Update on the status of the electron cloud studies at KEKB

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Brief review of our studies
Updates
  Clearing electrode
  Groove structure
  SEY measurement
Summaries and Future plans
EC Studies at KEK

- A pressing issue for the upgrade of KEKB (SKEKB): To establish effective and applicable EC mitigation techniques in a magnetic field
  - At drift space: “Solenoid field + Beam ducts with antechamber” is a basic and a very effective remedy.
  - In magnets, the antechamber-scheme and TiN coating is also effective. But more definitive techniques are required.

- Focused items in these years are:
  - Clearing electrode
  - Groove structure
  - Measurement of SEY
  - Coatings (TiN, DLC)
EC Studies at KEK

- Experiments of clearing electrodes and groove structures using the positron ring of KEKB
  - Energy = 3.5 GeV,
  - Current ~1600 mA (~ 6 ns spacings, 1585 bunches)
  - Bunch length ~ 6 mm
  - Measure the electron density around beam orbit by using electron monitors with RFA.
- Measurement of SEY at laboratory, in parallel.
  - Surface analysis
- Development of TiN coating apparatus

Reported here are about the recent progress on the clearing electrode and the groove structure, and some results of SEY measurements.
Experimental setup at KEKB e+ ring

- A test chamber was installed in a wiggler magnet.
  - For tests of a clearing electrode or a groove structure
  - With a RFA, flange insertion

- Wiggler magnet:
  - Magnetic field: 0.78 T
  - Effective length: 346 mm
  - Aperture (height): 110 mm
  - The monitor and insertion are placed at the center of a pole.

- Irradiated photons: $2 \times 10^{17}$ photons/s/m at 1600 mA
Experimental setup in KEKB e⁺ ring

- A test chamber with an electron monitor (with RFA) and a clearing electrode or a groove structure.

- Applied voltage
  Collectors: +100V
  Retarding Grid: 0 ~ -1 kV
- Measurement: DC mode

Electron monitor with RFA and 7 strips to measure spatial distribution

Electrode

Al-alloy chamber (Not coated)
Clearing Electrode

- Very thin electrode structure was developed.
  - 0.2 mm alumina-ceramics and 0.1 mm tungsten electrode formed by a thermal spray method.
- Good heat transfer
- Low beam impedance

Clearing Electrode

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

Electron monitor

Inside view

Electrode

2009/10/1

LCWA09, Albuquerque
Clearing Electrode

- **Results**
  - Drastic decrease in the electron density by applying $V_{elec}$ was observed.
  - The electron density decreased to less than 1/100 at $V_{elec} > \sim +300$ V

- **Diagram**
  - (a) Electrode
    - $V_{elec} = 0$ V
    - $V_{r} = -1$ kV
    - $1/1585/3.06$
  - (b) Electrode
    - $V_{elec} = +300$ V
    - $V_{r} = -1$ kV
    - $1/1585/3.06$

- **Graphs**
  - 6x10^{-7}
  - 6x10^{-9}

- **Note**
  - 1585 bunches ($B_s \sim 6$ ns)
Clearing Electrode

- New connection was tested in the last run
  - No extra connection parts.
  - Very smooth surface.
- No increase in the leak current, no discharging
  - Leak current $\leq 1$ $\mu$A at $\pm 1$ kV after $\sim 2$ months operation.
- But, poor electric contact to electrode (line contact) can be a problem in some cases.
Clearing Electrode

- A revised connection structure will be tested in the next run.
  - Minor change
  - Line electric contact $\rightarrow$ surface contact
- Thermal spray test using a test sample is now undergoing.
Clearing Electrode: Next plan

- It is a promising method for a wiggler section.
  - That is, a straight chamber
- A test beam duct (copper) with two clearing electrodes is under manufacturing and will be installed to LER in November.
  - The electrodes have a revised connection structure.
Clearing Electrode : Next plan

- Electrode
  - 900 mm long
  - Welded to copper beam duct by EBW
  - Have a curvature radius of 45 mm
  - Have a revised connection structure
Clearing Electrode : Next plan

- Heat load test during EBW
  - Insulated resistance did not change after EBW at back side of samples (1 m and 200 mm)
  - Penetration thickness = 2~3 mm
- No degradation of insulated resistance was found.
Groove structure

- Groove geometrically reduces the effective SEY.
  - The effect was demonstrated in a magnetic field.
- The latest model has a shallow groove structure.
  - Shallow groove has a low impedance.

Groove structure

Result

- The electron density decreased to 1/6~1/10 compared to the case of a flat surface.

Flat

[circle6]

[5 mm groove]

Groove

(c) Flat surface (TiN)

\[ V_r = -1 \text{ kV} \]
\[ 1/1585/3.06 \]

(d) Groove structure (TiN)

\[ V_r = -1 \text{ kV} \]
\[ 1/1585/3.06 \]
Groove structure

Result

- The shallow groove showed the comparable reduction of electron density to that of the previous one (5 mm), although no TiN coating (after sufficient conditioning).

![Diagram showing electron current and beam current for 5 mm and 2.5 mm grooves.]

- 5 mm groove:
  - Groove structure (TiN)
  - $V_r = -1 \text{kV}$
  - 1/1585/3.06

- 2.5 mm groove:
  - Groove structure [2.5 mm depth] (No TiN)
  - $V_r = -1 \text{kV}$
  - 1/1585/3.06

[Linear scale]

1585 bunches ($B_s \sim 6 \text{ ns}$)

$V_r = -1 \text{kV}$
Groove structure

- Compared to the case of TiN-coated flat surface;
  - Groove structure: 1/6~1/10
    - Effect of structure is larger than that of TiN?
    - Further investigation is required (Next plan).

![Graph showing electron current vs beam dose](image)

- Parameters: $I_b = 1450 - 1560 \text{ mA}$, $1/1585/3.06$, $V_r = -1 \text{ kV}$, $\times 2009$
- Key labels: Flat (TiN), Groove (2.5mm, SUS)*, Groove (5mm, TiN)

2009/10/1

LCWA09, Albuquerque
Groove and Clearing electrode

- Compared to the case of TiN-coated flat surface:
  - Clearing electrode (> +300 V): $1/100 \sim 1/500$
  - $\sim 1/50$ of groove structure
Groove structure: Next Plan

- Test of aluminum and copper groove structure (2.5 mm depth) with/without TiN coating in the next run
- Install a new second test chamber
  - An electron monitor with RFA and 14 strips collectors
Groove structure: Next Plan

- TiN coating system for grooved block are under development.
- A square Ti target is used to uniformly coat the grooved surface.

Square Ti target

Grooved block (sample) set in the chamber
Groove structure: Next Plan

- Aluminum-alloy beam pipe for a bending magnet
  - Under manufacturing
  - Several groove blocks are welded at the top and bottom of beam channel.
  - Extrusion with groove is impossible.
SEY Measurement at Laboratory

- SEY of sample pieces (without magnetic field)

**Sample Corn**

Test chamber

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Sample Corn
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I_e = 250 eV (100 – 2000 eV)
Irradiation area: 13 ~ 20 mm²
Current: 1 ~ 2 µA
SEY = I_r / (I_i + I_r)
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SEY Measurement at Laboratory

- SEY of sample pieces (without magnetic field)
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2009/10/1

LCWA09, Albuquerque
SEY Measurement at Laboratory

- Typical results
  - TiN coating decrease Max. SEY to 0.9~0.8. (Al, Cu)
  - Groove structures decrease it to ~0.7 even without TiN (Al); the effect of groove structure seems larger
SEY Measurement at Laboratory

- A plan to measure SEY in a strong magnetic field is under consideration.
  - Still only idea: a big problem is how to separate and absorb secondary electrons.....
Summaries

- The improved clearing electrode and the shallow groove structure are being tested.
- Clearing electrode
  - The problems at connection to feed-through found before was much improved.
  - Quality of thermal spray?
- Groove structure:
  - A groove with a depth of ~2.5 mm is promising.
  - The coating system is now under development.
- SEY measurement continues in parallel with beam tests.
- Beam pipes with these countermeasures are under manufacturing.
**Study schedule at KEKB**

- Beam test of groove structure and clearing electrode in the final phase.
- Next year.....Unknown.

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- Clearing electrode:
  - Assembling test (model): 2009/10/1
  - Electrode block: 2009/10/1
  - Pipe manufacturing: 2009/10/1
  - Beam test: 2009/10/1

- Groove structure:
  - Test chamber: 2009/10/14
  - Short shutdown (exchange): ~2009/11/17
  - Beam test: 2009/12/24
For SuperKEKB

- In the present design parameters (Low emittance option), the beam pipe of the positron ring will be made of aluminum alloy.
  - TiN coating should be indispensable.
  - We are requiring a dedicated facility for the coating.

- Present countermeasures against ECE:
  - Arc section: Beam pipe with antechambers
  - Drift space: Solenoid and TiN coating
  - In quadrupole magnets: TiN coating
  - In bending magnets: TiN coating and grooves
  - In wiggler magnets: Clearing electrodes (or grooves)