BEAM TESTS OF A CLEARING ELECTRODE FOR ELECTRON CLOUD MITIGATION AT KEKB POSITRON RING

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Contents

1. Electron cloud issues

- The electron-cloud effect is one of the most important problems in recent high-intensity positron/proton storage rings.
  - The electron cloud excites single or multi-bunch beam instabilities and deteriorates the performance.
- Various types of techniques for mitigating this effect have been studied so far, such as
  - Beam pipe with antechamber(s)
  - Solenoid around a beam pipe
  - Coatings with a low secondary electron yield (SEY)
    - TiN, NEG materials, Graphite
  - Grooved surface
  - Clearing electrode

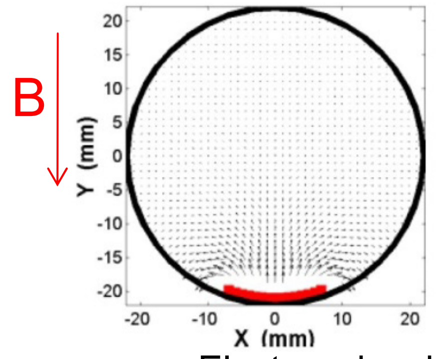
Here reported on R&D of the clearing electrode for positron rings.

2.1 Clearing electrode

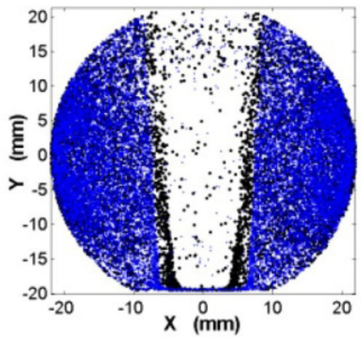
- The clearing electrode in a beam pipe had been said to be an effective method to reduce the electron density around the beam by absorbing electrons through a static electric field.
- Especially, it is available in a magnetic field, unlike a solenoid for drift space.
- However, the heating and impedance problem have been precluding the use of electrodes to high-intensity positron rings (≥1mA/bunch), where the bunch length is relatively short (≤ 1 cm).

New electrode structure has been developed in KEK and tested with an intense positron beam.

Electric potential



Electron density

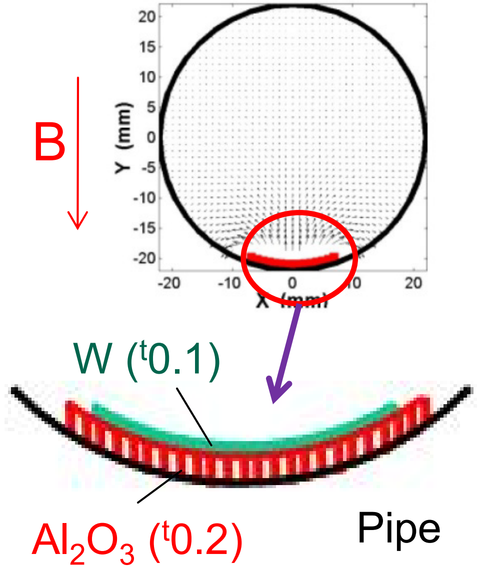


Simulation by L. Wang

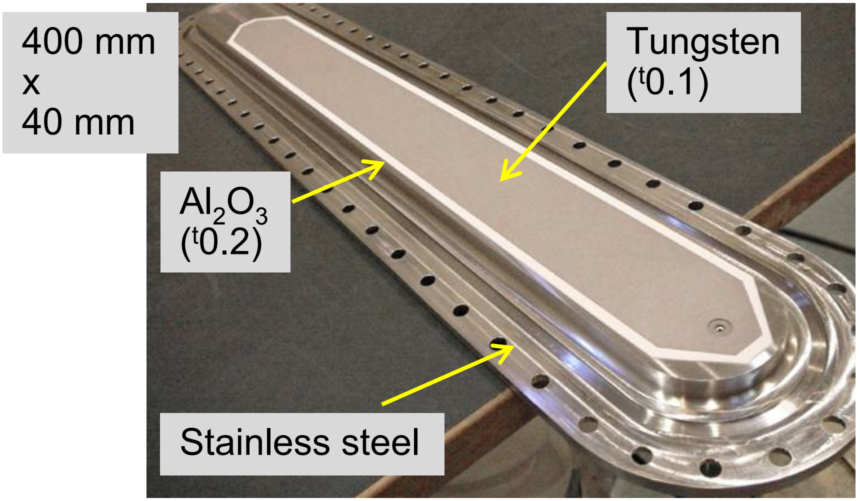
2.2 Newly-developed clearing electrode

- Very thin electrode structure
  - 0.2 mm Al_2O_3 insulator and 0.1 mm tungsten (W) electrode formed by a thermal spray method.
  - High adhesion

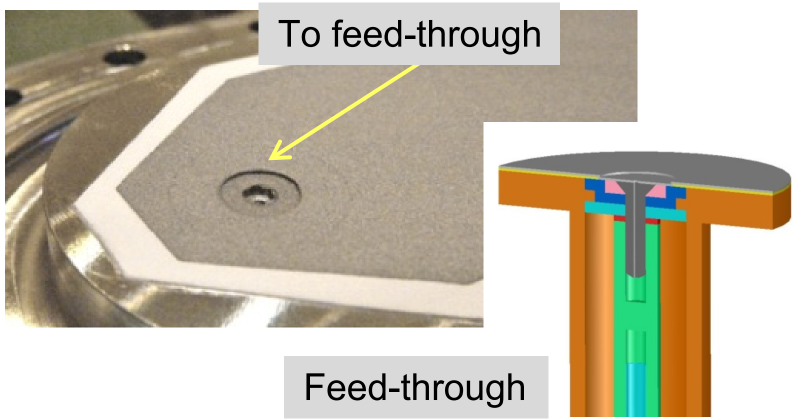
    ⇒ Good heat transfer and low beam impedance
- Flat connection between feed-through and electrode
  - Step ≤ 0.3 mm except for a small hole on screw head.



An insertion for test with a thin electrode



Connection to feed through



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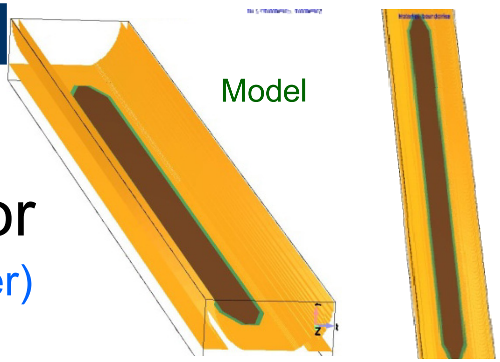
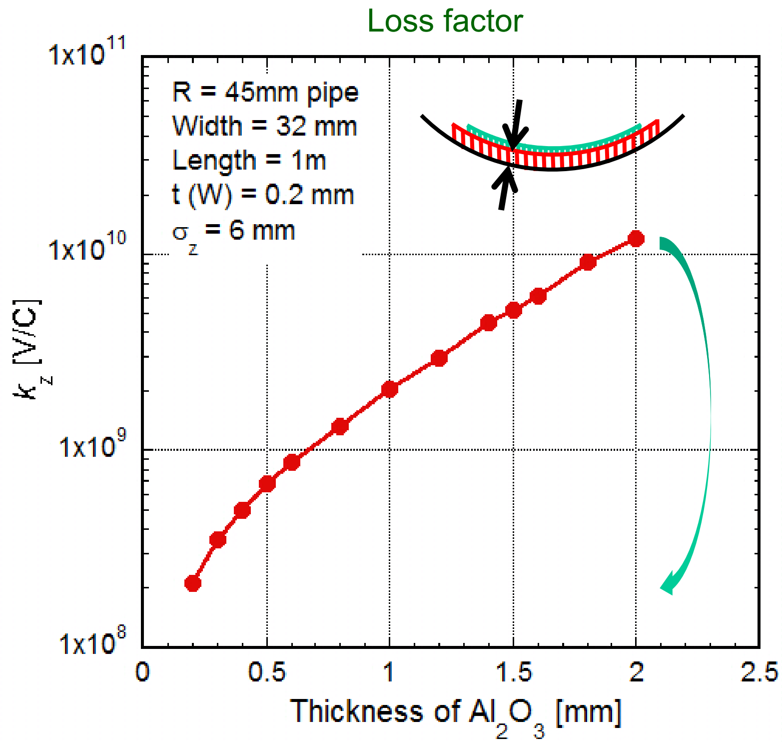
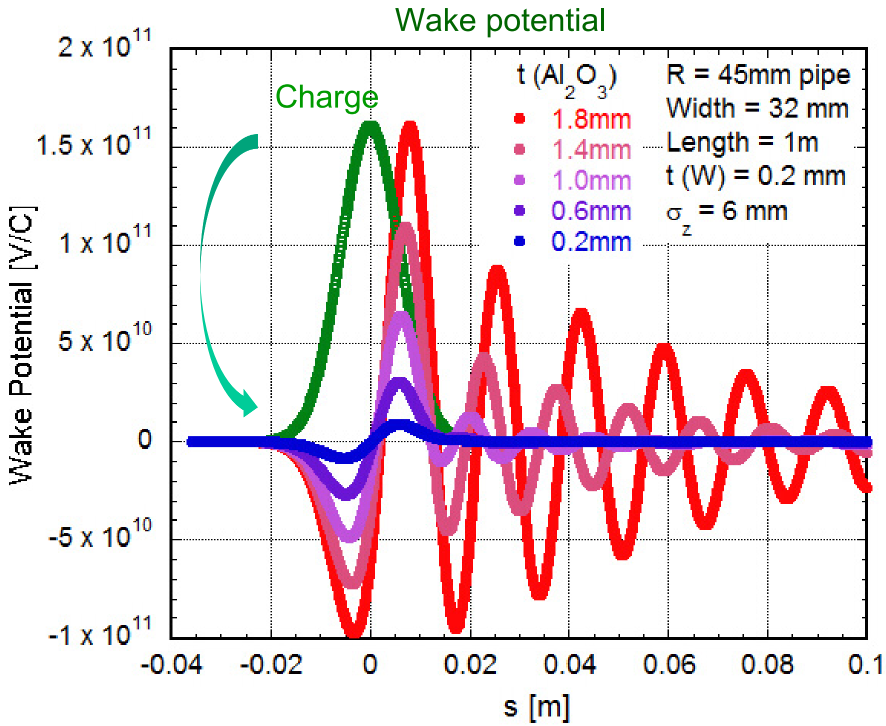
2.3 Merit of the thin electrode -1



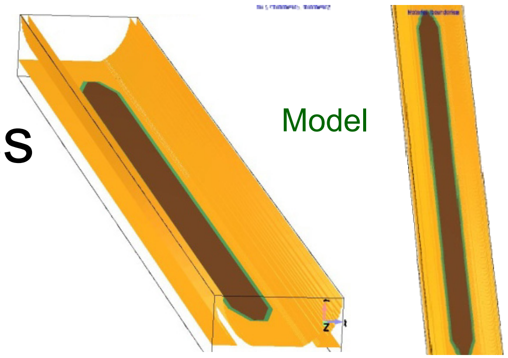
- Dependence of loss factor and wake potential on the thickness of Al_2O_3 insulator
  - Calculated by using GdfidL (1m model, half chamber)
  - ^{t}0.2 mm ~ 2.0 mm (pipe: ϕ90mm)



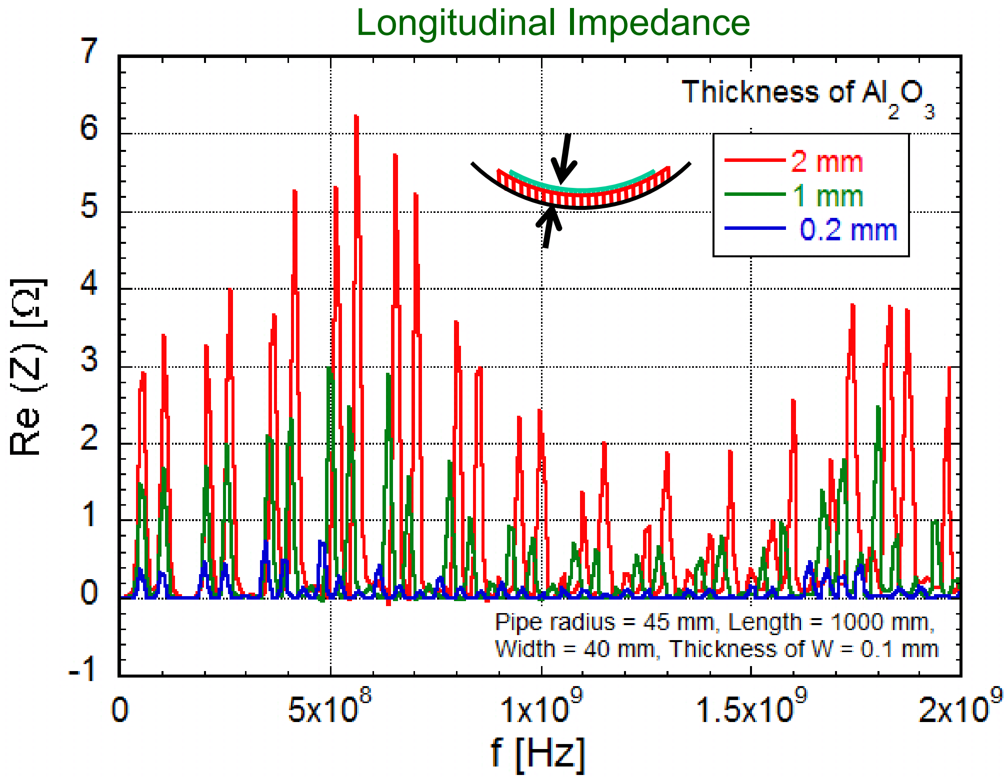


- With a decrease in the thickness of insulator, the loss factor decrease.
- The wake potential also decreases, and is inductive for thin insulator.

2.3 Merit of the thin electrode -2



- Dependence of impedance on the thickness of Al_2O_3 insulator
  - ^{t}0.2 mm ~ 2.0 mm



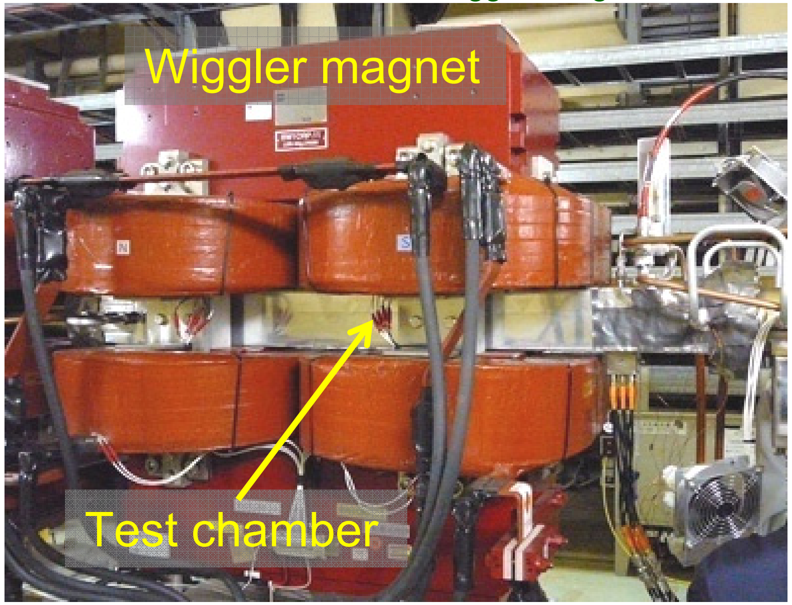
- Calculated for 20 m (for σ_z = 20 mm).
- A periodic impedance is found as in the case of a usual strip line.
- The peak values become small with decreasing the thickness of insulator.
- The values are less than 1 Ω. Q ~ 20.

- Relatively easily manufactured by using the thermal spray.
  - Open space above the surface is required.

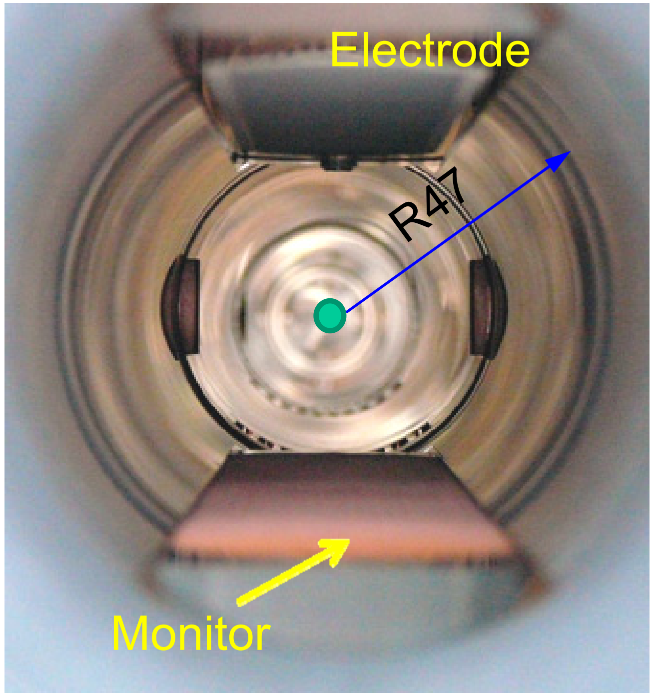
3.1 Beam test in a wiggler magnet -1

- A test chamber was installed in a wiggler magnet. [2008]
  - Magnetic field: 0.78 T
  - Effective length: 346 mm
  - Aperture (height): 110 mm
  - Photons: $1x10^{14}$ photons/s/m/mA

Test chamber in a wiggler magnet



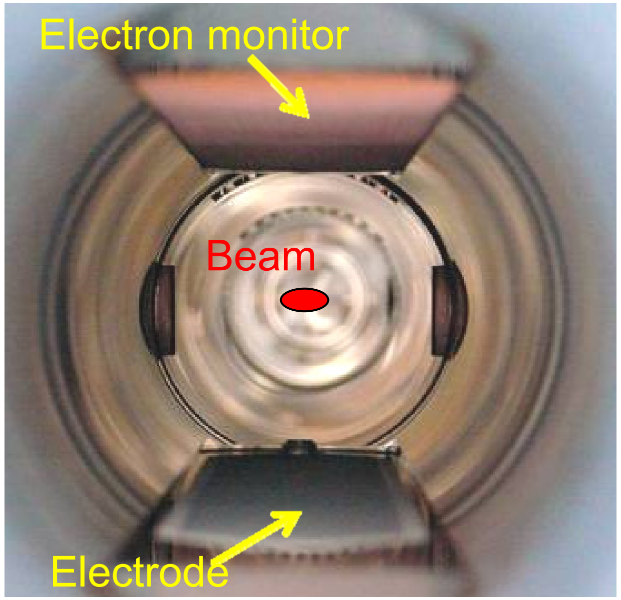
Inside view

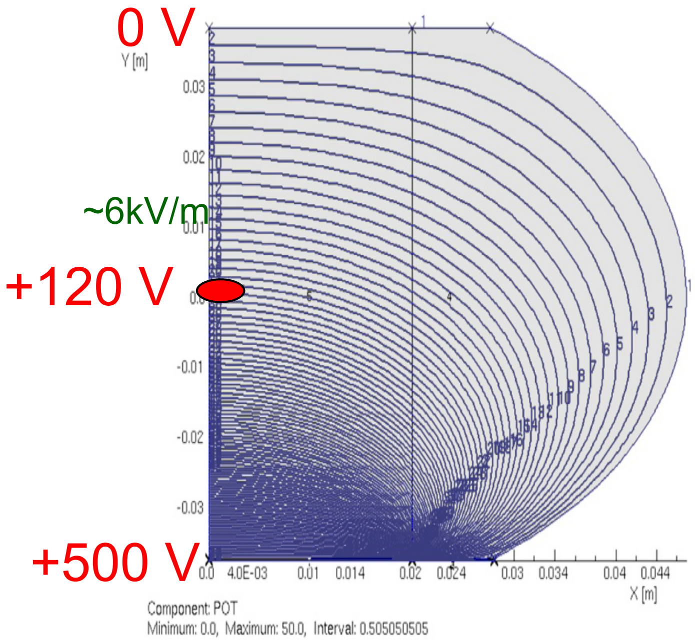


- An electron monitor and an insertion with an electrode are placed at the center of a pole, face to face.
- Electron monitor has an RFA and 7 strips to measure spatial electron distribution (~40 mm width in total).

3.1 Beam test in a wiggler magnet -2

- Electric potential in the test chamber
  - ~6 kV/m at the beam orbit, when 500 V is applied to the electrode.

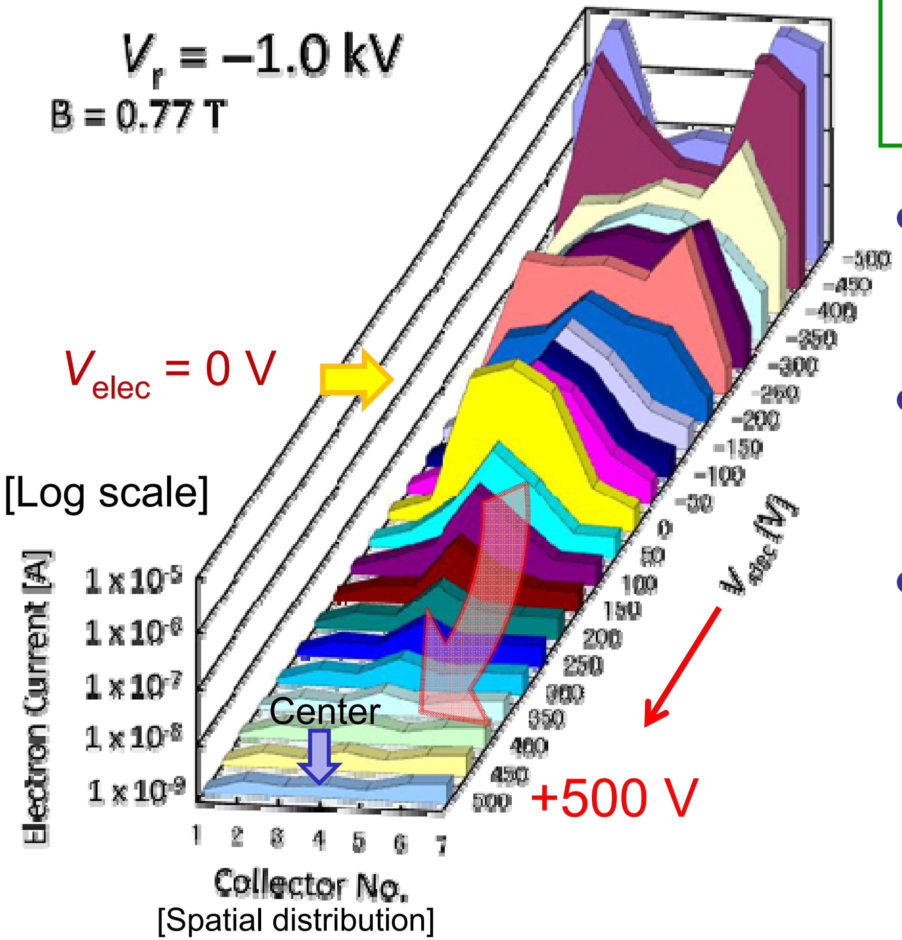




- KEKB positron ring
  - Energy = 3.5 GeV
  - Beam current ~1.6 A with 1585 bunches (~1 mA [=10 nC] /bunch)
  - Typical bunch spacing ~ 6 ns (4 ~ 16 ns in study)
  - Bunch length ~ 6 mm at 1.6 A

3.2 Results -1

- Effect of electrode voltage (V_{elec})
  - Drastic decrease in the electron currents by applying V_{elec} was observed.



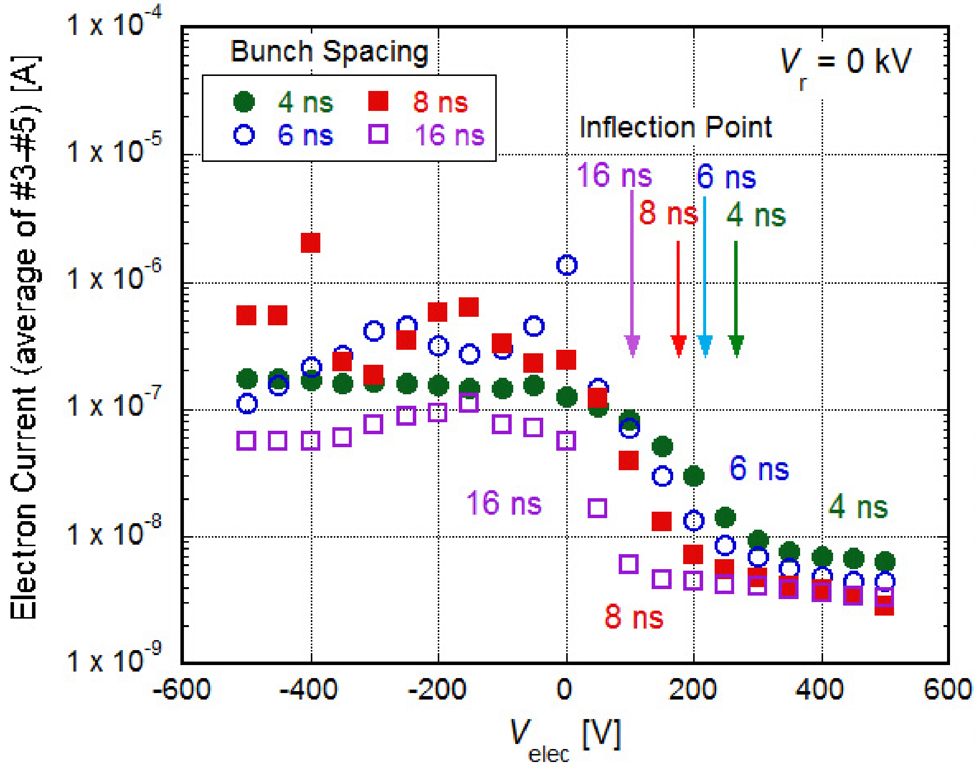
1585 bunches
(B_s ~ 6 ns)
~1600 mA
(~1mA/bunch)

- The electrons with an energy > 1 kV comes from near the beam
- The electron currents reflect the electron density around the beam.
- For negative V_{elec}, electrons flows into the monitor. Detailed simulation will be required to understand the complicated behavior of measured data.

3.2 Results -2

- Effect of electrode potential (V_{elec})
  - Similar effect was observed for 4 ~ 16 ns spacing.

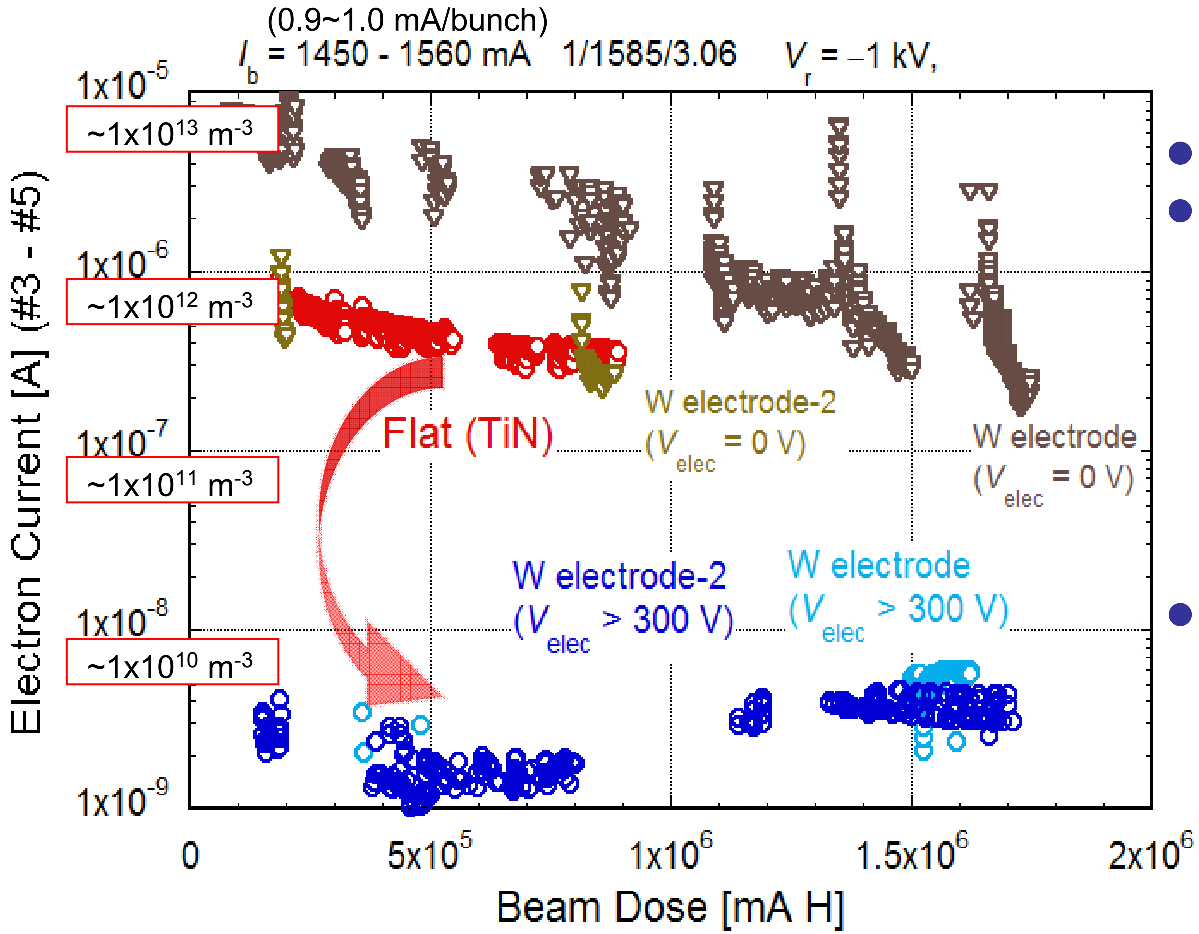
(0.9~1.0 mA/bunch)



- The density greatly decreased by V_{elec}~300 V.
- The electrode seems more effective for the bunch filling patterns with longer bunch spacing.

3.2 Results -3

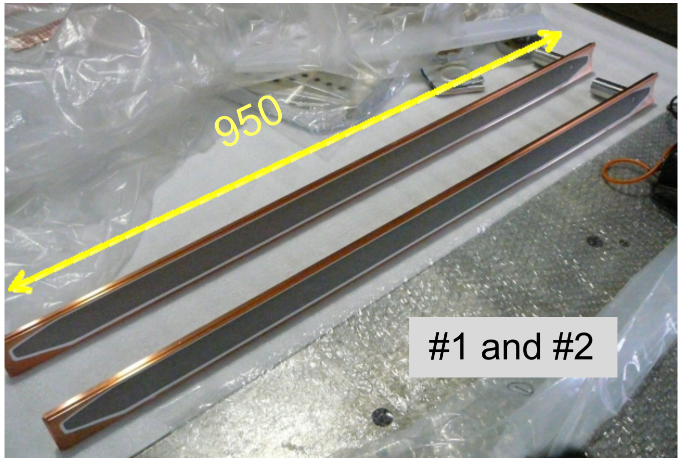
- Comparison with a flat TiN-Coated surface
  - The electron density decreased to less than ~1/100 at V_{elec} > ~+300 V compared to the values at V_{elec} = 0 V (W) and a TiN-coated flat surface.

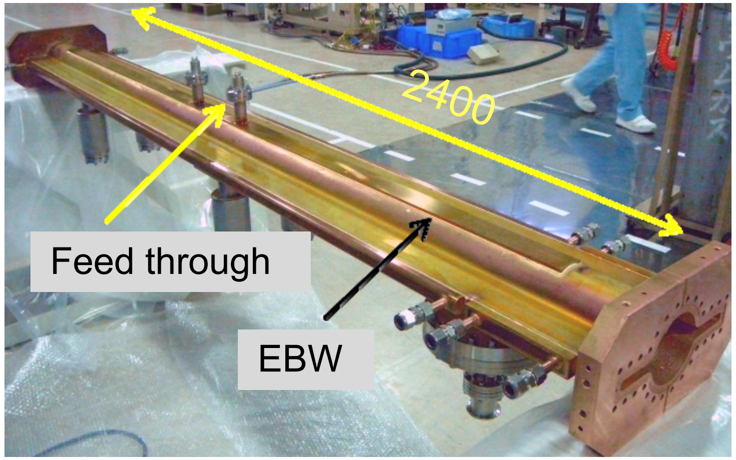


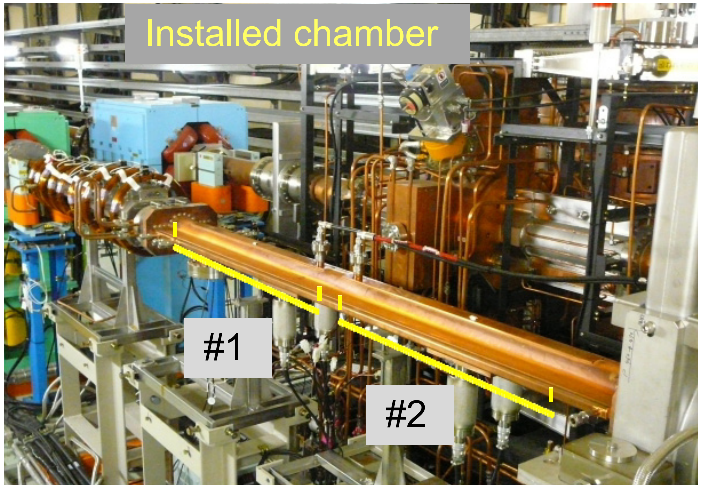
- Two-time experiments.
- Electron currents for the thermal-sprayed tungsten (V_{elec} = 0V) is similar to the case of flat TiN-coated surface. ←Rough surface?
- No extra heating of electrode and feed-through was observed.

4.1 Application to a beam pipe with antechamber

- Final check of heating of electrode and feed through [2009]
  - Beam pipe with antechamber will be used for the wiggler section of Super KEKB.
- The beam pipe was installed at a magnetic-free region.
  - But the length was adjusted to fit the real wiggler magnet.
  - Length = 950 mm, width = 32 mm.

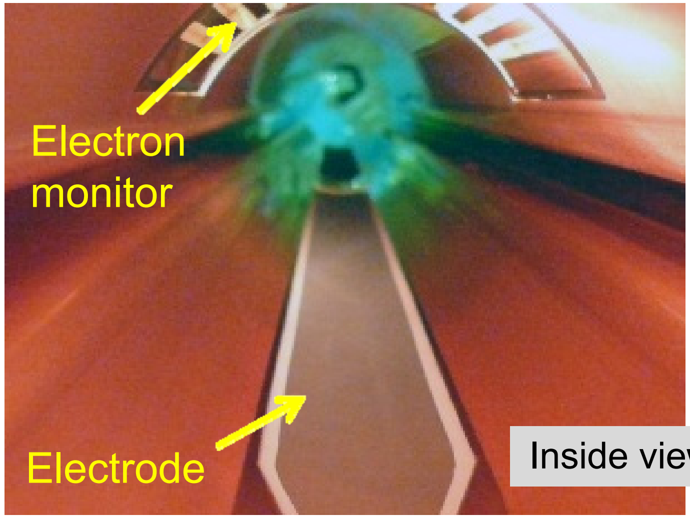


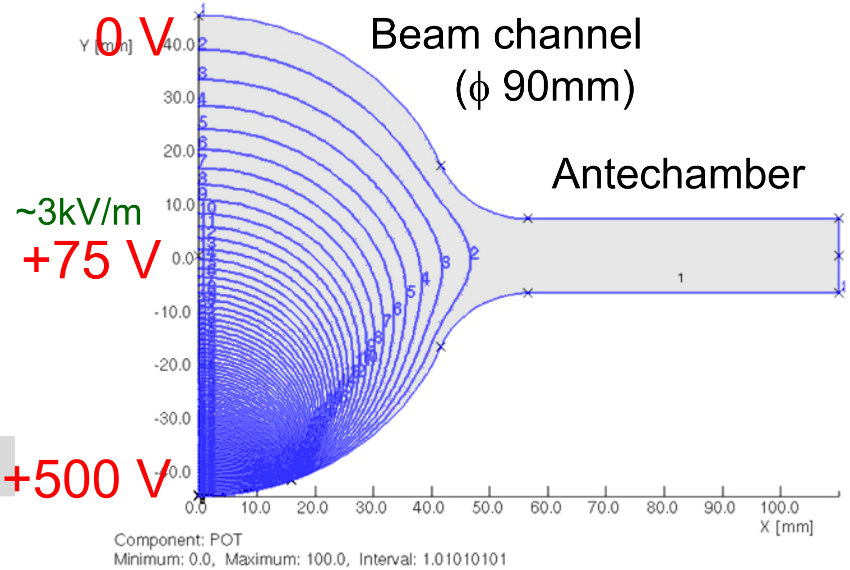




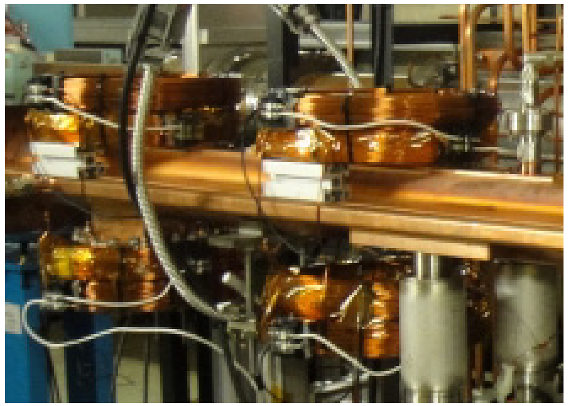
4.1 Application to a beam pipe with antechamber

- Electric potential in the beam pipe
  - ~3 kV/m at the beam orbit, when 500 V is applied to the electrode.



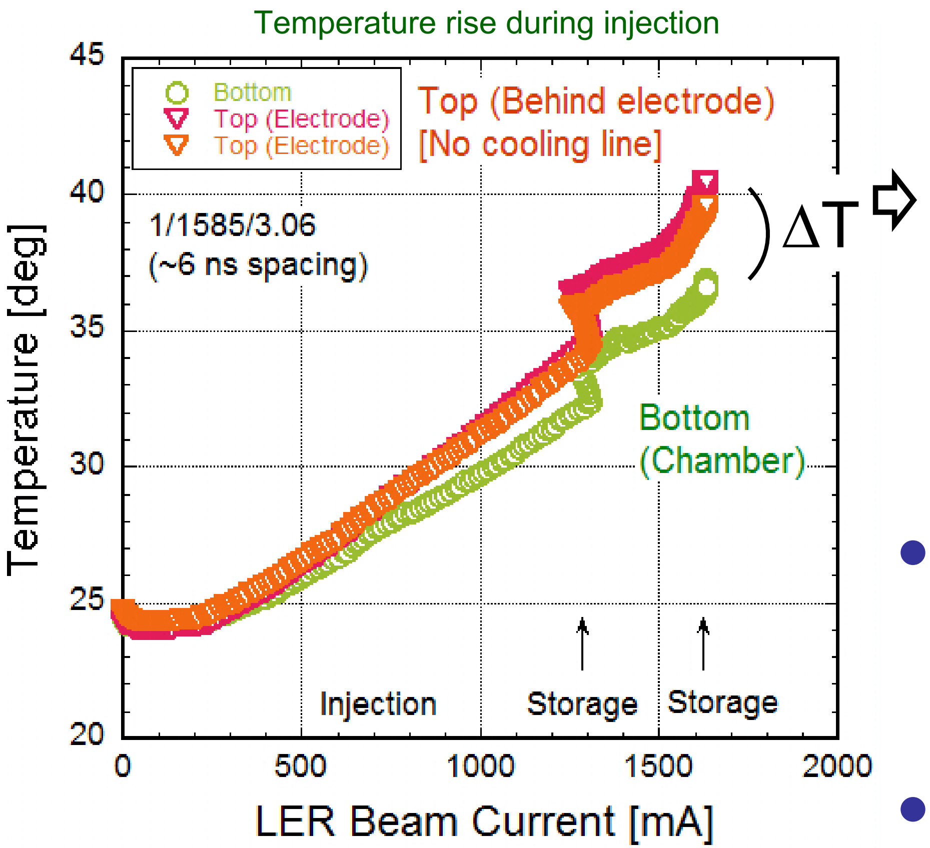


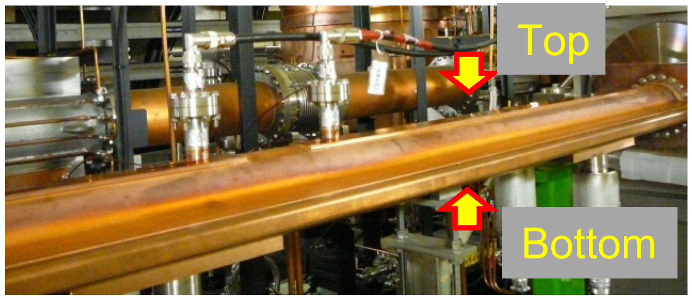
- Vertical field was applied by solenoids for test at the position of an electron monitor.
  - ~ 70 G at max.

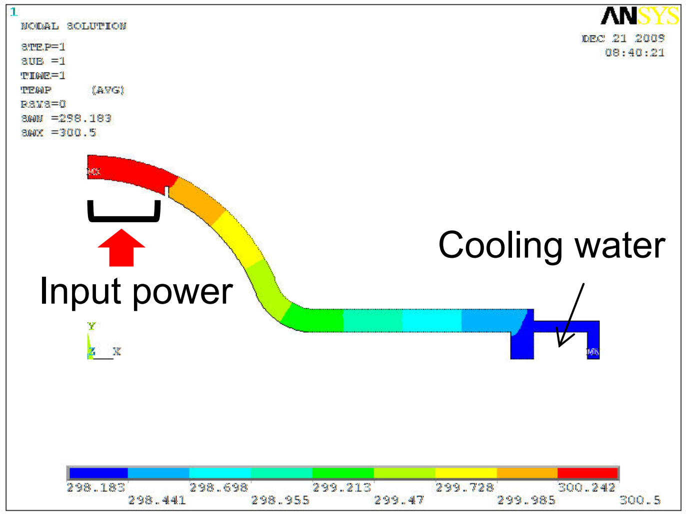


4.2 Results -1

- Heating of electrodes
  - Temperature behind the electrode was measured.
  - No cooling channels in the back



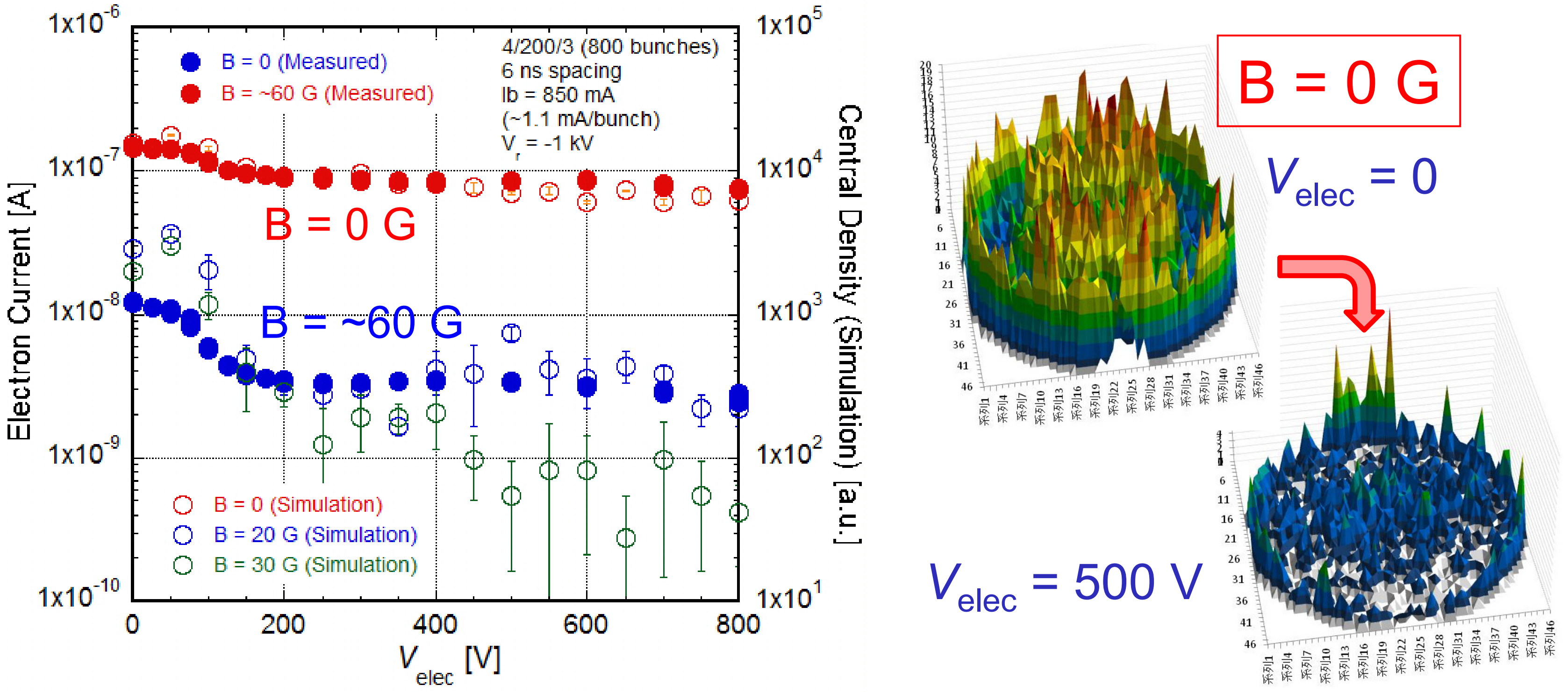




- Estimated input power was ~40 W/m: reasonable value considering Joule loss and parasitic loss.
- No heating at feed through: < 30°

4.2 Results -2

- Effect of electrode voltage (V_{elec}) in magnetic-free condition
  - Electron density decreased with an increase in electrode voltage. But the reduction was much smaller than the case inside wiggler magnet.
  - The reduction became larger by applying a vertical field of B ~ 60G.
  - The reduction rate seems reasonable from a simulation:
    - Effective to electrons near the electrode for B = 0 G



5. Impedance issues

- Influence estimation of the impedance on a storage beam has recently started assuming that the electrode is used for the wiggler section of Super KEKB.
  - The total length of the electrodes will be approximately 160 m (100 electrodes) out of 3016 m circumference.
- Preliminary result (σ_z=6 mm, ϕ = 90 mm)

Total loss factor	O	1.7×10^{11} V/C << 1.8×10^{13} V/C in total for one ring
Microwave instability	O	By simulation
Longitudinal coupled bunch instability	O	Total $R_s \leq 100\ \Omega$, R_s/Q = 0.1~1 Growth rate ~1 1/s < 30 1/s
Transverse coupled bunch instability		To be evaluated
Transverse mode coupling instability	O	Total kick factor ~ 1.6×10^{13} V/C/m. Threshold bunch current ~ 430 mA/bunch.

8. Summary of clearing electrode

- The newly developed thin electrode structure works well even under an intense positron beam.
  - No heating of electrode and feed-through in the latest version.
- The effect on reducing the electron cloud is drastic in a strong magnetic field.
  - Much larger than other methods, such as coatings, grooved surfaces.
  - It worked even in a magnetic-free condition, but the effect was smaller than in the strong magnetic field. More studies are required in the future.
- The electrode seems to be available for the wiggler section in Super KEKB
  - The final beam test is ongoing.
  - The influence of impedance on the storage beams seems small.
  - Further detailed investigation will continue.