Study of a Clearing Electrode at KEKB
- First beam test -

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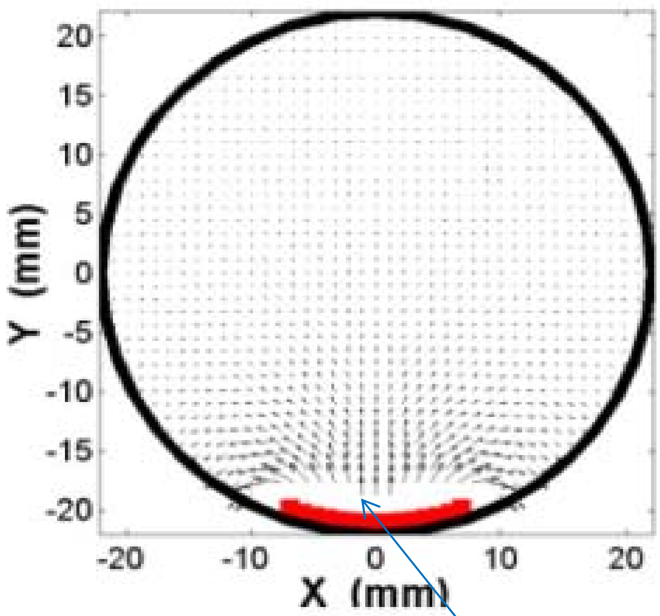
Background

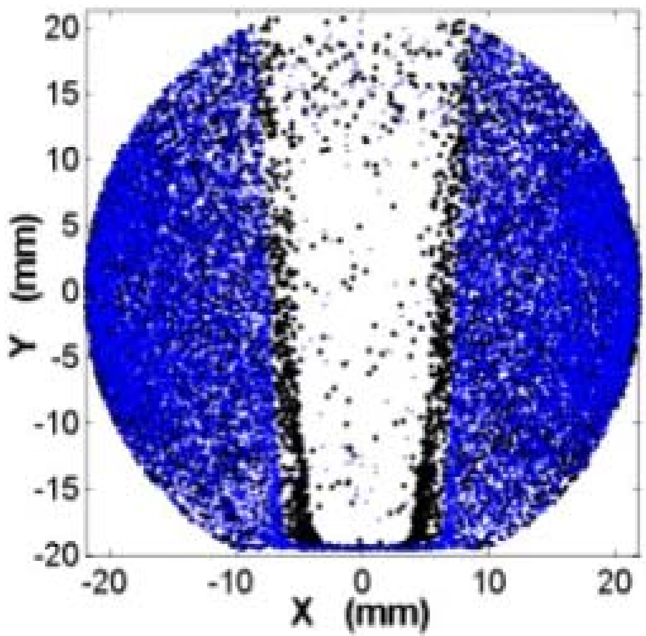
- Clearing Electrode = A possible solution to suppress electron cloud in magnets.
  - Drift space :Beam duct with antechamber (against photoelectrons) + TiN coating (against secondary electrons) + Solenoid will be OK.
- Experimental study on a clearing electrode using KEKB positron ring is planed, as a chain of ILC DR R&D study.
- Goal
  - Establish the technique of clearing electrode for ECI, which is available for high current machine and with a low beam impedance.
  - Demonstrate the effect on electron cloud formation.

Clearing Electrode

- Simulation (by L. Wang)



Electron density



L. Wang et al, EPAC2006, p.1489

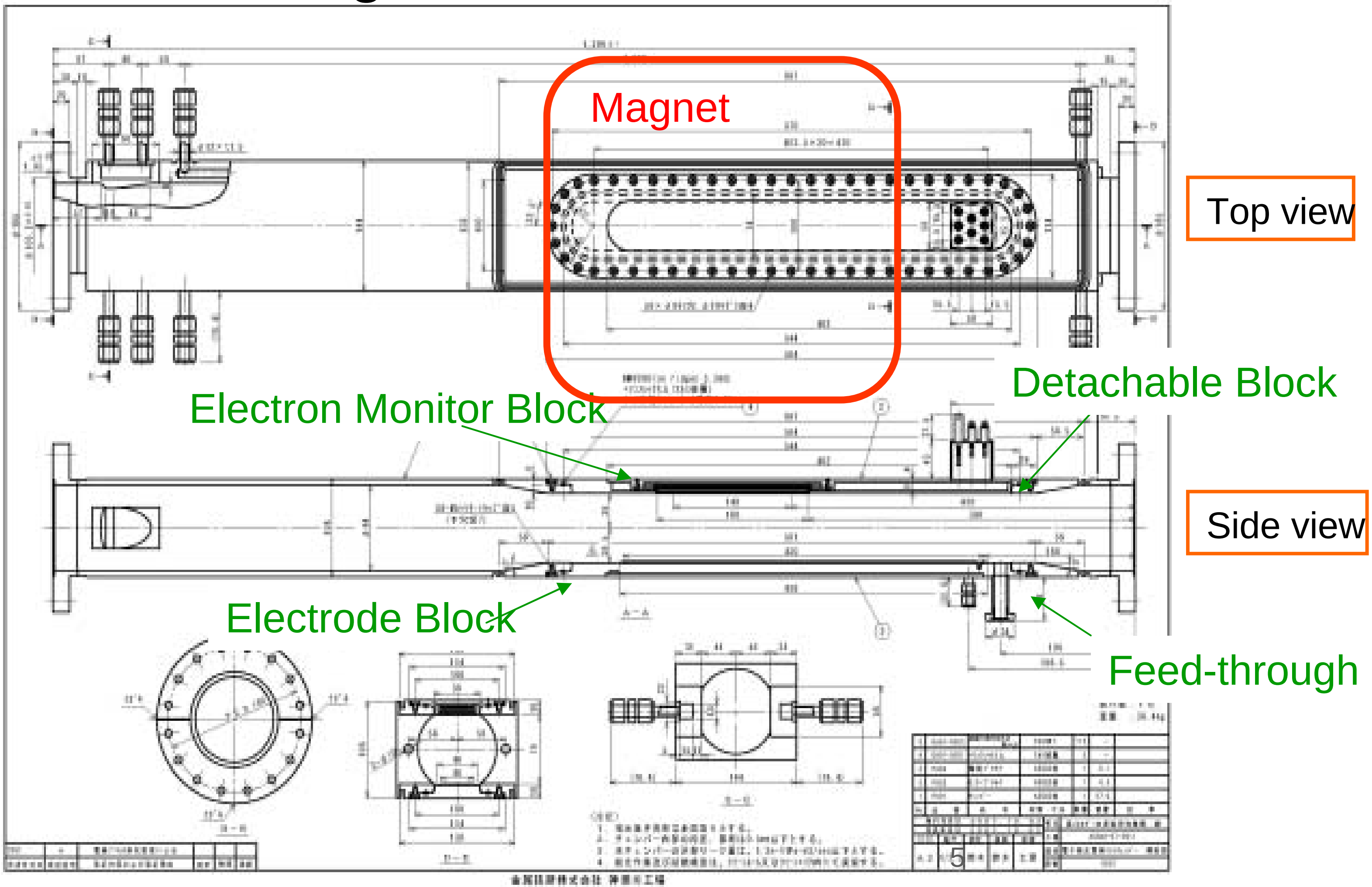
Test plan

- Install a test chamber with an electron monitor and a clearing electrode into a wiggler magnet of LER (Oho straight section).
  - At the most upstream side of wigglers
    - Very weak SR
  - Magnetic field: 0.75 T
  - Effective length: 346 mm
  - Aperture (height): 110 mm

Wiggler magnets

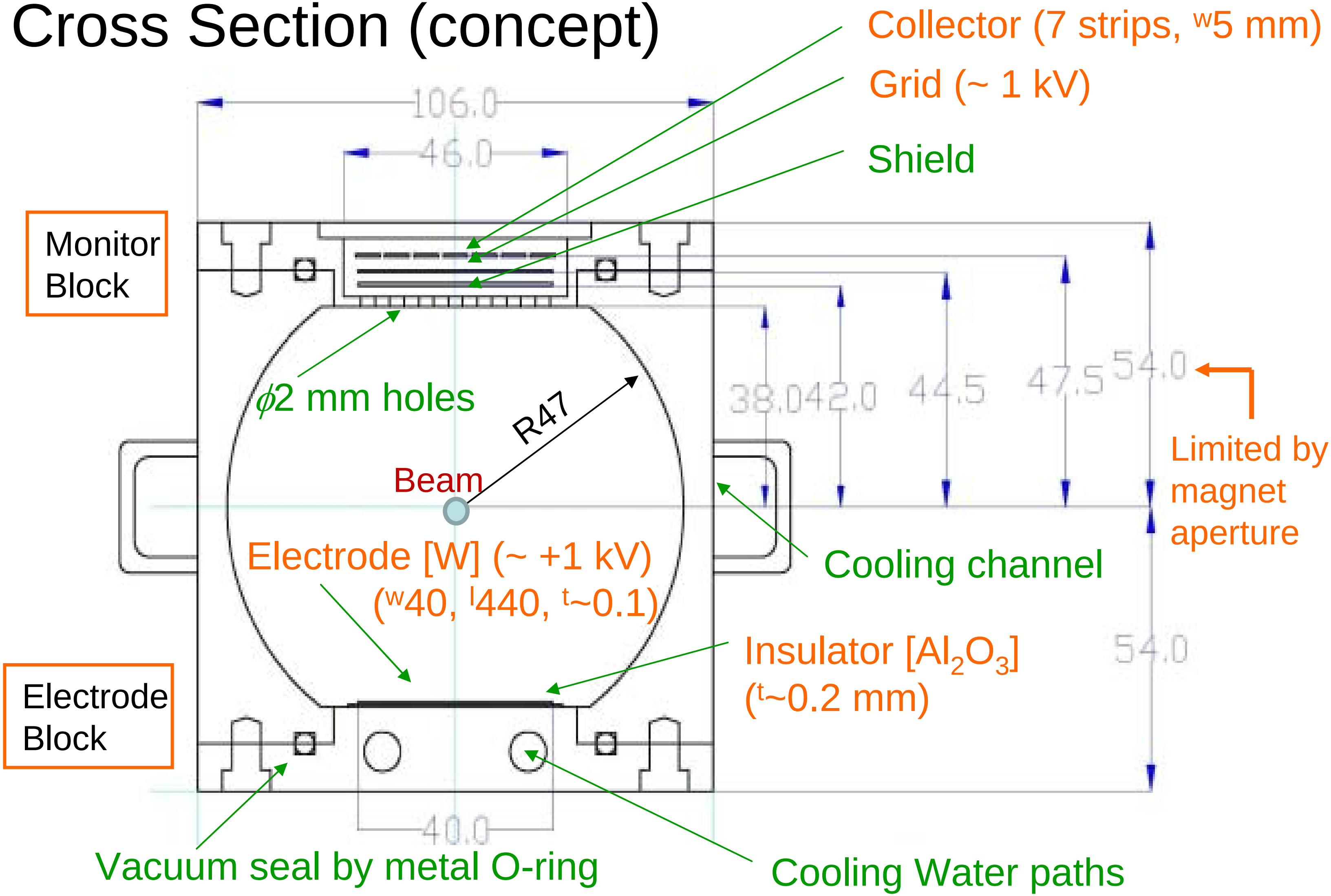
Test Chamber

- Over all design of the test chamber



Monitor and electrode

- Cross Section (concept)



Features of the test chamber

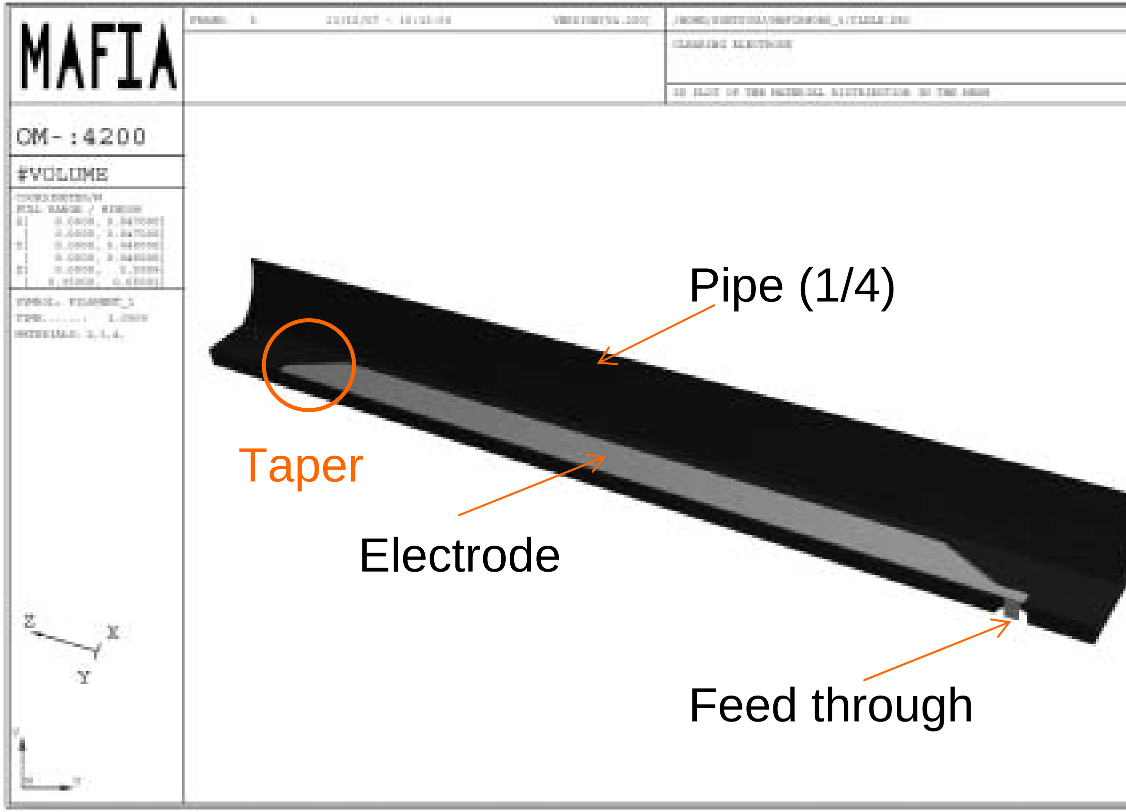
- Electron monitor
  - Monitor and electrode are exchangeable.
  - Electron collectors are seven strips to measure the spacial distribution.
- Electrode
  - Strip type electrode.
  - Very thin electrode and insulator.
    - Electrode: ~0.1 mm, Tungsten, by thermal spray.
    - Insulator: ~0.2 mm, Al_2O_3, by thermal spray.

    →Small beam impedance.
  - Water cooling just behind of the electrode.
    - Absorb dissipated power in the electrode and the insulator.

RF properties

- Model (By MAFIA)

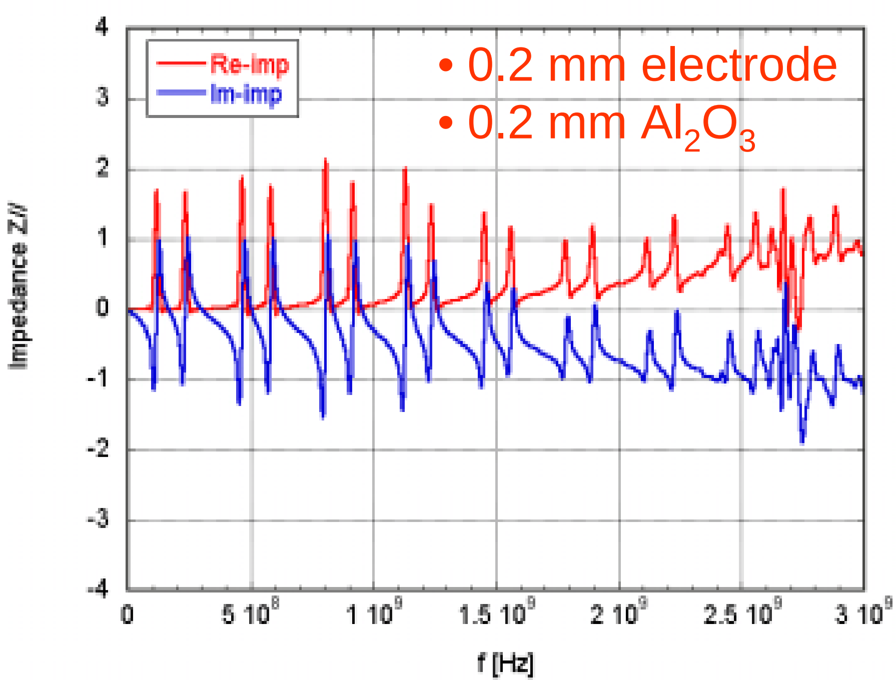
- Length = 2 m
- 1/4 model
- Electrode position = 195-625 mm (430mm)
- Width = 40 mm
- Mesh sizes = 0.5 x 0.1 x 0.4 mm
- Bunch length = 6-8 mm
- Electrode thickness = 0.2 mm
- Alumina thickness = 0.2 mm
- Alumina ε_r =9.9
- Port = 14 mm (o), 6 mm (i) (50Ω)

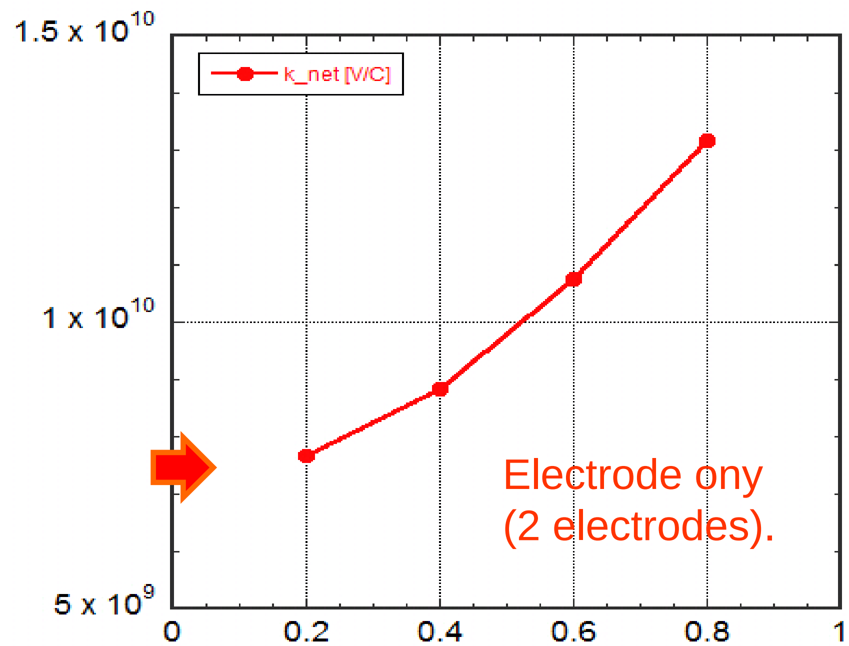


Embedded + Taper + Feed through

RF properties

- Impedance($z_{//}$) (by MAFIA)





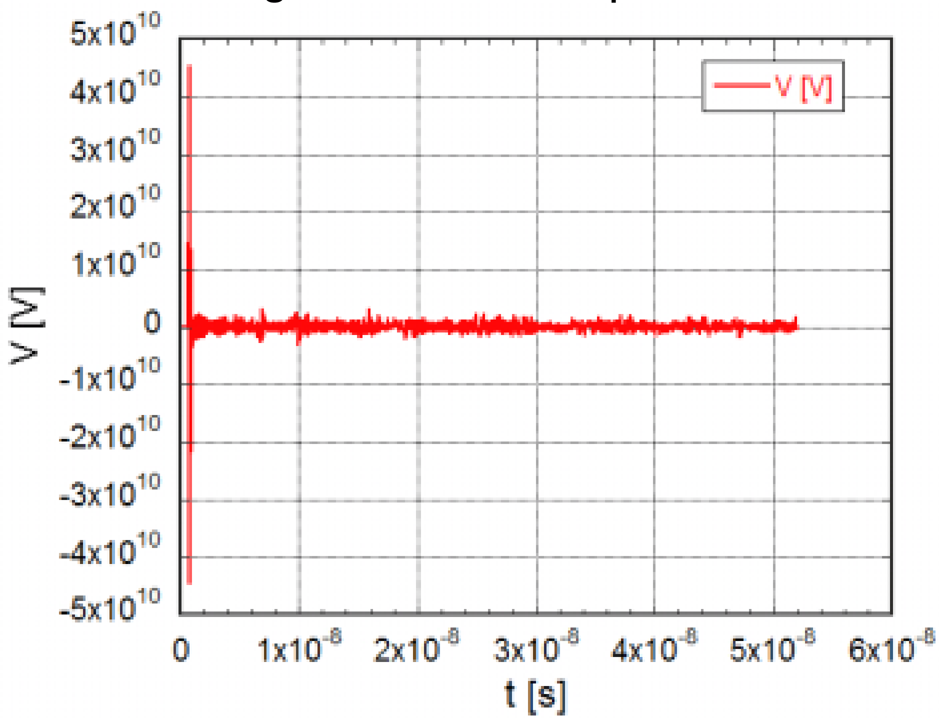
$Z_{//}$ ~ a few Ohm
$Z_{//}$ reduced to ~1/5 by decreasing the thicknesses

k ~1.5x10^{10} V/C including the connection part (2 electrodes).
Dissipated power is ~ 120 W for 1
electrode. (@1.6 A,1585 bunches

RF properties

- Voltage at feed through
  - σ_z = 6 mm

Voltage at the end of port @ 1C

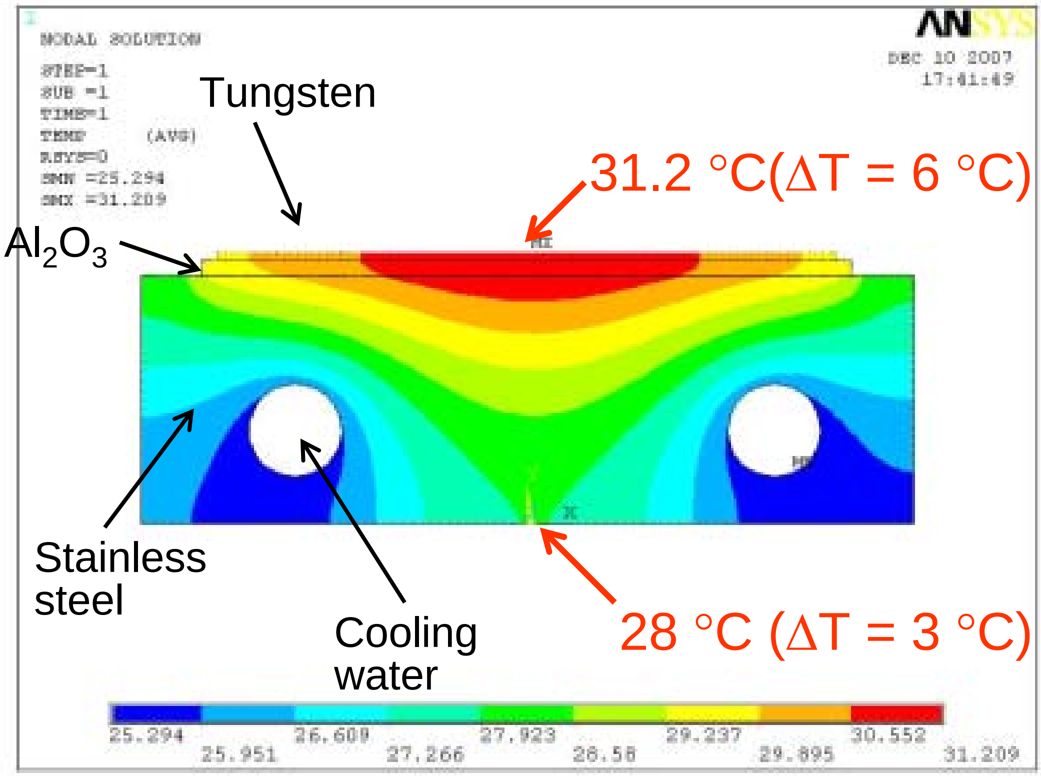


At 1.6 A (1585 bunches),

- Output voltage:
  V_O ~450 V (If no resonance)
- Output power from feed – through:
  P_O ~ 45 W (if R=50Ω)
- Voltage between electrode and chamber:
  V ~ 9 V (If no resonance)

Thermal calculation

- For the case of 100 W input on the surface



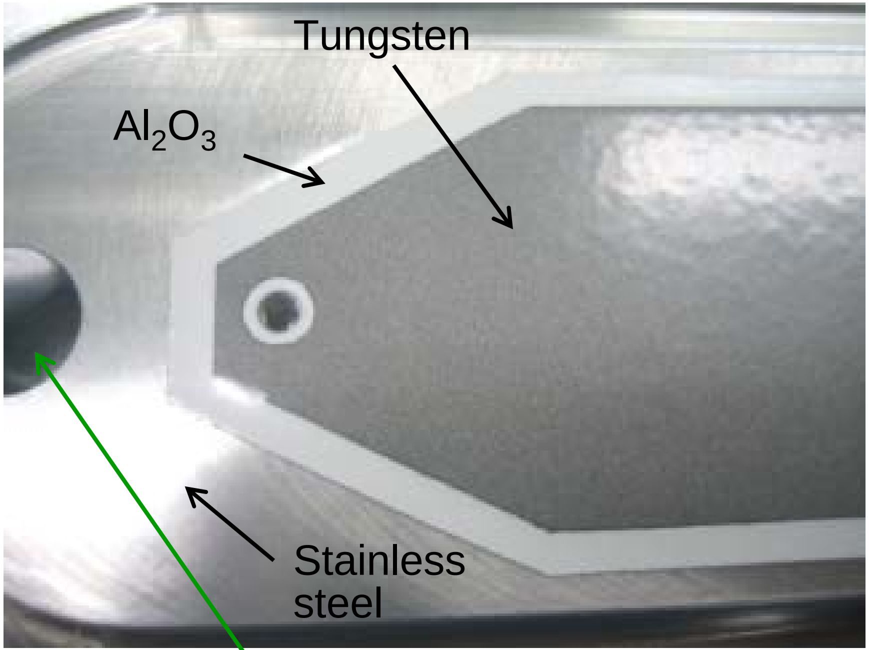
0.5 mm electrode
1.0 mm Al_2O_3

- Heat transfer coefficient between chamber and water = 0.01 $W/mm^2/K$
- Temperature of water = 25 degrees.

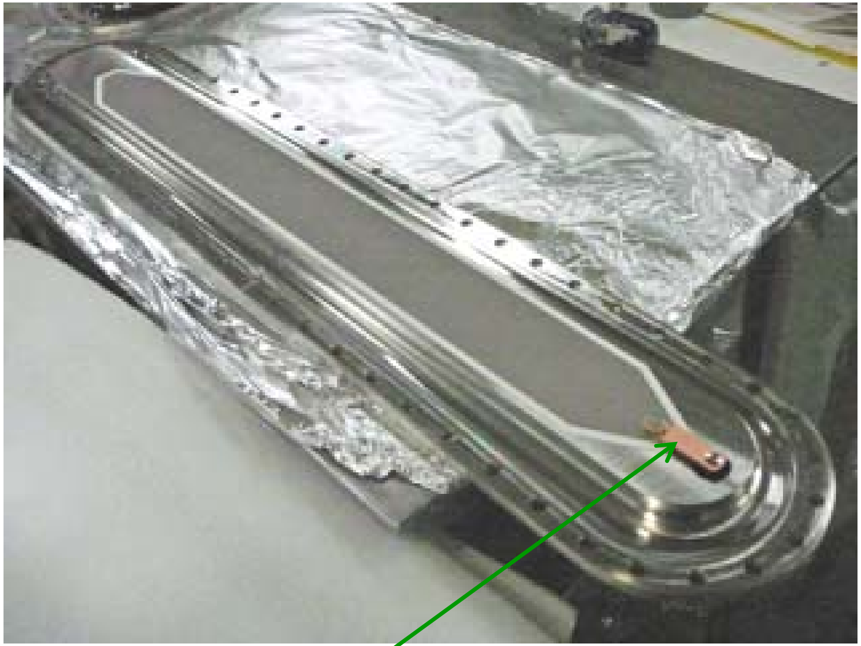
Material	Thermal Conductivity [W/mm/K]
SUS	0.017
Al_2O_3	0.03

Manufacturing of electrode

- Electrode = Hot spray of tungsten (0.1 mm)
- Insulator = Hot spray of Al_2O_3 (0.2 mm)



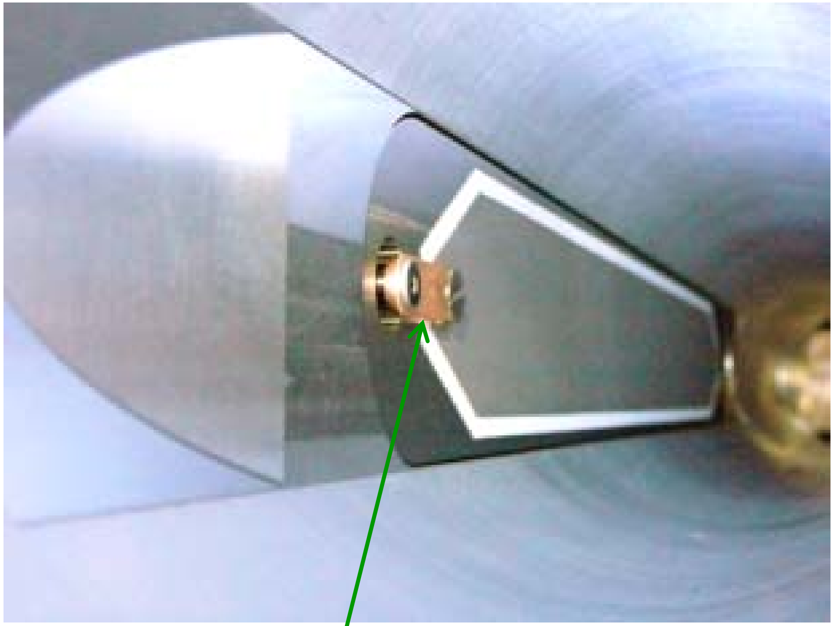
Hole for feed-through

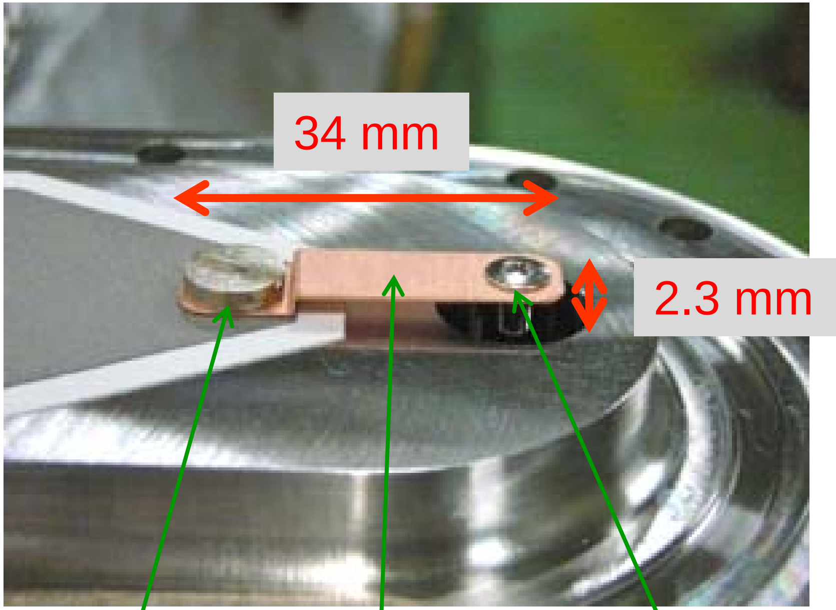


Connection between electrode and feed-through

Assembly of electrode

- Connection part





Connection to feed-through

Bakable up to 140 °C

Metal-coated Al_2O_3 screw

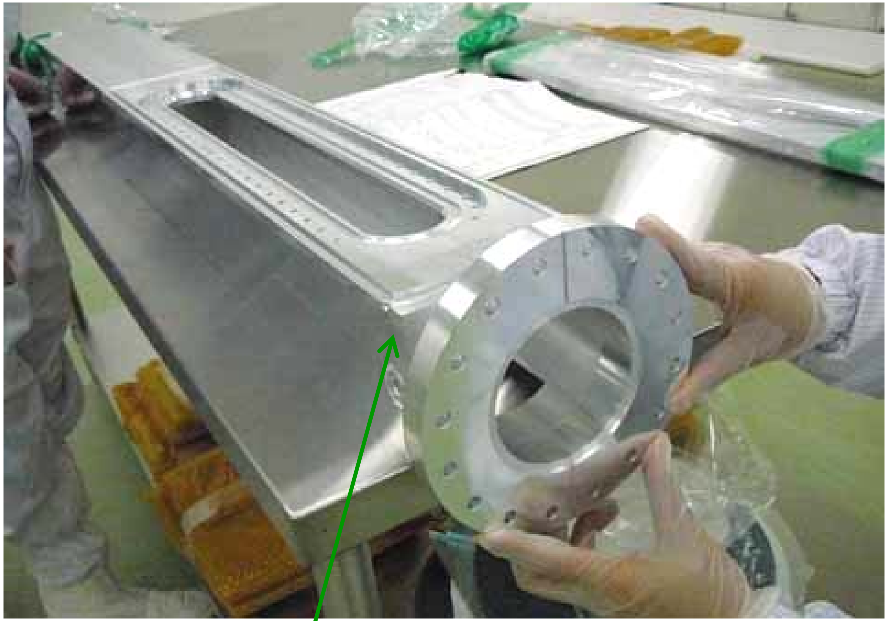
Copper bridge

Metal screw

Manufacturing of chamber

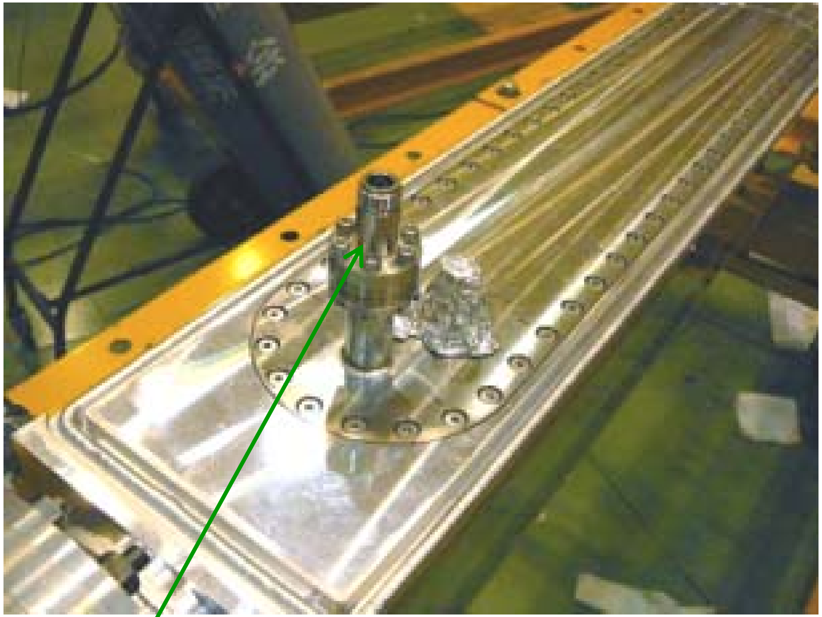
- Test chamber

Chamber



Aluminum-alloy chamber

Feed through



N-type connector

Manufacturing of monitor

- Monitor block

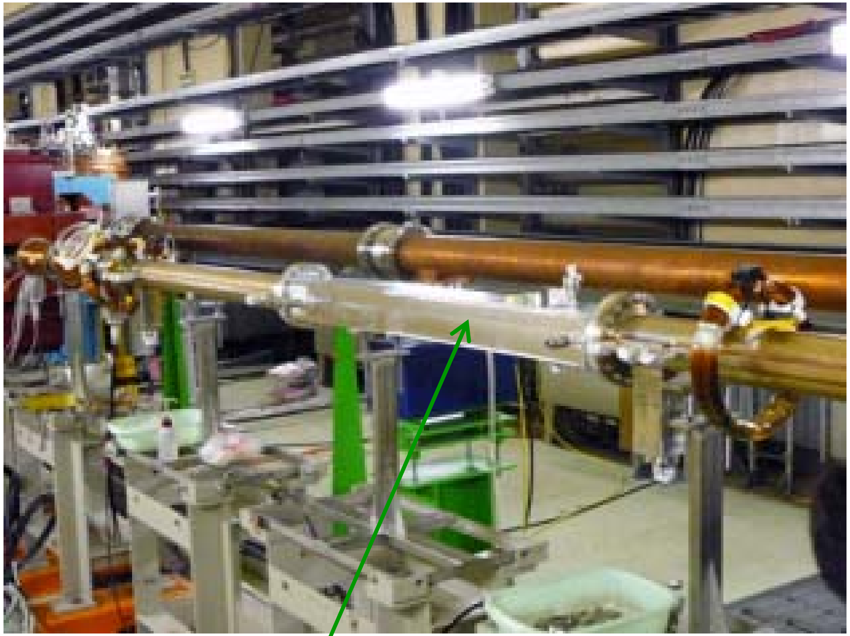
Monitor part

Output feed-through

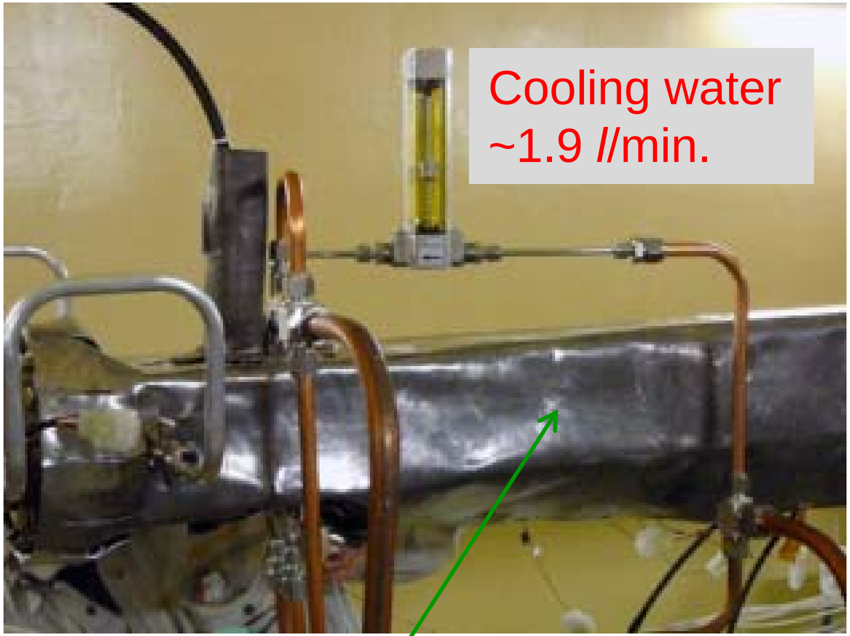
Collector (7 strips)

Installation into KEKB

- Test chamber with only electrode was installed at first in Jan., 2008.
  - To check basic properties, such as heating.
- Outside of magnet in case.



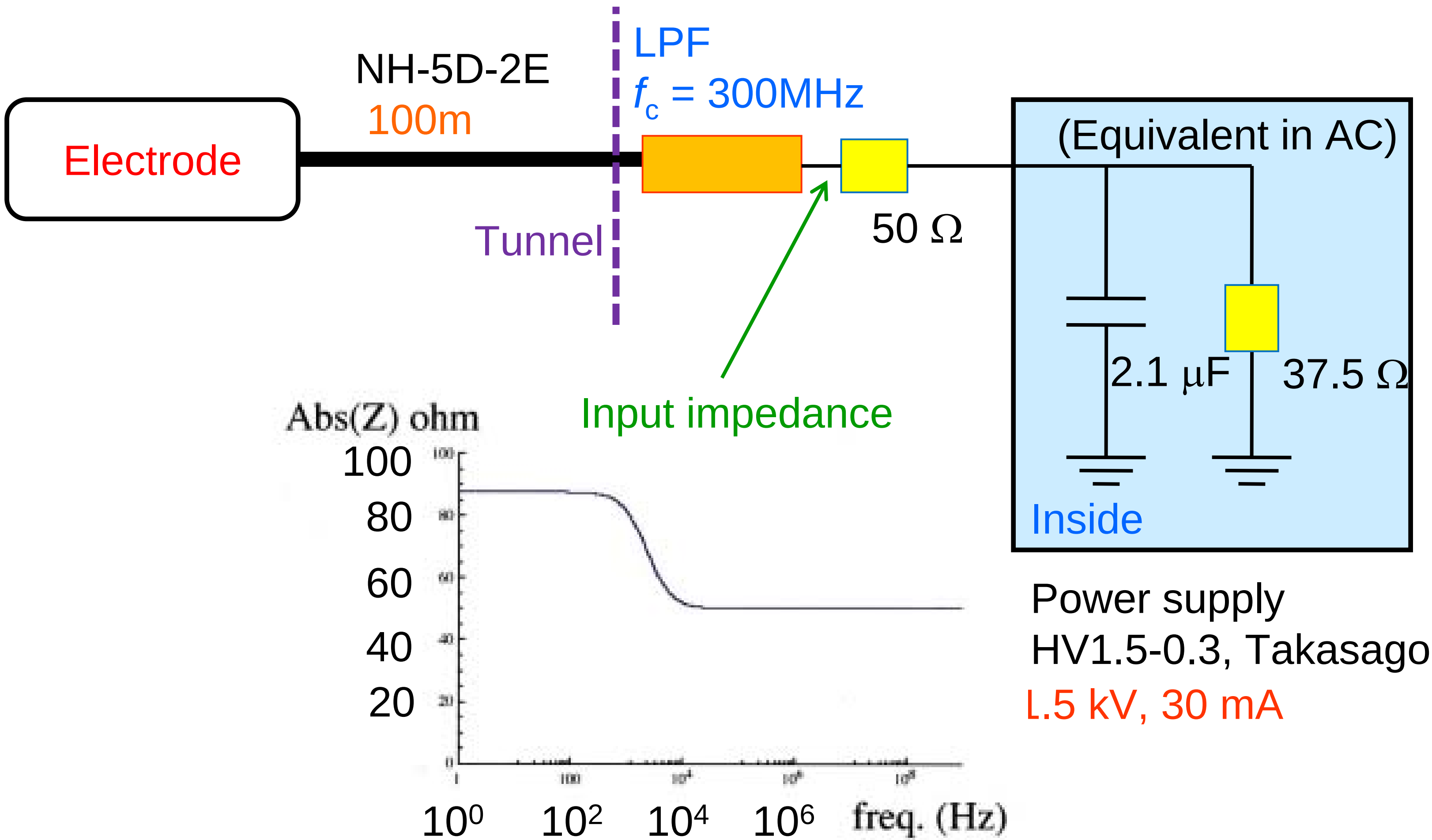
Test chamber



Lead shielding

Power Supply

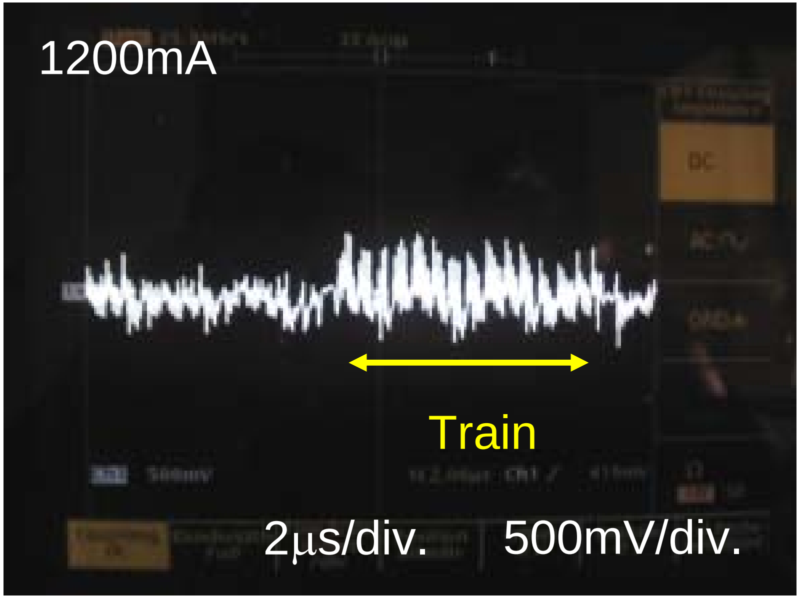
- Basic configuration of power supply

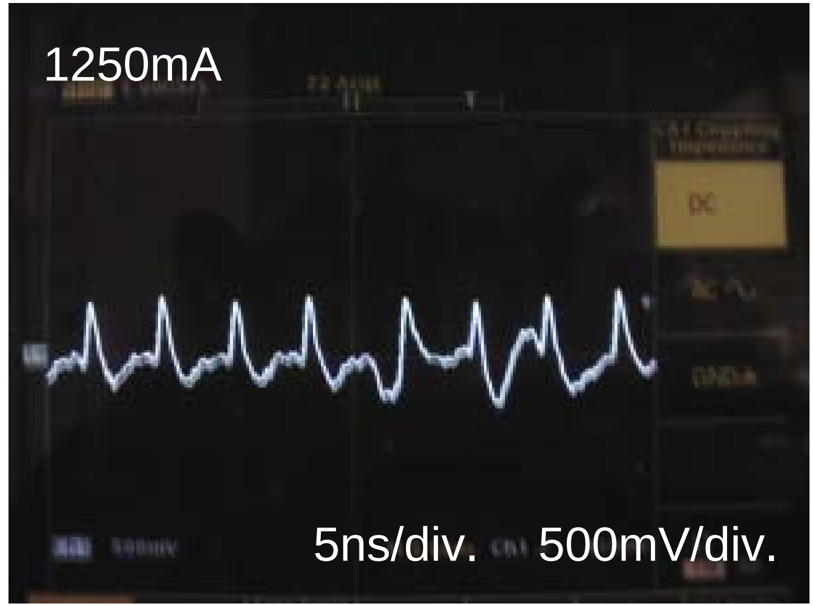


Beam test

- Measurement of bunch signals
  - 1585 bunches

Without LPF

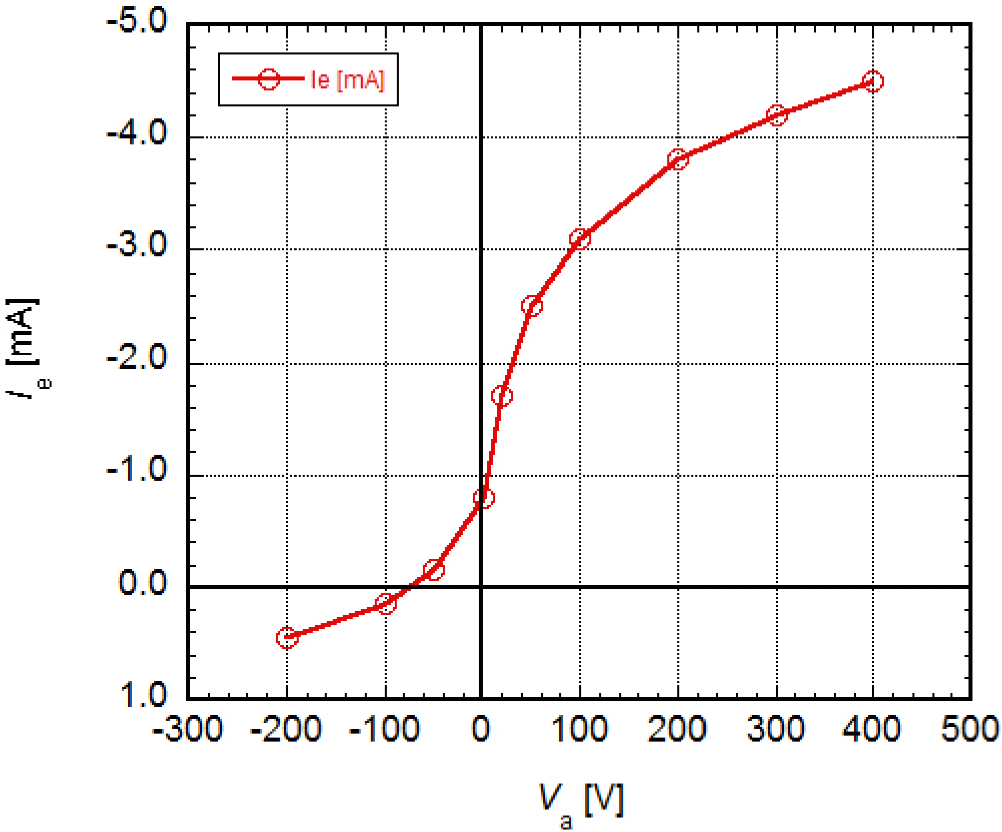




Measured: 1 $V_{p\text{-}p}$ at 1250 mA.
If attenuation of the cable is about 30db, the voltage at feed-through is about 30 V.
Lower than expected. Mismatch of impedance?

Beam test

- Measurement of electron current (DC mode)
  - 1585 bunches, at 1.6 A



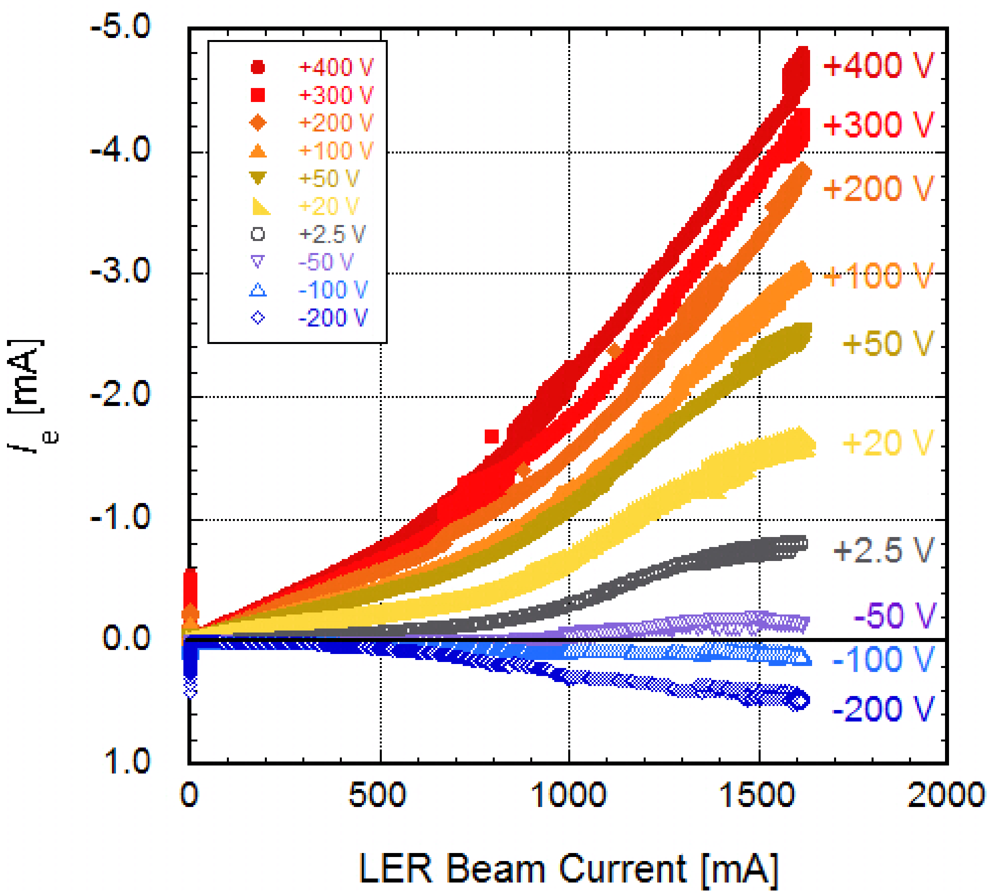
- I_e increases with V_a, but slowly for V_a >300 V.
- Small I_e for negative V_a.

→Main electrons are photoelectron from side walls.

- Photon density at the test chamber is ~2x10^{17} photons/s/m.If the photoelectron yield is 0.2, the expected electron current is ~2.6 mA (for 0.4m).

Beam test

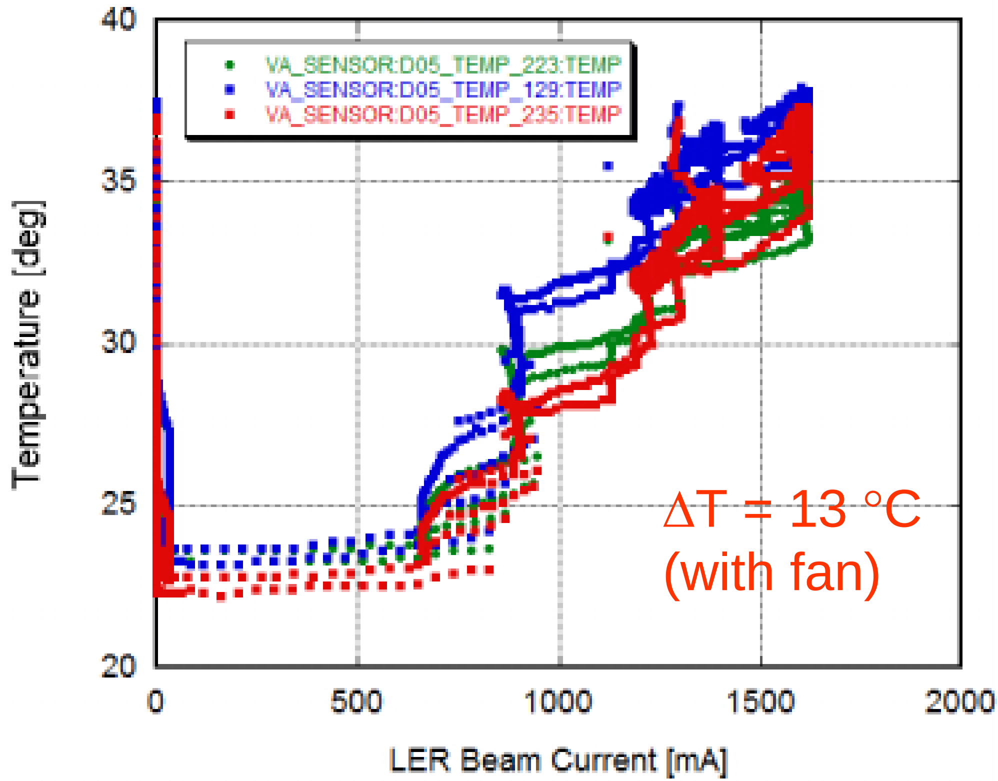
- Measurement of electron current (DC mode)
  – 1585 bunches

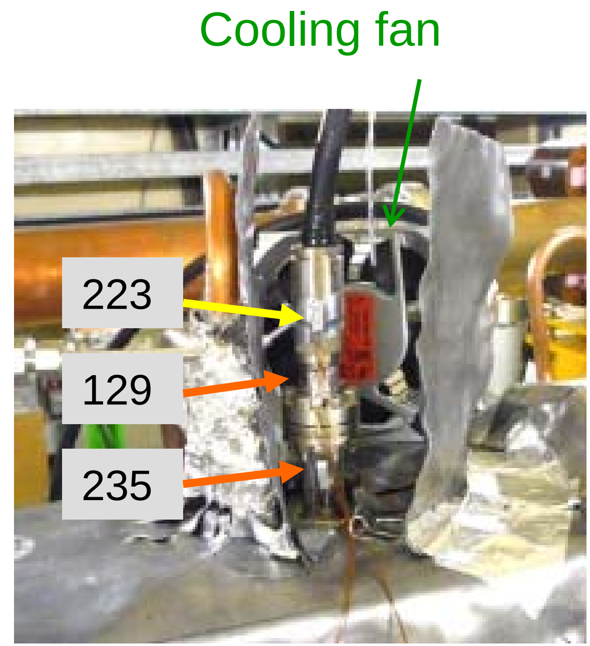


- I_e dependence on the beam current approaches to a line as increasing V_a, especially for high current region.
- Why? Multipactoring of electron is suppressed??
- Further study using monitor is required.

Beam test

- Heating of feed-through



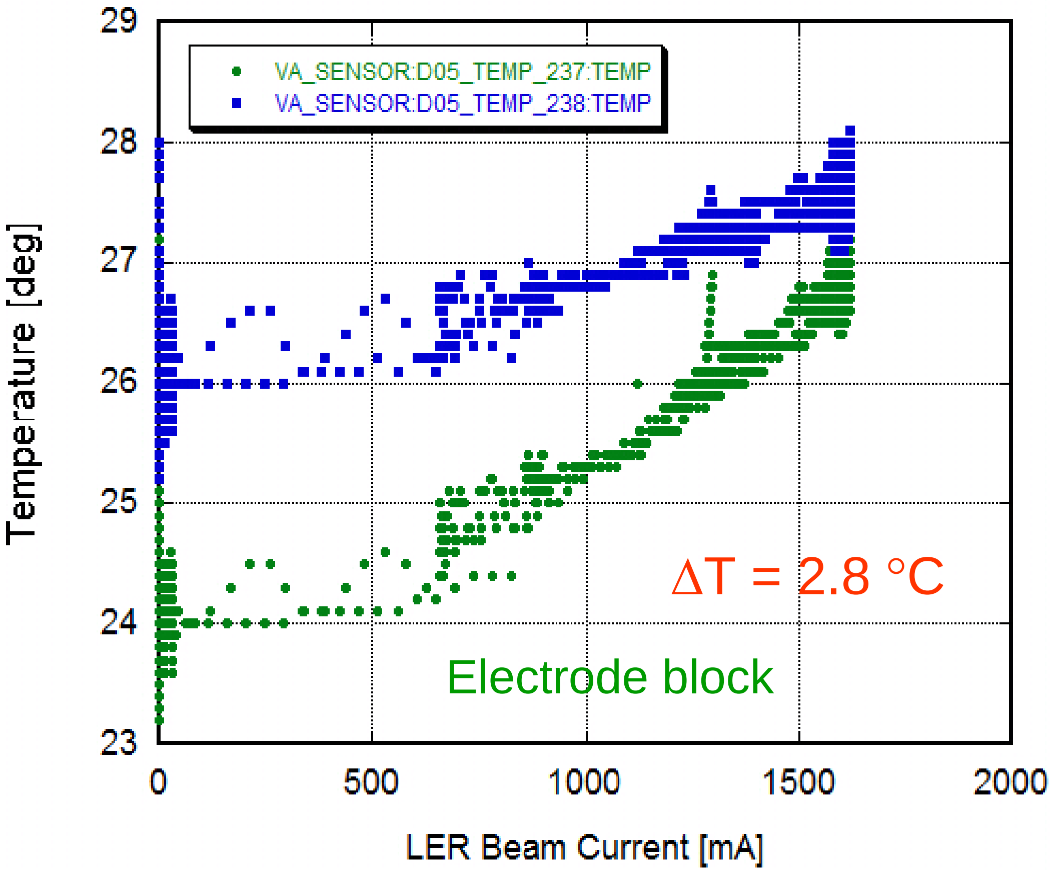


May be ΔT = 100 °C without fan

The feed-through is now cooled by air fan.
The neck will be cooled by a block with cooling water.
Heating due to mismatch of impedance?

Beam test

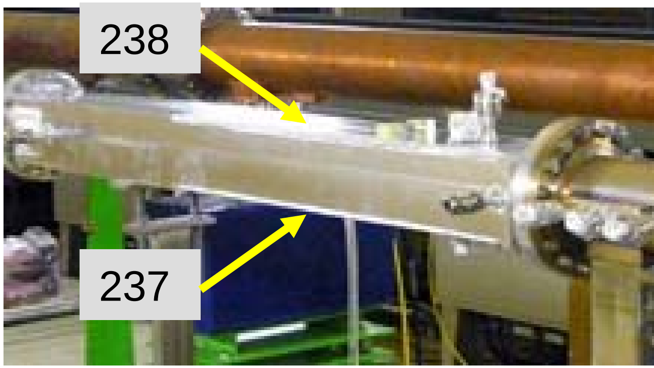
- Heating of electrode block and dummy block



Just behind of electrode block

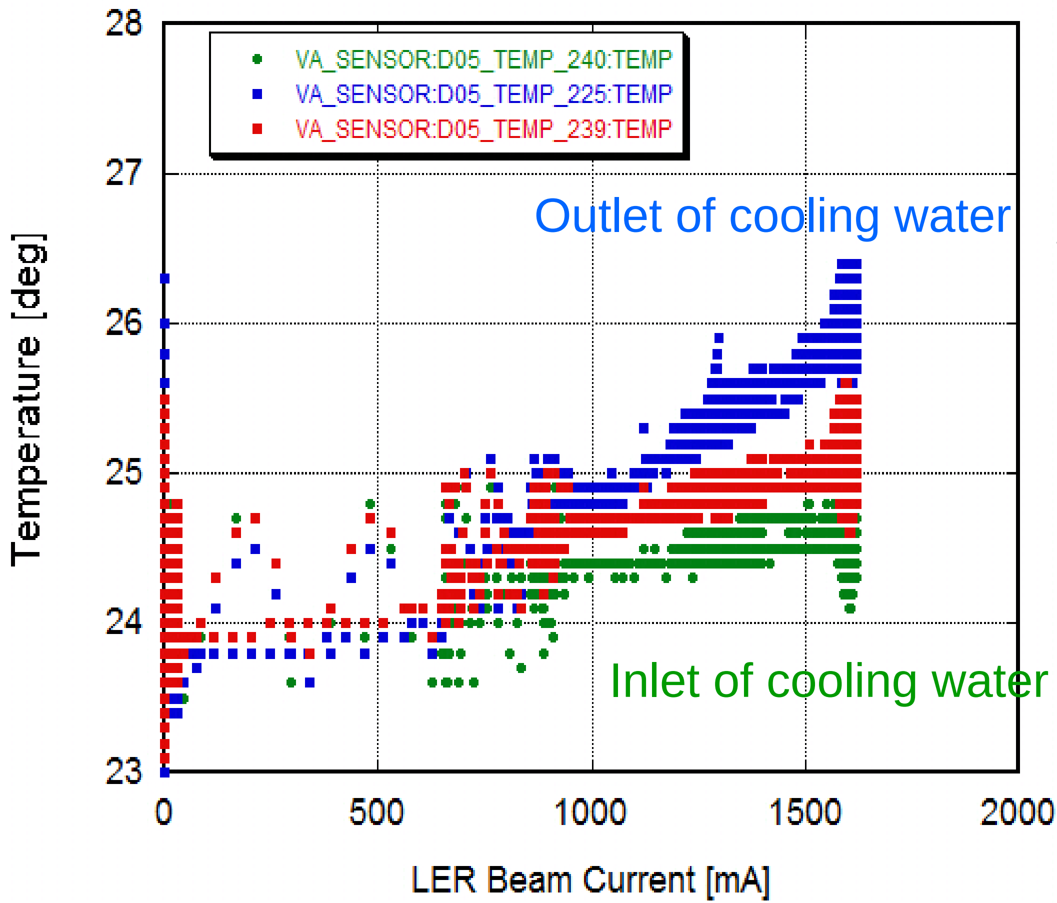
ΔT = 2.8 °C @ 1.6A

Near to expectation.



Beam test

- Absorbed power



Temperature rise:

ΔT = 1.4 °C @1.6 A

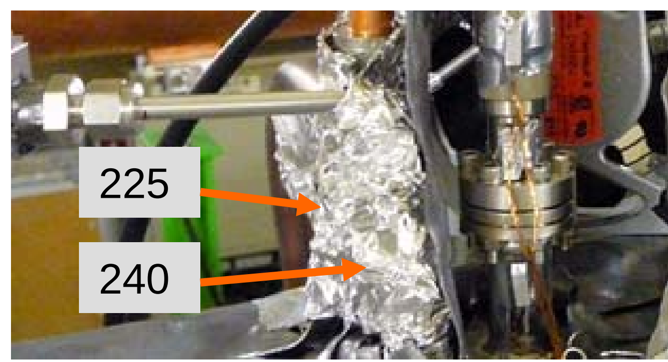
Flow rate: 1.9 l/min.

∴ Absorbed power:

P = 70x1.9x1.4 = 190 W

Calculation: ~130 W

The value is reasonable considering the additional loss by tapers



Summary

- Clearing electrode has been studied for a cure of EC in magnets at KEKB.
  - Thin electrode and insulator contribute to decrease the impedance.
- Beam test of the electrode started from February.
  - The heating is almost reasonable, except for that at feed-through port.
  - The behavior of electron current is reasonable.
  - The first available clearing electrode for high current (~1.6 A) and short bunch (~7mm) machine.
- Problem to be solved
  - Heating at feed through
    - Mismatch of impedance?
  - Long-term stability
    - Change of insulating resistance ?

Test schedule

√ • First step (from February, 2008)
√ – Install outside of magnet (upstream side)
√ – Check the heating of electrode
  – Measurement with electron monitor.→ Next week?
- Second step
  - Install into the wiggler magnet with electron monitor
- Third step
  - Groove surface, Rough surface, and other promising methods.