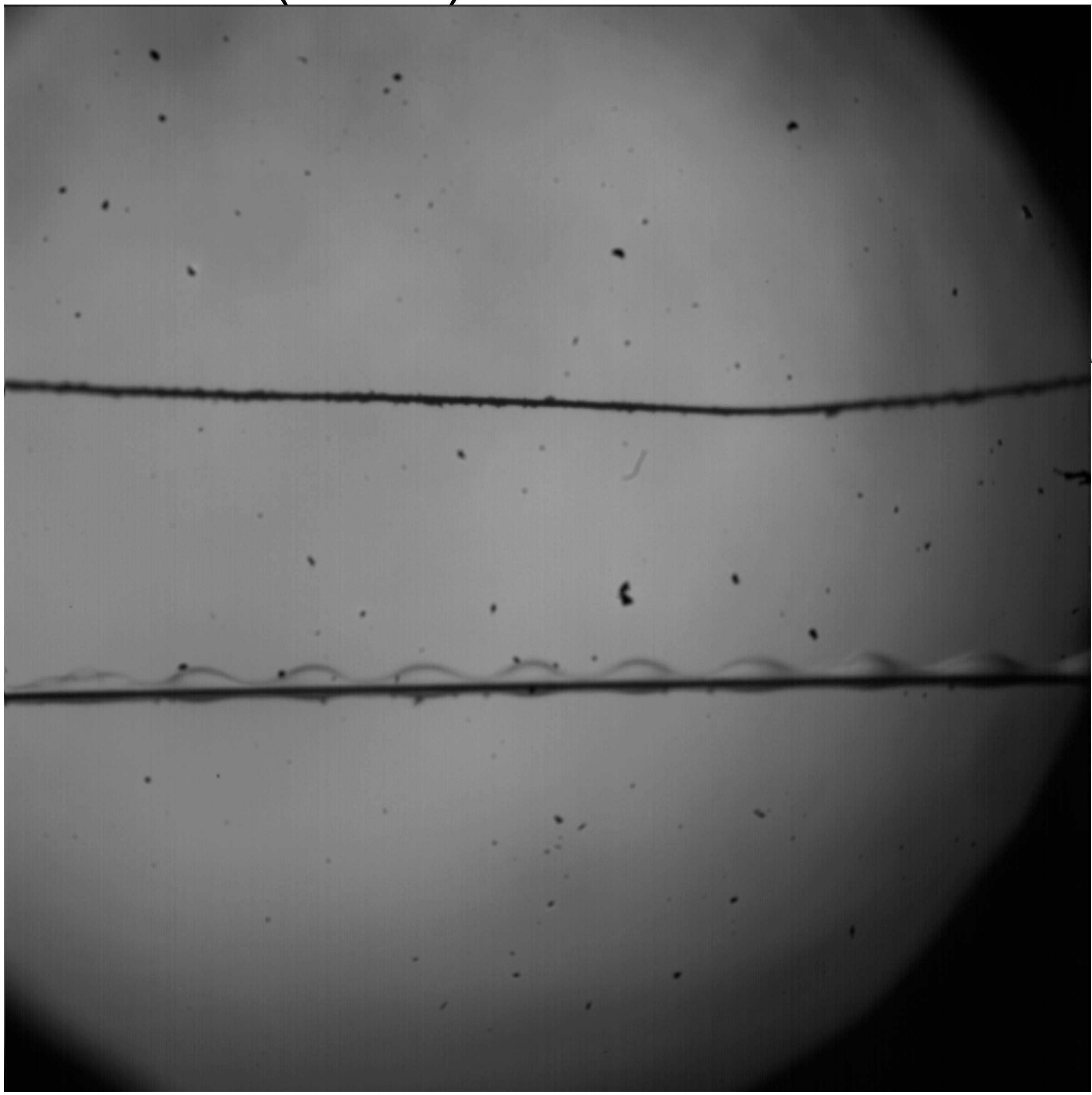
Small cryostat equipped with optical windows <20 kg （designed by Dr. Kimura ）



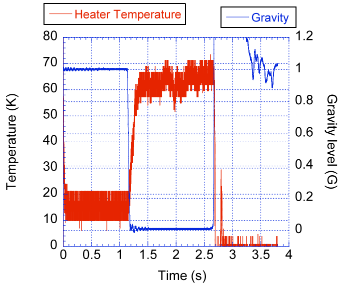


15 times of experiments was carried out successfully in a day !!

Visualization result (movie)



T = 2.0 K,1.93～2.01 W/cm^2 Running 11.5 times slower



T = 2.0 K,1.93～2.01 W/cm^2

Summary

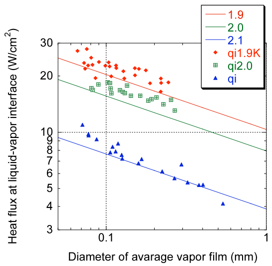
- The film boiling experiments in He II was successfully conducted rather wide pressure range

  1 atm ～saturated vapor pressure

- Four film boiling modes exist in He II independently on heater geometry
- Peak heat flux appear around 10 kPa, that is depending on heater geometry

- The experiment system of He II under microgravity condition was successfully developed.

Relation btw film thickness and heat flux



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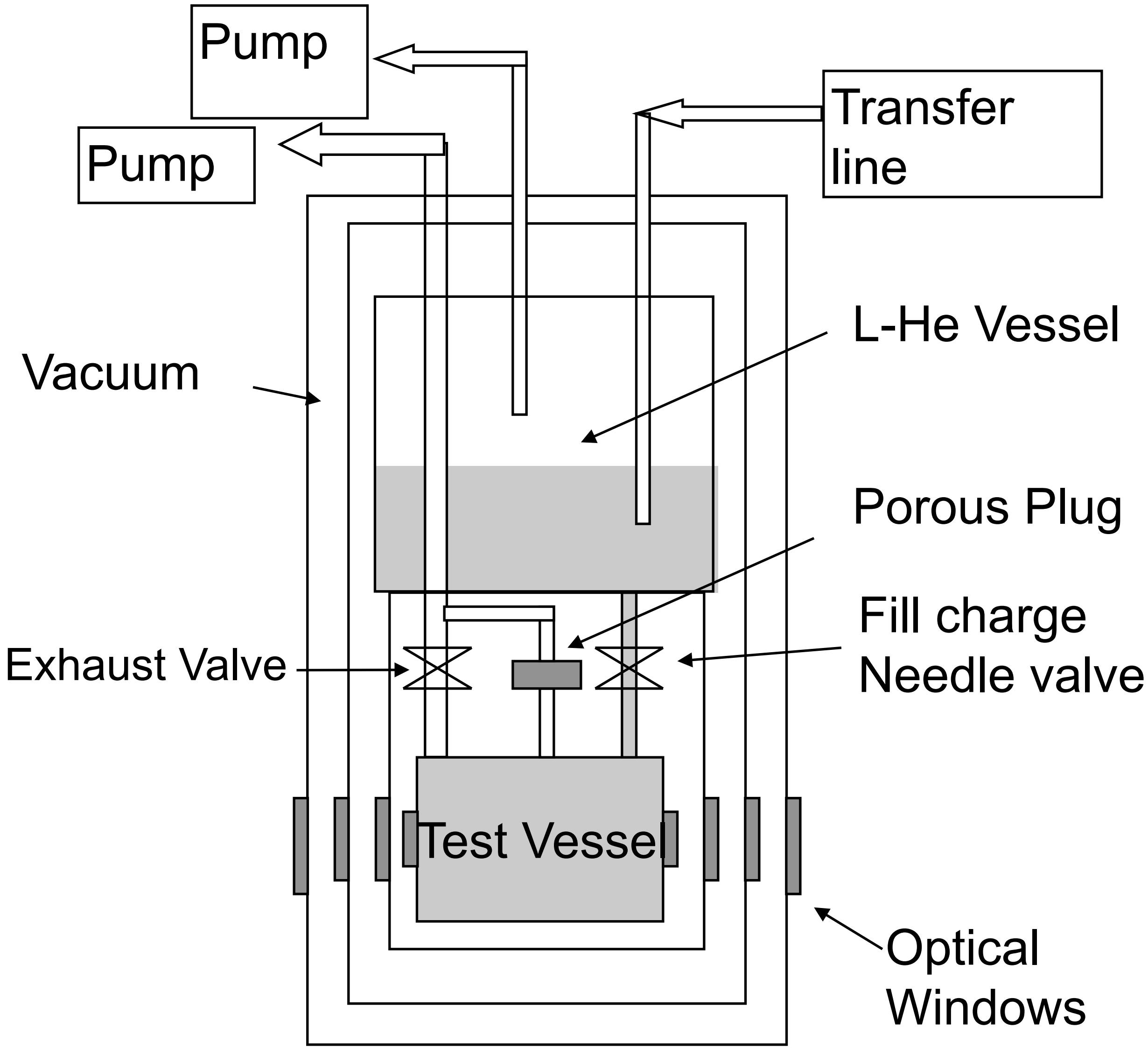
Pump
Pump
Transfer line
L-He Vessel
Vacuum
Porous Plug
Fill charge
Needle valve
Exhaust Valve
Test Vessel
Optical
Windows

Comparison with liquid Nitrogen