Vacuum,Antechamber,Masks,Bellows,etc.

(Feb.26　9:00- 9:20　Y.Suetsugu)

Vacuum System Issues for KEKB Upgrade

26/Feb/2002
KEKB VAC Y.Suetsugu

Contents

Main Parameters

- Parameters Considered Here

	LER (e^-)	HER (e^+)
Energy [GeV]	3.5	8.0
Beam Current [A]	9.4	4.1
Bunch Length [mm]	3	3
Bunch Number	5018	5018
Bending Radius [m]	16.31	104.46
Beam Duct Aperture[mm]	Φ94	104 x 50 (Race Track)

Assumptions at present:

- No change for B, Q and SX magnets basically.
- Changeable for ST magnets (structures & positions).

Guideline in Designing Chamber

- SR power is too high to use present beam ducts (see below).
- Photoelectron should be suppressed in beam duct for positron ring.
- About 100 l/s/m of pumping speed is necessary.
- Impedance should be kept as small as possible.

→ Ante-Chamber

	LER (e^-)	HER (e^+)
Total Power [MW] (two times if with Wiggler)	7.65 (2.11)*	14.21 (3.81)*
Max. Line Density [kW/m] (for present beam duct)	53.6 (14.8)*	21.6 (5.8)*
Max. Density [W/mm^2] (0.4 mm width) (for present beam duct)	134.0 (37.0)*	54.0 (14.5)*
Ave. Photons [photons/m/s]	1.20×10^{19}	1.20×10^{19}
Ave. Gas Load [Torr l/s/m]**	3.65×10^{-7} (1.01×10^{-7})**	3.65×10^{-7} (0.98×10^{-7})**

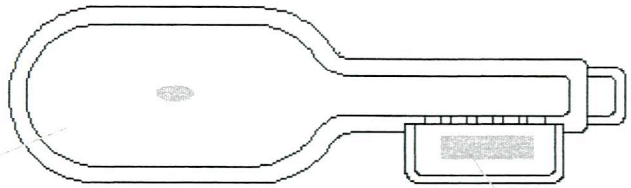
* Present value.

** $\eta = 1\times10^{-6}$ [mole./photon] is assumed.

Basic Design for HER (e^+) _1

- Ante-Chamber
  - Photoelectrons reduces in beam duct.
  - No pumping port in beam duct lowers impedance.
  - Copper is a prospective material.

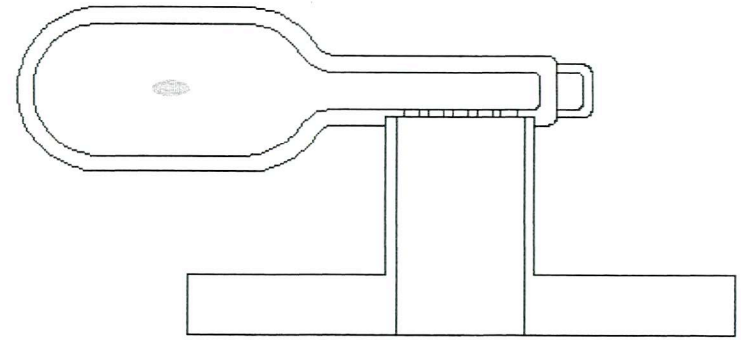
[B Magnets and Straight Section]



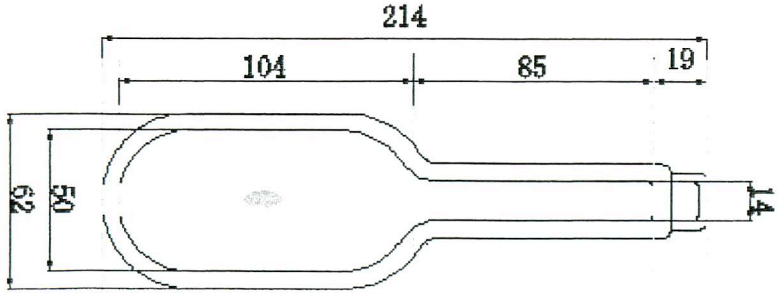
Beam Duct

NEG Strip

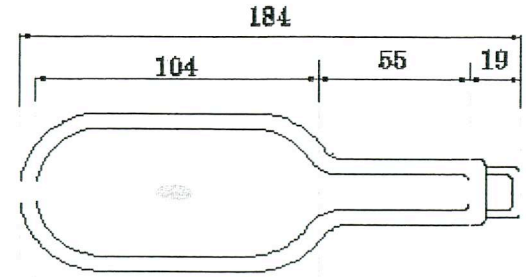
[Ion Pump Section]



[QS Magnets]



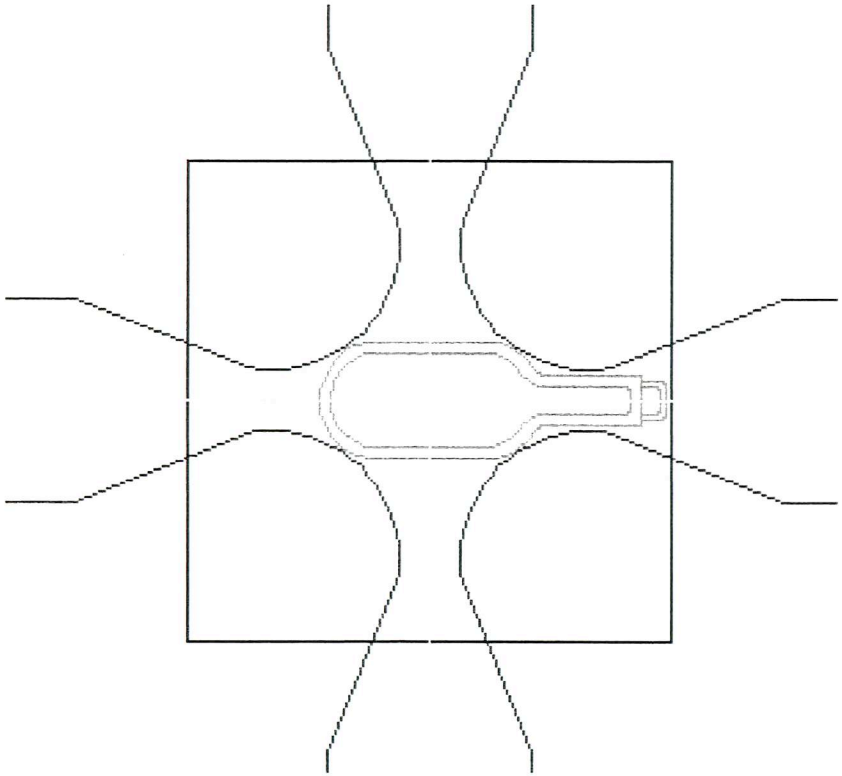
[QA, QB, SX Magnets]



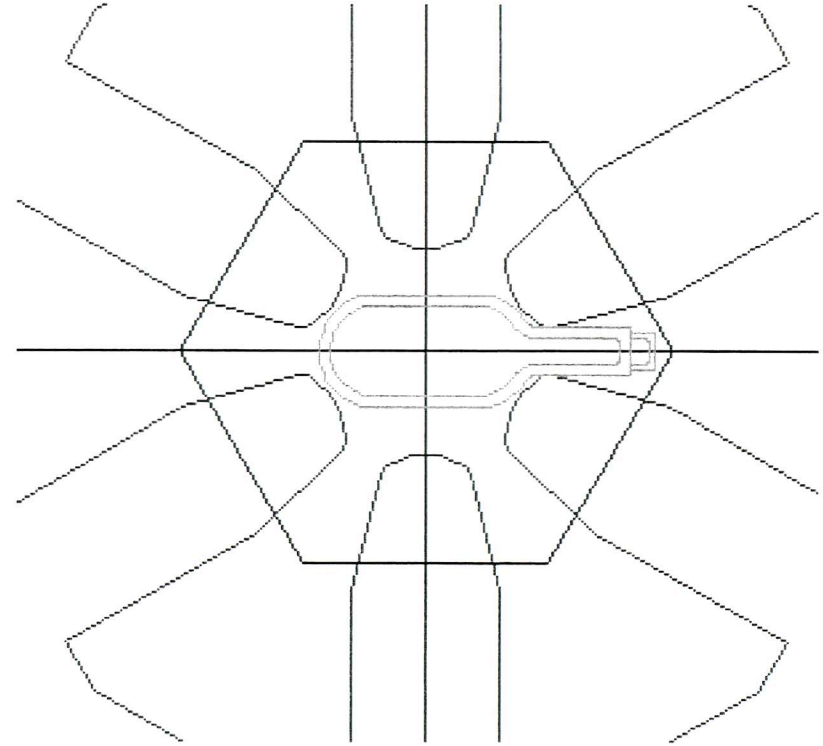
Basic Design for HER (e+)_1.1

- Cross section and magnet core

[Q-Magnet (QA)]

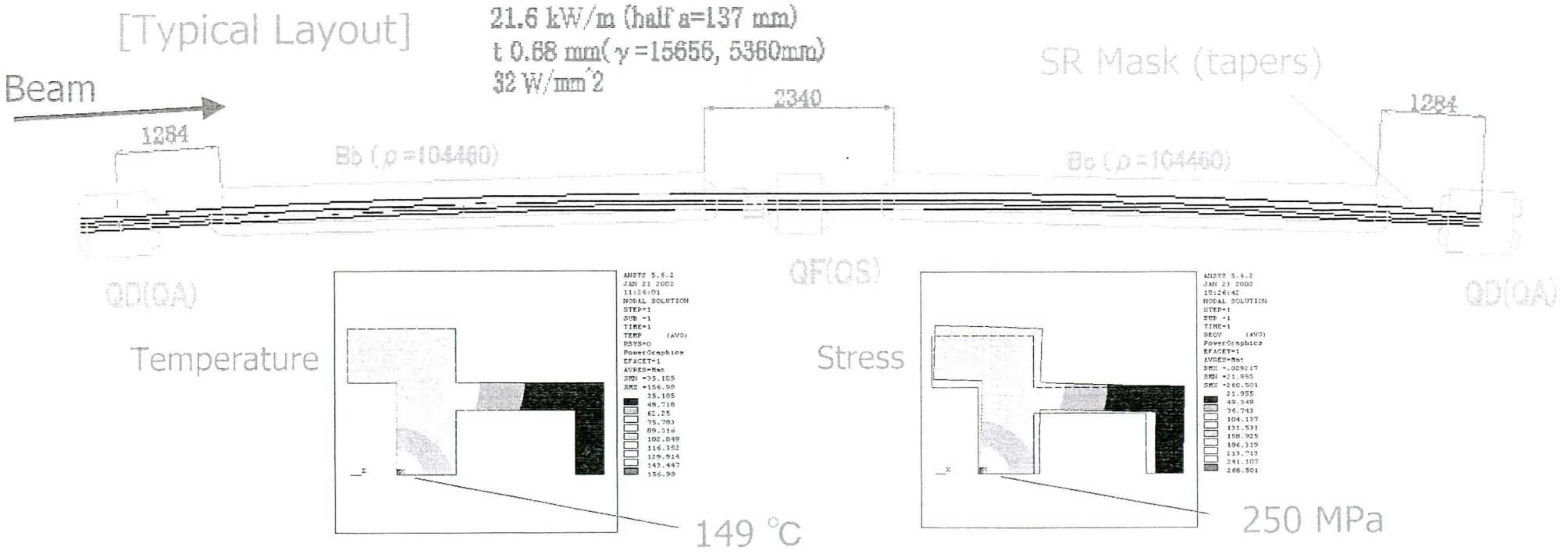


[SX-Magnet]



Basic Design for HER (e^+) _2

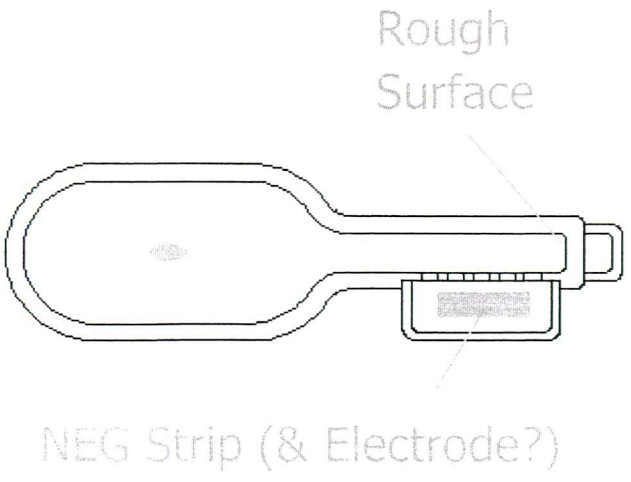
- Ante-Chamber
  - SR irradiates the side wall of ante chamber (no photon stop).
  - Max. SR linear power density is tolerable.
  - Max. power density is comparable to present LER (37 W/mm^2).
  - SR masks (tapers) are necessary just before some Q-magnets sections and bellows.



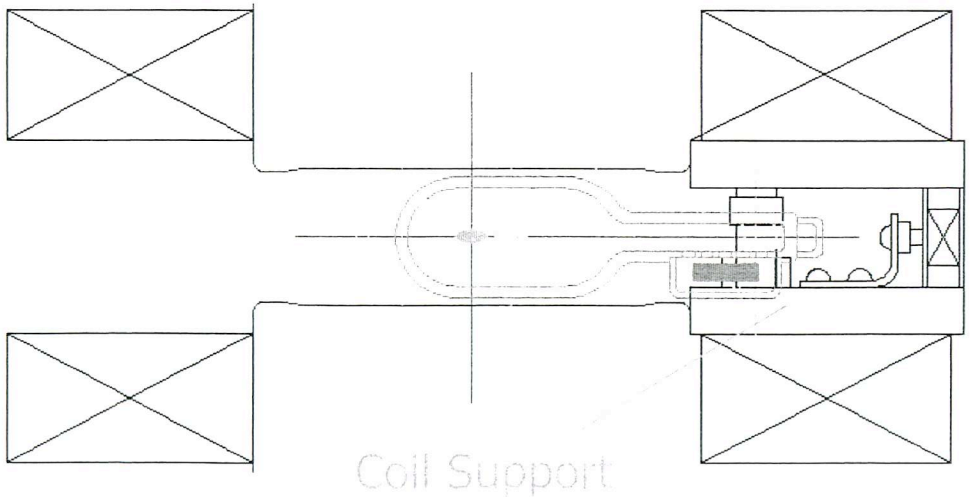
Basic Design for HER (e^+) _3

- Ante-Chamber
  - Rough surface (saw-tooth surface) will reduce photoelectron emission and reflection of SR (described later).
  - Distributed pumping scheme gives sufficient linear pumping speed.
  - Reversal of present B-magnets is unnecessary. Coil support should be changed.

[Straight Section]



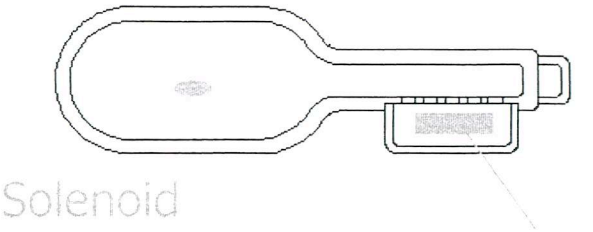
[B Magnets Section]



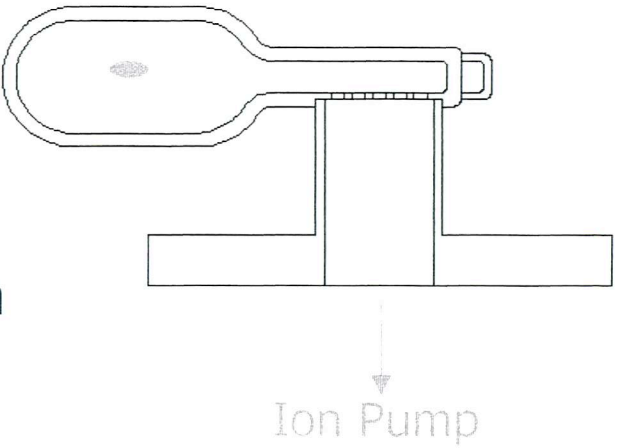
Basic Design for HER (e^+) _4

- Solenoid
  - Indispensable to suppress multipactoring
  - Winding before installation
- Pumps
  - NEG + Ion Pumps
  - NEG strips to increase linear pumping speed
- No Flanges
  - Decrease impedance
  - Welding *in situ*.
  - Welding between stainless-steel or aluminum
- Bellows between Q-Magnets
  - Bellows will be necessary to absorb thermal movement and miss-alignment.

[B Magnets and Straight Section]



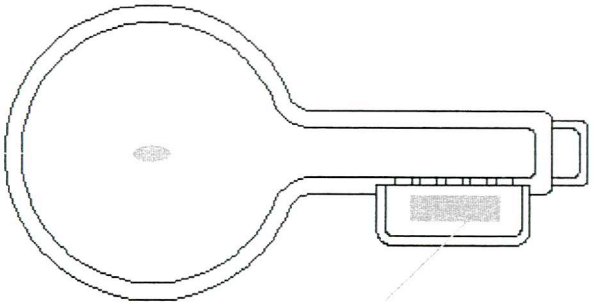
[Ion Pump Section]



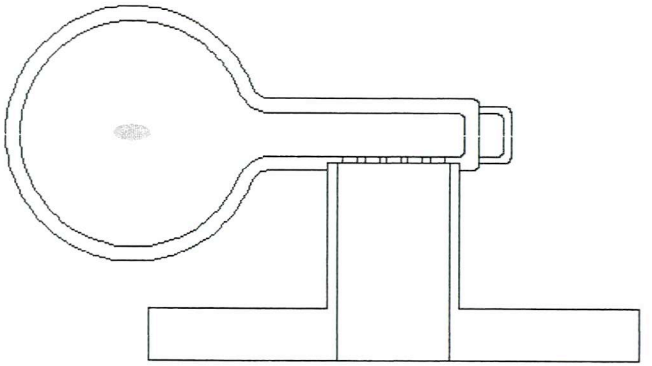
Basic Design for LER (e^-)_1

- Ante-Chamber
  - No pumping port in beam duct lowers impedance.
  - Copper is a prospective material.

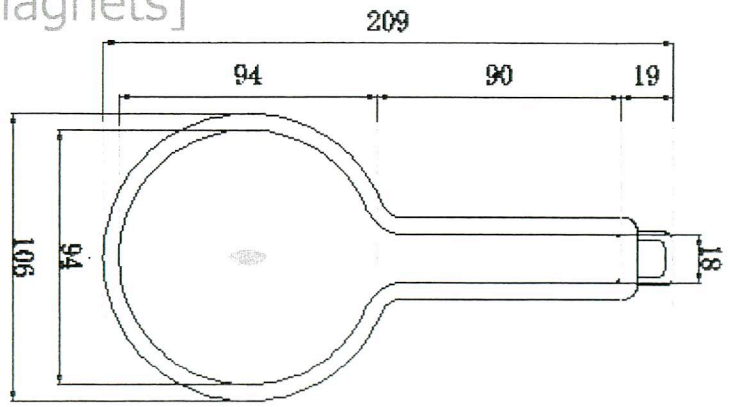
[B Magnets and Straight Section]



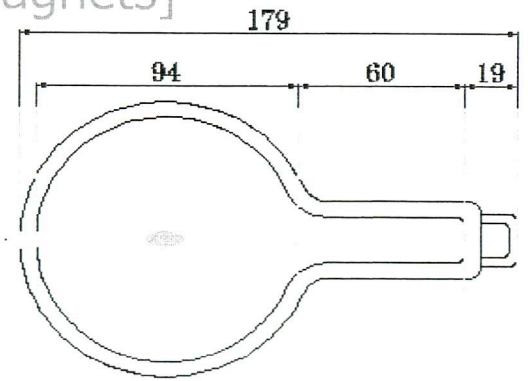
[Ion Pump Section]



[Q Magnets]

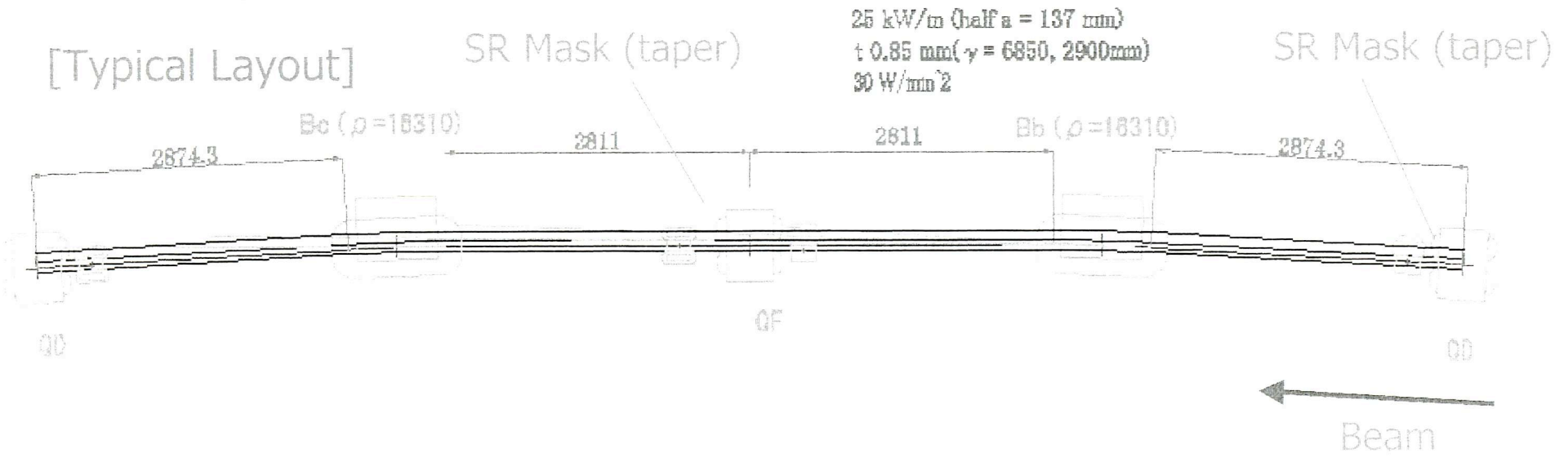


[SX Magnets]



Basic Design for LER (e^-)_2

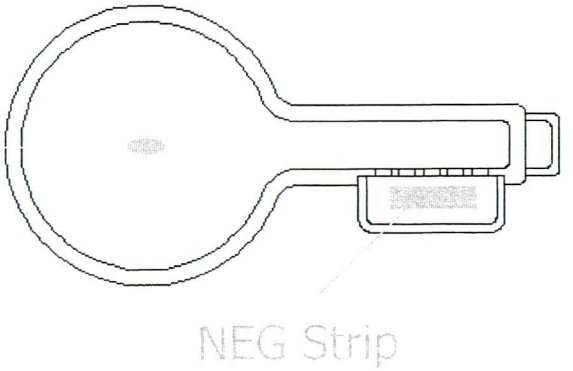
- Ante-Chamber
  - SR irradiates the side wall of ante chamber.
  - Max. SR linear power density and power density are similar to the previous HER case.
  - SR masks (tapers) are necessary just before some special magnet sections and bellows.



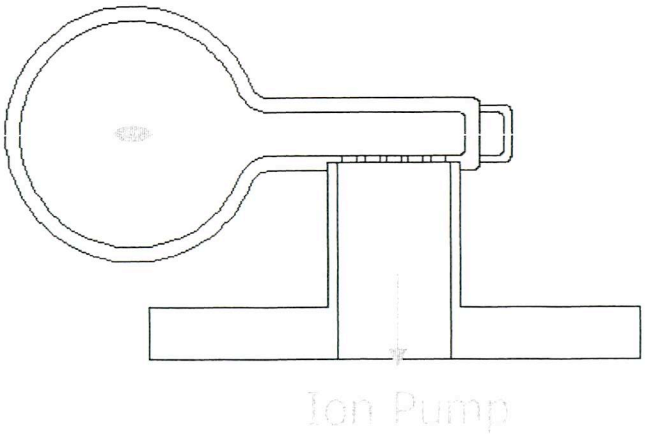
Basic Design for LER (e^-)_3

- Pumps
  - NEG + Ion Pumps
  - NEG strips to increase linear pumping speed.
- No Flanges
  - Welding *in situ*.
  - Welding between stainless steel or aluminum
- Bellows between Q-Magnets
  - Bellows will be necessary.

[B Magnets and Straight Section]

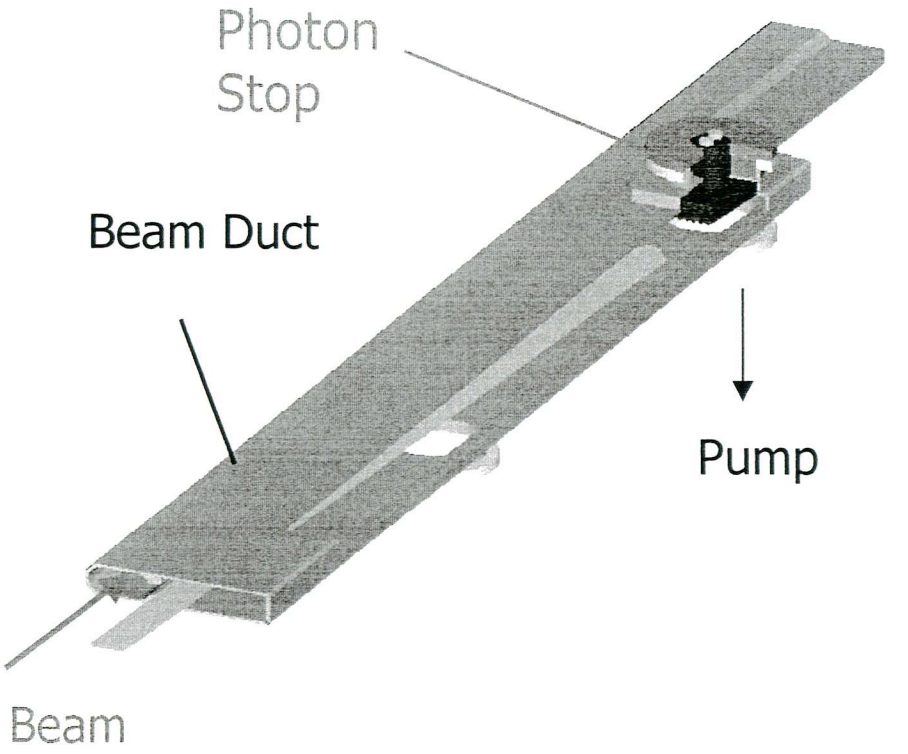


[Ion Pump Section]



Design Options_1

- Photon Stop Scheme



  - Localized pumps
  - Localized photoelectron emission
  - Localized cooling water
  - Aluminum chamber is available?
    -> Low cost
  - No bellows design is possible ??
  - Severe SR power at photon stop
  - Solenoid is necessary in any way to suppress electron multipactoring.

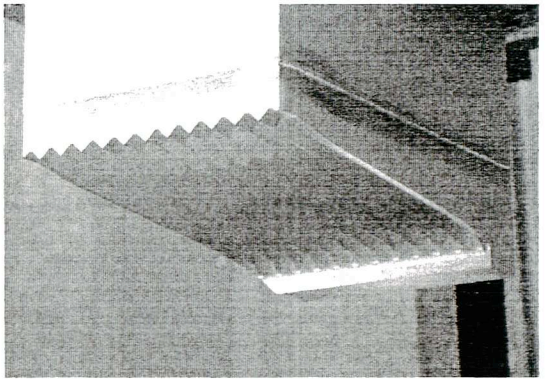
Design Options_2

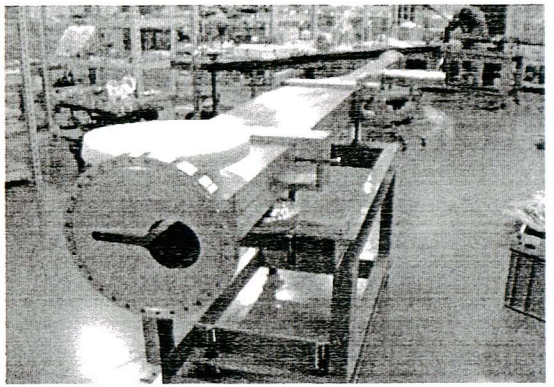
- Aluminum Chamber Combined with Copper
  - Copper for intensely irradiated surface
  - Low cost
    - Easy to welding, easy to handling
    - Easy to extruding an ante-chamber
  - High photoelectron (secondary electron) yield? [HER]
    - Coating? → R&D
  - Lead shielding will be necessary for whole chamber.

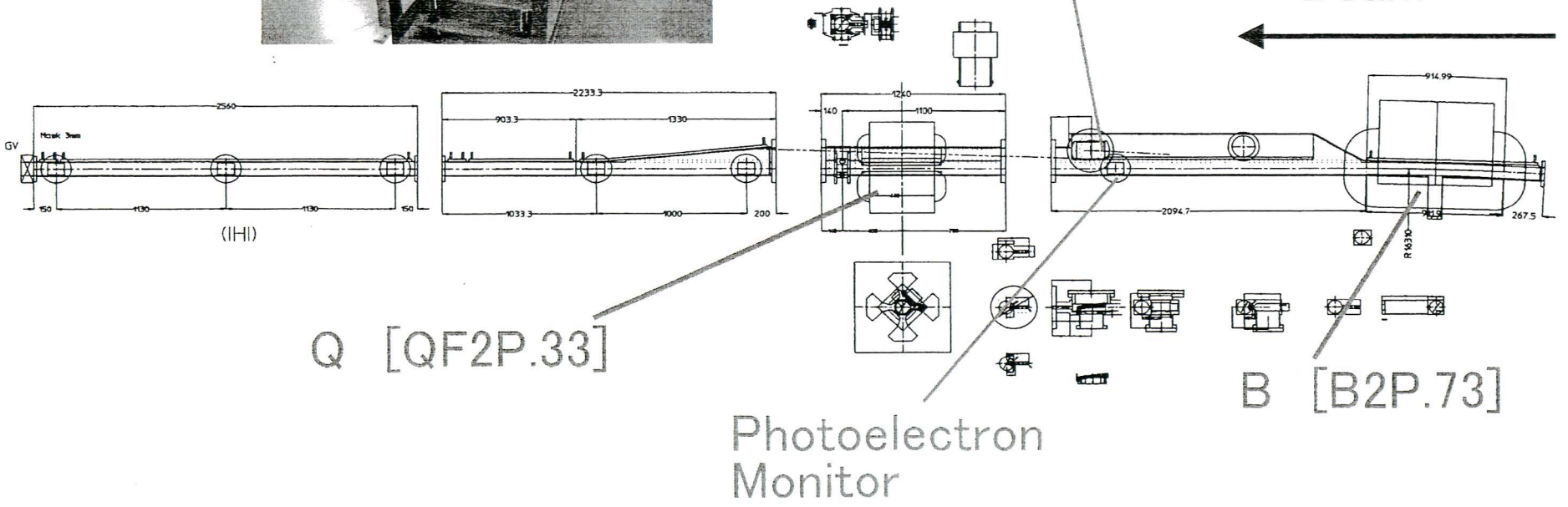
- No Bellows
  - No heating problem by HOM.
  - How to connect adjacent chambers?
  - How to absorb thermal movement of chambers?

Experiments in KEKB _1

- Ante-Chamber
  - Already talked by Kanazawa







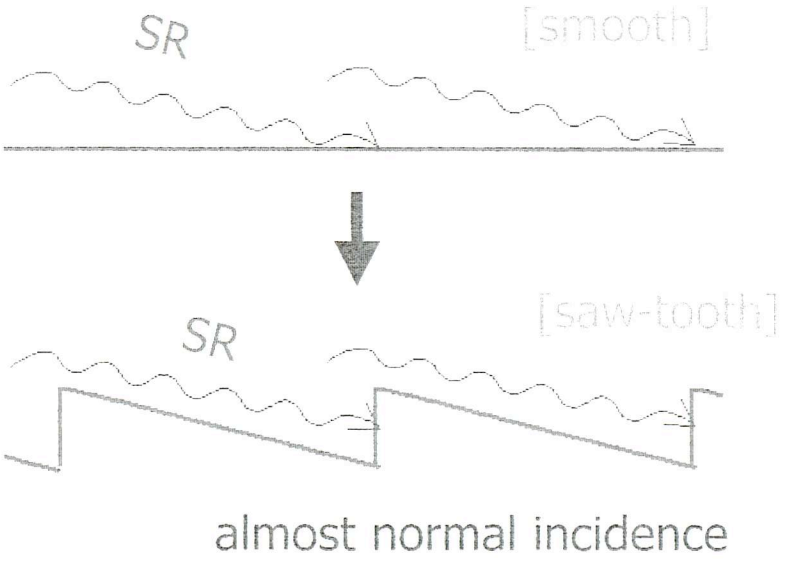
Results of Ante-Chamber

- Photoelectrons in beam duct
  - Number of electrons measured by a photoelectron monitor reduced to about 1/7 compared to the usual single duct.
  - Solenoid is still effective to reduce number of electrons (->1/2).
- Manufacturing
  - No technical problem was found for Cu ante-chamber.
- RF-shield for pumping port
  - RF shield seems necessary even for pumping ports at ante-chamber.
- Photon stop
  - No trouble up to 4.3 kW input.

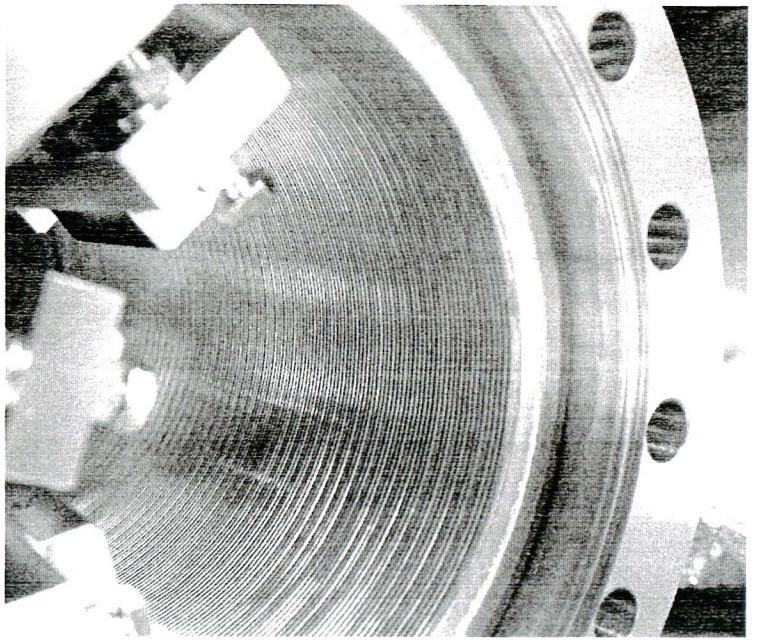
Experiments in KEKB _2

- Saw-Tooth Surface
  - Saw-Tooth surface has been said as an effective way to reduce photoelectron yield against a slant SR incidence.
  - Saw-Tooth surface with a pitch of 1 mm and a depth of about 0.4 mm was manufactured using a present LER beam duct.
  - Photoelectron yield was measured in PF and KEKB.

Effect of saw-tooth surface



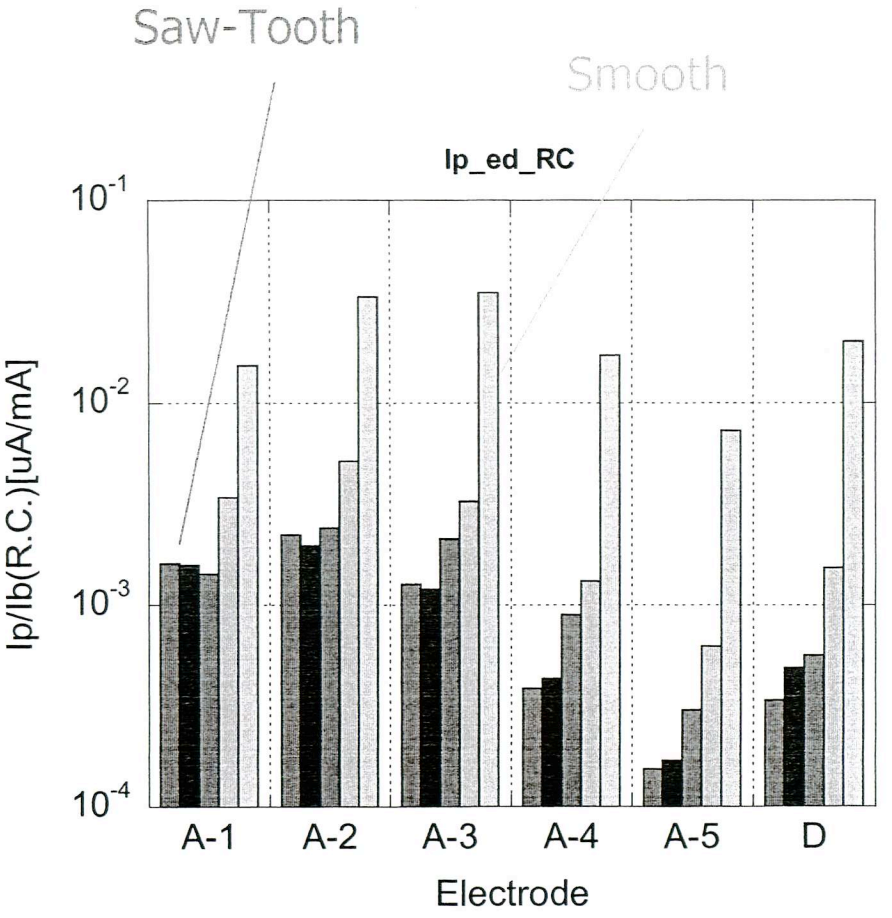
Inside of saw-tooth chamber



Results of Saw-Tooth Surface _1

Experiment in PF

- Photoelectrons
  - Experiment at PF (E_{cr}=4.1 keV) beam line using a 300 mm test chamber is performed.
  - The saw-tooth surface can reduce the photoelectron yield to about 1/17 compared to the smooth surface.
  - Without beam field
- Reflection
  - Reflectivity of SR is reduced by two order of magnitude.

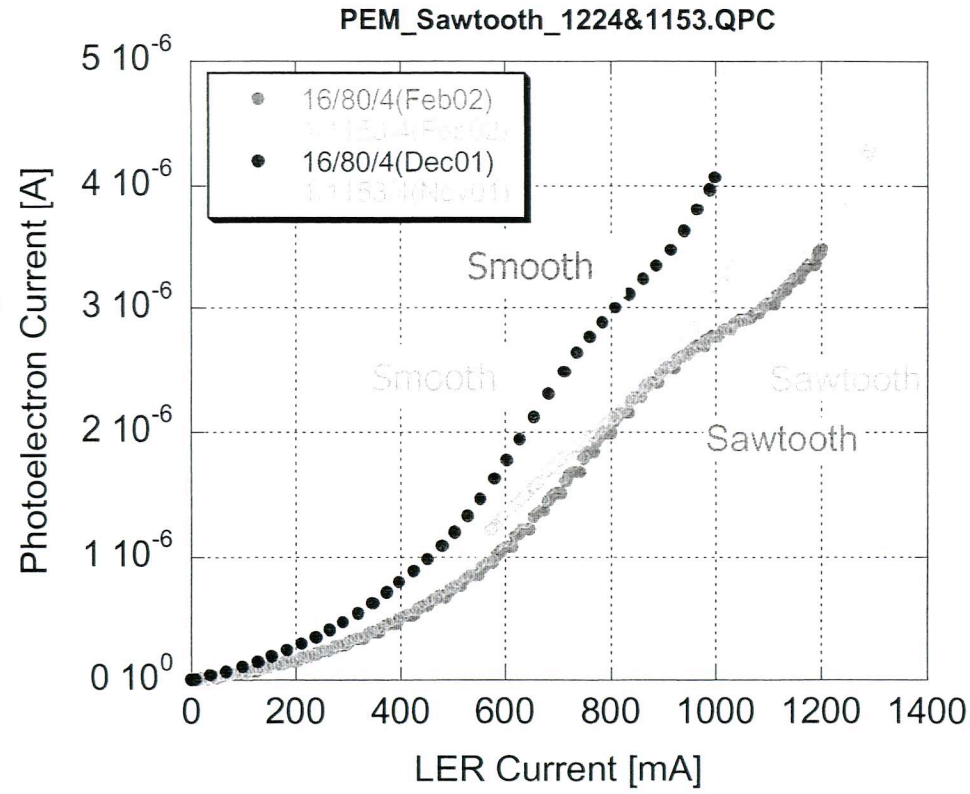


Results of Saw-Tooth Surface _2

Experiment in LER ring

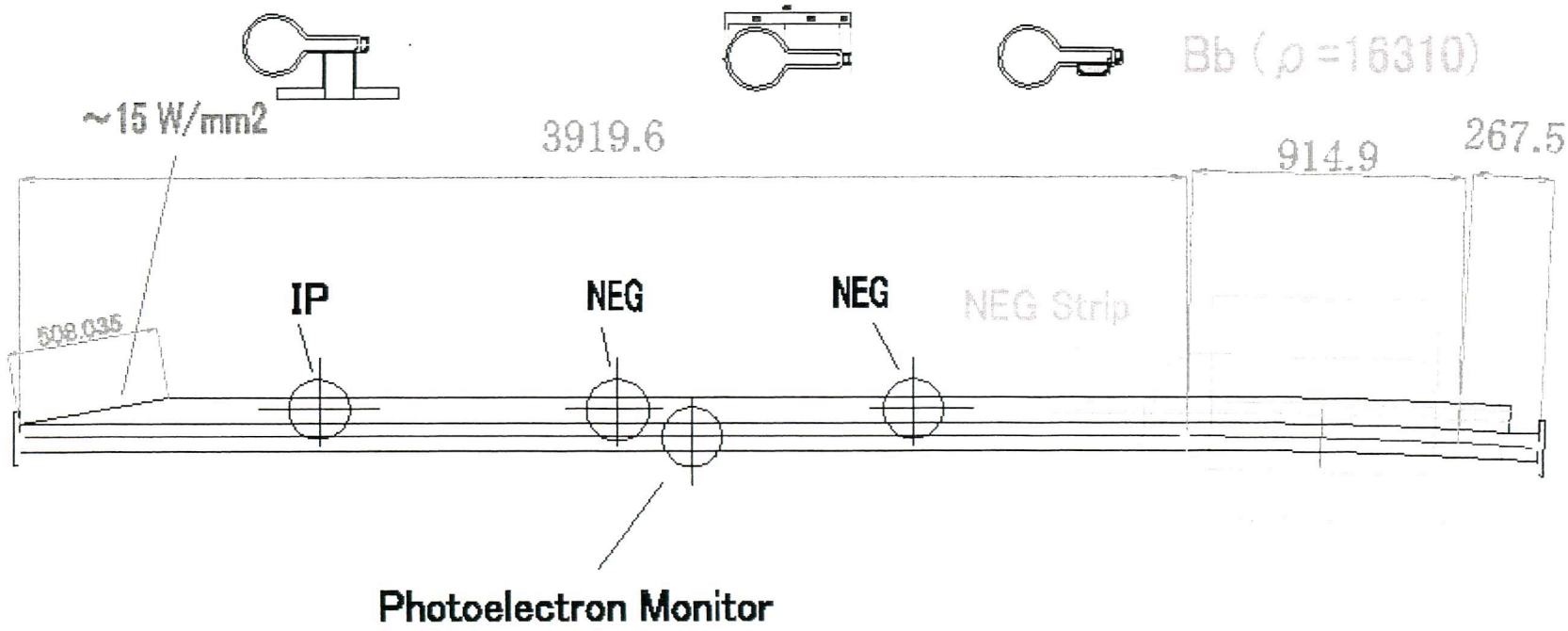
- To check the affectivity with beam field, a 2.7 m chamber is installed at downstream side of ante chamber.

- Photoelectron Current (preliminary)
  - The current reduce to 70 % of smooth chamber(@1200 mA).
  - The reduction is not so drastic as the result in PF (without beam field).
    - Helpless against the multipactoring ?
    - Ineffective with beam field?
  - The saw-tooth surface will be still useful to reduce reflection of SR.
  - The reduction is expected at the side wall of antechamber where the beam field is weak.



R&D Plans_1

- Ante-Chambers Without Photon Stop
  - It is no use if the photoelectrons do not reduce (HER).
  - Apply external magnetic field (solenoid or permanent magnets).
  - Install NEG strip (and use as an electrode?).
  - Install in present LER and measure photoelectron current.
  - Design is now undergoing.



R&D Plans_2

- Bellows
  - Bellows will be necessary.
  - We need about 500 bellows for each ring at least (now about 900).
  - The key point is how to reduce HOM heating.
  - Study for high wall currents (peak and RMS) are also necessary.

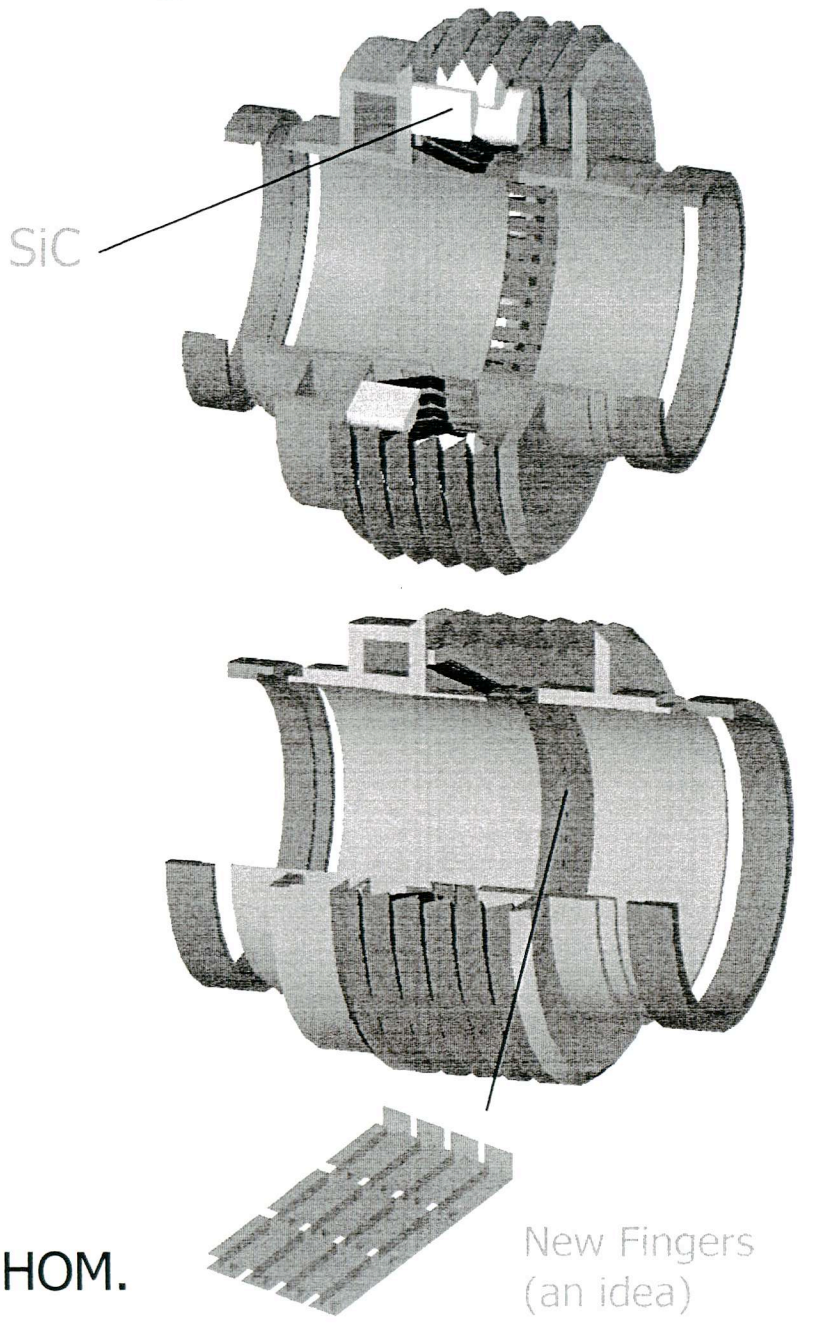
	HER (ϕ50) [Results up to now]	LER (ϕ94) [Upgrade Design]	Bench Test [Using 508 MHz]
Current [A]	0.9	9.4	
Bunch Length [mm]	6	3	
Bunch Number	1150	5016	
Bunch Current [mA]	0.78	1.87	
Peak Wall Current Density [A/m]	1000	2496	1700
RMS Wall Current Density [A/m]	64	237	130

R&D Plans_3

- Bellows Design
  - Design-1
    - HOM Absorbers inside bellows
    - Reliability of absorber

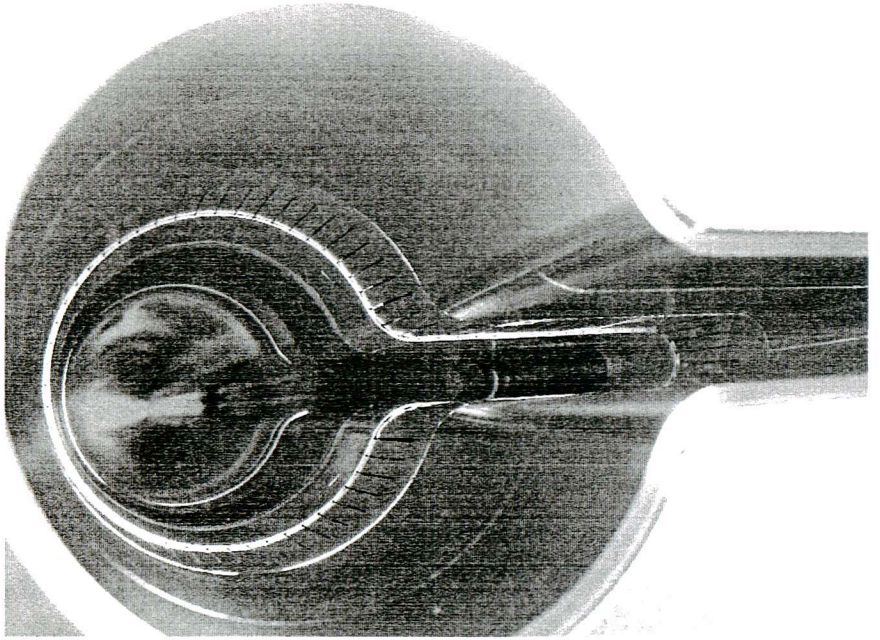
      ->How much the absorbed power?
  - Design-2
    - Small holes between fingers

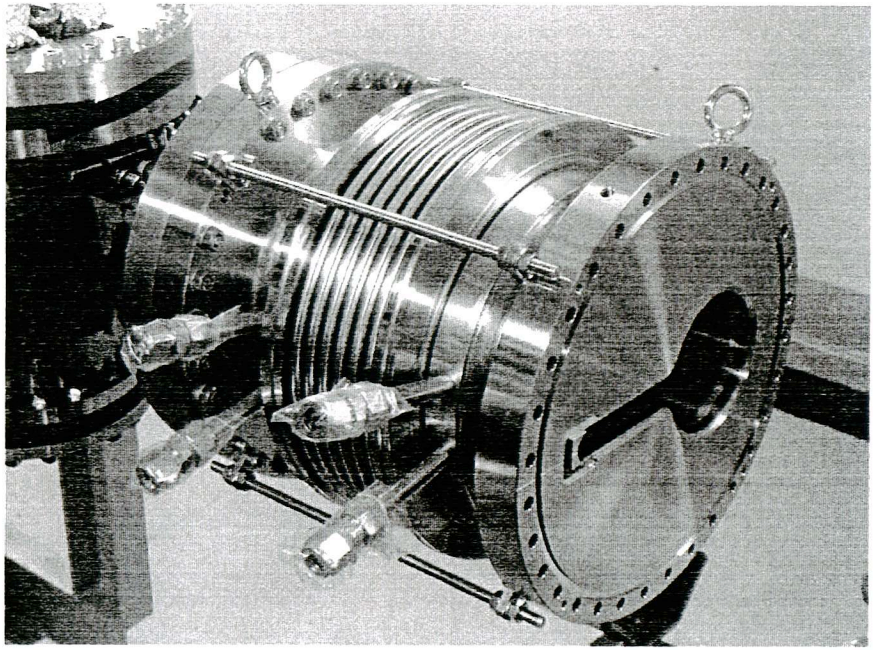
      -> Prevent HOM from intruding inside bellows
    - Make space inside bellows small.
- R&D
  - Apply to the bellows near the present movable mask bellows where the temperature is high even now due to HOM.



R&D Plans_4

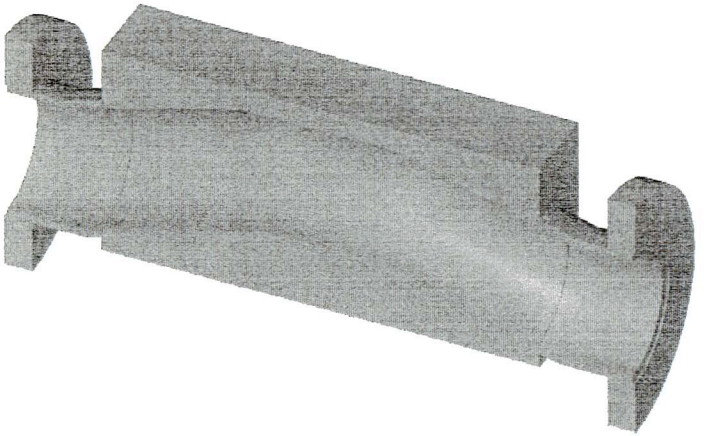
- Bellows (ante-chamber type)
  - No technical problem was found in manufacturing bellows with ante-chamber type aperture.



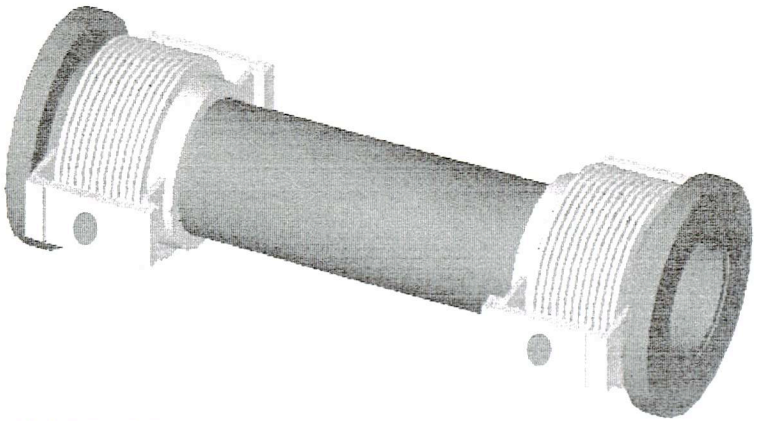


R&D Plans_5

- Movable Mask
  - Movable mask is necessary to reduce the back ground of detector.
  - For the movable masks at arc section, a mask head with the radiation Length of about 1 seems enough to reduce the back ground of detector.
  - To avoid giving a large radiation dose to the detector in abnormal beam loss, the number of mask should be increased.
  - Steering beam scheme solves bellows heating problem, if possible.

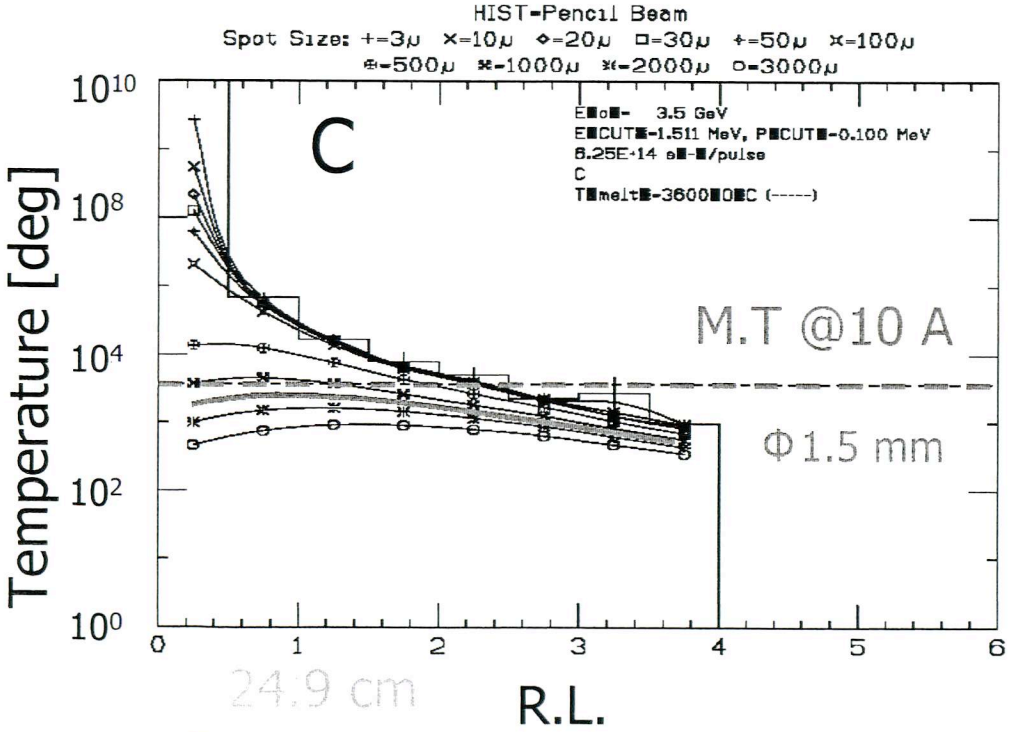


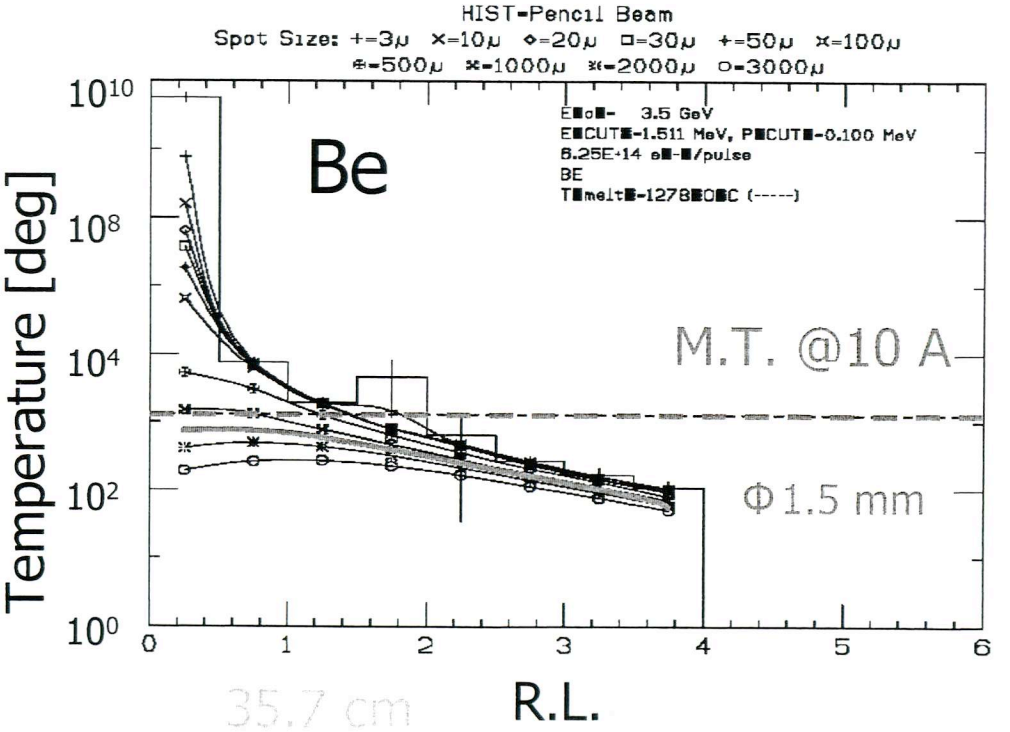
Mask Ver.4



R&D Plans_6

- Mask Head
  - Calculation by EGS4 for 3.5 GeV10 A beam
    - C or Be is prospective if beam size is ~1.5 mm
    - Need more detailed calculation.
    - Spoiler type?
  - Ver.4 will be used considering the mask length.
  - Test in the present LER?

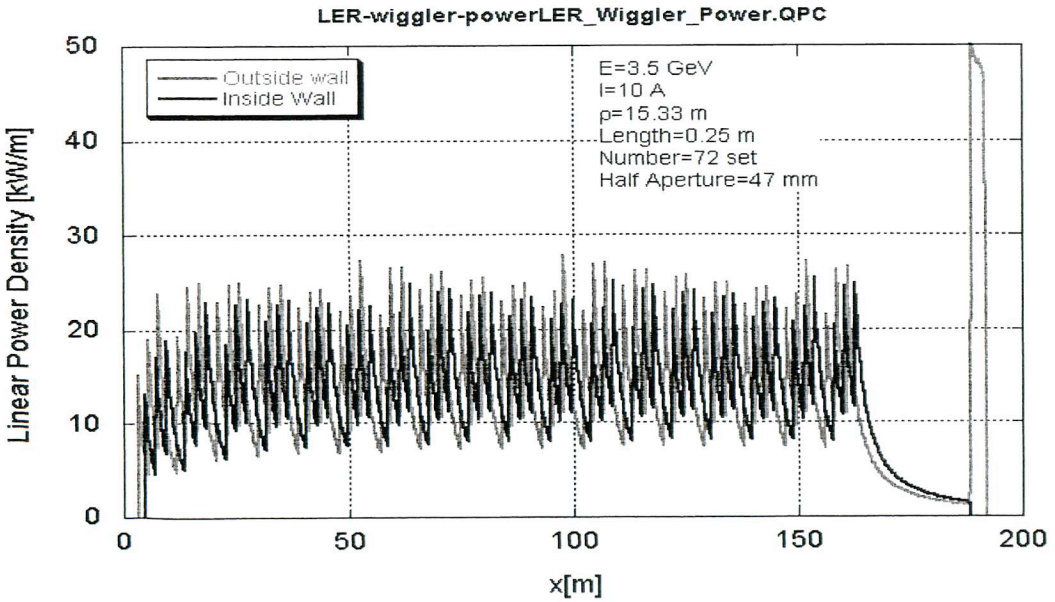




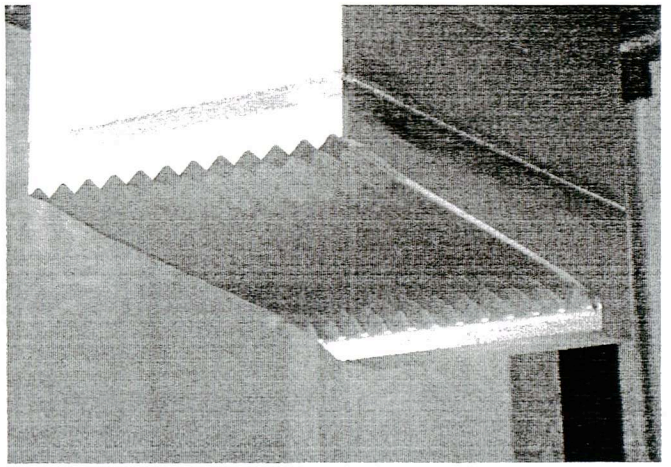
R&D Plans_7

- Photon Stop
  - Option at present
  - It may be necessary for downstream side of wigglers.
  - Calculation → Test using lasers or electron beams
    → Test in the present LER?

SR powers at wiggler section



Photon stop for KEKB LER



Others to be considered

- Cooling power capacity
  - Total Power is about 22 MW (30 MW with wiggler).
- Pumping scheme
  - About 100 l/s/m pumping speed is necessary for a goal pressure of 3×10^{-7} Pa. (Beam life time of about 20 hours from Brems.)
- Surface treatment to reduce photoelectron yield
- Design of special chambers (IR, Injection, Abort,..)
- Estimation of impedances (Flanges, Gate Valves, Ante-Chambers,…)
- Rapid and safe beam abort system

  (Abort Window, Beam Orbit Monitor, Loss Monitor,..)
- High reliable interlock system (Cooling Water, Temperature, ..)
- Radiation shielding
- ……..

Summary

- Chamber Design
  - Ante chamber should be used to deal with the intense SR (HER & LER) and to avoid electron cloud instabilities (HER).
  - No special photon stop design is considered now.
  - Ante-chamber with a photon stop worked almost as expected.
  - Solenoid will be necessary to suppress electron multipactoring.
- R&D Plans
  - Verification of ante-chamber scheme without photon stop
  - Development of bellows, movable mask, photon stop -> Test in KEKB
- Others to be considered
  - Design of special chambers (IR chambers etc.)
  - Estimation of impedances such as gate valves
  - Etc. .....