Possible Remedies to Suppress electron cloud in ILC damping ring

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Objective

- Completely clear the E-cloud along the whole ring, include drift region and various magnets (dipole, quadrupole, wiggler....) so that we can release the limitation of Ecloud on the design of damping ring, such as, circumference, beam pattern, the aperture of beam pipe, SEY.
Cures of e-cloud

- Weak Solenoid (work well in drift region, but not in magnets)
- Chamber surface preparation (Vacuum chamber coatings, ribbed structures, Beam scrubbing)
- Electron Clearing devices

Remained Problem for ILC:
How about electron cloud inside magnet (dipole, wiggler ...) if we want to save one RING?

More creative and permanent solutions are needed!

- Solenoid ----drift region
- Electrode -----magnet
- Grooved surface-----magnet

Robert E. Kirby, etc,

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use CLOUDLAND program (PIC and Monte Carlo method)
A weak solenoid can suppress the electron multipacting by confining the electrons beam the pipe surface.
Solenoid effect in KEKB LER

H. FUKUMA

After last installation of solenoid, blowup was disappear up to 1300mA.
Electrode inside magnets--I

Stripline type in Dipole magnet (EPAC 2006, TUPLS003)

- The electrode is curved with the same shape of the chamber (round one here)
- The electrode is positively polarized in order to capture all the electrons to the electrode. It is electrically and thermally isolated to operate at a few hundreds voltage with respect to the beam pipe. There is a similar design for LHC dipole*
- The width of low electron density region increases with the size of the electrode

* P. McIntyre and A. Sattarov, Proceedings of PAC2005, TPAP047, 2005

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Electrode inside magnets--II

Curved coradial type in dipole magnet (M. Pivi)

BEND chamber with curved clearing electrodes

Simulation using POSINST code of electron cloud build-up and suppression with clearing electrodes.

ILC DR positron: assuming one single 6 km ring.

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Electrode inside magnets--III

Wire type for various magnets (KEK Preprint-137)

The electric field must be along the magnetic field line in order to effectively repel the electron.

The wire electrodes must have negative potential relative to the grounded chamber!!!

The field is perfect!!! (very weak field at chamber center, strong vertical field around both the top and bottom of the chamber, where multipacting could happen.)
Grooved surface in a magnet

(L. Wang, T. Raubenheimer, Submitted to NIMA)

(a) Isosceles triangular surface

(b) Sawtooth surface

(c) Rectangular

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Sawtooth Surface

Mechanism

Some of the secondary electrons emitted from the surface return to the surface within their first few gyrations, resulting in a low effective secondary electron yield.

Requirement:
\( \alpha > 70^\circ, W > 0.38 \text{mm} \)

Effective SEY from sawtooth surface in a dipole magnetic field. \( \delta_{\text{max}} = 1.74, E_{\text{max}} = 330 \text{eV}, B_0 = 0.2 \text{Tesla} \).

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Isosceles triangular surface I

Sensitive to slope angle $\alpha$

Weak dependence on $W$. (saturated at larger $W \sim 2.0\text{mm}$, no upper limitation on $W$!!)

Very weak dependence on $B$.

Requirement: $\alpha > 70^\circ$, $W > 0.38\text{mm}$

$\delta_0 = 1.740$, $B = 0.2\text{ Tesla}$

$\alpha = 65^\circ$, $\beta = 50^\circ$

$\alpha = 70^\circ$, $\beta = 40^\circ$

$\alpha = 75^\circ$, $\beta = 30^\circ$

$\alpha = 80^\circ$, $\beta = 20^\circ$

$B = 0.2\text{ Tesla}$ (dipole magnet of ILC)

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Isosceles triangular surface II

Effect of B

$\delta_0=1.740, B=0.2 \text{ Tesla}$

$\delta_0=1.6, B=1.6 \text{ Tesla}$

Energy (eV)

$W=0.38 \text{ mm}$

$W=0.75 \text{ mm}$

$W=1.13 \text{ mm}$

$W=1.51 \text{ mm}$

SEY

$B=0.2 \text{ Tesla}$ (dipole magnet of ILC)

$B=1.6 \text{ Tesla}$ (Wiggler magnet of ILC)

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Rectangular Surface

- Sensitive to size and magnetic field
- Requirement: \((a \ll b)\)

- 0.08mm < \(W\) < 0.51mm in 0.2 Tesla field
- 21\(\mu\)m < \(W\) < 63\(\mu\)m in 1.6 Tesla field
Rectangular grooves can reduce the SEY without generating geometric wakefields.

**Macro fins (mm scale)**

*USE IN STRAIGHT*

*Without B field*

*By=0*

**Micro fins (μm scale)**

*USE IN BEND, WIGG, QUAD?*

*With B field*

*By=0.19T*
Application and impedance

A rectangular grooved vacuum chamber cover the whole chamber surface increases the impedance by a factor of 48% [1]

The impedance enhancement due to the sawtooth and isosceles triangular surface is small due to the small percentage (for example 7.2% in dipole) of the coverage of the grooved surface.

Summary

Besides Solenoid, Coating and Beam scrubbing, we also consider the following two approaches to clear electrons in magnet

- **Clearing electrode in magnet**
  - Traditional Stripline Type located at the bottom of chamber. (EASY to be manufactured)
  - Coradial stripleline type with gaps between electrode and beam pipe (impedance…)
  - Wire type (work in various magnets, Support, impedance…?)

- **Grooved surface in magnet**
  - Both sawtooth and isosceles triangle surface can significantly reduce the effective SEY with a weak dependence on the size of surface and magnetic field. They work at dipole, quadrupole and wiggler (1.6 Tesla), No limitation on magnetic field! No upper limitation on size.
    - **Requirement:** $\alpha > 70^0$, $W > 0.38\text{mm}$
  - The effect of rectangular surface is sensitive to size and magnetic field.
    - **Requirement:** $0.08\text{mm} < W < 0.51\text{mm}$ in *0.2 Tesla field*
      - $21\mu\text{m} < W < 63\mu\text{m}$ in *1.6 Tesla field*