Updates on EC mitigation studies at KEKB

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on behalf of KEKB Vacuum Group

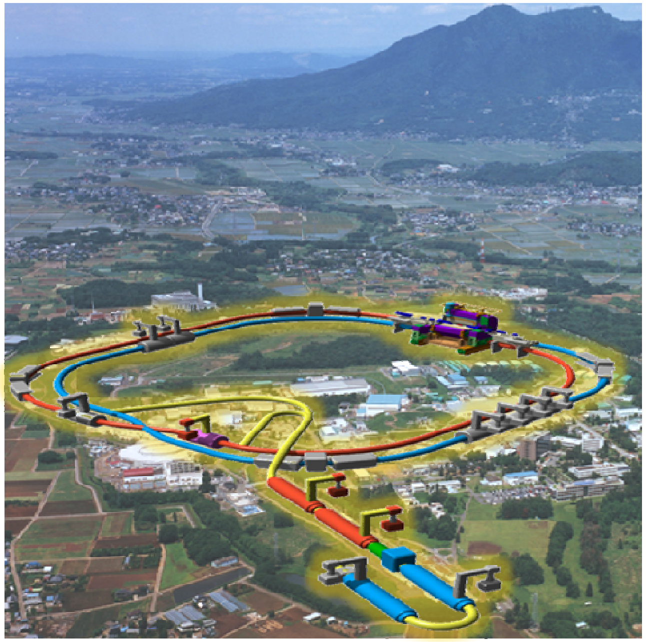
- Electron cloud issues for Super KEKB
- R&Ds about
  - Clearing electrodes
  - Grooved surfaces
- Summary and Remained issues

EC issues for SKEKB_1

- **Electron cloud instability** can be a serious problem for positron/proton rings, and the Super KEKB positron ring is no exception.
- The threshold of average electron density to excite the single-bunch instability for SKEKB is ~1×10^{11} e^-/m^3.
(from a recent simulation by K. Ohmi and Y. Suzaki @LER2010)

L =	8E35 $cm^{-2}s^{-1}$
ε_x =	1.7(e^-) ~ 3.2(e^+) nm
Circumference =	3016 m
Energy =	4.0 GeV
Beam current ~	3.6 A
Bunch numbers =	2500
Bunch current =	1.4 mA
Bunch charge =	14 nC
Bunch spacing =	4 ns
Bunch length =	6 mm
Bending radius =	71 m

Super KEKB site (Tsukuba)



EC issues for SKEKB_2

- **On the other hand, the expected average electron density without any cures is**

  $<n_e>\sim 5\times10^{12}\ e^-/m^3$

  – Estimated from experiments so far at KEKB, for a circular **copper** pipe (ϕ 94mm), 4 ns spacing, 1 mA/bunch, and no solenoid field.

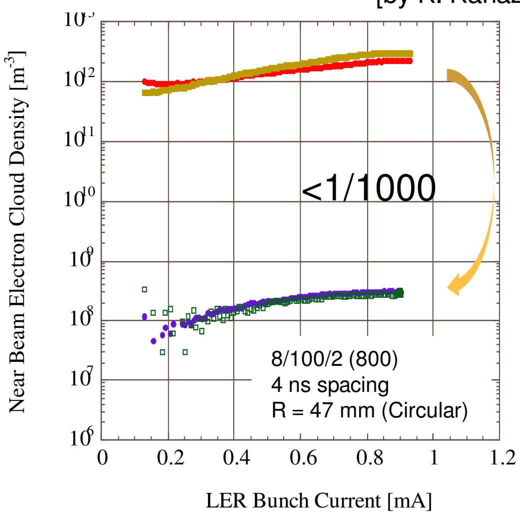
- **Any countermeasures are required to reduce $<n_e>$ down to 2%! (to $\sim 1\times10^{11}\ e^-/m^3$)**
  – Main contributions are from drift (field free) regions and corrector magnets regions : ~90 %
  – **Solenoid field**, beam pipes **with antechambers** and **with TiN coating** (if aluminum pipe) should be used for these region.
  – Beam pipes with antechambers and with TiN coating (if aluminum pipe) will be also used in magnets.

EC issues for SKEKB_3

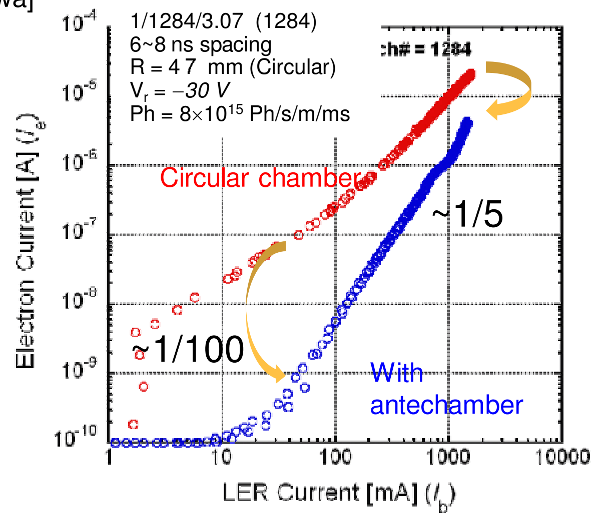
- **Established counter measures**
  (from simulations and experiments at KEKB LER [ϕ94])
  - **Solenoid filed** at drift section (~50 G): Effective to both photoelectrons and secondary electrons →~1/50
  - **Ante-chamber scheme** : Effective to photoelectrons. Adopted at PEPII LER →~1/5
  - **TiN coating** : Effective to secondary electrons. Adopted at PEPII LER →~3/5

Effect of solenoid

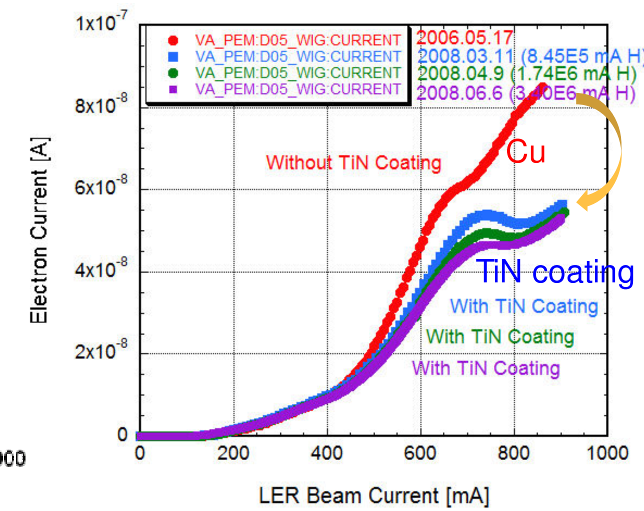
[by K. Kanazawa]



Effect of antechamber



Effect of TiN coating



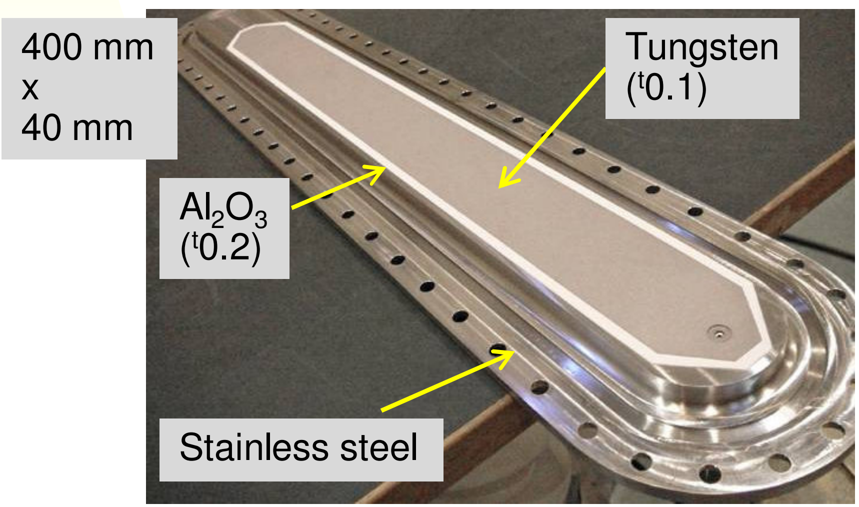
EC issues for SKEKB_4

- However,
  - Even if these countermeasures are applied, the <n_e> is still a borderline value.
- The remaining electrons are mainly in dipole regions (bending magnets and wiggler magnets). →Other effective cures in dipole field regions are required!
- The following countermeasures has been studied at KEK.
  - Clearing electrode
    - Absorbs electrons by an electro-static field
  - Grooved surface
    - Reduces effective SEY geometrically
- Experiments have been proceeding at KEKB LER.
  - Also as a part of US-Japan collaboration for ILC DR

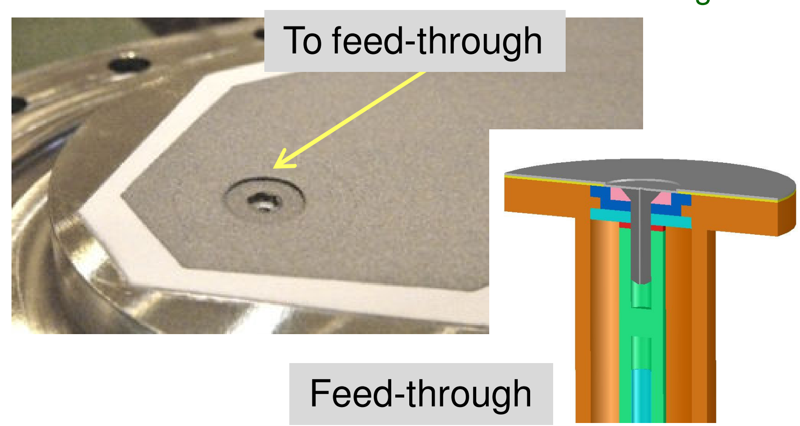
Clearing Electrode_1

- **Very thin electrode structure** was developed.
  - 0.2 mm Al_2O_3 insulator and 0.1 mm tungsten (W) electrode formed by a thermal spray method
  - Good heat transfer and low beam impedance
  - ±1 kV is OK.
  - Flat connection between feed-through and electrode

An insertion for test with a thin electrode



Connection to feed through



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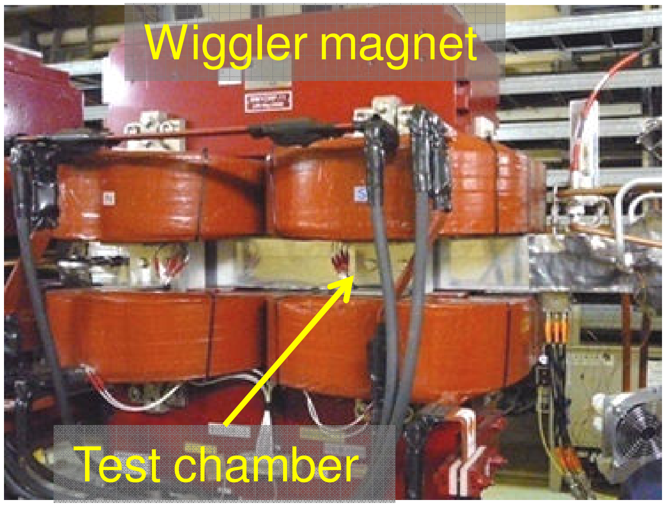
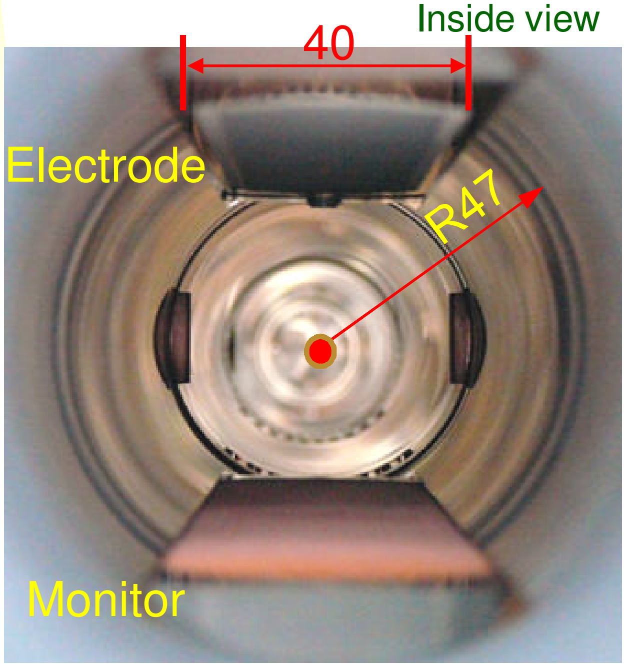
Clearing Electrode_2

- A test chamber was installed in **a wiggler magnet**.
  - Magnetic field: 0.78 T
  - Effective length: 346 mm
  - Aperture (height): 110 mm
  - Photons: 1×10^{14} photons/s/m/mA

Test chamber in a wiggler magnet



Inside view



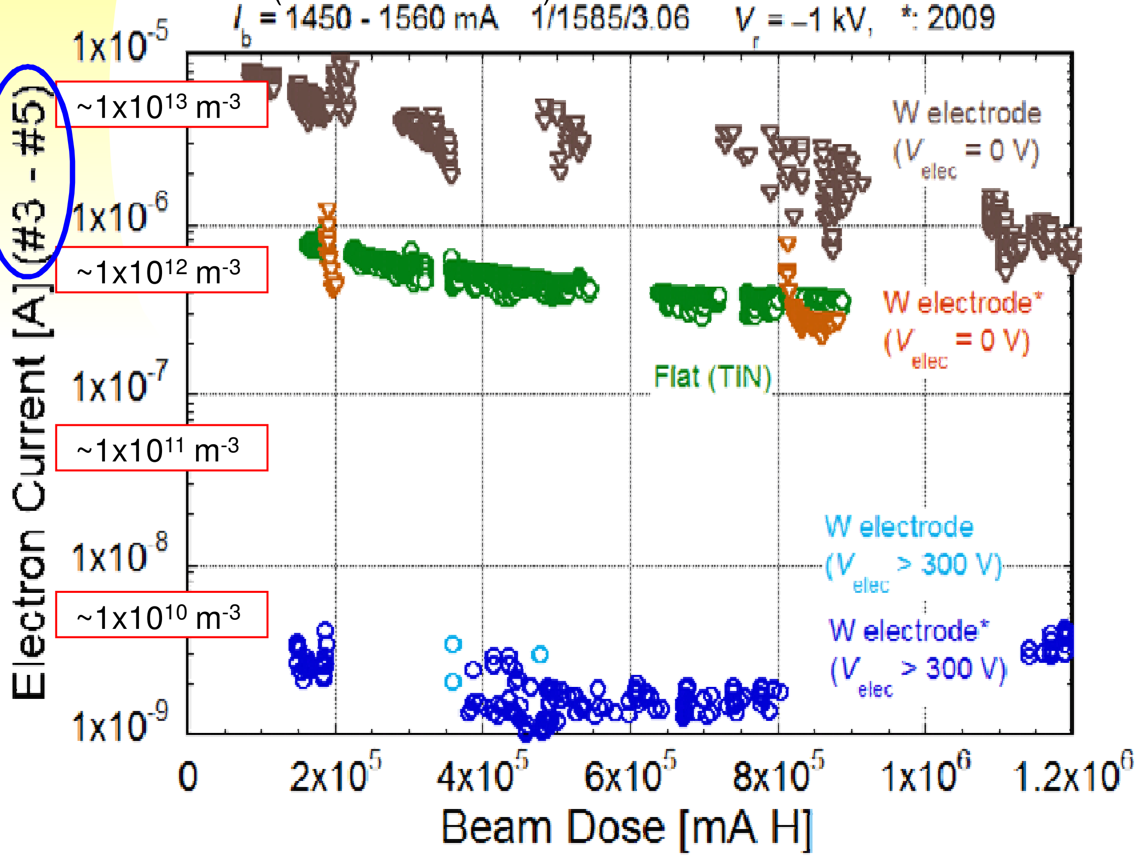
- An electron monitor and an insertion with an electrode are placed at the center of a pole, face to face.
- Electron monitor has an RFA and 7 strips to measure spatial electron distribution (~40 mm width in total).

Clearing Electrode_3

- **Results:** Comparison with a flat surface with TiN
  - 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.

(Central collectors of monitor)

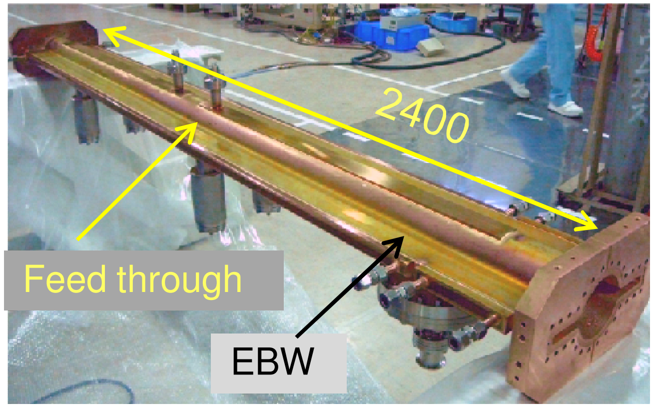
(0.9~1.0 mA/bunch)

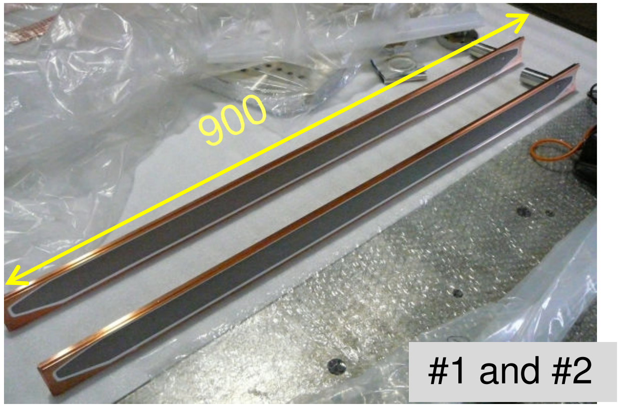


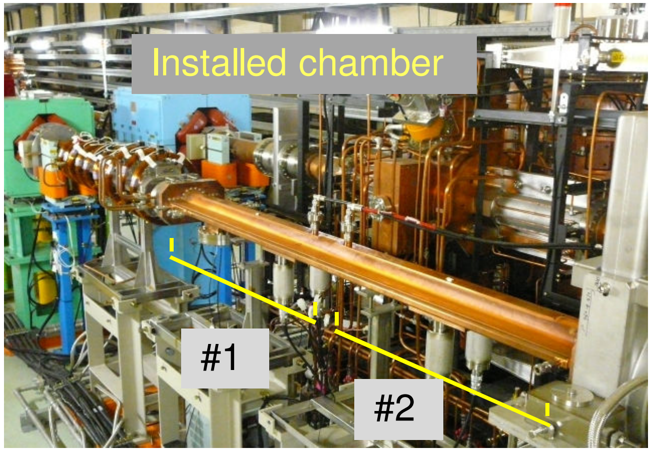
- Two-time experiments.
- Electron currents for the case of tungsten (V_{elec} = 0V) is similar to the case of flat TiN-coated surface. ←Rough surface?
- The second result was lower than the first one. ← Aging of surface?
- No extra heating of electrode and feed-through was observed.

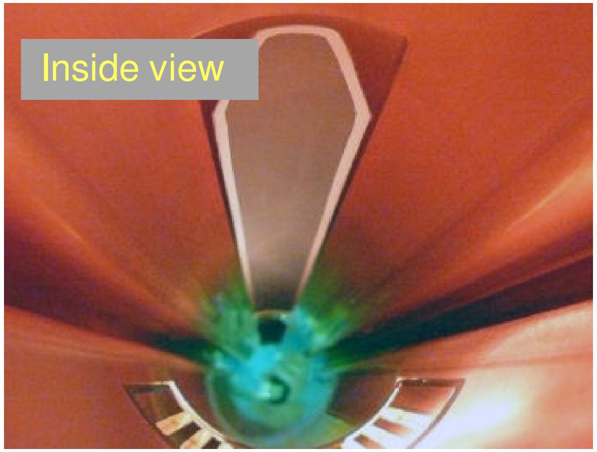
Clearing Electrode_4

- **Recent tests**: Application to a real beam pipe with antechambers.
  - Final check of feed through and heating of electrode.



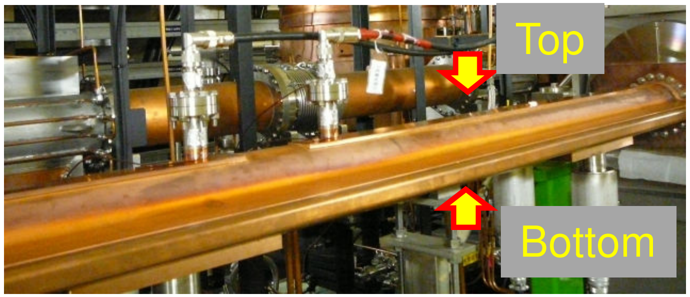


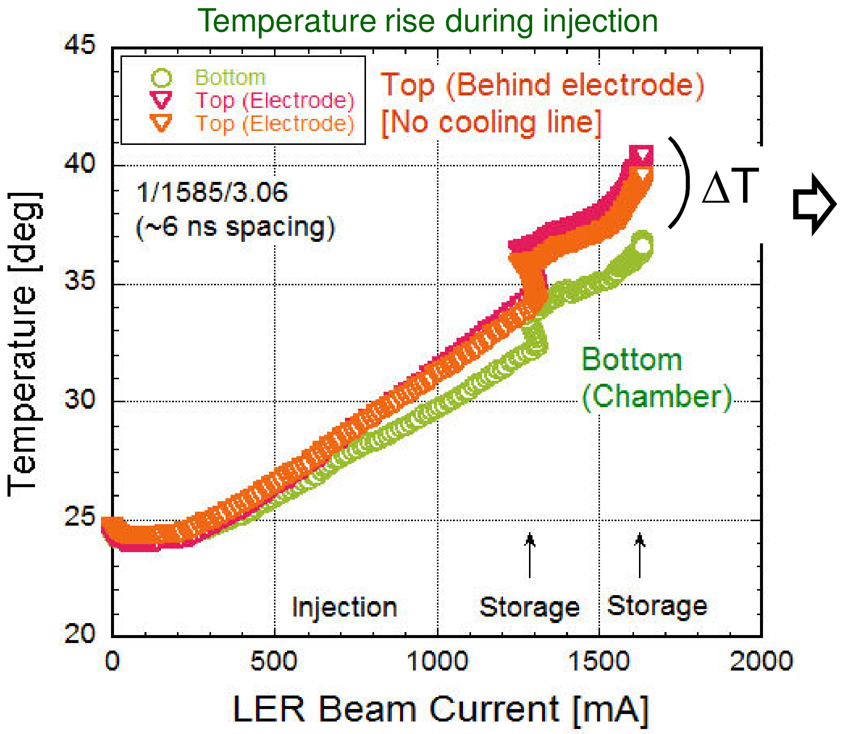


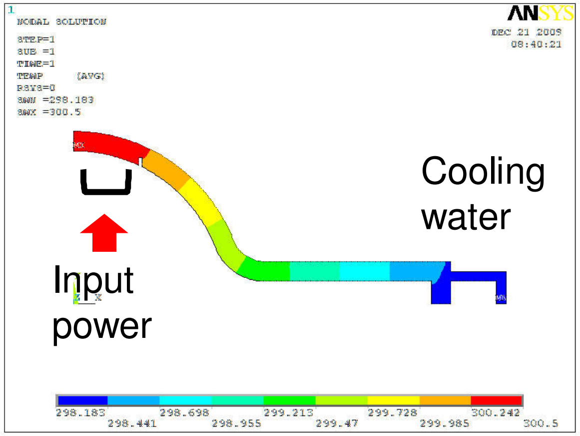


Clearing Electrode_5

- **Results_1**: Heating
  - Temperature behind the electrode was measured.
  - No cooling channels in the back of the electrode



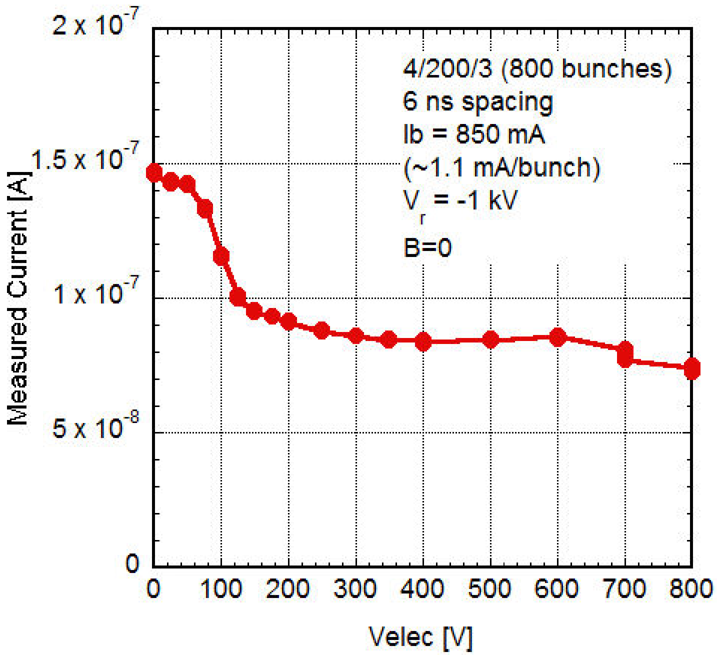


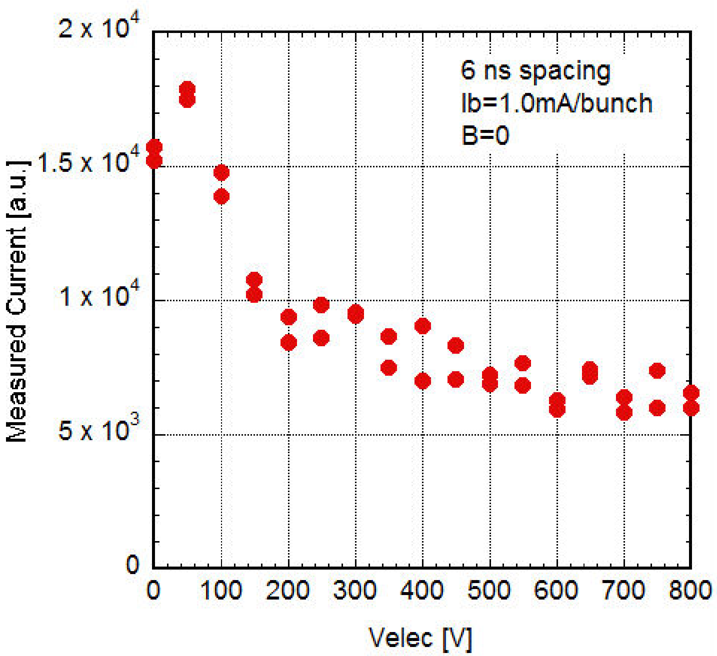


- Estimated input power was ~40 W/m: reasonable value.
- No heating at feed through.

Clearing Electrode_6

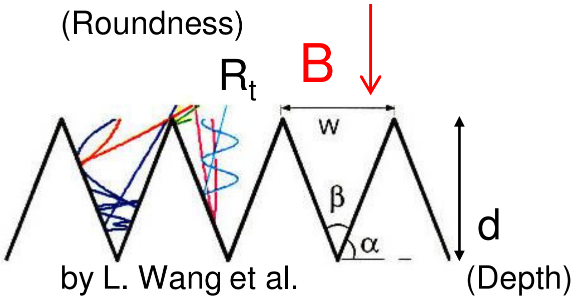
- **Results_2**: Effect of electrode
  - Electron numbers around the beam orbit were measured using an electron monitor with no magnetic field (B=0).
  - Reduction in the electron number by a half was observed.
  - The effect was smaller than the case in a wiggler magnet. But it is expected from a simulation.
  - An experiment in a magnetic field is planed.

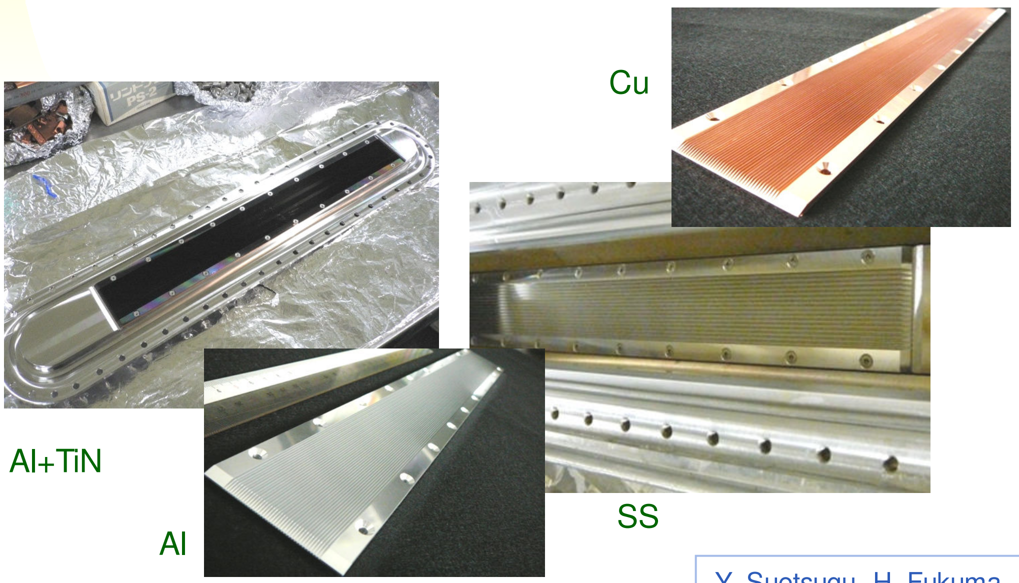


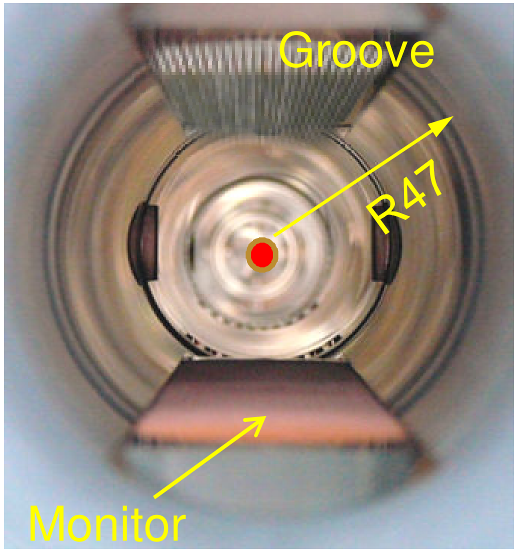


Groove Surface_1

- **Grooved surface** reduces SEY geometrically.
  - The properties have been also studied using the same experimental setup to that of the clearing electrode.
  - B = 0.78 T
- Parameters of grooves investigated:
  - Material: Cu, Al-alloy, SS
  - β : 20~30°, R_t:0.1~0.2 mm
  - d: 2.5~5 mm







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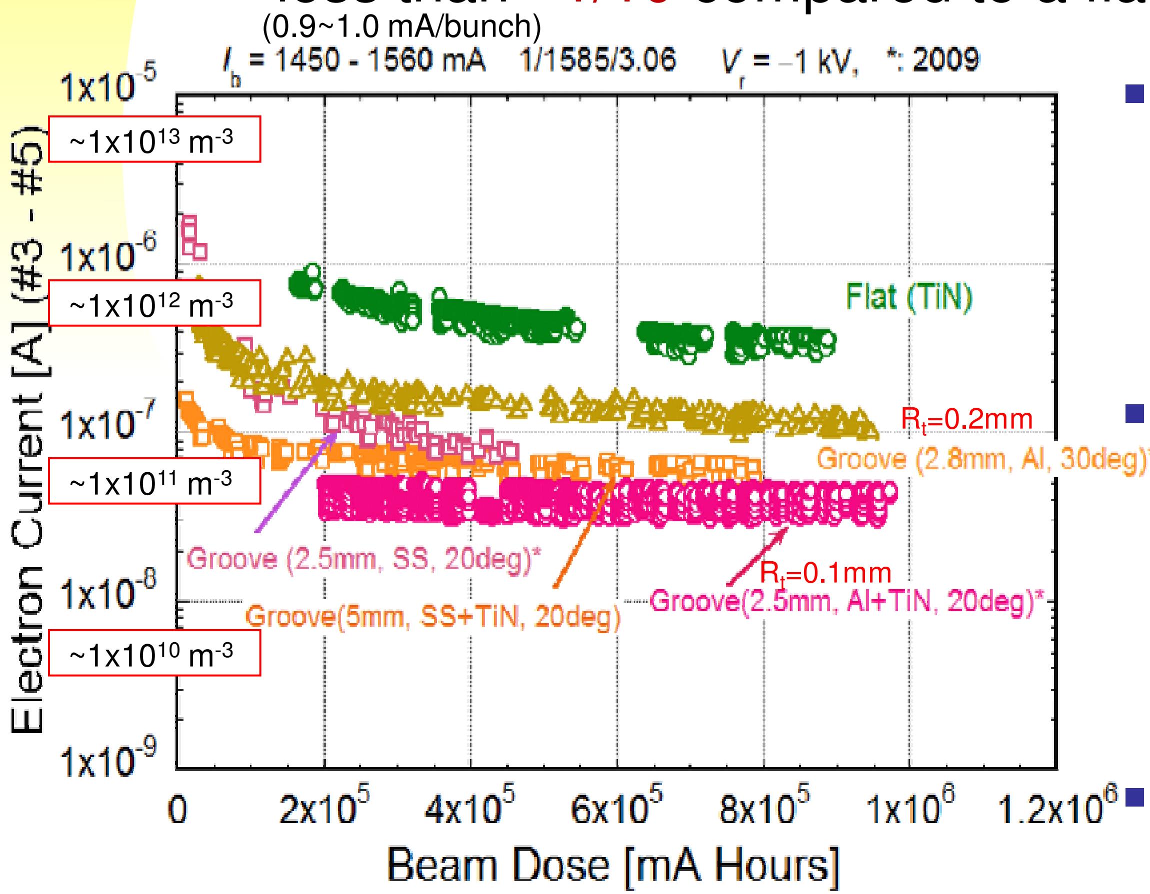
Groved Surface_2

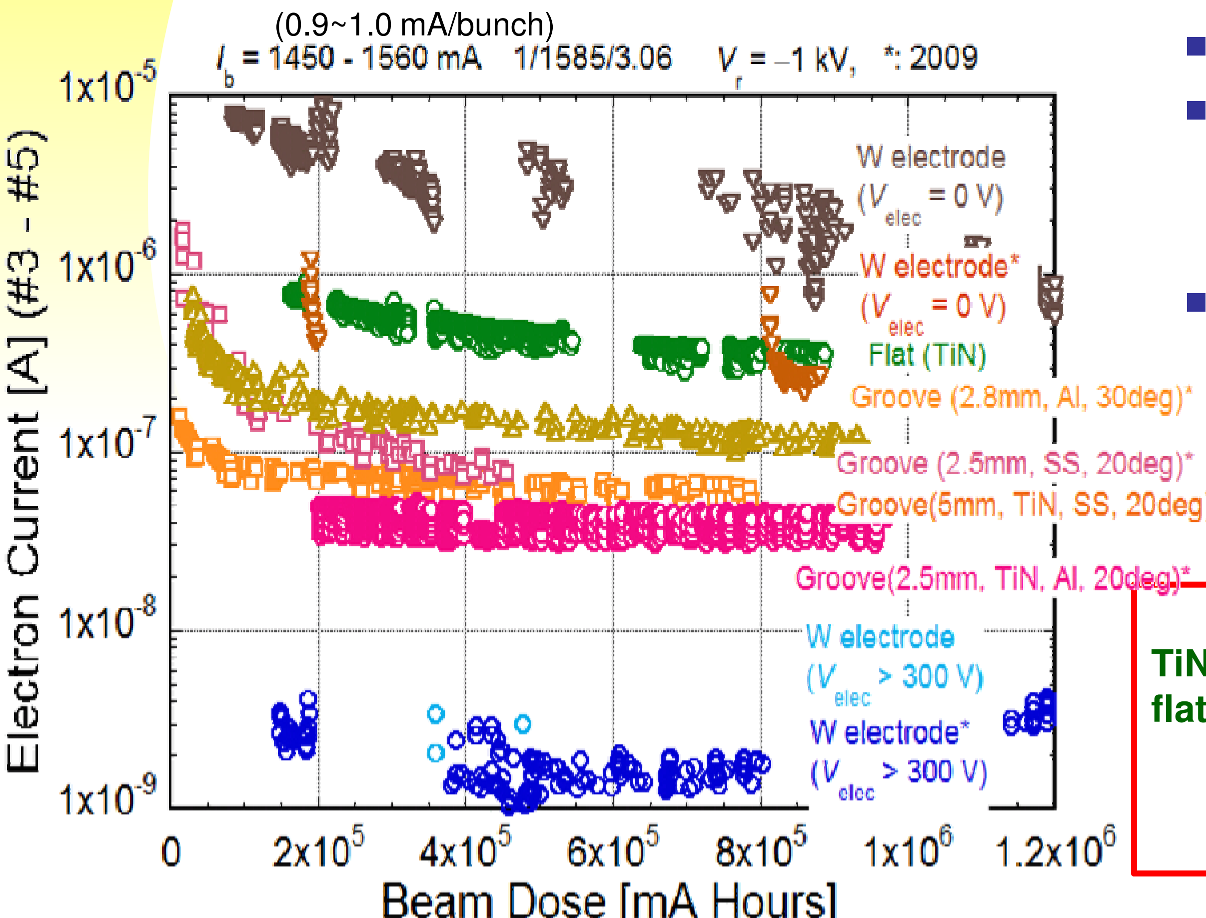
- **Results:** comparison with a flat surface with TiN
  - The electron density decreased to 1/6~1/10 compared to the case of a flat TiN-coated surface (β = 20°). That is, less than ~1/10 compared to a flat copper.



- Electron densities for grooves surfaces in these parameters were lower than the case of a flat TiN-coated surface.
- Smaller electrons even if no-coating: TiN coating improves the effect, but the groove structure seems much effective to reduce SEY.
- Less density for smaller β and R_t.

Grooved Surface_3

- Comparison between clearing electrode and groove
  – All data so far are plotted in one figure



- For B = 0.78 T
- Measured with the same monitor at the same location.
- Clearing electrode is much effective in reducing electron density compared to other methods.

TiN-coated flat surface 〉〉 **Grooved surface (β~20°)** 〉〉 **Clearing electrode**

1/6~1/10 ~1/10

Summary of countermeasures

- **Updated comparison among mitigation techniques**
  - Based on the experiments so far. Standard = Cu (circular pipe)

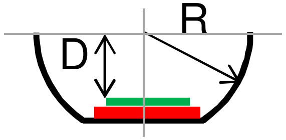
Materials, methods	Relative effect	Notes
Al	~20	Coatings are indispensable.
Cu (Circular pipe)	1	Standard
Solenoid [Drift space]	~1/50	~50 G, considering gaps (<1/1000 if uniform)
Antechamber	~1/5	<~1/100 for photoelectrons
Cu (Al) +TiN coating	~3/5	Relatively high gas desorption
Groove (β~20°) [in B]	~1/10	More effective for top and bottom
Electrode [in B]	~1/100	Most effective

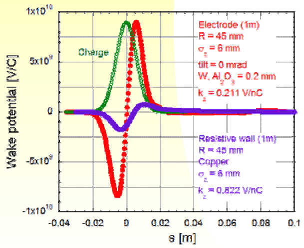
- Clearing electrodes and grooved surfaces can be strong countermeasures in dipole fields, more effective than any coatings.

Impedance issues

- **Impact on the beam impedance** **(just started)**
  - Compared to the resistive wall (ϕ90 mm, Cu)
  - **Clearing electrode**, assuming;
    - One electrode (top)
    - Resistive wall of W is included.

D=40
R=45

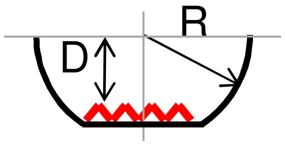


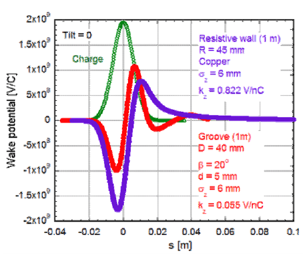


	1 piece (1.7m)	Total 100 (~170 m / 3000 m) [in wiggler magnets]
Loss factor	~x1.3	~x 1.02
Wake potential (height)	~x 4	~x 1.17

  - **Grooved surface**, assuming;
    - Grooves at top and bottom
    - Increase in resistive wall of 50 % by grooved surface is included.

D=40
R=45
d = 3





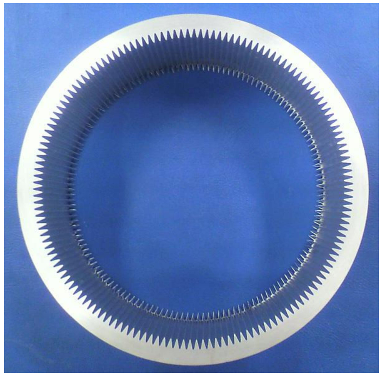
	1 piece (4 m)	Total (~520 m / 3000 m) [in Dipole magnets]
Loss factor	~x 1.03	~x 1.005
Wake potential (height)	~x1.25	~x 1.05

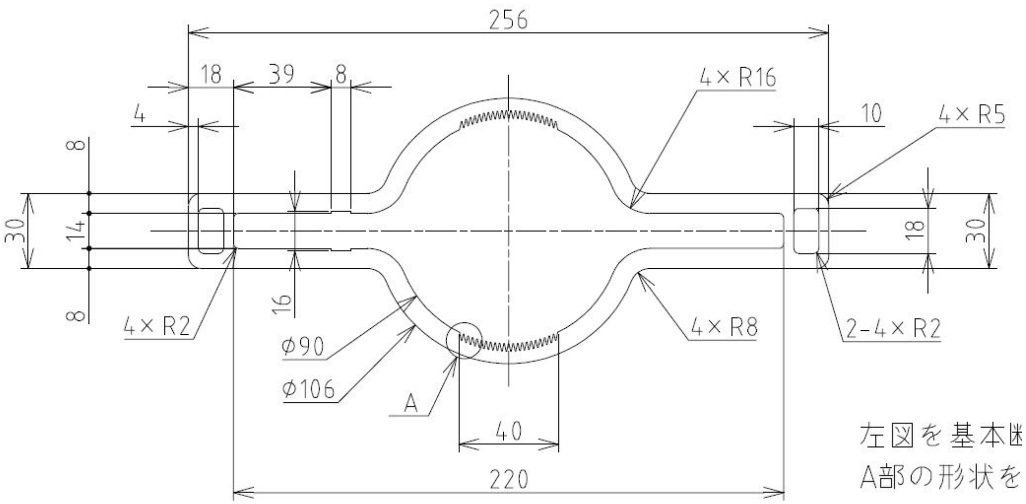
Summary & Remained issues_1

- **Super KEKB is challenging for the vacuum system.**
- **For countermeasures against electron cloud in a dipole field, clearing electrodes and grooved surface are found to be very effective.**
  - Ante-chamber and solenoid reduce main part of electrons.
  - By using clearing electrodes and grooved surface in dipole field, the average electron density further decrease.
    - Grooves were also effective in drift space (experiment of SLAC).
  - The affect on the beam impedance should be considered carefully.
    - Estimation about the effect of transverse impedance will start soon using SAD.

Summary & Remained issues_2

- **Beam test for the clearing electrodes will continue in the next run (from May)**
  - Effect of magnetic field
- **R&D for aluminum beam duct with grooves is undergoing**
  - Extrusion
  - Beam test in a drift space





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