TiN Coating and Baking of Beam Pipes

The 18th KEKB Accelerator Review Committee
March 4, 2013
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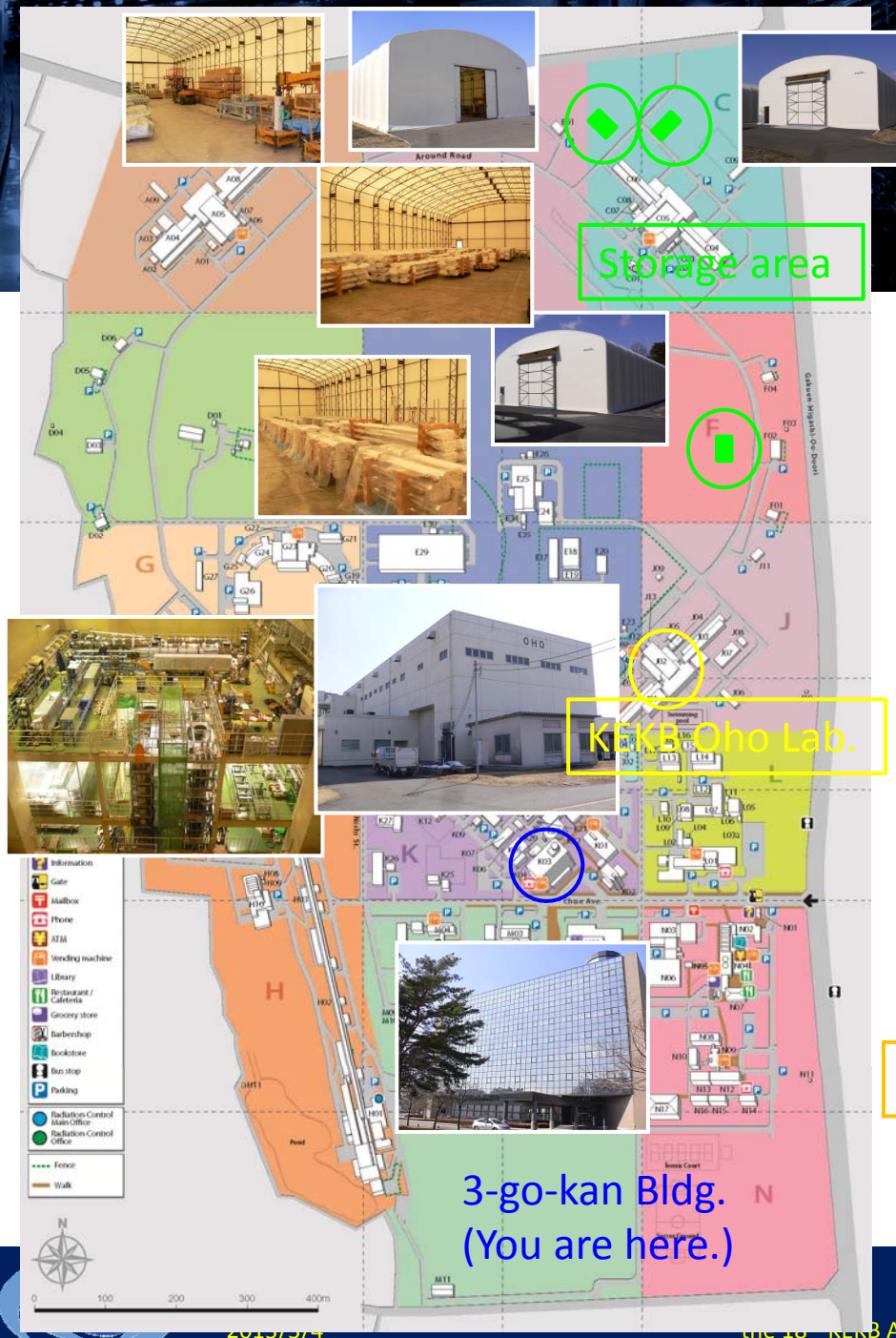
Introduction 1

- What should we do before the installation of new beam pipes?
  - For HER (e-) : Baking at the laboratory(not *in-situ*)
  - For LER (e+) and Damping Ring : Baking & TiN coating at the laboratory
- How many beam pipes should be processed?
  - For HER (e-) : ~180
  - For LER (e+) : ~1000 (of which ~ 25 have electron clearing electrodes and TiN coating is unnecessary.)
  - For Damping Ring : ~100
- Pre-installation works (coating and baking) started on last April.
  - Pre-installation work means:

    Bringing beam pipes to KEKB Oho Lab. from storage area -> Coating (only for LER, 3days) -> Baking (3days) -> returning the beam pipes to storage area
  - Large-scale works by 10 workers with 4 coating equipments and 4 baking equipments started on last September.

Flow chart of pre-installation work



Bringing beam pipes to KEKB Oho Lab. from storage area

Visual check on the beam pipe

LER beam pipe without electrode

TiN Coating

HER beam pipe

LER beam pipe with electrode

Assembling (NEG pump & BPM electrode)

Baking

KEKB Oho Lab.

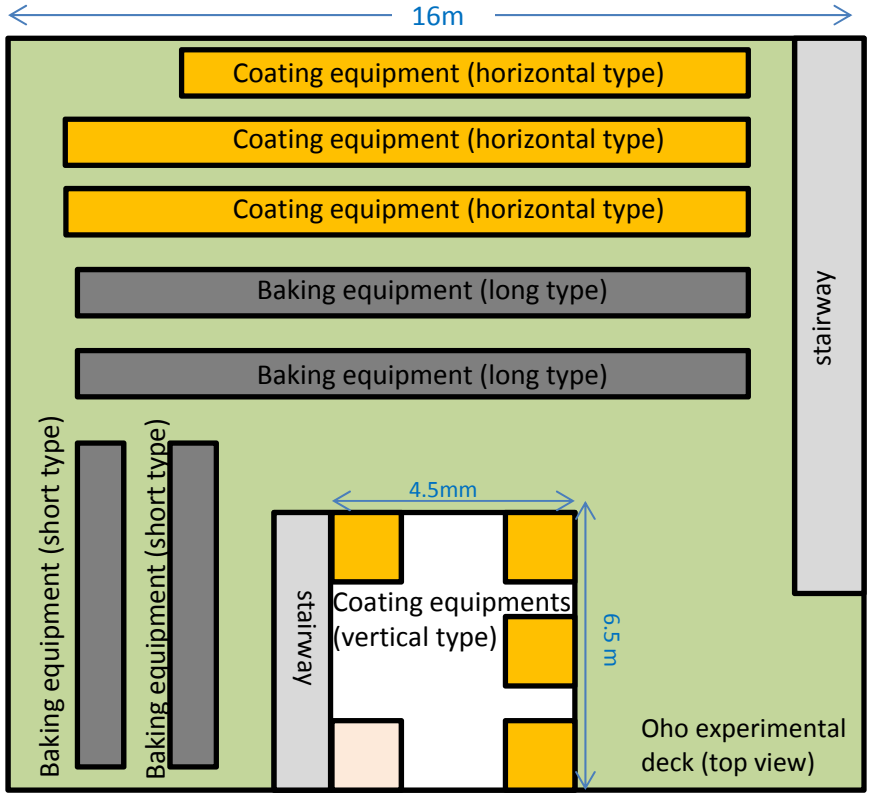
Returning the beam pipes to storage area

Introduction 2

- What we did after last KEKB Review are
  - Setting up 2 more baking equipments and 4 coating equipments (vertical).
  - Large-scale work in this facility. (This will continue this year.)
  - Setting up 3 horizontal coating equipments for bent beam pipes. (in progress now)
- Topics discussed in this talk are
  - Baking & TiN coating facility, Evaluation of TiN coating, Status report on baking and coating works and Future plan.

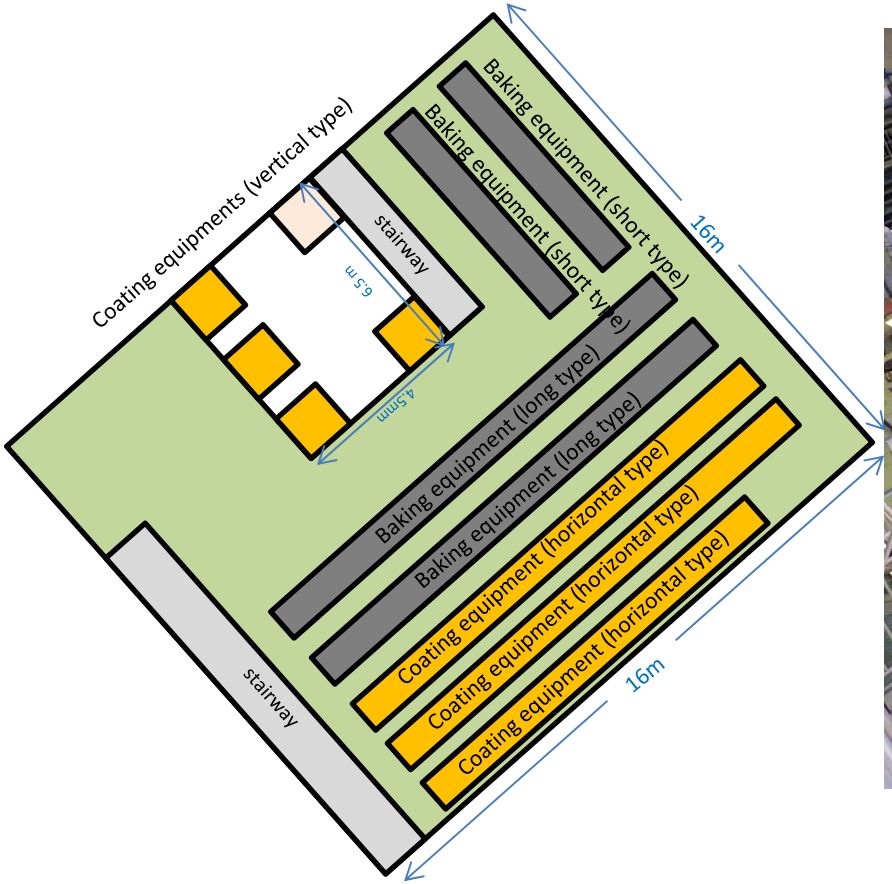
Layout of Oho laboratory 1

- 4 baking equipments : 2 long type (~5 m) and 2 short type (~3 m)
- 5 vertical TiN coating equipments (for straight beam pipes. one of them is back up.)
- 3 horizontal TiN coating equipments (for bent pipes. In preparation now.)



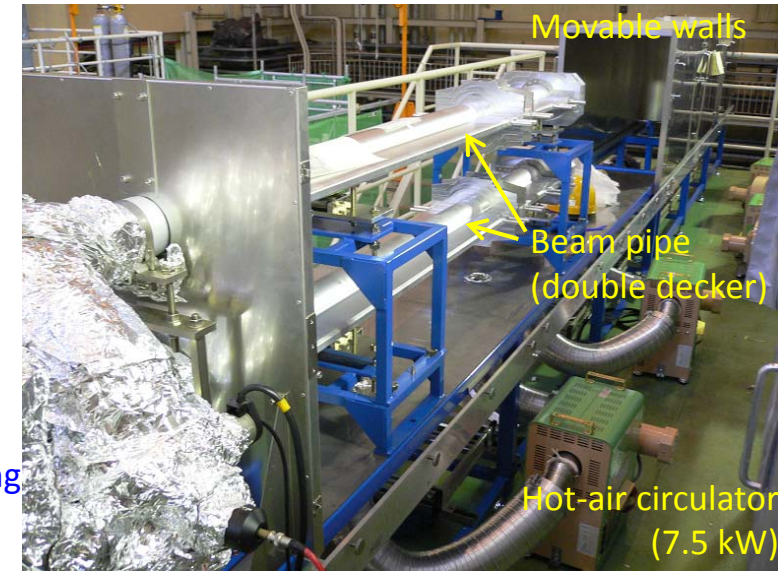
Layout of Oho laboratory 2

- View from different place.



Baking 1 : Equipment

- Hot-air heating method was 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.



Short type

Long type

Baking 2 : Baking conditions

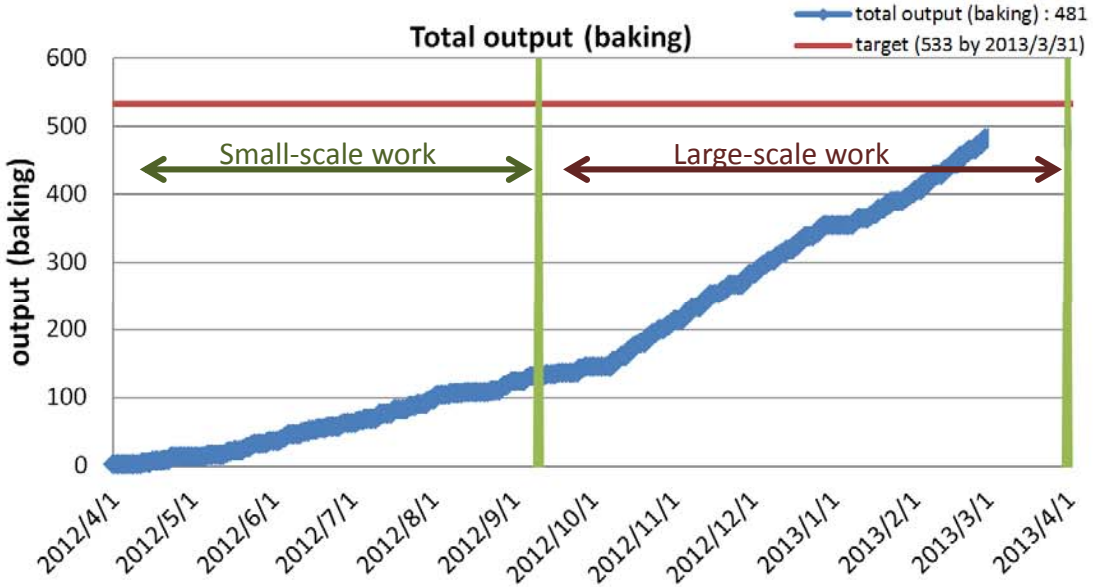
- Baking conditions
  - Temperature : ~150 °C (~120 °C for beam pipes with electrodes)
  - Baking period : ~26 hours
    - It was confirmed that the temperature of the beam pipes in the oven became ~150 °C within a several hours if the temperature setting of the hot-air circulator was ~175 °C.
  - Targeted pressure after baking : $< 10^{-7}$ Pa
  - NEG pump is activated 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 storage area until the installation.

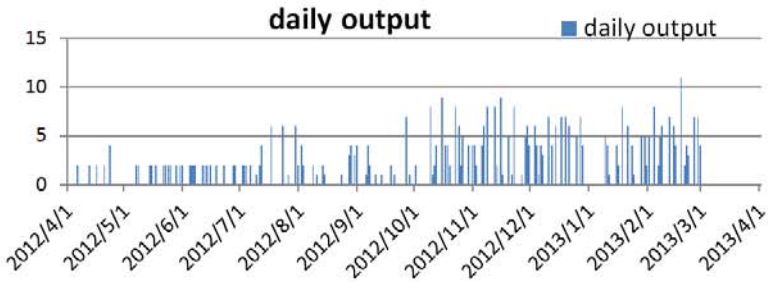
Clean room

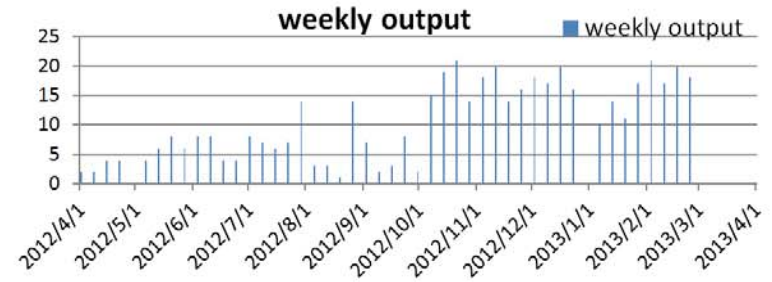
Storage area (Oho lab.)

Baking 3 : Rate of baking output

- Baking work started on last April.
  - Baking work started on small scale with 2 baking equipments on last April.
  - On last September large-scale works with 4 baking equipments started.
- Total output by last month (2013/2/28) is 481.
  - Averaged daily output : 0.8 (small-scale), 2.0 (full-scale), 1.4 (total)
  - Averaged weekly output : 5.5 (small-scale), 13.9 (full-scale), 10.0 (total)

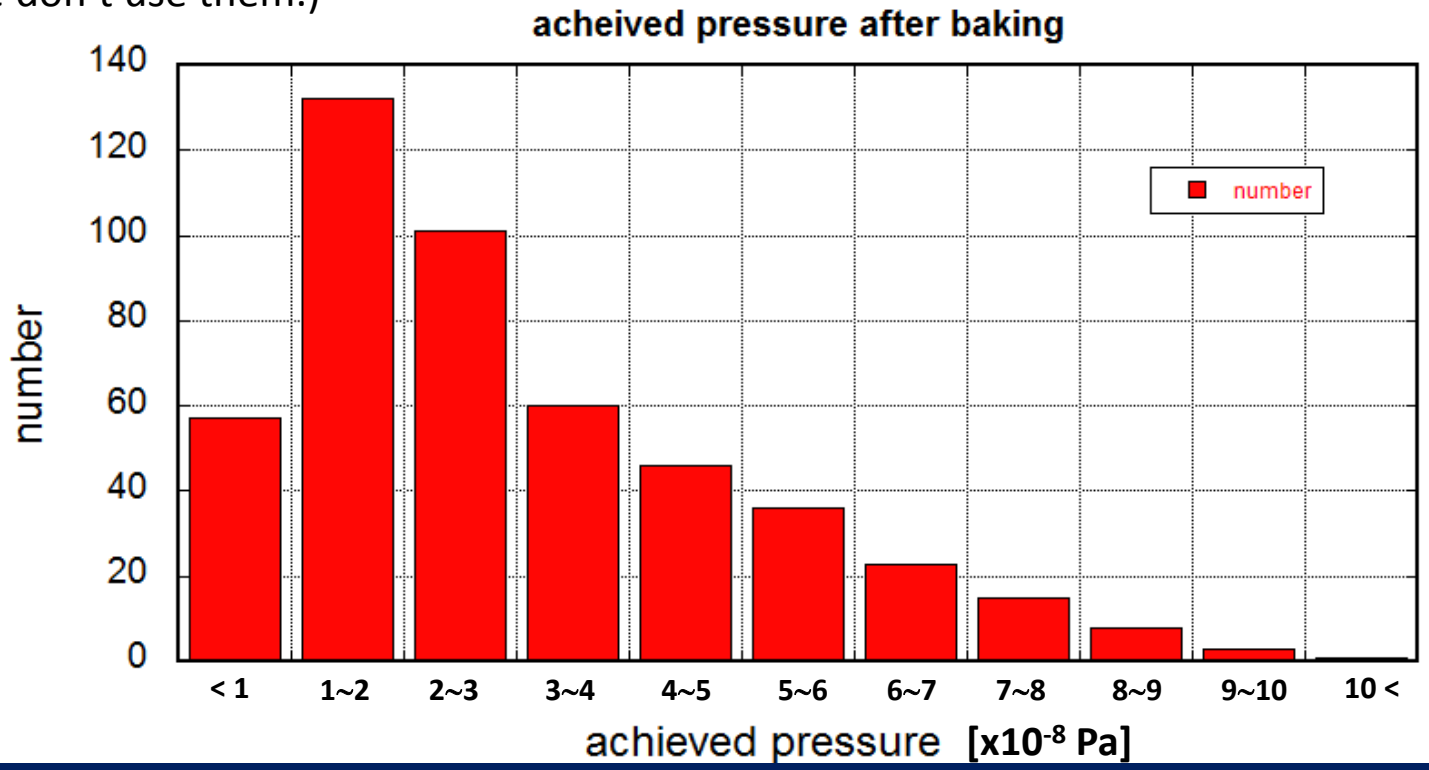






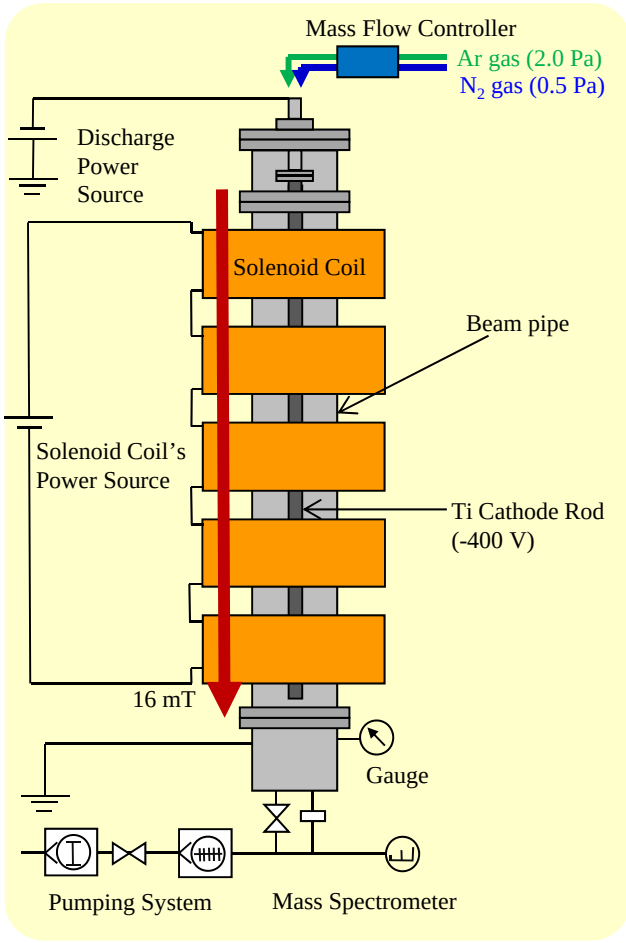
Baking 4 : Achieved pressure after baking

- For almost all beam pipes, achieved pressures after baking are below 1×10^{-7} Pa.
  - If achieved pressure is higher than 1×10^{-7} Pa, the beam pipe is baked again. (only 3 cases so far)
  - Mass pattern after baking is not monitored. (Although 2 of 4 baking equipment have RGAs, we don't use them.)



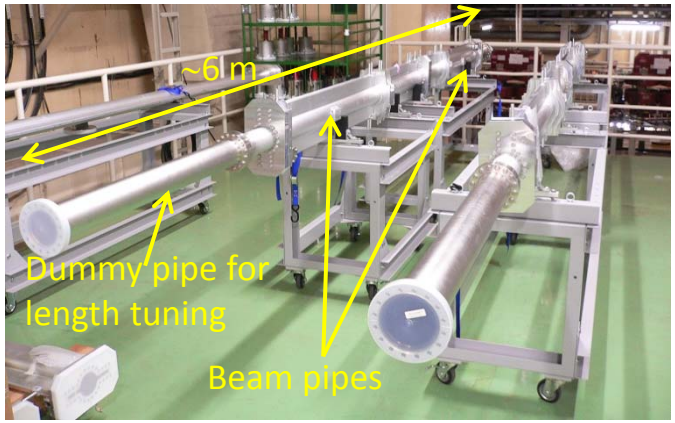
TiN coating 1 : Coting method

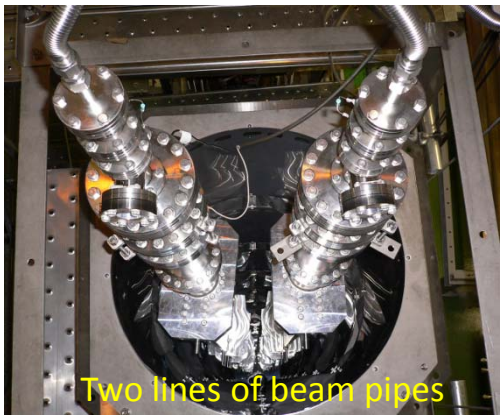
- For SuperKEKB LER, it is an important issue to mitigate the electron cloud instability.
  - In order to reduce the electron cloud, inner surfaces of almost all LER beam pipes are coated with TiN (except beam pipes with clearing electrodes).
  - TiN coating tests had been performed and the coating method was established.
- TiN coating is done by a DC magnetron sputtering of Ti in Ar and N_2 atmospheres.
  - A Ti cathode rod (-400 V) is set on the center axis of beam pipe (hung from the top on in case of the vertical type).
  - Gases are supplied into the beam pipes uniformly though the Ti rod.
  - Magnetic field (16 mT) is supplied by solenoid coils.
  - Preliminary experiments were performed at a test stand to decide the coating parameters.
  - Thickness of TiN coating : 200 nm (at least)
  - Straight beam pipes are coated by vertical type and bent pipes are coated by horizontal type.



TiN coating 2 : Facility (vertical)

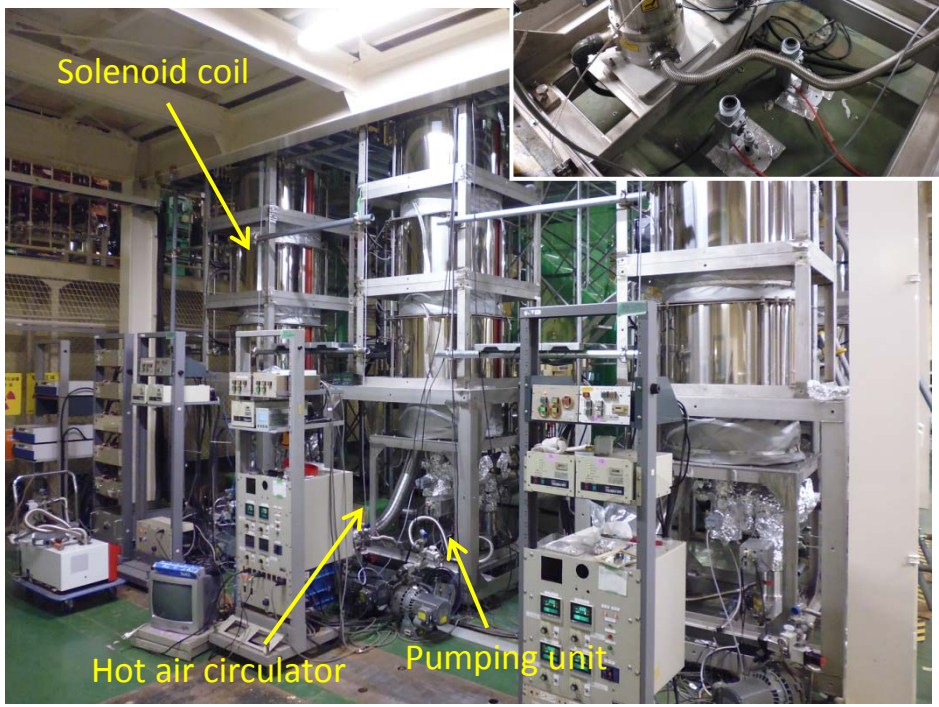
- 5 vertical equipments for straight beam pipes were built last year.
  - Large-scale work started on last September with 4 vertical equipments.
  - 1 equipment is backup and not available now.
  - Beam pipe with a length up to 5.5 m can be coated.
  - Short beam pipes and dummy pipes are connected to make total length ~6 m.
  - Two lines of the beam pipes can be mounted side-by-side in one equipment.
  - Combination of hot-air oven and circulators are adopted for pre-baking.
  - It is not available for bent beam pipes.





TiN coating 3 : View from bottom and middle floor

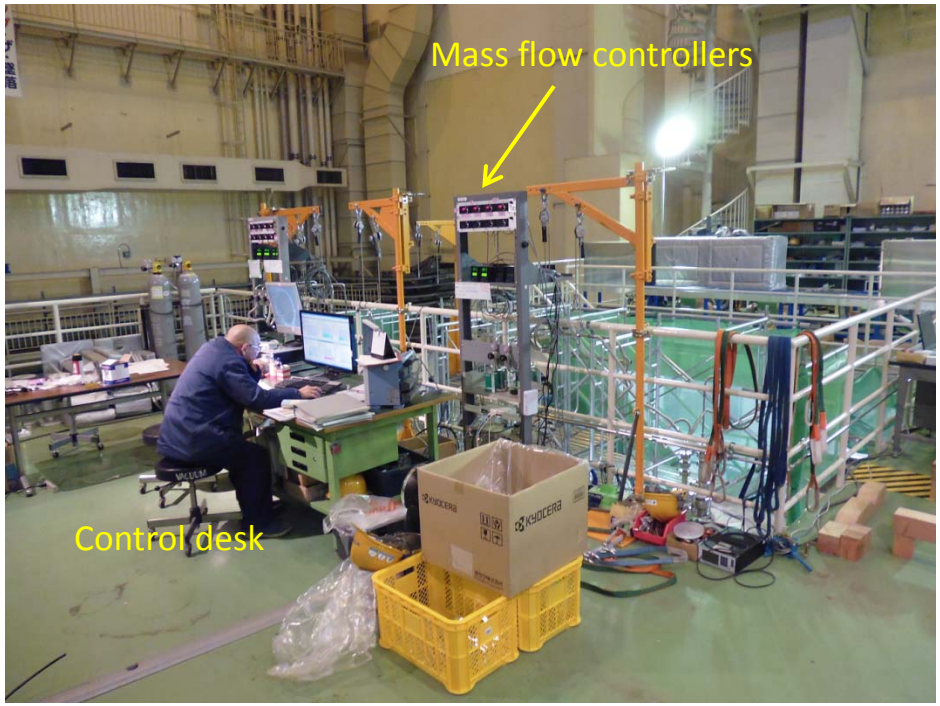
Viewing port and camera at the bottom to observe discharge

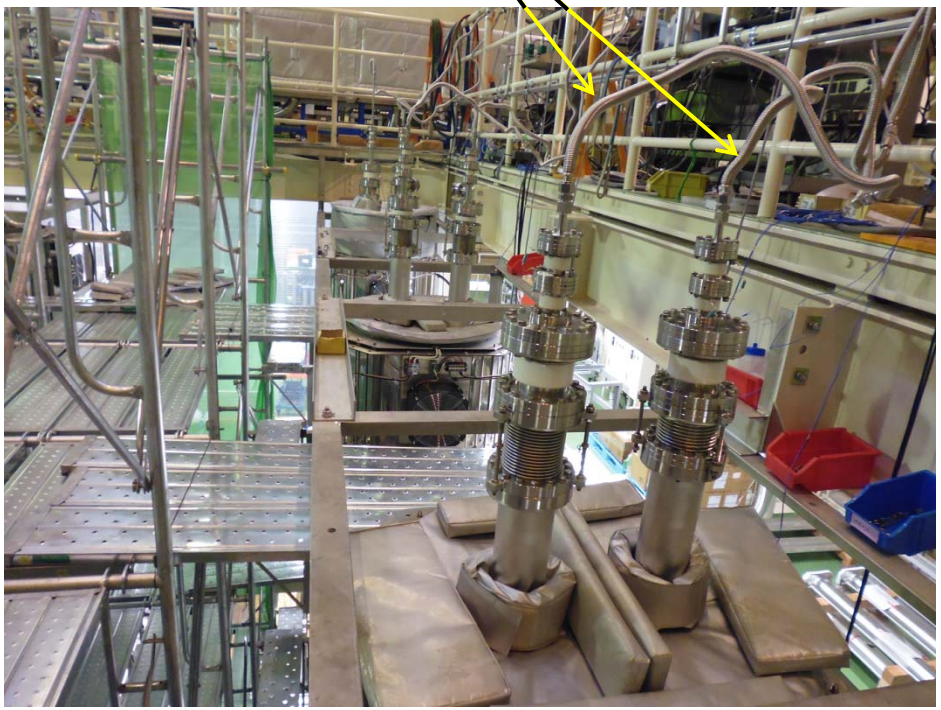


Bottom floor

Middle floor

TiN coating 4 : View from top floor



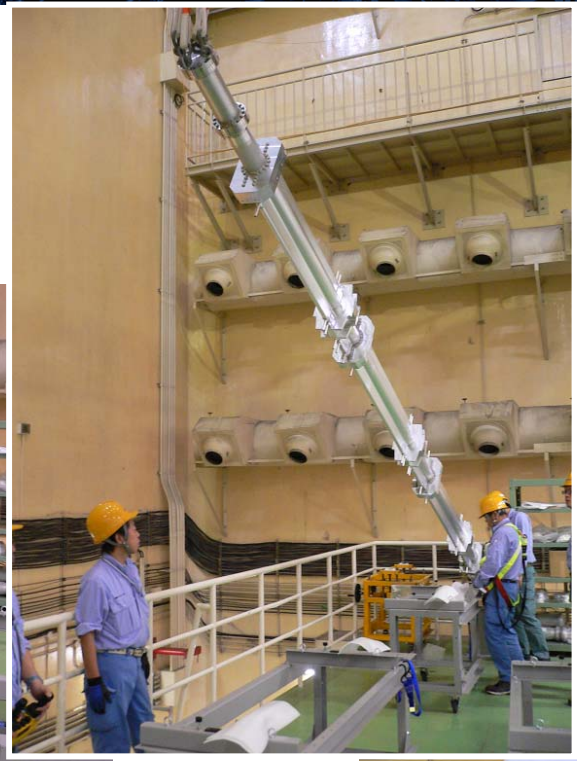


TiN coating 5 : Working process

- Before coating (at Oho clean room)
  - Visual check on the beam pipe.
  - Putting blank flanges on pumping ports and BPM ports.
  - Connecting beam pipes and dummy pipes for length tuning. (if necessary)
  - Leakage test
  - Installation of beam pipes on coating equipment.
- In coating equipment
  - Leakage test
  - Pre-baking (~150 °C, ~24 hours)
  - TiN coating (Discharge duration : ~80 min.)
- After coating
  - Filling with dry nitrogen up to atmospheric pressure.
  - Dismantling beam pipes
  - Installation of NEG pumps and BPM electrodes at Oho clean room.
  - Baking

Leakage test before installation

TiN coating 6 : Installation of beam pipes 1



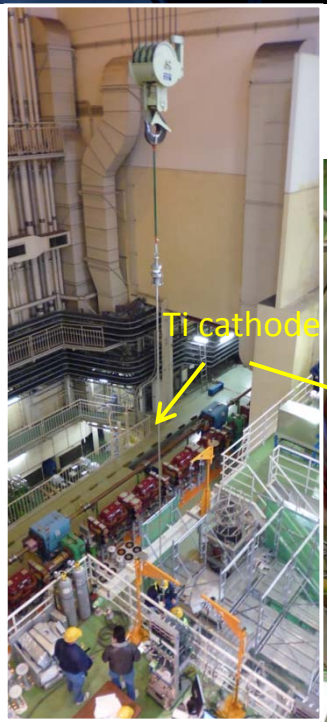
Hinge assembly to get beam pipe upright

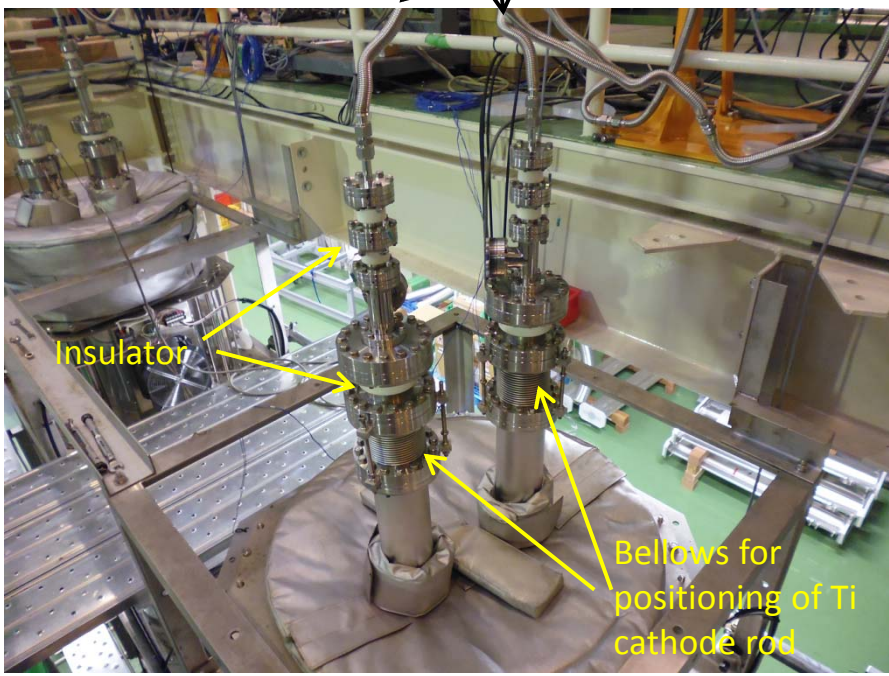
- Beam pipes are transported and installed on the coating equipment by crane.

TiN coating 7 : Installation of beam pipes 2

- Beam pipes are transported and installed in the coating equipment by crane.

TiN coating 8 : Installation of beam pipes 3



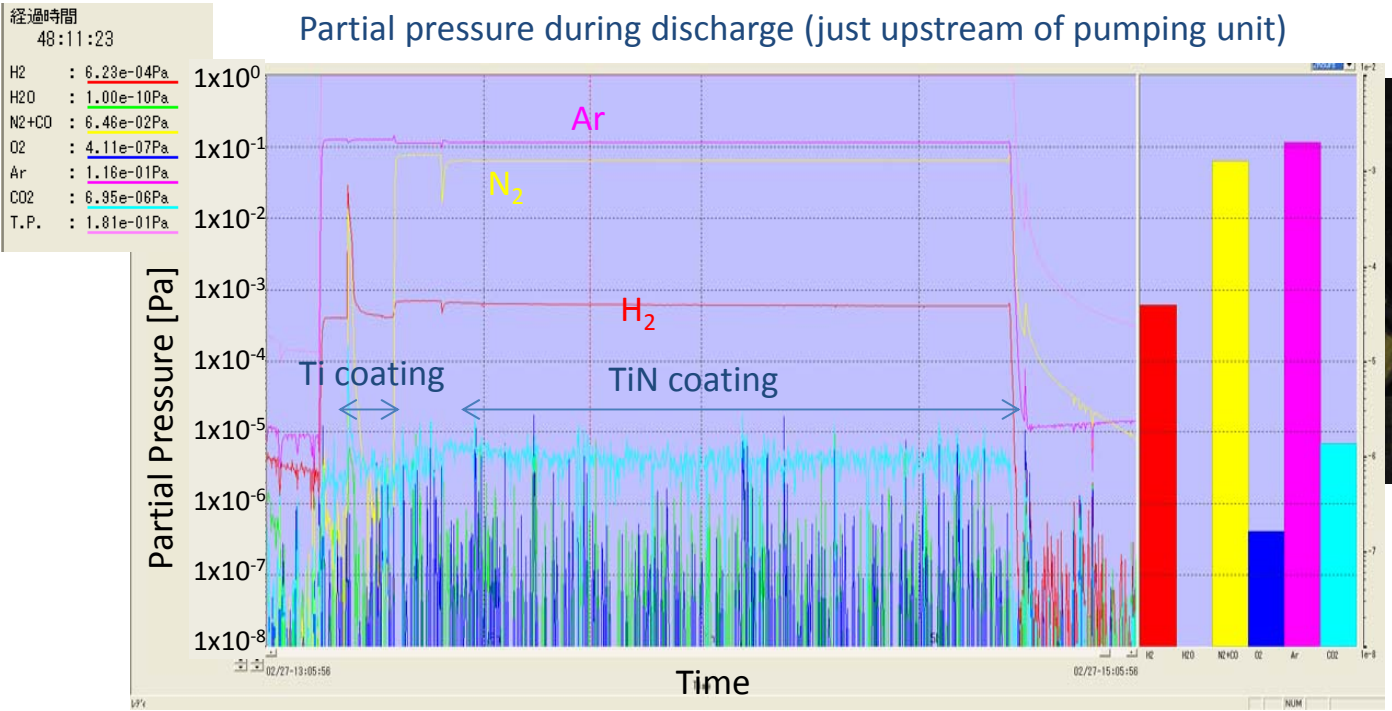


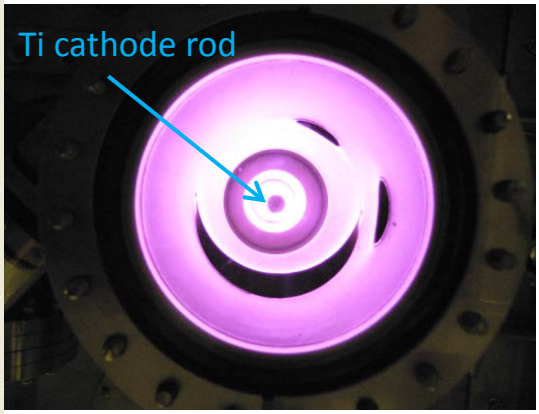
- Ti cathode rod (~6m) is also installed by crane.

TiN coating 9 : Coating 1

- Introduced gases : Ar (~2.2 Pa), N2 (~1.8 Pa)
- Discharged current : 6.3 A
- Required time : 5 min (Ti coating for base of TiN) + 75 min (TiN coating)

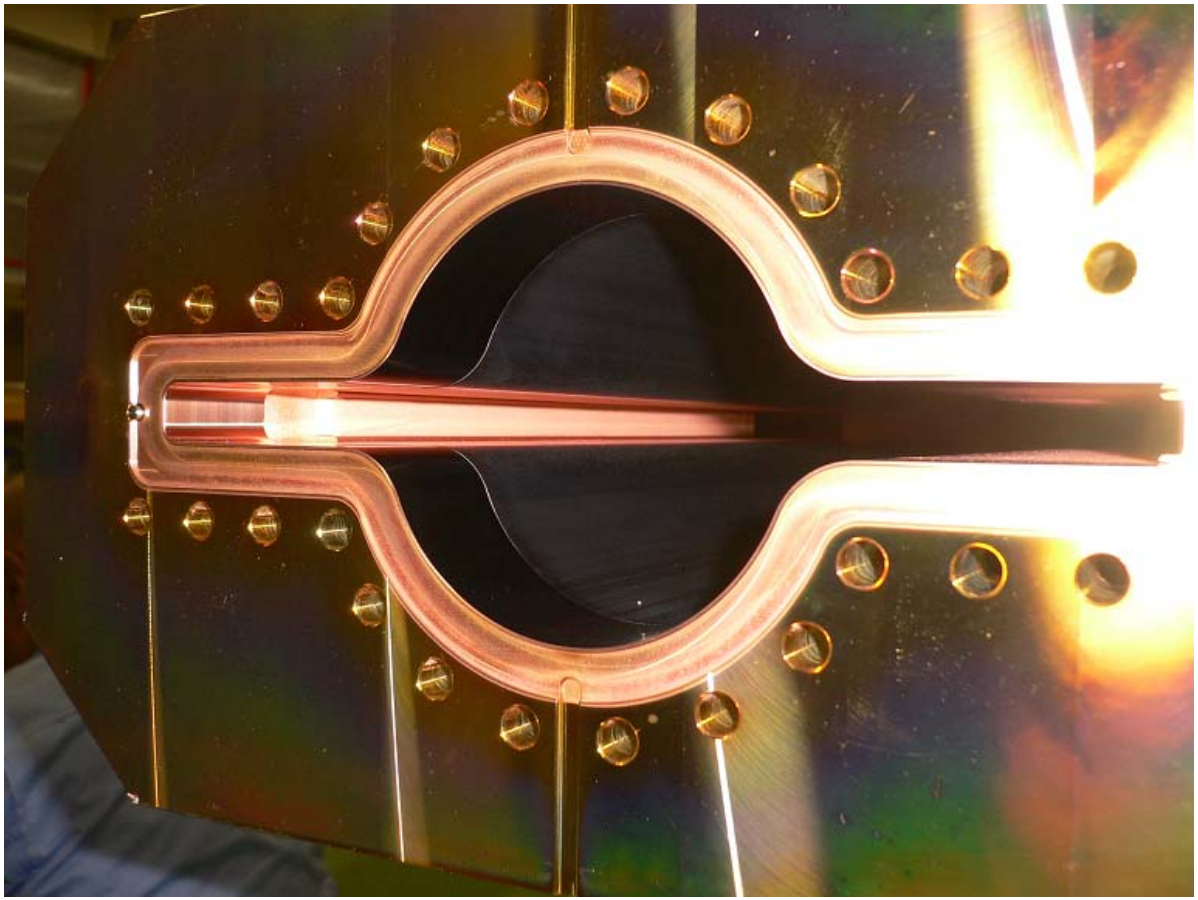
Partial pressure during discharge (just upstream of pumping unit)



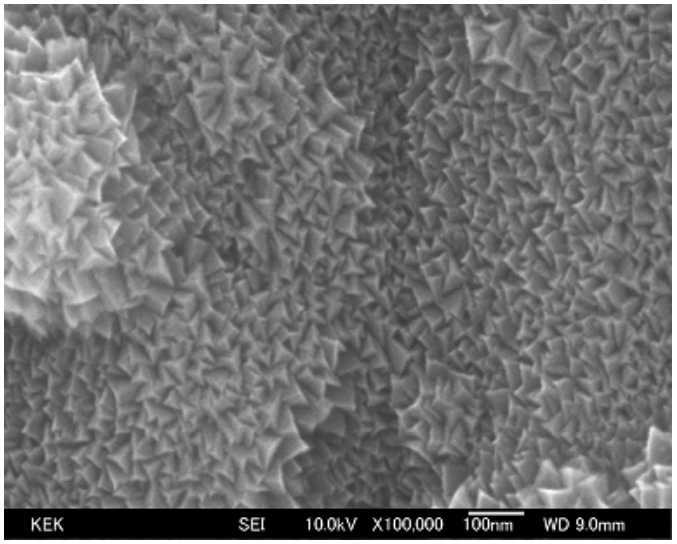


View from viewport
at the bottom

TiN coating 10 : Coating 2



Cu beam pipe coated with TiN



Electron microscopic image of TiN coating

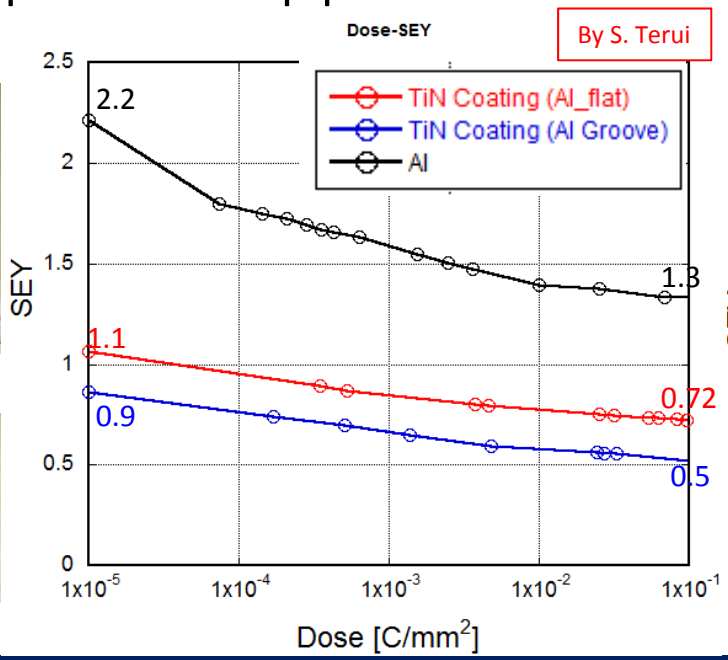
TiN coating 11 : Performance evaluation

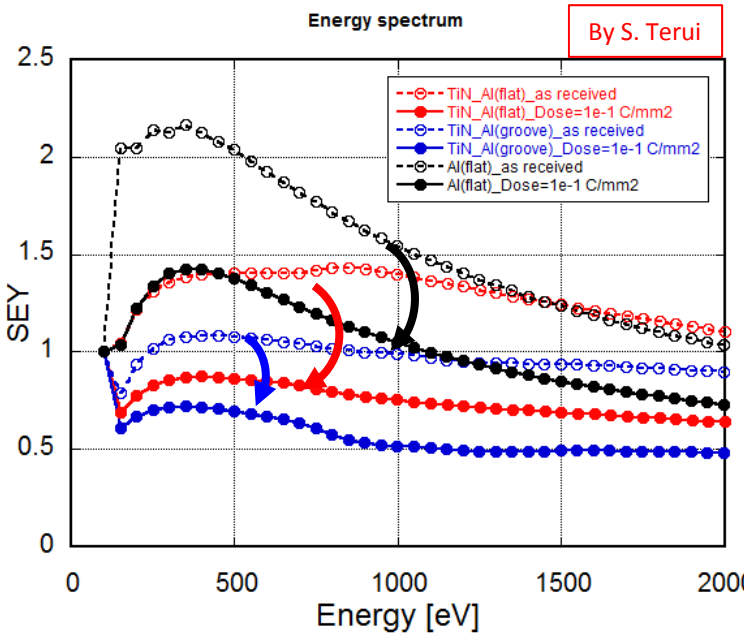
- SEY of Al samples coated with TiN at this facility were measured.
  - It was confirmed that SEY of TiN coating drops to below 0.8 after electron irradiation (incident electron energy : 250 eV)
  - It was also confirmed that the cylindrical cathode rod is available for grooved surface adopted in bent pipes.

Al samples before coating

TiN coated samples

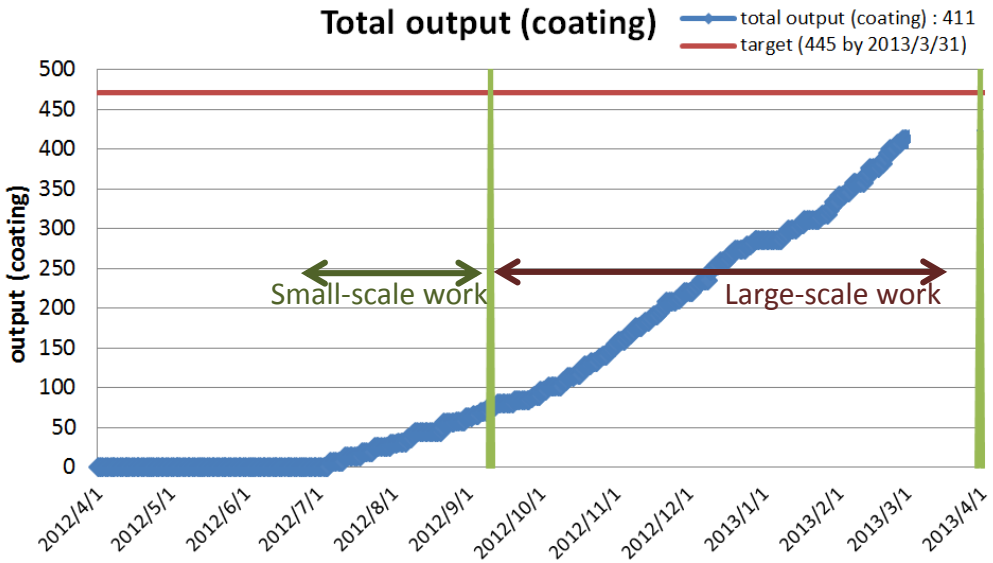
Al flat　　Al groove

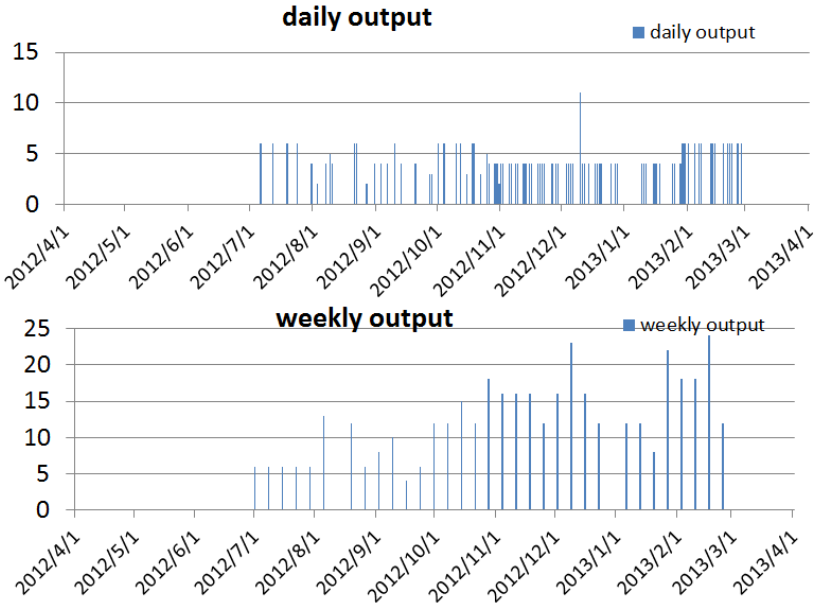




TiN coating 12 : Rate of coating output

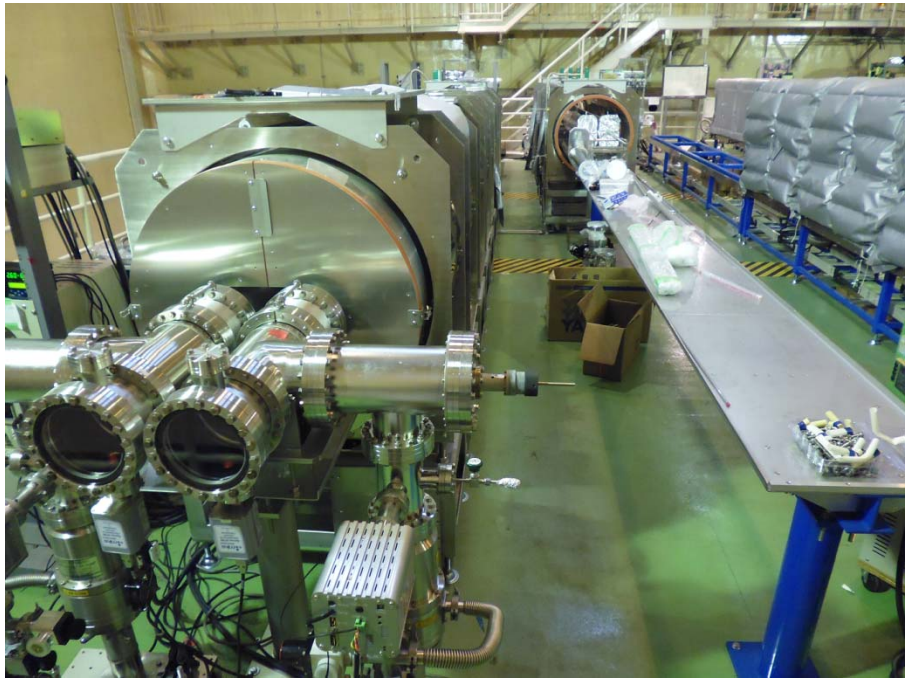
- Coating work started on last July.
  - Coating work started on small scale with 1 coating equipment on last July.
  - On last September large-scale works with 4 coating equipments started.
- Total output by last month (2013/2/28) is 411.
  - Averaged daily output : 1.0(small-scale), 1.9 (full-scale), 1.7 (total)
  - Averaged weekly output : 6.9 (small-scale), 13.6 (full-scale), 11.8 (total)

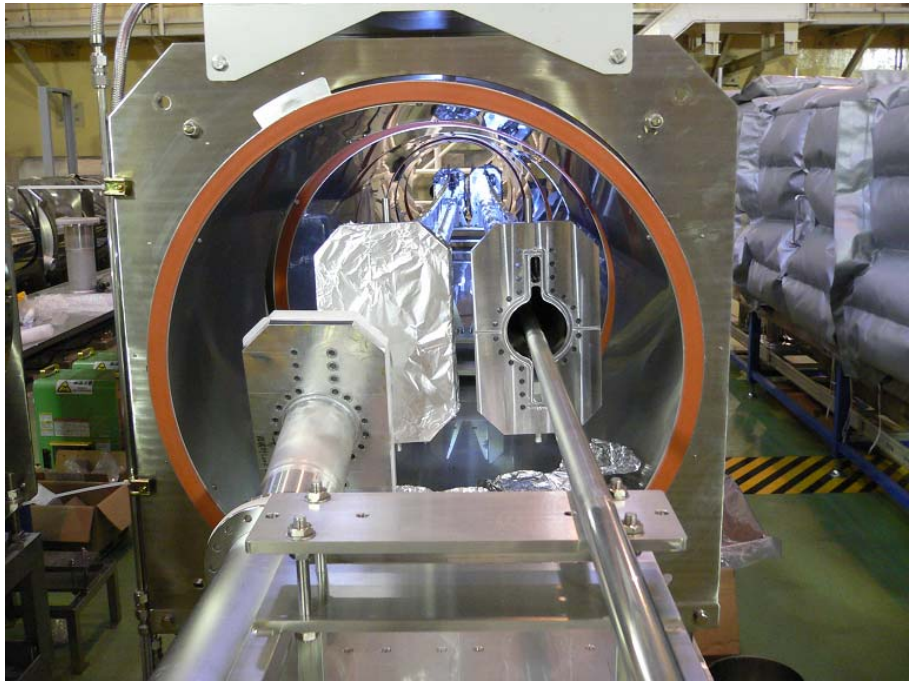




TiN coating 13 : Horizontal type 1

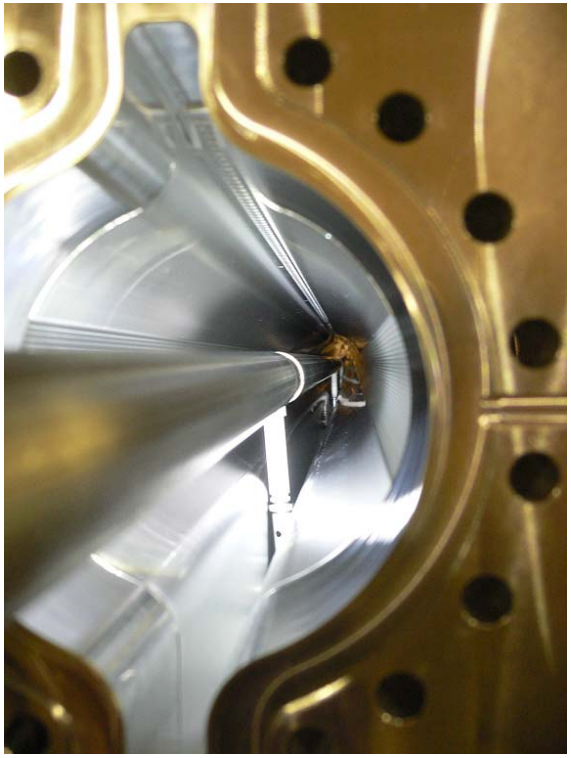
- Horizontal coating equipments for bent beam pipes are in preparation now.





TiN coating 14 : Horizontal type 2

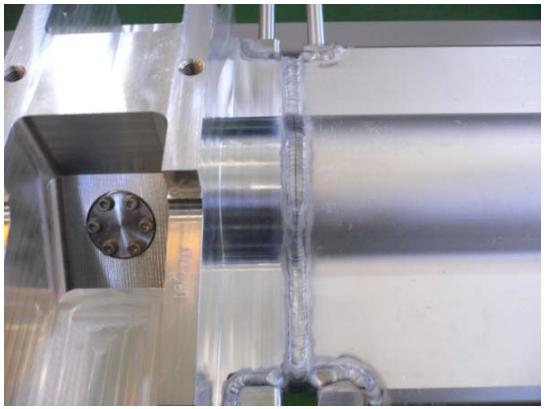
- Discharge test will be done this month
- Large-scale work with 2 equipment will start on April.



Installation test of Ti cathode rod in bent pipe

Troubles

- We had some troubles especially in the early stage.
  - Deformation (1 Cu pipe) and cracks (3 Al pipes) of pipes at welding lines.
    - Caused by stress mainly added during crane works.
    - Change in our assembly and handling processes to decrease stress.
    - Damaged beam pipes will be repaired.
  - Vacuum leak at a welding line between connection flange and pipe
    - Repaired by extra welding
  - Interruption of baking due to shutdown of pumps cased by earthquake or electrical outage.
    - Returning to the starting point of baking.
  - Melting of NEG pump (GP50) during activation
    - Change in power feeding method.
  - Abnormal discharge during TiN coating.
    - Caused by insulation failure.
    - Removal of coating from insulator.
  - Difficulty reducing residual H_2O in coating equipment .
    - Removal of dust on the bottom of coating equipment.
- We have a lot less trouble recently.
  - MO flange (Al) has the quality to last long and we had no problem with it after coating and baking so far.

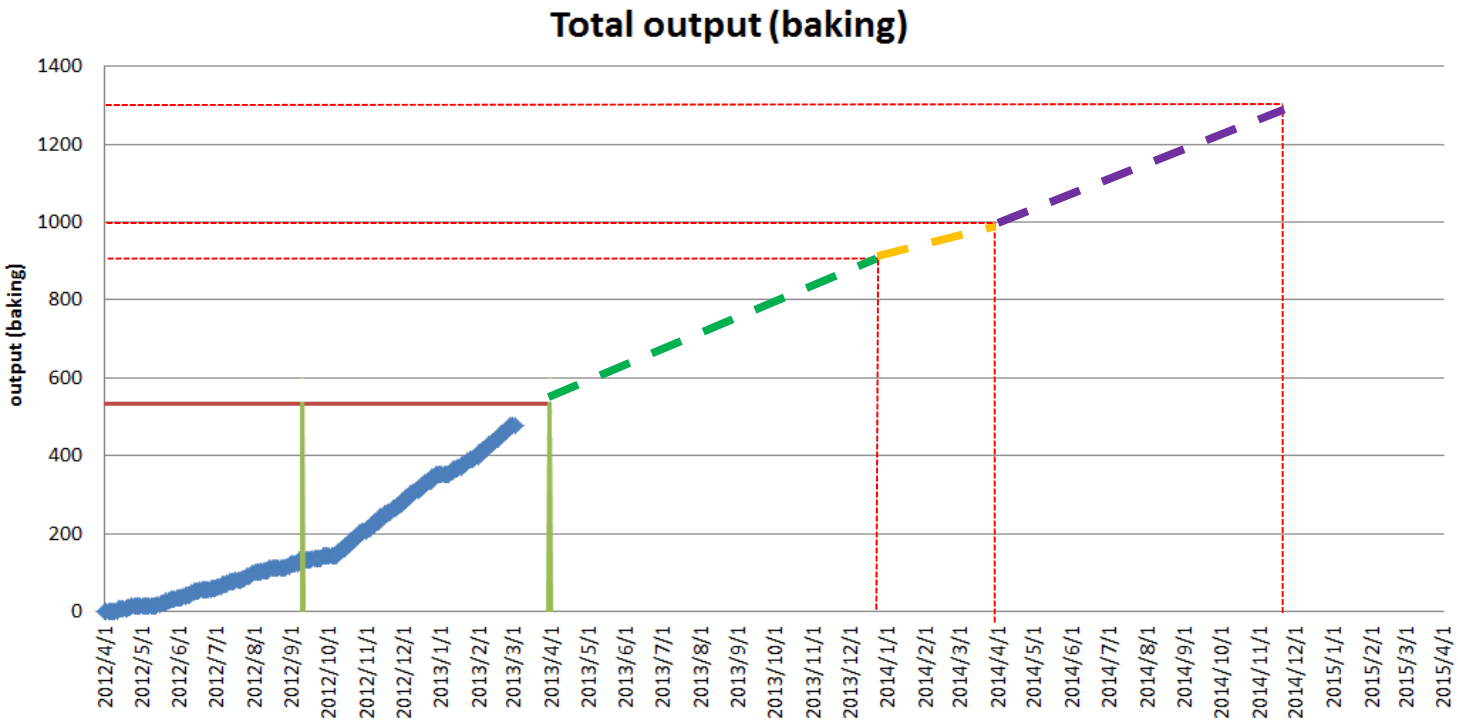


Crack at welding line

Melted NEG pump

Future plan

- Apr. 2013 ~ Dec. 2013 : ~390 beam pipes for LER and HER
- Jan. 2014 ~ Mar. 2014 : ~80 beam pipes for Damping ring
- April 2014 ~ Dec. 2014 : ~250 beam pipes for LER, HER and Damping ring



Summary

- Pre-installation works (coating and baking) started on last April.
  - Large-scale works by 10 workers with 4 vertical coating equipments and 4 baking equipments started on last September.
  - So far 411 beam pipes were coated and 481 beam pipes were baked.
  - Though we had some troubles at the early stage, we have a lot less trouble recently and we are on schedule.
- Horizontal coating facility will be operated on large scale from next month.
  - Coating test will be performed this month.
- During next fiscal year (April 2013 - March 2014), ~470 beam pipes will be treated.