Vacuum Components R&D for High Current Machine

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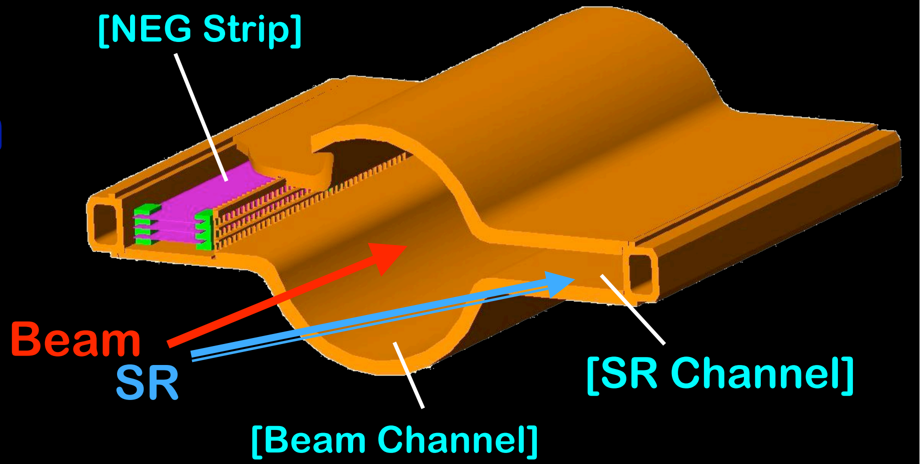
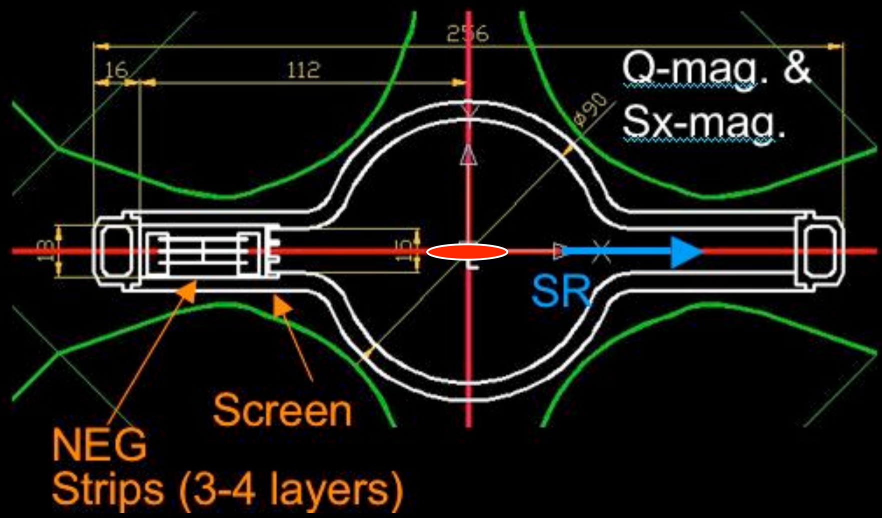
Contents

1. Beam Duct with Ante-chambers

- **Features**
  - Low SR power density at side wall
  - Little photoelectrons in beam channel
  - Low impedance
- **R&D points**
  - Trial Manufacturing
    - Use Copper
    - Establish fabrication methods
    - Get base of cost estimation
  - Experimental demonstration of photoelectron reduction

Beam duct with antechamber

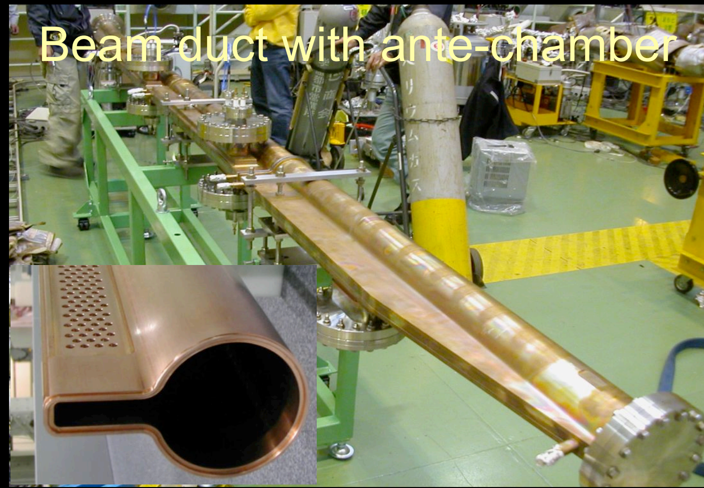




1. Beam Duct with Ante-chambers

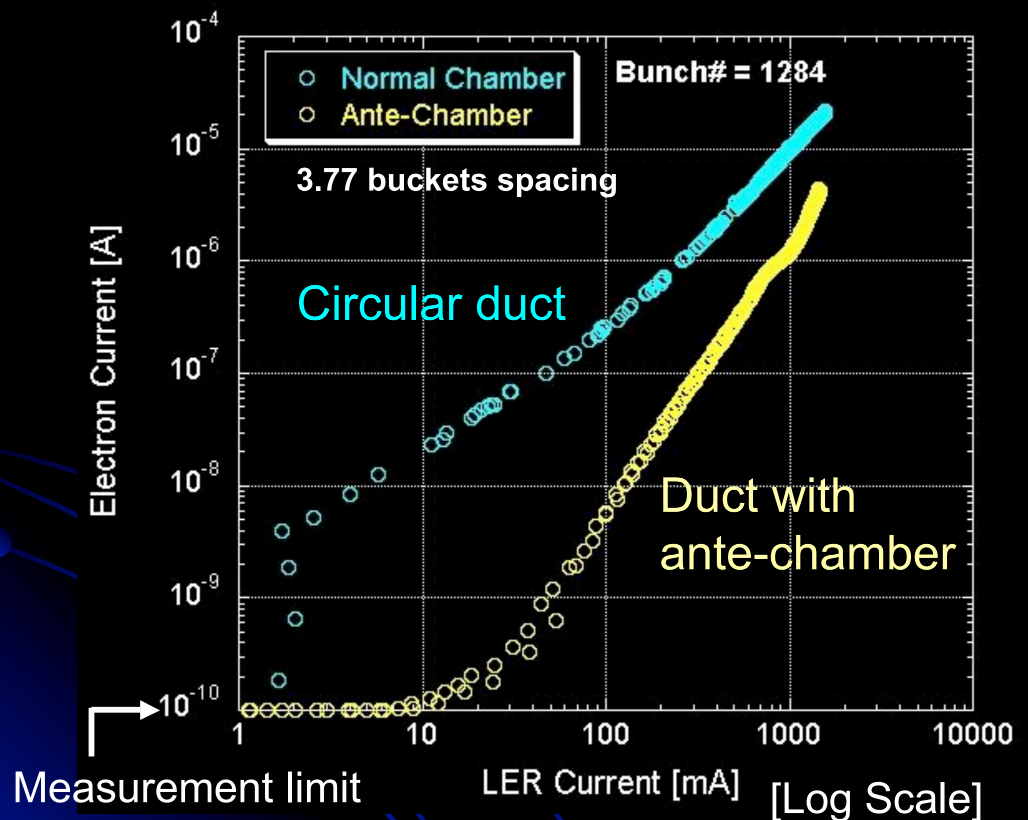
- **Beam duct with one antechamber (2003-2004)**
  - Model: for arc section
    - OFC(^{t}6), ^{w}159, ^{h}94, ^{L}5.4 m
  - Fabrication methods:
    - Forming (from plates)
    - Cold drawing
  - **Both methods were possible.**
  - Test chambers were installed into LER arc (2003).
    - No serious problem was found up to now.
    - At the beginning, pressure bursts were observed at (may be) transverse connection.

      → To be cared in practical cases



1. Beam Duct with Ante-chambers

- Electron number in the beam channel (2003)



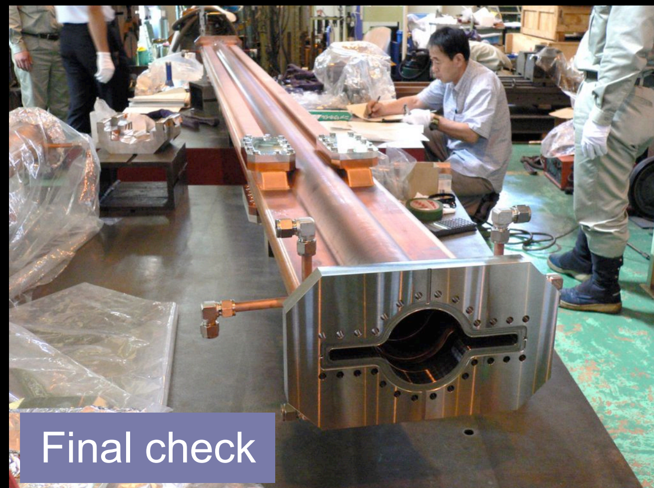
- Measured by an electron monitor at the bottom of duct (Bias = -30V)
- The reduction was by orders at low current ($I_b \leq$ 100mA).
- The reduction was by factors at high current ($I_b \geq$1000 mA).

  →Multipactoring becomes important at higher current.

1. Beam Duct with Ante-chambers

- Beam duct with two antechambers (2005)
  - Model: for wiggler section
    - OFC(^{t}6), ^{w}224, ^{h}94, ^{L}4.7 m
  - Fabrication methods:
    - Forming (from plates)
  - Manufacturing was successful.
    - Degree of accuracy should be improved in future

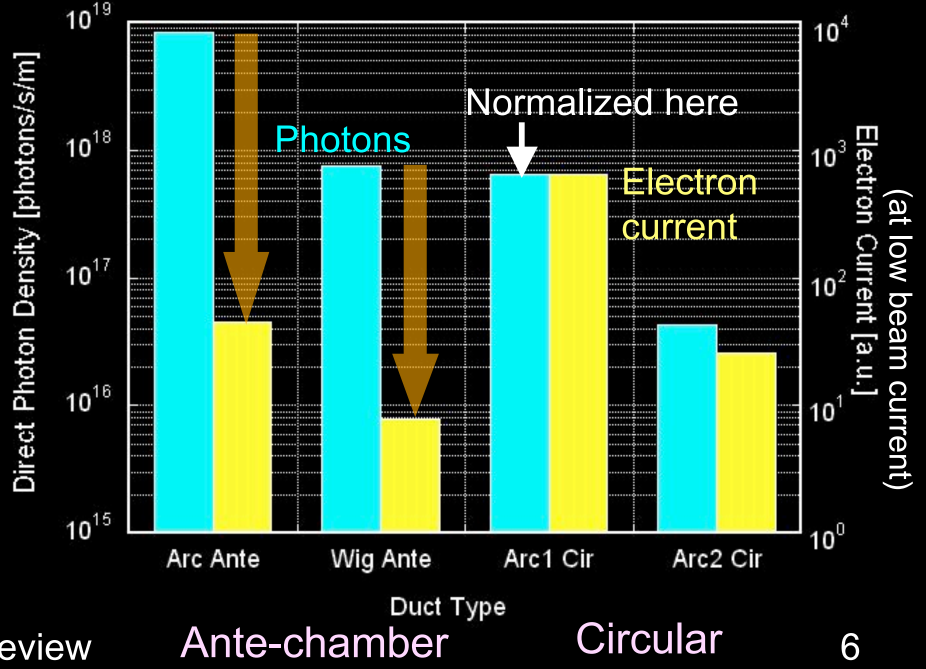

Forming


Final check


Inside view

1. Beam Duct with Ante-chambers

- **Beam test (2005)**
  - Test duct was installed into LER wiggler section.
  - No problem was found up to 1.7 A stored current.
  - No pressure burst was found.
  - Electron density in the beam channel was also measured.
    - Reduction of photoelectrons were confirmed again.

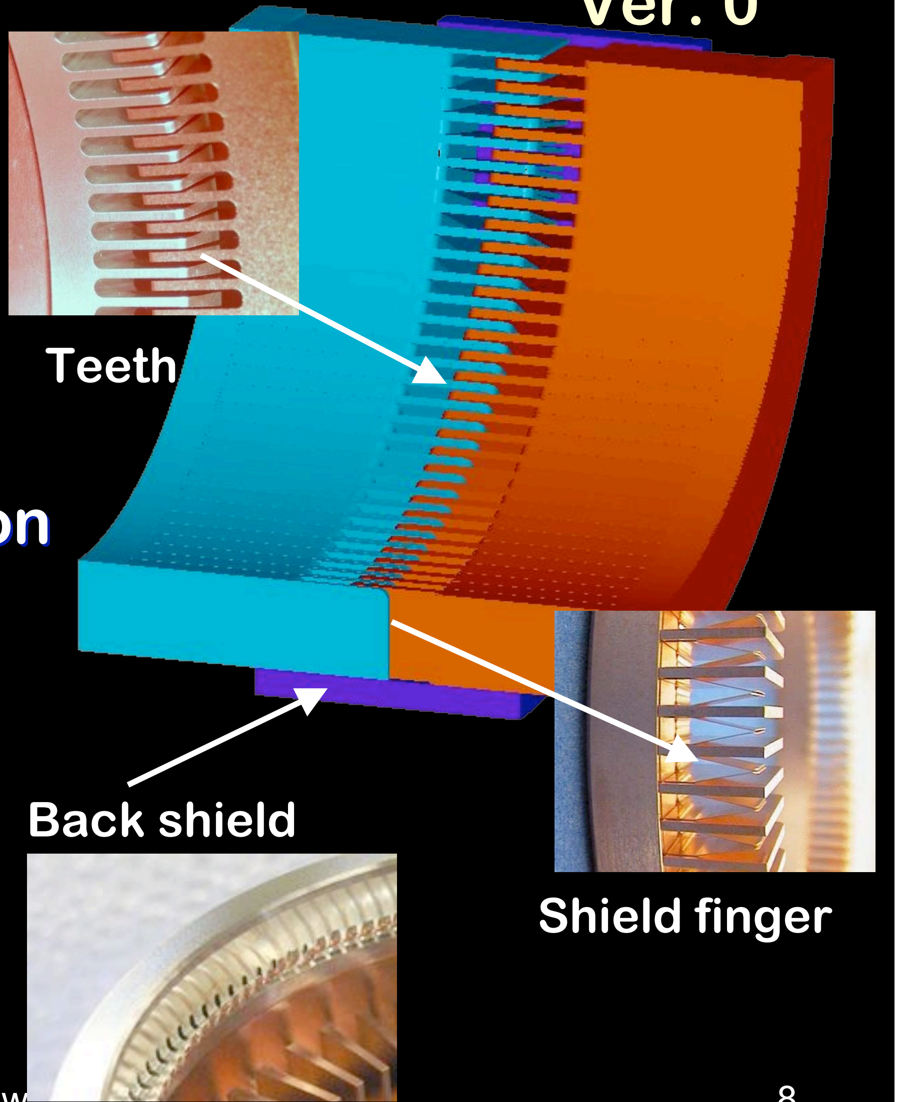


1. Beam Duct with Ante-chambers

- **Next step**
  - Reduction of secondary electrons in the beam channel.
    - **Study on surfaces with a low SEY is undergoing in parallel.**
  - Further studies for more practical cases
    - **Combination with a coating with a low SEY to suppress electron multipactoring.**
    - **Bending for arc section.**
    - **Manufacturing of beam duct with BPM for Q or SX magnet.**

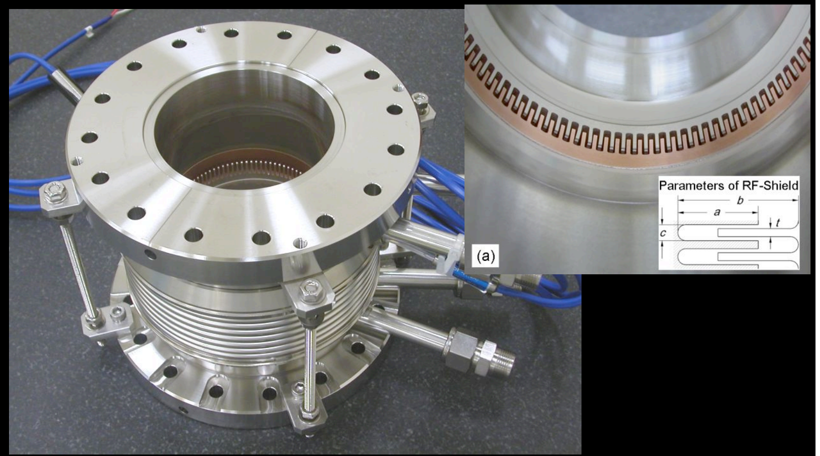
2. Bellows Chamber and Gate Valve

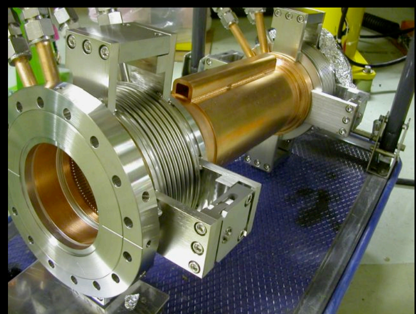
- Comb-type RF-shield
  - Has been studied from 2003
- Features
  - High thermal strength
  - Low impedance
  - Effective RF shielding
  - Applicable to any cross section
- R&D points
  - Experimental demonstration
  - Trial manufacturing
  - Cost reduction
    - Simplification

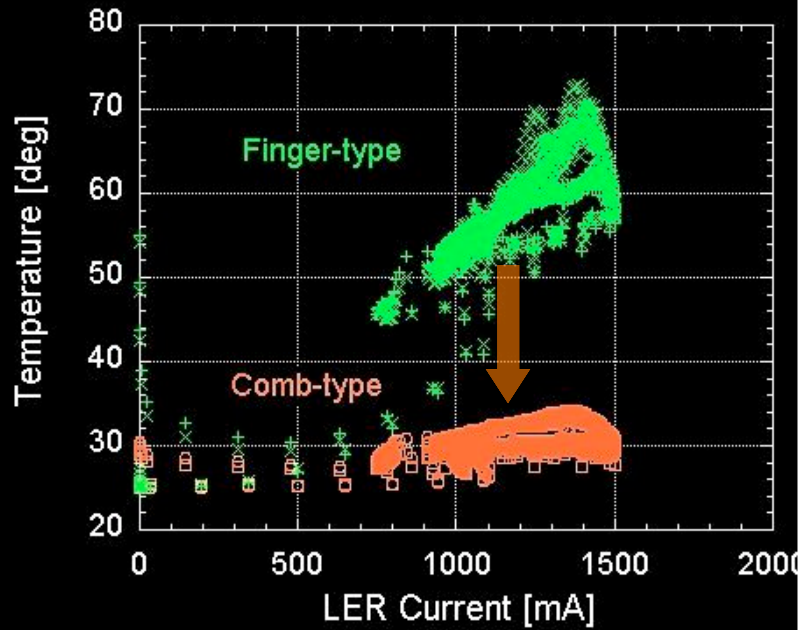


2. Bellows Chamber and Gate Valve

- **Ver.0 (2003)**
  - **With back shield and shield finger**
  - Trial model (ϕ94) was installed into LER (2003)
  - **Temperature of bellows decreased to 1/6 of conventional one.**
  - Temperature of teeth was about 50°C at 1.5 A.
  - **No problem was found up to 1.7 A.**
  - Applied to bellows for movable masks (2004).

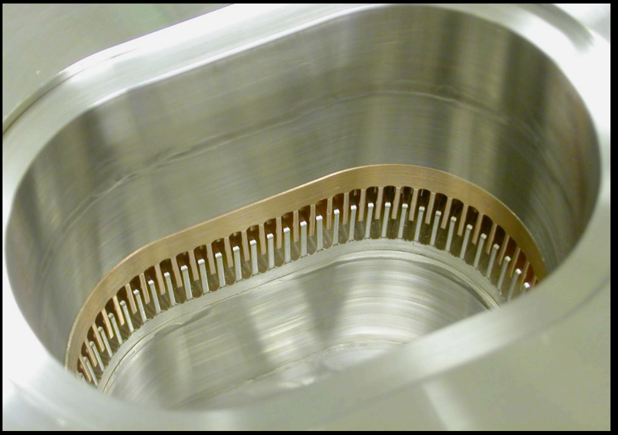


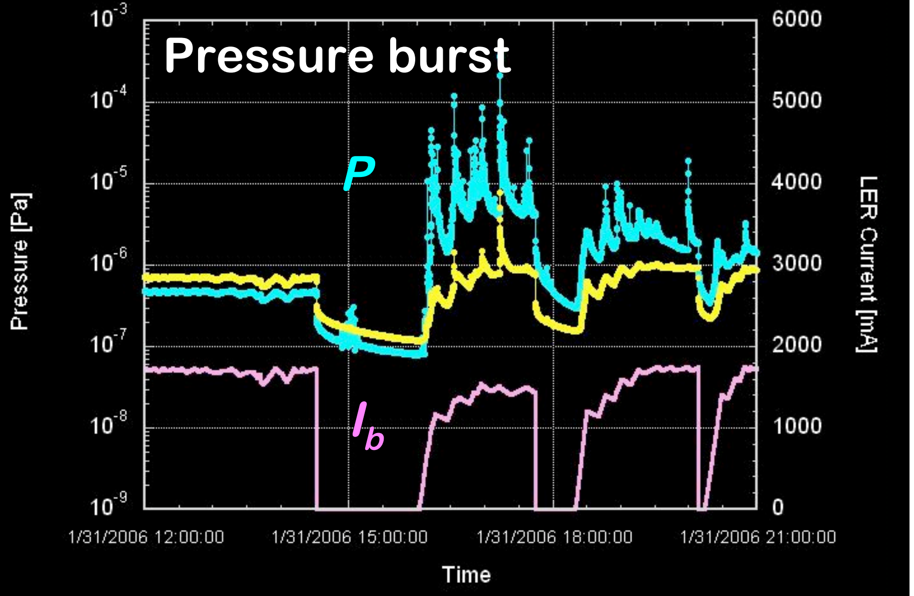




2. Bellows Chamber and Gate Valve

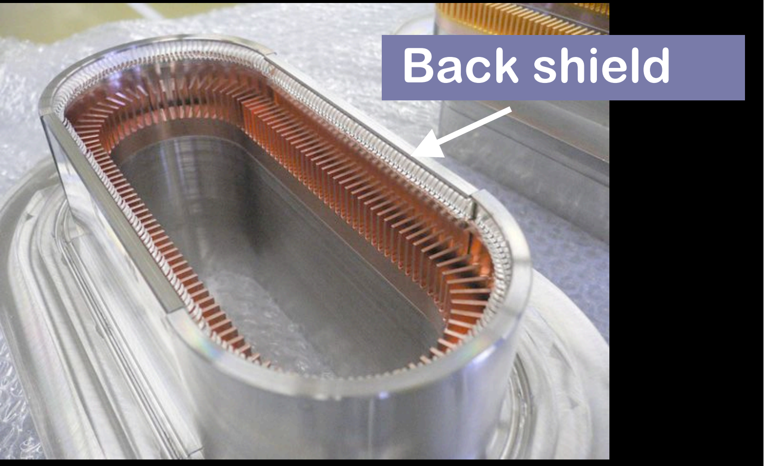
- Ver.1 (2004)
  - Without back shield to simplify the structure
- Test model was installed into LER (2004).
- Temperature of bellows was almost same as the conventional one.
- Pressure burst (may be due to arcing) was observed during operation in 2005.
- Will be removed and investigated during this shutdown (2006).

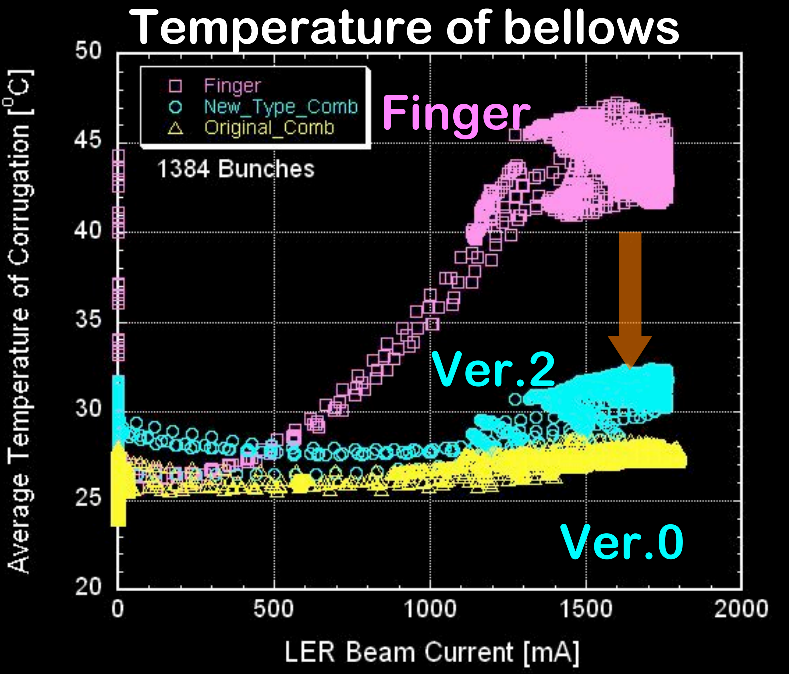




2. Bellows Chamber and Gate Valve

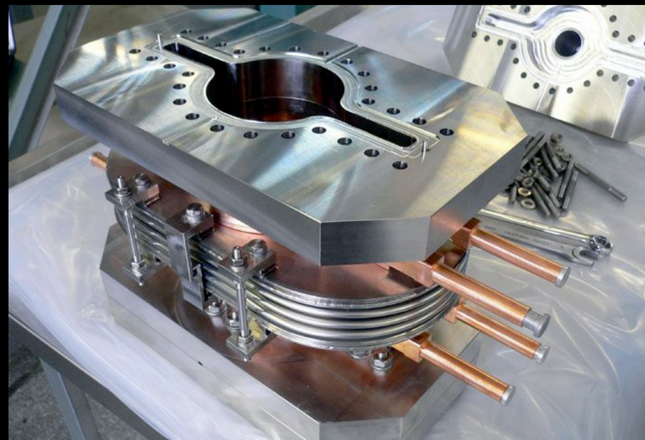
- Ver.2 (2004)
  - Without shield finger to simplify the structure
  - Test model was installed into HER (150x50) and LER (ϕ94) (2005)
  - Temperature of bellows was about 1/3~1/4 of conventional one.
    - RF shielding is still effective.
    - Structure is much simplified.
  - Temperature of teeth was 90° C at 1.7 A.
  - Applicable to gate valve.
    - No abrasion between teeth

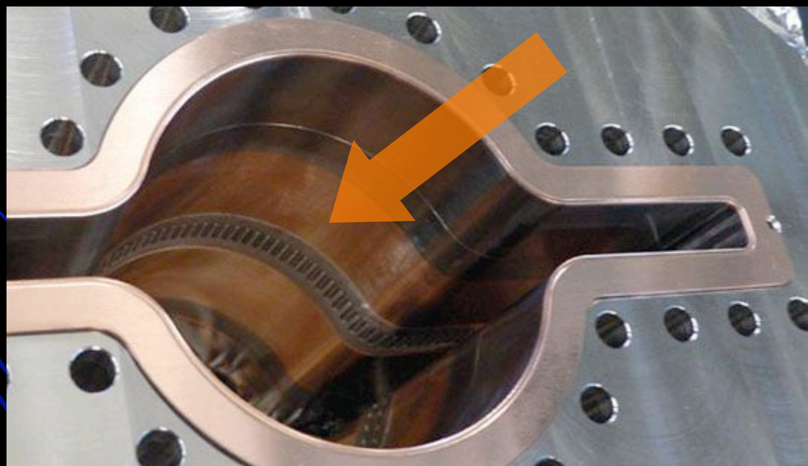


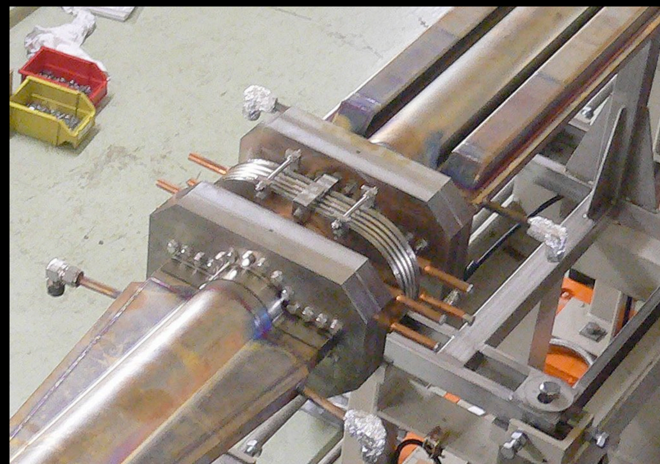


2. Bellows Chamber and Gate Valve

- Application of Ver.2 to antechamber-type bellows
  - Manufactured at BINP (2005)
  - Copper cooling channel
    - Improve cooling of teeth
  - Two bellows chamber were installed into LER wiggler (2005).
  - No problem was found up to 1.7 A.

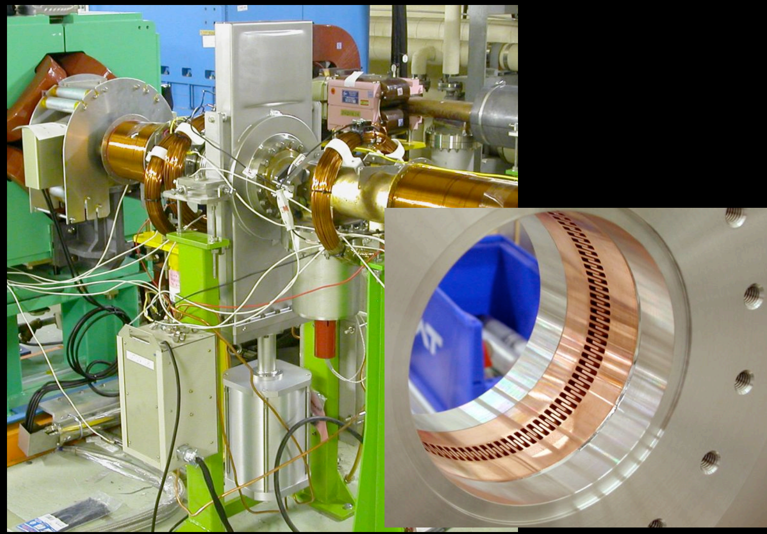


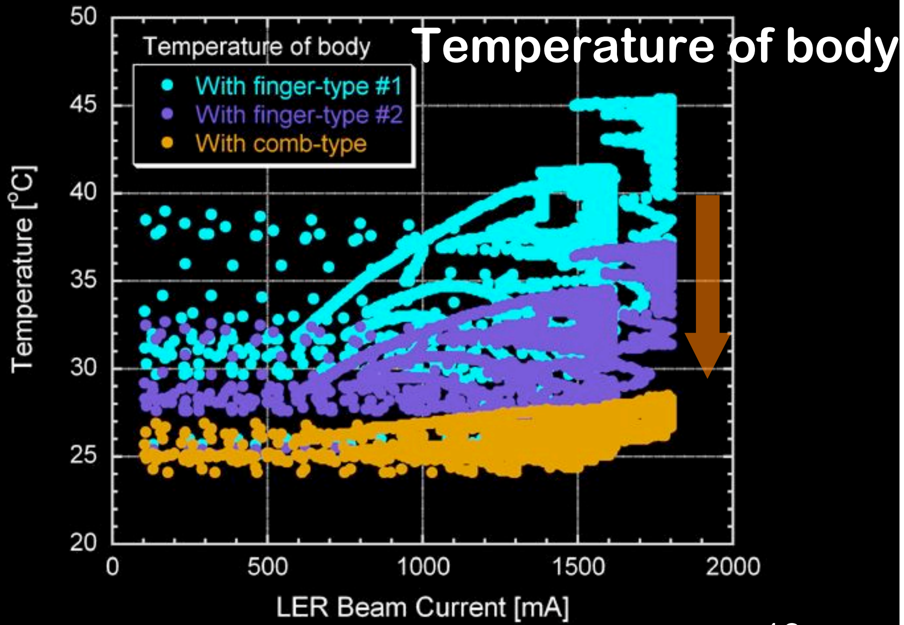




2. Bellows Chamber and Gate Valve

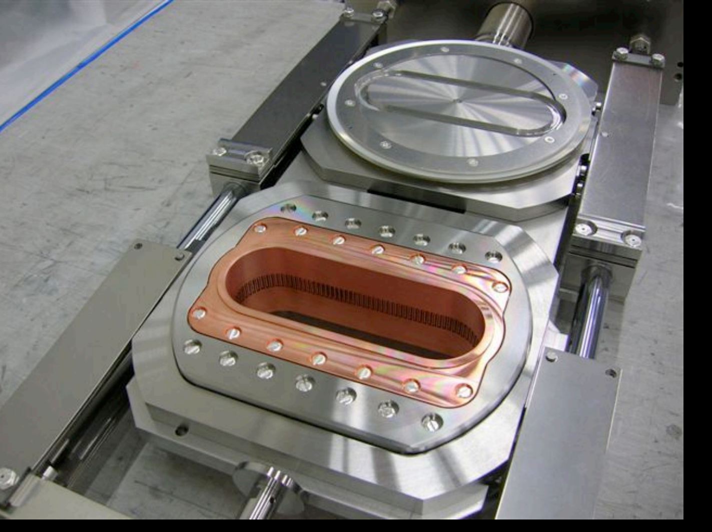
- Gate valve with Ver.2 shield
  - Manufactured by VAT Co. (collaborative project)
  - Circular type was installed into LER (2005)
  - Temperature of body was about 1/3~1/6 of conventional one.
  - No problem was found up to 1.7 A

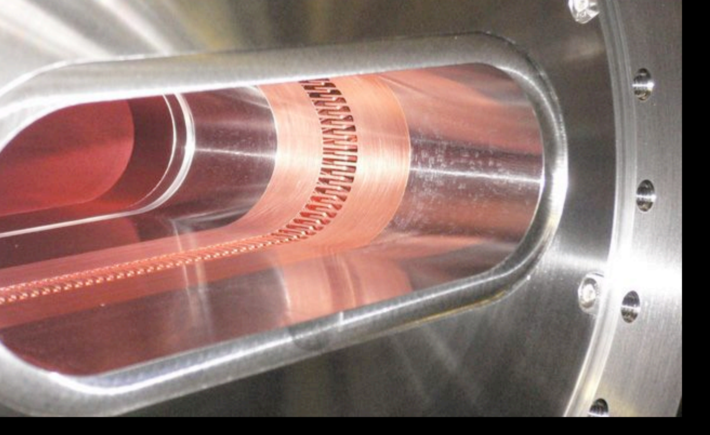




2. Bellows Chamber and Gate Valve

- **Next step**
  - Understand the reason of failure of Ver.1 shield.
    - Inside check
    - It was OK in calculation. Why?
  - Expand application of Ver.2 shield to bellows chambers and gate valves.
    - Replace with broken bellows chamber in KEKB.
    - Racetrack gate valve with Ver.2 shield will be installed in KEKB this spring (2006), and the performance will be checked.

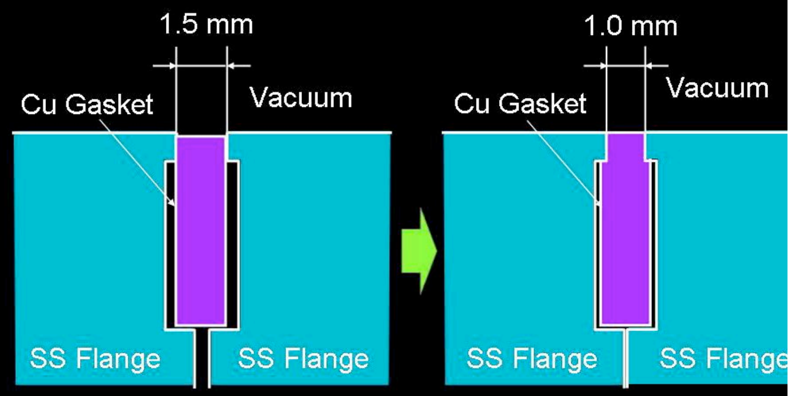


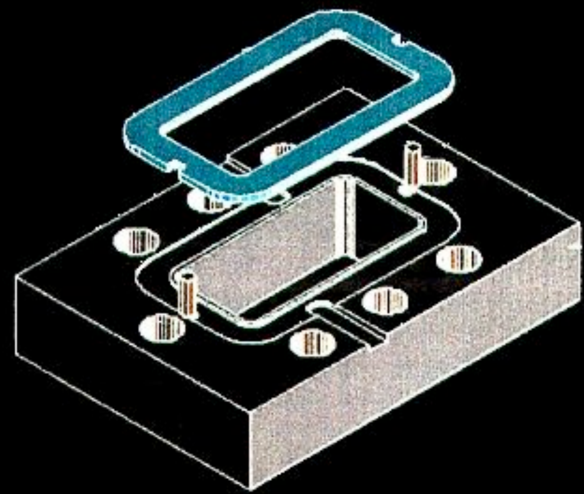


Inside view of racetrack gate valve

3. Vacuum Flange

- **MO (Matsumoto-Ohtsuka) type flange**
  - Has been studied since 2003
- **Features**
  - Seal a vacuum at only the inner surface
  - Vacuum seal doubles as RF bridge
  - No gap and step at the inner surface
  - Can follow the complicated cross section
- **R&D points**
  - Experimental demonstration for non-uniform cross section
  - Beam test



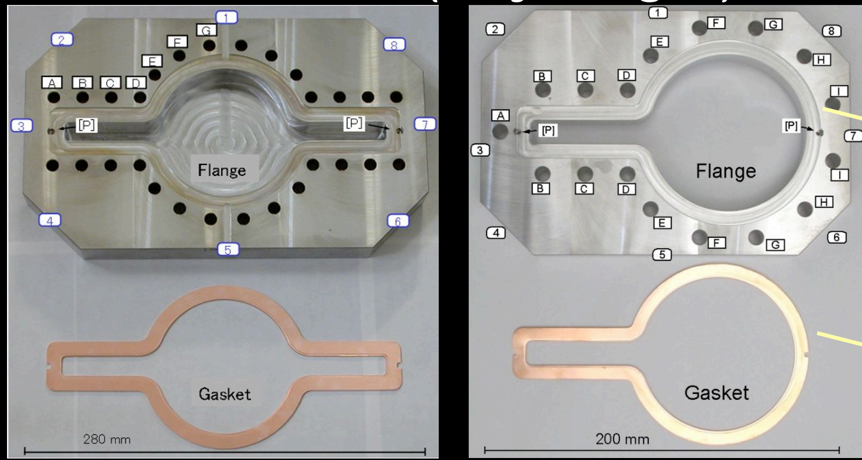


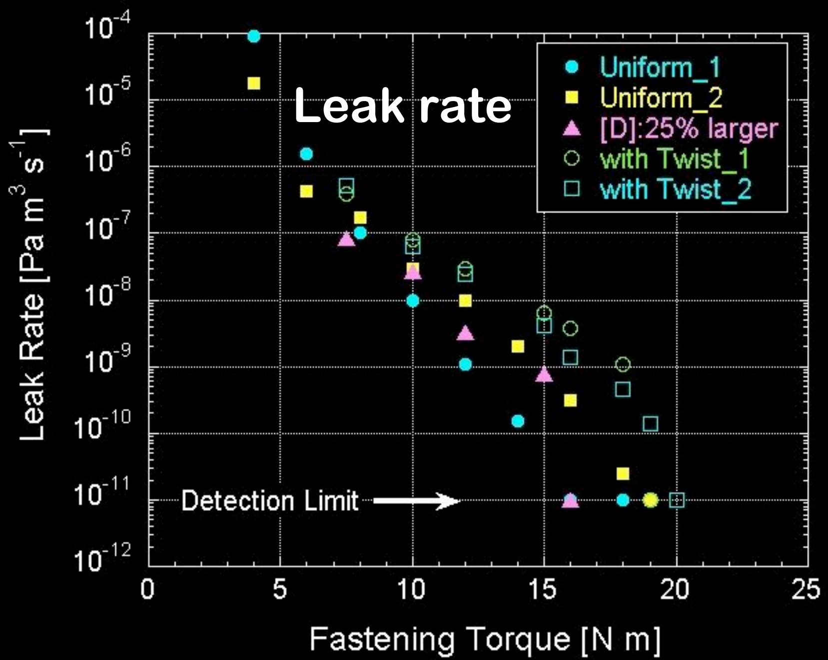
Rectangular model (for waveguide)

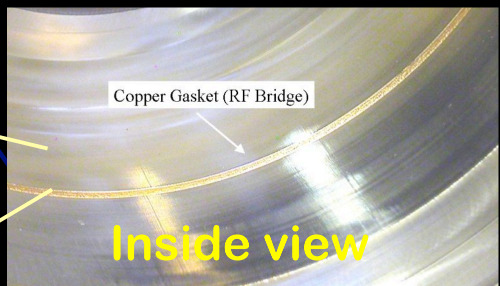
3. Vacuum Flange

- **Bench test (2003-2004)**
  - Using blank flanges
  - Vacuum sealing was possible with a reasonable fastening force.
  - Stress of bolts is well below the tensile strength.
  - Baking up to 250°C, twist up to 5 mrad were OK.
  - **Promising results were obtained.**

Trial models (only flanges)

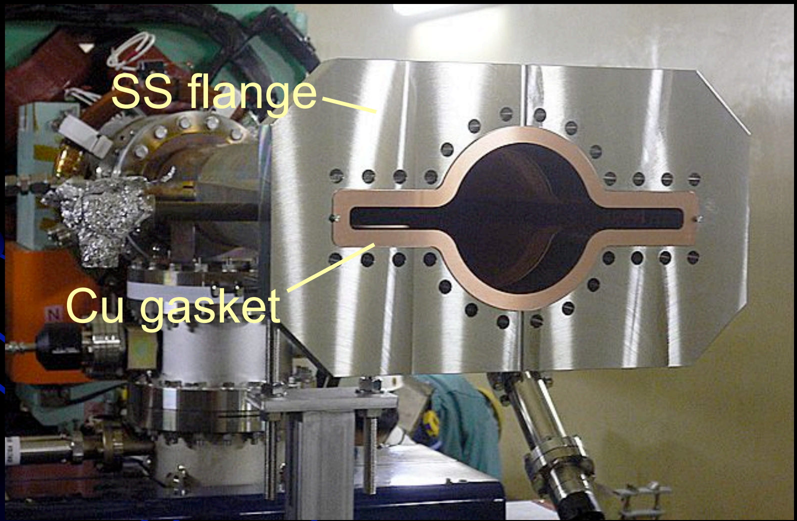






3. Vacuum Flange

- **Application to bellows chamber and ducts (2005)**
  - **MO-flange was applied to beam duct with ante-chambers and their bellows chambers, and installed into LER.**
  - **No problem was found up to 1.7 A.**
    - **Temperature of bellows was almost same to conventional ones (circular). ~30 °C .**

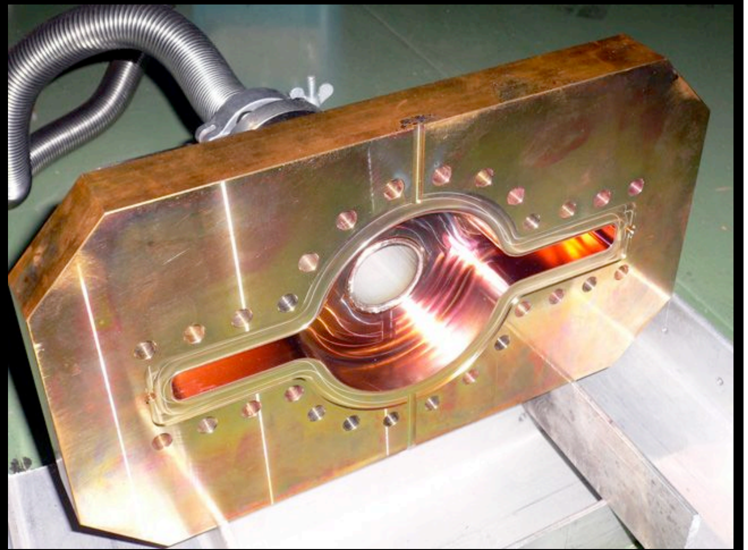


MO-type flange for beam duct with antechambers for wiggler section

MO-type flange for bellows chamber

3. Vacuum Flange

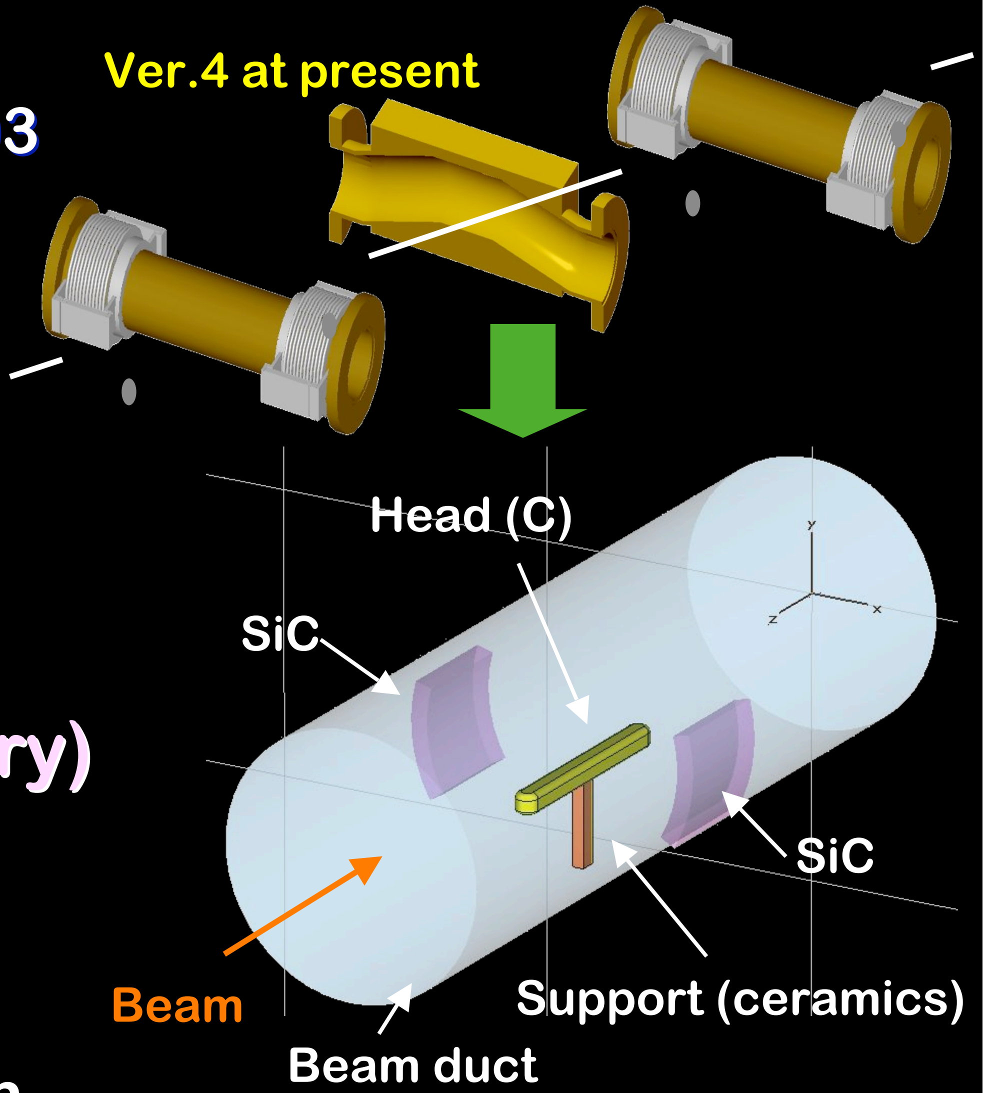
- **Next step**
  - Need further assessment of performance in real machine.
  - Application of **copper-alloy flange** was also tested, and good results were obtained (2005).
    - Continue further study.



Copper-alloy MO-type flange (courtesy of K. Sennyu, MHI)

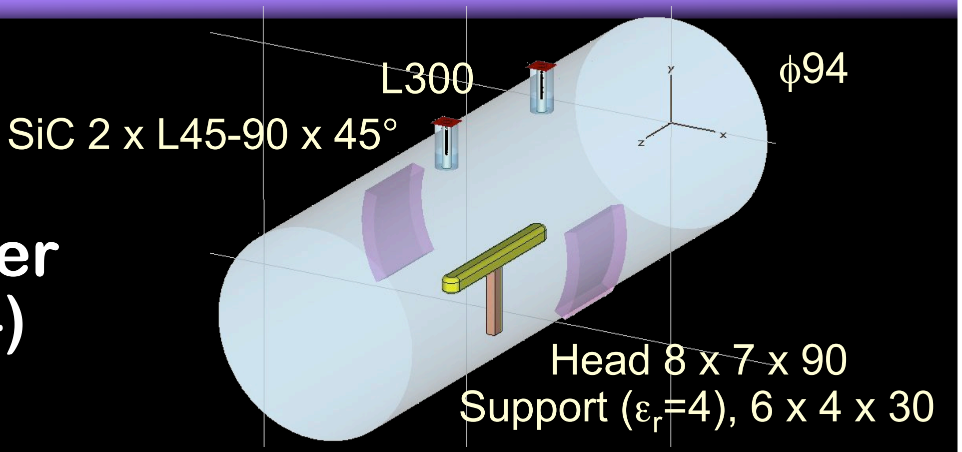
4. Movable Mask

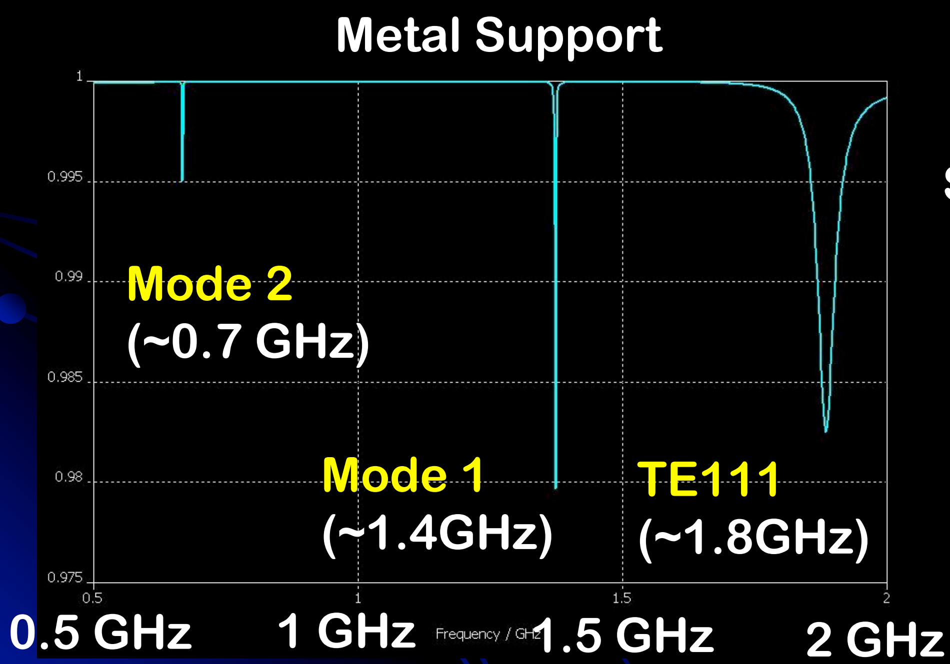
- Stealth type
  - Has been studied since 2003
- Features
  - Ceramics support
    - Little interference with beam
  - Carbon head
    - Little damage by beam
  - With HOM absorber (SiC)
- R&D points (still preliminary)
  - Trapped mode
  - Heating of head
  - Charge up
  - Experimental demonstration

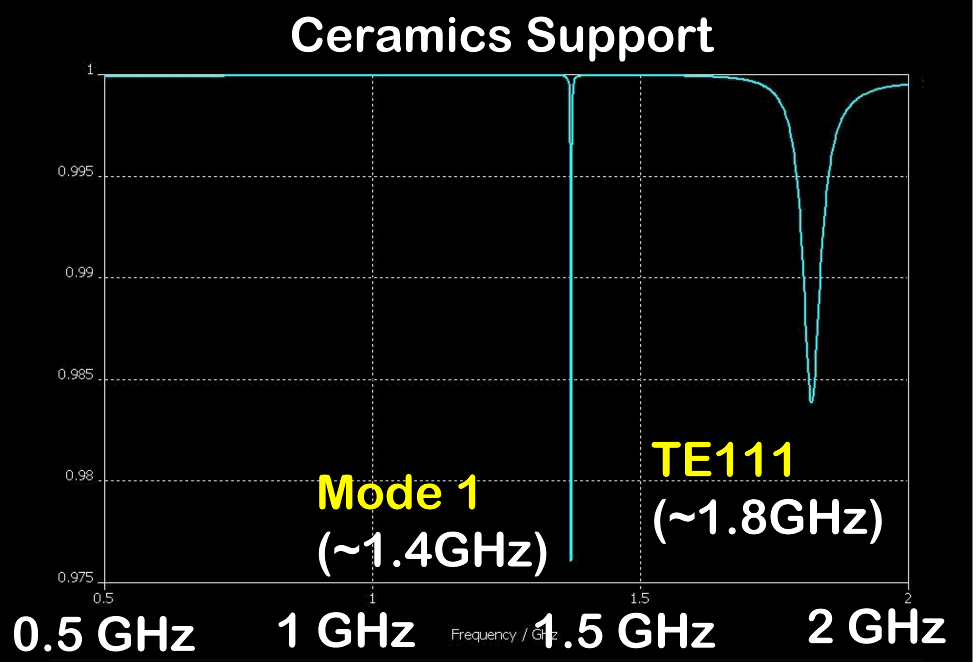


4. Movable Mask

- **Trapped modes**
  - S11 were calculated.
  - Two modes are trapped under TE11 cut off (1.87GHz @ φ94)

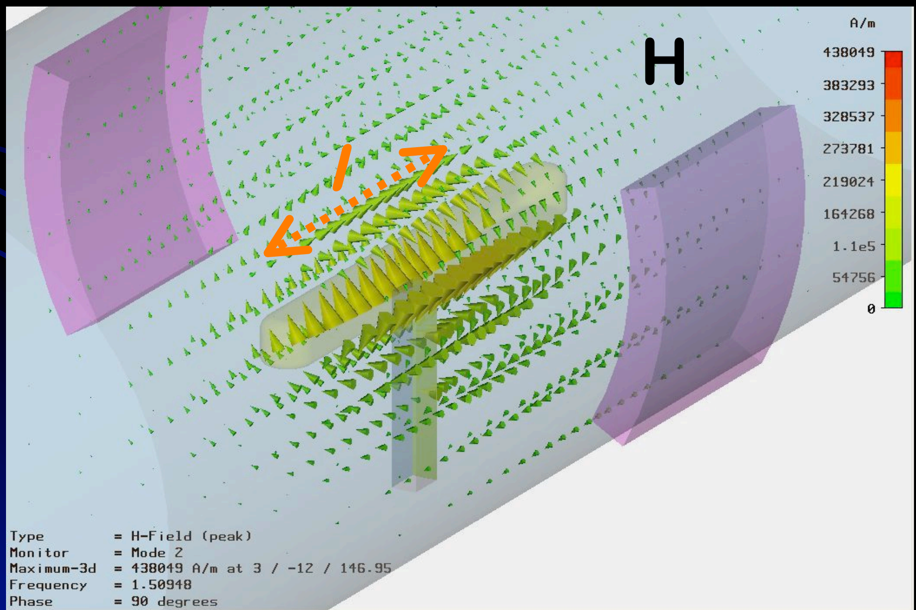


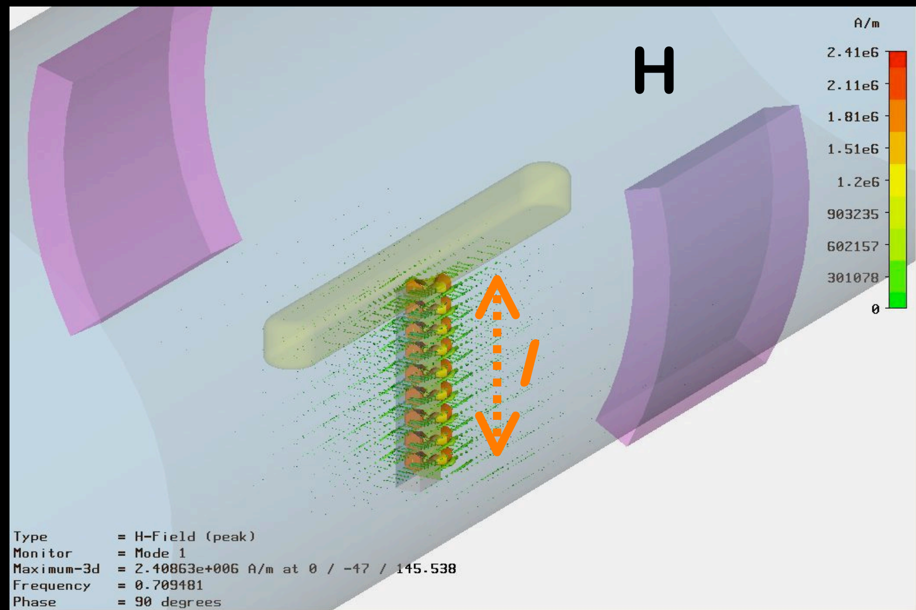




4. Movable Mask

- **Mode 1**
  - *f* ~ 1.38 GHz
  - Current flows back and forth along head
- **Mode 2**
  - *f* ~0.68 GHz
  - Current flows back and forth along support.
  - The mode that troubled Ver.1~ 3 masks.





4. Movable Mask

- **Mode 1 (f~1.38 GHz)**
  - Little dependence on the conductivity of support.
  - For metal or ceramics support, Rs=100~10Ω, Q~1000
    - With SiC 2 x 45° x 45mm
  - Not problem for CBI
- **Mode 2 (f~0.68 GHz)**
  - Rs (should) depend on the conductivity of support.
  - For metal support, Rs~100kΩ, Q~1000 (even with SiC)
  - Big problem for CBI, if metal support
    - To achieve a growth rate less than 30 s^{-1} for SKEKB, Rs should be less than ~500 Ω.
    - How much is the tolerable conductivity? - not obtained yet.

- Required τ^{-1} for SKEKB
  - Damping time = 30 msec
  - α=2.7E-4, f_s=3.1E3, 9.4 A, 5120 bunches
  - # of mask=16

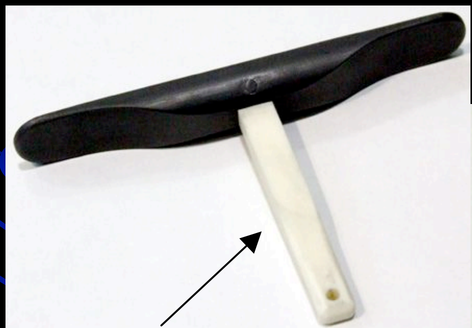
4. Movable Mask

- **Heating of head**
  - If only radiation is considered, temperature ~ 800° C for an input power of ~100 W.
    - Emissivity ~ 0.5 for rough (dark) surface
  - Joule loss: ~50W (10A, Cu head, 10mm form beam)
  - Trapped mode: ??   → Need Rs!

- **Charge up of head**
  - Metal coating (ex.Ti) with 0.1~1μm thick on the support is considered at present.
  - Otherwise, TiN coating, or any paint with large resistivity, as used in DAFNE.
  - Coating method depends on the required conductivity.

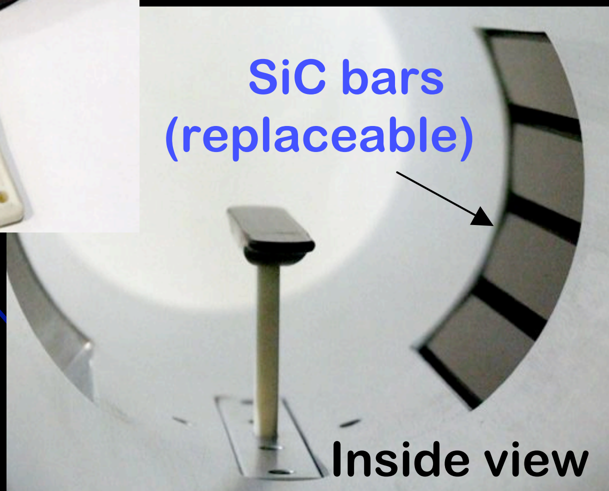
4. Movable Mask

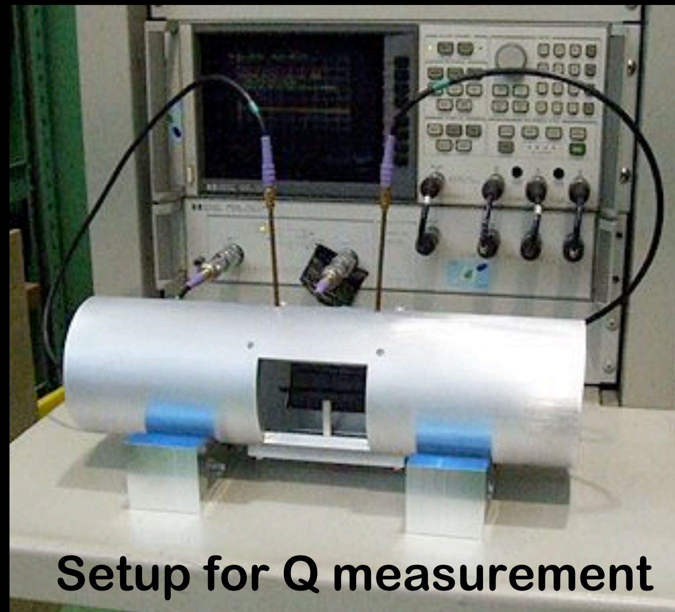
- **Cold model**
  - Al pipe, $^{L}300$ mm, $\phi 94$ mm
  - Carbon head with relatively complicated structure was successfully manufactured.
  - BN support: possible, but coating was found to be difficult.
    - Consider possibility of Al_2O_3 ($\varepsilon_r \sim 8$)
  - Measurement of RF characteristics is planed.



Trial carbon head

BN support

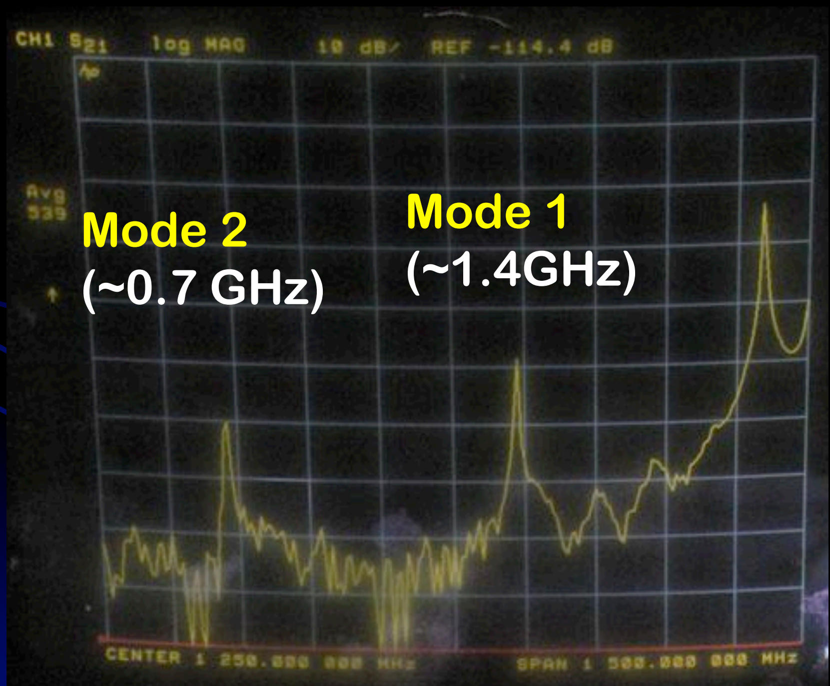




4. Movable Mask

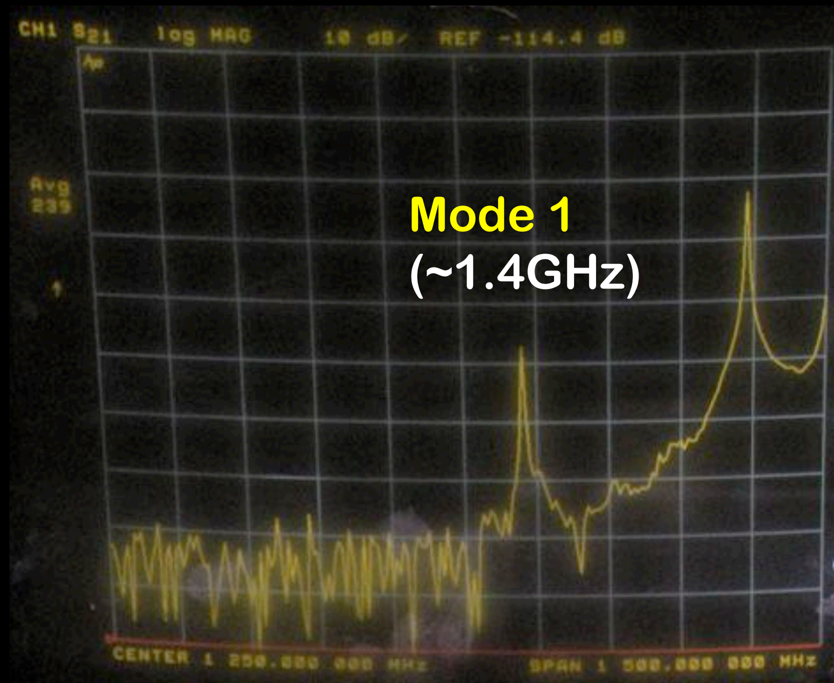
- **Ex. S12 Measurement**
  - Al head ($^w8$ x $^t7$ x $^L90$)
  - Measure Q, f_r, and Rs (How?)

Metal Support (Al)



S12

Ceramics (BN) Support



0.5 GHz 2 GHz 0.5 GHz 2 GHz

4. Movable Mask

- Next step
  - Evaluate RF properties for a support with a thin finite-conductive layer.
    - Calculation by simulation codes (Microwave Studio and Mafia) has been tried, but not yet completed.
    - Actually, the R&D stopped in this point.
    - Just in the midst of a struggle.
  - Check RF characteristics by a cold model.
    - How control the conductivity of support? This is also a problem.
  - Continue further study.
    - Can we get any hint for clearing electrodes??

5. Summary

- **R&D of vacuum components are progressing steadily.**
  - Beam duct with ante-chambers
  - Bellows chamber and gate valves with comb-type RF shield (Ver.2)
  - MO-type vacuum flange
  - Stealth type movable mask
- **Beam duct with antechamber, comb-type RF-shielding and MO-type flange are close to practical use.**
  - Apply to KEKB and accumulate practical experience.
- **Further studies are required for stealth-type movable mask.**
  - RF characteristics for a support with a thin finite-conductive layer is required at first.