Baking and TiN Coating Equipments

The 17th KEKB Accelerator Review Committee
2012.02.21
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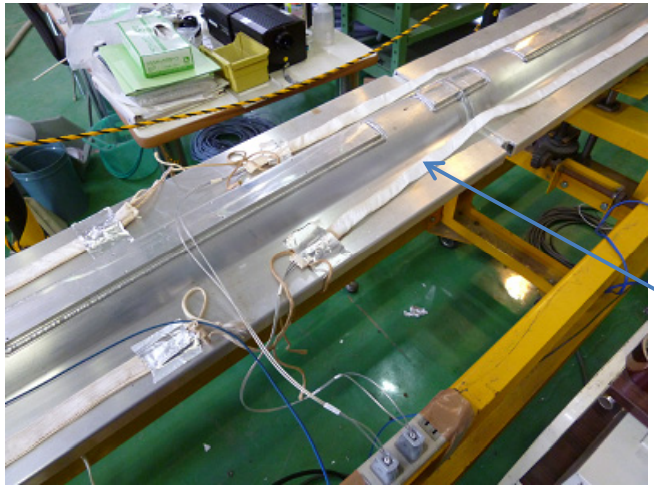
Introduction

- What should we do before the installation of new beam pipes?
  - For HER (e-) : Baking at the laboratory in Tsukuba site(not *in-situ*)
  - For LER (e+) : Baking & TiN coating at the laboratory in Tsukuba site
- How many beam pipes should be processed?
  - For HER (e-) : ~180
  - For LER (e+) : ~1000 (of which ~ 25 have electron clearing electrodes and they are not coated.)
- Topics discussed in this talk
  - New baking equipment by hot-air method, output estimation
  - TiN coating equipment, preliminary experiments, production status and output estimation
  - Working Schedule

Baking equipment 1
Conventional baking method

- Breaking away from the conventional style
  - Sheathed heaters or tape heaters were usually used in KEKB's era.
  - However, the process was laborious, requiring putting the heaters, covering the beam duct with aluminum foil and thermal insulators, uncovering them after the baking, and so on…

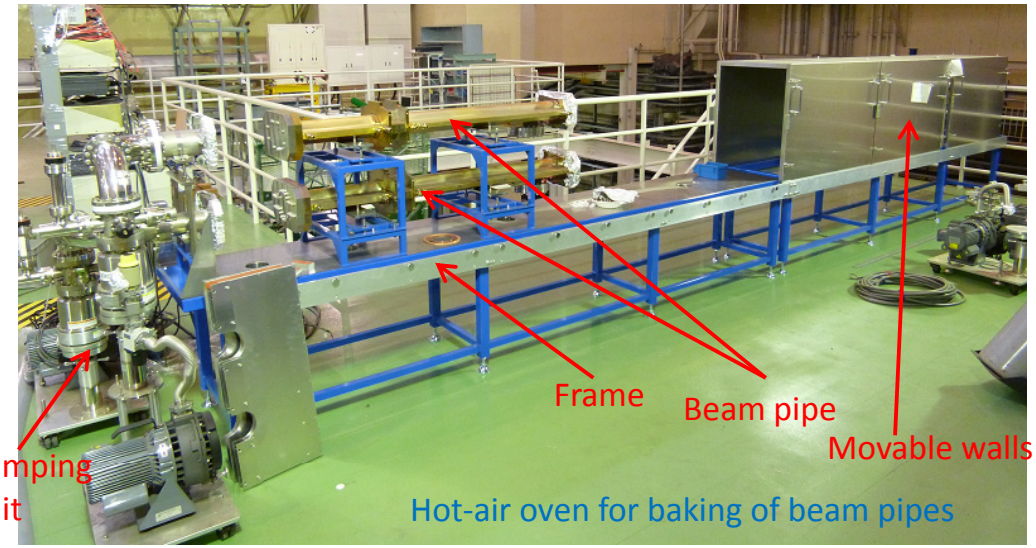
⇨ Simple and convenient process is required.



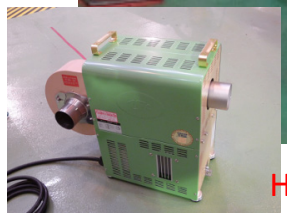
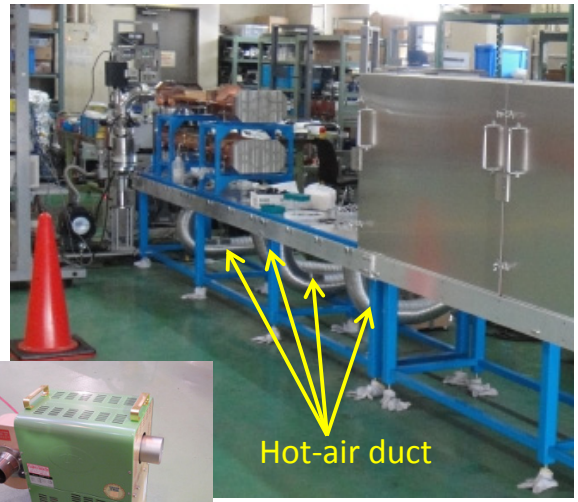
Conventional baking style with tape heaters and Al foils

Baking equipment 2
New baking method by hot air heating

- Hot-air heating method is adopted.
  - Two beam pipes are mounted up and down in one hot-air oven.
  - Hot-air oven consists of movable insulated walls and insulated frame.
  - Hot air is circulated in the hot-air oven.
  - Each pipe is evacuated by a turbo molecular pump (0.3 m^3/sec) during the baking.



Hot-air oven for baking of beam pipes

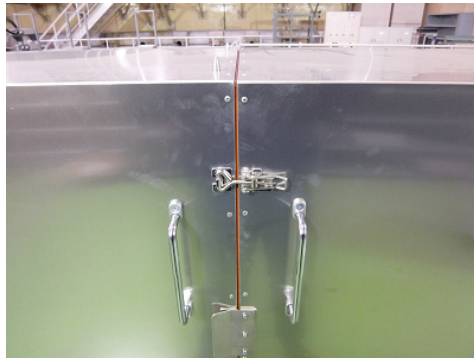
Hot-air circulator (7.5 kW)

Baking equipment 3
Procedure for baking

- We can save a great deal of time by avoiding the trouble of having to cover and uncover the aluminum foils and insulators.
  - What we have to do are
    - Opening the insulated walls,
    - Mounting the beam pipes on the frame,
    - Connecting the beam pipes to the pumping units,
    - Closing the insulated walls,
    - Turning on the vacuum pumps and hot-air circulators.

Baking equipment 4

Baking station for long beam pipes.



Insulated walls can be jointed easily
using Velcro fastenings or latch clamps.

Baking equipment 5
Baking conditions

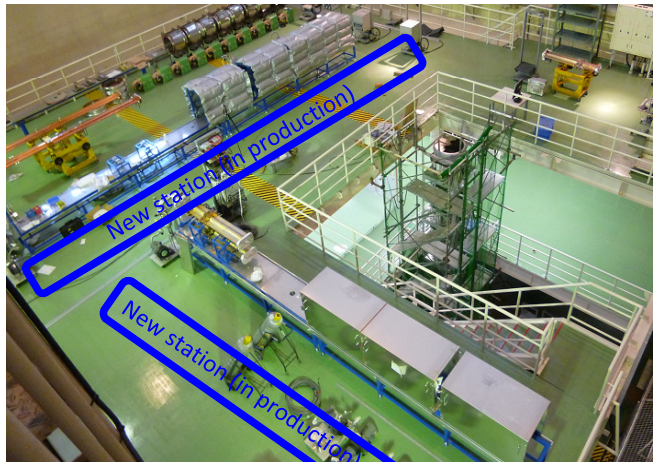
- Baking conditions
  - Temperature : ~150 °C (~120 °C for beam pipes with electrodes)
  - Duration : ~24 hours
    - It was confirmed that the temperature of the beam pipes in the oven became ~150 °C within a several hours if the temperature setting of the hot-air circulator was ~175 °C.
  - Targeted pressure after baking : $< 10^{-8}$ Pa
  - NEG pump activation is performed at the same time.
- Before baking
  - TiN coating (if necessary)
  - Installation of NEG pumps and BPM electrodes at Oho clean room.
- After baking
  - Filling with dry nitrogen up to atmospheric pressure.
  - Isolating the beam pipe and putting a blank flange on the beam pipe.
  - Keeping the beam pipe in the stockroom until the installation.

Clean room (Oho lab.)

Stockroom (Oho lab.)

Baking equipment 6
Estimation of output of baking

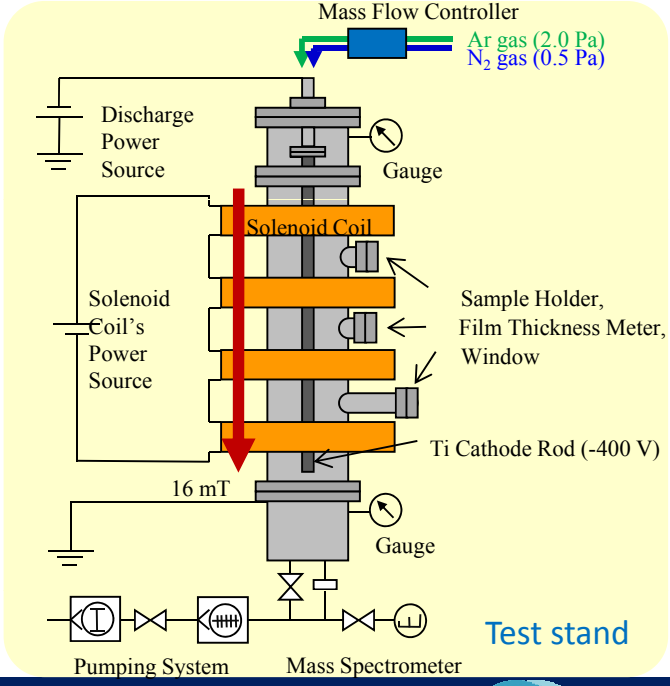
- 4 baking stations will operate in the Japanese fiscal year of 2012.
  - 2 stations have already been installed at KEKB Oho laboratory.
    - One is for short pipes (~2.5 m) and another is for long pipes (~5 m).
  - More 2 stations are now in production.
- Output estimation:
  - One baking process will take 2 days from mounting to dismounting the beam pipes.
  - Up to 24 pipes can be baked per one week by our baking stations.
  - 3.4 pipes/day, 544 pipes/year assuming 160 working days/year



	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
8 pipes (2 pipes x 4 stations)		Mounting, baking	Baking, cool down	Dismounting			
8 pipes				Mounting, baking	Baking, cool down	Dismounting	
8 pipes		Dismounting				Mounting, baking	Baking, cool down

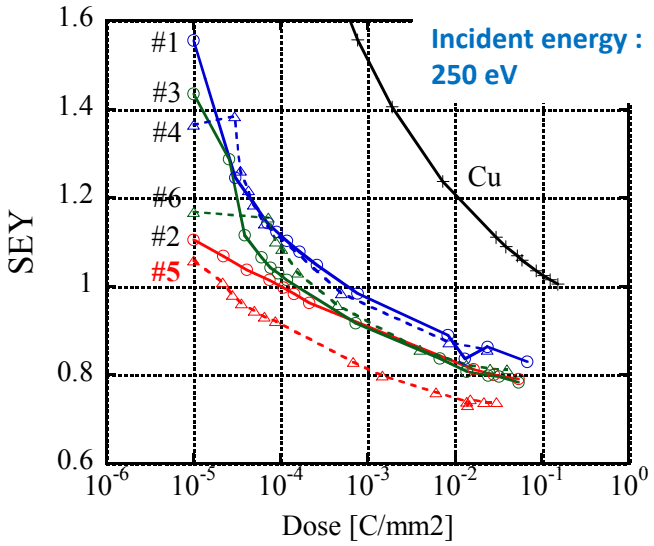
TiN coating 1
Preliminary experiment

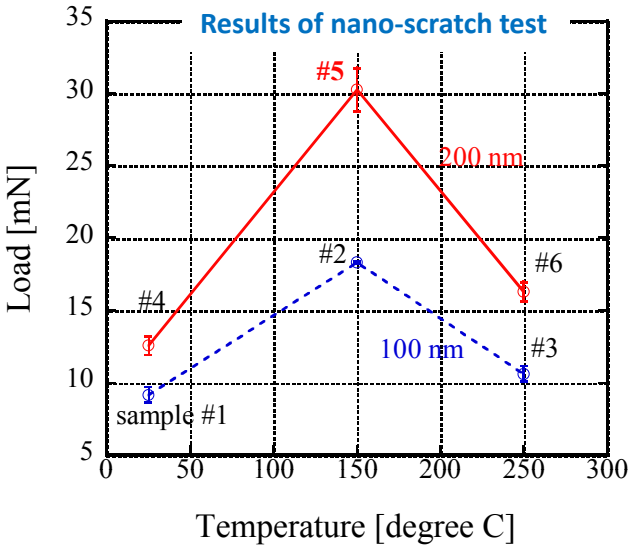
- For SuperKEKB LER, it is an important issue to mitigate the electron cloud instability.
  - In order to reduce the electron cloud, inner surfaces of almost all LER beam pipes are coated with TiN (except beam pipes with clearing electrodes).
- Preliminary experiments were performed at a test stand to decide the coating parameters.
  - The coating was done by a DC magnetron sputtering of Ti in Ar and N_2 atmospheres.
  - A Ti cathode rod (-400 V) was hung from the top on the center axis.
  - Gases were supplied into the test chamber uniformly though the Ti rod.
  - Magnetic field (16 mT) was supplied by a solenoid coil.

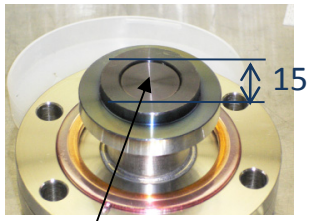


TiN coating 2
Result of preliminary experiment

- Results of preliminary experiments:
  - We made some samples varying the thickness of TiN and the temperatures of samples during process, and compared the adhesion strength and secondary electron yield of them.
  - It was found that parameter combination (200 nm-150°C) is best from the view point of the SEY and adhesion strength.





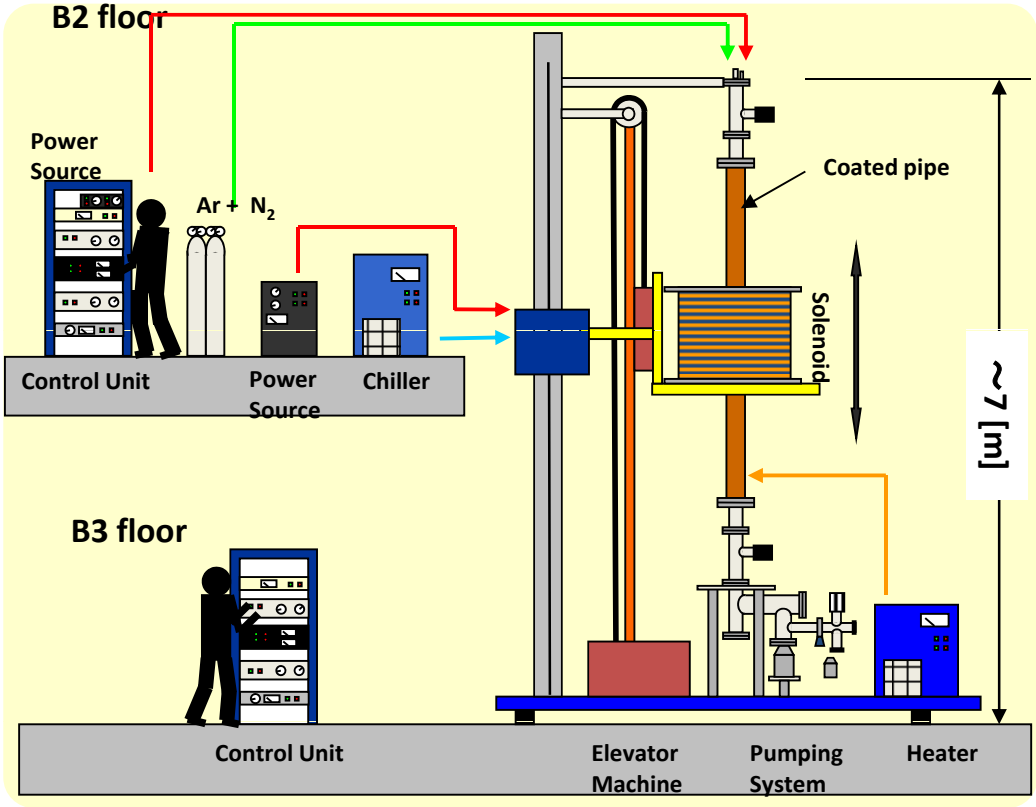


ID number of samples	thickness of TiN [nm]	Temperature [deg. C]
#1	100	25
#2	100	150
#3	100	250
#4	200	25
#5	200	150
#6	200	250

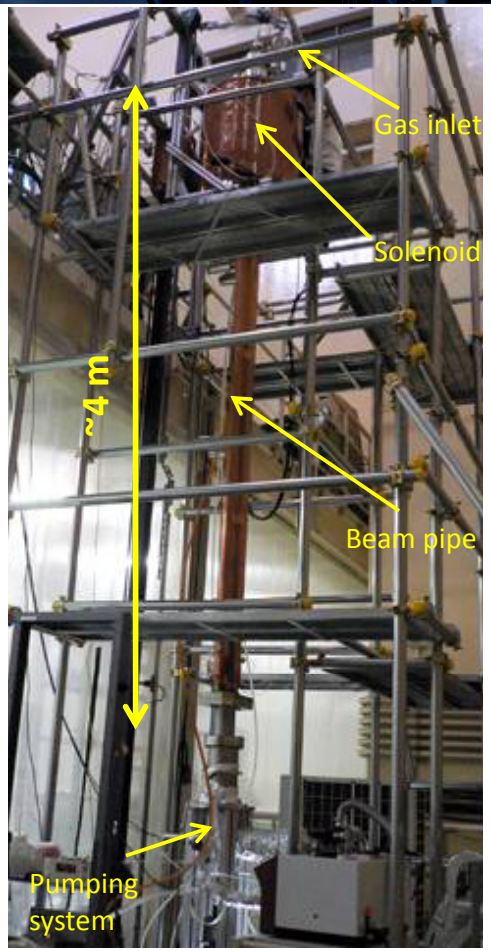
TiN coating 3
Test station for KEKB beam pipe

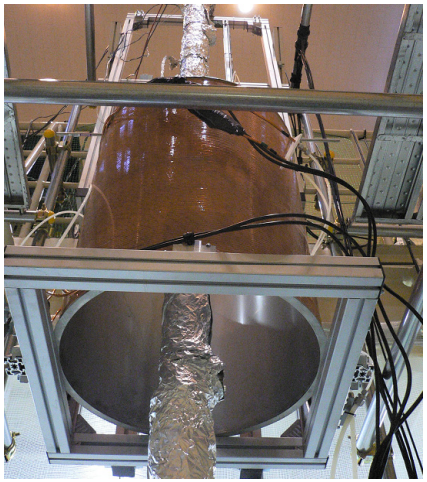
- To perform the beam test at KEKB LER, test coating station for long beam pipe was built at KEKB Oho Laboratory.

– One beam duct was set vertically.
– Ti cathode rod (4.2 m) was hung from the top on the center axis of the pipe.
– A movable solenoid coil with a length of 800 mm was mounted.
– To make an uniform TiN film with a thickness of 200 nm all over the pipe, the position of the coil was moved 200 mm step-by-step at an interval of 2 hours. (10 hours/m)
– Baking heaters were put on the pipe and the temperature of the pipe during the coating process was controlled.
– Parameters (magnetic field, gas pressure, discharge voltage) was same as those of the preliminary experiment.

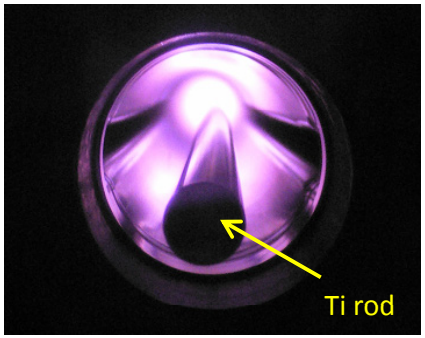


TiN coating 4
Pictures of test station

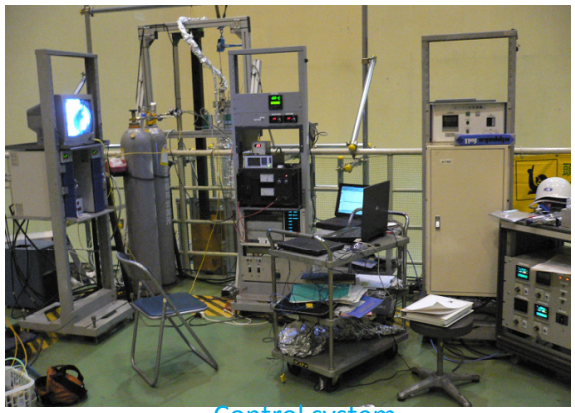




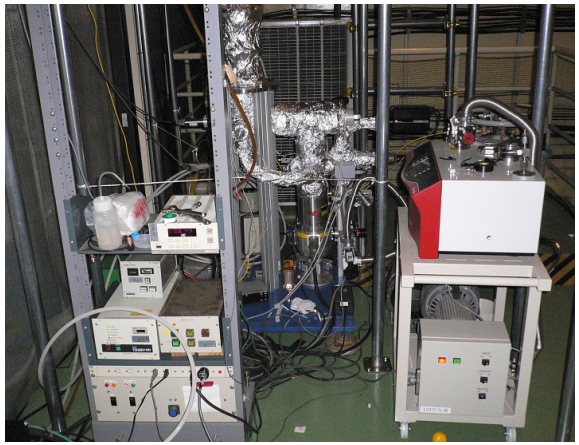
Movable solenoid coil



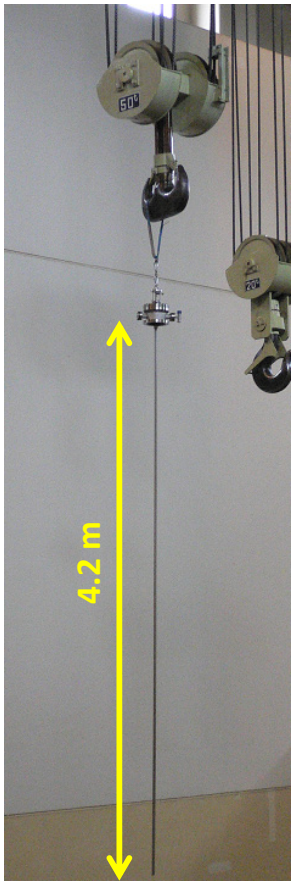
Now processing



Control system



Pumping System

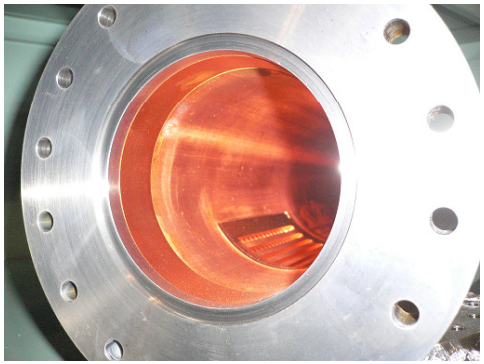


Titanium Rod (4.2 m)

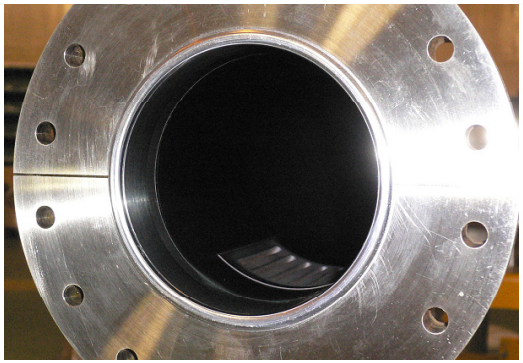
TiN coating 5
Beam test at KEKB LER

- Test chambers with/without TiN coating were installed into KEKB LER, and the electron cloud densities in them were measured.
- Test chambers (circular duct with a diameter of 94 mm):
  1. Copper chamber (Cu, OFC C10100)
  2. Copper chamber with TiN coating (Cu+TiN)
  3. Aluminum alloy chamber (Al, 5052)
  4. Aluminum alloy chamber with TiN coating (Al+TiN)
  - Thickness of TiN coating : 200 nm

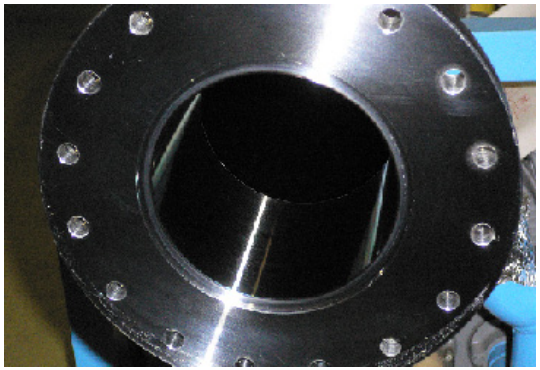
Cu



Cu + TiN

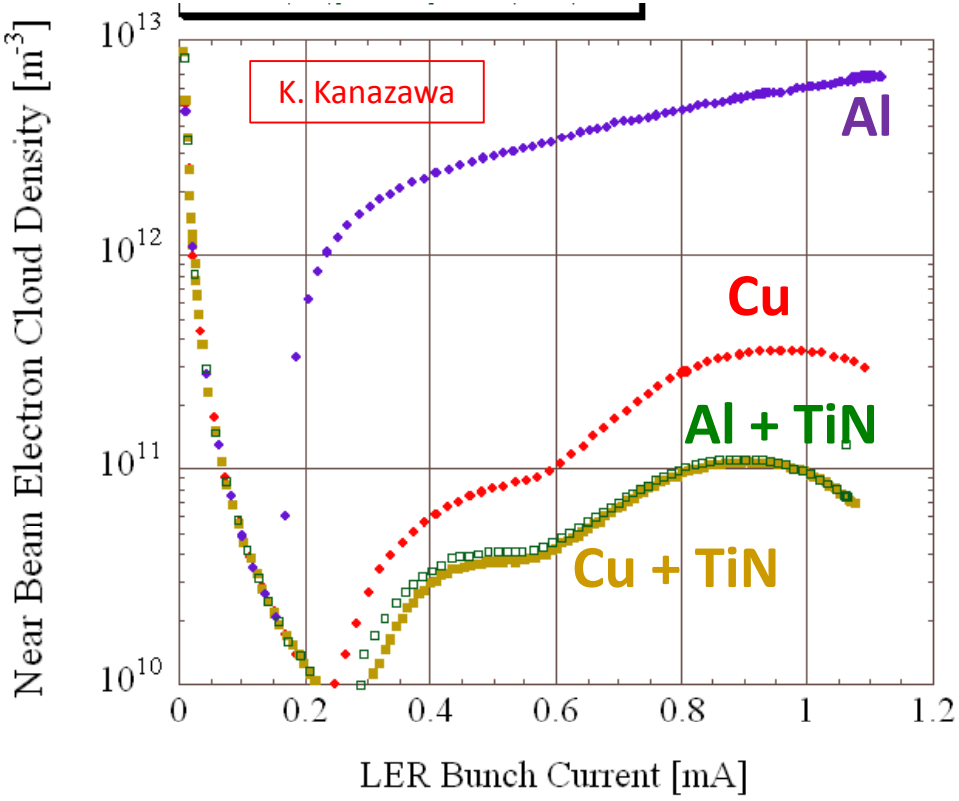


Al + TiN

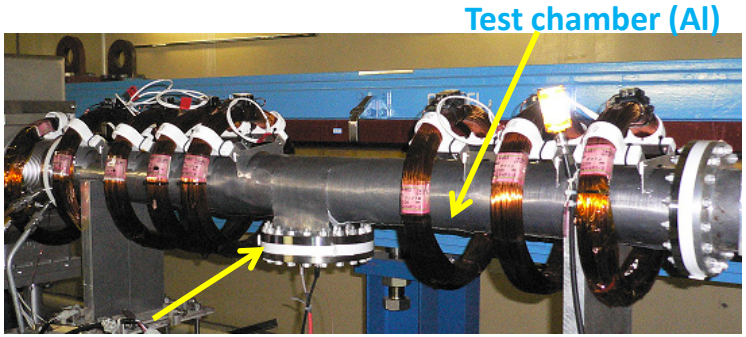


TiN coating 6
Beam test at KEKB LER (cont.)

- Result of beam test at KEKB LER:
  - It was confirmed that our TiN coating is effective for both Cu and Al chambers.

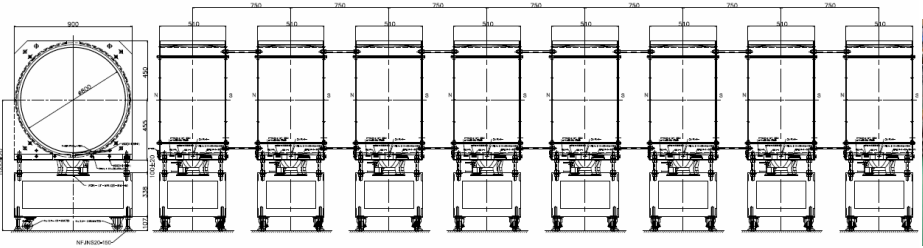


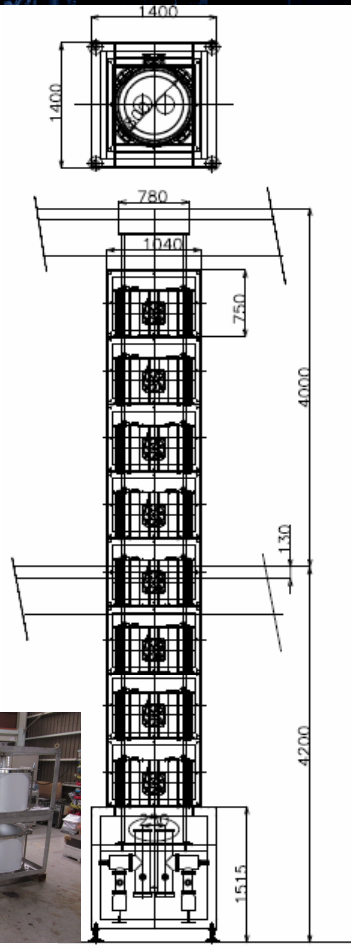
- Energy : 3.5 GeV
- Beam current : ~1600 mA
- Number of bunch : ~1585 (~1 mA/bunch, ~10 nC/cunch)
- Bunch spacing : 6 ns
- Bunch length : 6 mm
- Number of photon : 3×10^{12} photons /s/m/mA
- Drift space (straight section)
- No solenoid field



TiN coating 7
New coating stations for SuperKEKB

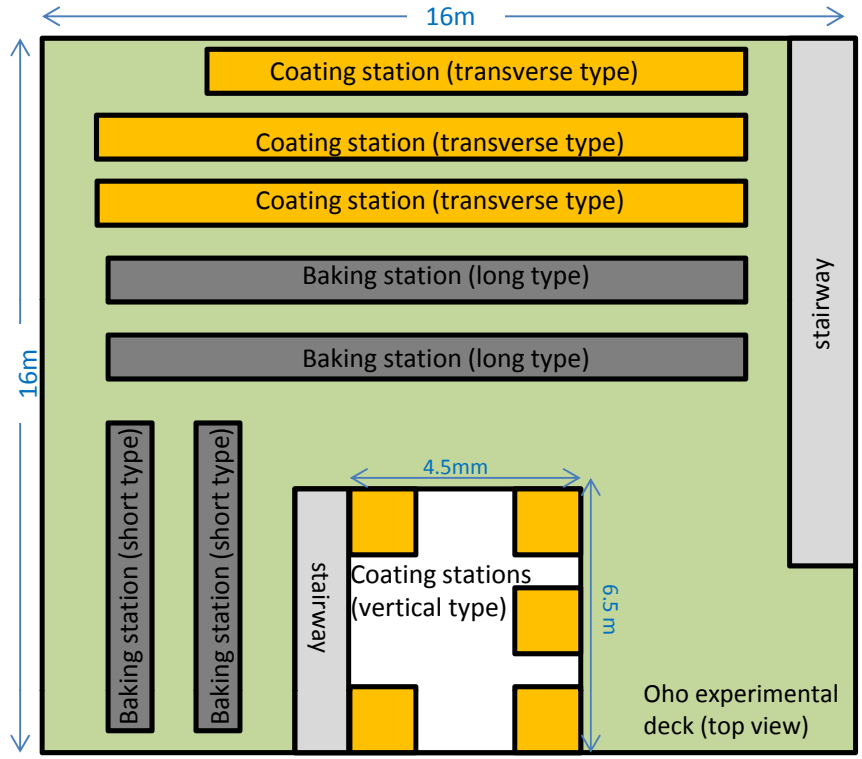
- New coating stations for large-scale production are under construction now.
  - 5 vertical stations for straight beam pipes.
  - 3 transverse stations for bent pipes (of which one is test station).
- Modifications to improve efficiency of the coating work:
  - Two beam pipes can be mounted side-by-side in one station.
  - One station have 8 fixed solenoid coils instead of one movable coil.
  - Combination of hot-air oven and circulators are adopted to avoid the trouble of having to cover and uncover the aluminum foils and insulators.





TiN coating 8
Layout of Oho laboratory

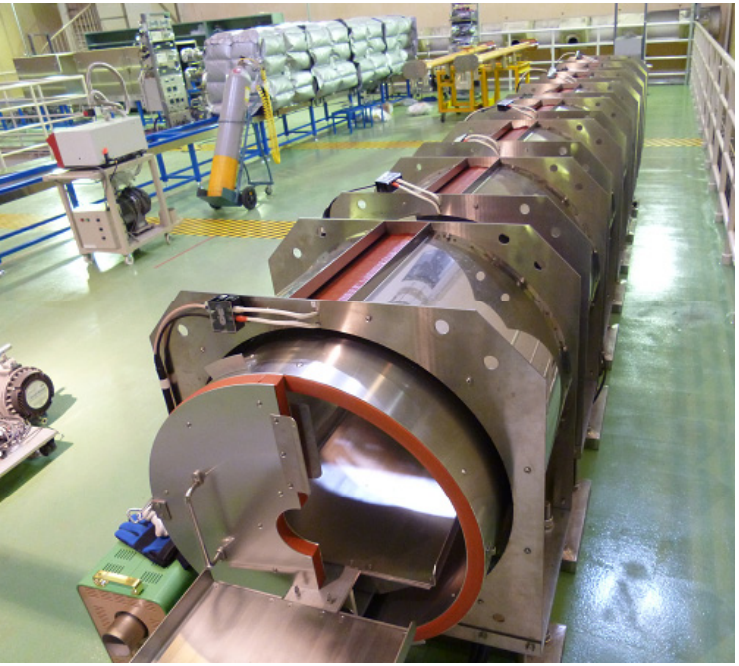
- Solenoid coils and hot-air ovens for one vertical station and one transverse station have been installed at KEKB Oho laboratory.



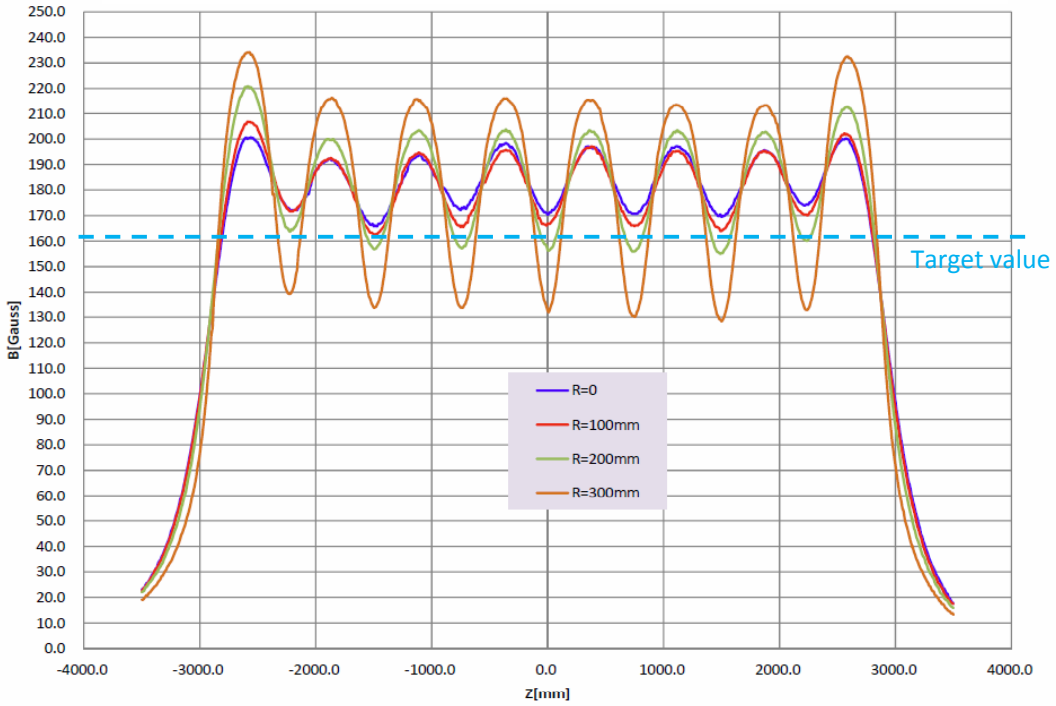
TiN coating 9

TiN coating 10

TiN coating 11



Results of magnetic field measurement in solenoid coils



TiN coating 12
Estimation of output of coating 1

- 5 vertical stations will start operations from this spring.
  - One vertical station is being started up now and operation test will be done in March.
  - Transverse stations will start operations after the summer.
- Output estimation of straight pipes(vertical stations):
  - One coating process will take 4 days from mounting to dismounting the beam pipes.
  - By jointing two beam pipes, up to 4 pipes can be coated in one station simultaneously.
  - Up to 20 pipes (4 pipes x 5 stations) can be coated per one week by vertical stations.
  - 2.8 pipes/day, 450 pipes/year (assuming 160 working days/year)

	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
Station 1 Max. 4 pipes		Mounting, baking	Baking, coating (~4 hours)	Cool down	Dismounting		
Station 2 Max. 4 pipes			Mounting, baking	Baking, coating (~4 hours)	Cool down	Dismounting	
Station 3 Max. 4 pipes		Dismounting		Mounting, baking	Baking, coating (~4 hours)	Cool down	
Station 4 Max. 4 pipes		Cool down	Dismounting		Mounting, baking	Baking, coating (~4 hours)	Cool down
Station 5 Max. 4 pipes			Cool down	Dismounting		Mounting, baking	

TiN coating 13
Estimation of output of coating 2

- Output estimation of bent pipes (transverse stations):
  - One coating process will take 4 days from mounting to dismounting the beam pipes.
  - Up to 2 pipes can be coated in one station simultaneously.
  - Up to 4 pipes (2 pipes x 2 stations) can be coated per one week by transverse stations.
  - 0.6 pipes/day, 90 pipes/year (assuming 160 working days/year)

	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
Station 1 Max. 2 pipes		Mounting, baking	Baking, coating (~4 hours)	Cool down	Dismounting		
Station 2 Max. 2 pipes			Mounting, baking	Baking, coating (~4 hours)	Cool down	Dismounting	

- Estimation of coating times for LER arc sections :
  - Assuming operation of 3/5 vertical stations and 1/2 transverse station, up to 12 straight pipes and 2 bent pipes can be coated per one week.
  - It is possible to coat beam pipes of LER arc sections (~1100 pipes) in 2 years.

Schedule

- Full-scale work will start from April.
- Baking and coating will be completed by the end of FY2013 (March 2014).

LER		FY2011	FY2012	FY2013	FY2014
Straight pipe with clearing electrode (wiggler section)	26	baking			
Straight pipe (wiggler section)	106		coating		
Straight pipe (Arc section)	581				
Bent pipe (Arc section)	106				
Other pipes (Local correction, Skew-Q, Injection, Abort, Fuji-cross)	120				

HER		FY2011	FY2012	FY2013	FY2014
Straight pipe (wiggler section)	34				
Straight and bent pipes (Arc section)	24				
Other pipes (Local correction, Skew-Q, Injection, Abort, Fuji-cross)	120				

END

Thank you very much for your attention.

Backup