Status of SLOWRI beamline construction

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To utilize rare RIs generated at BigRIPS as slow (~10 keV) ion beams, we have been constructing a 60 m long beamline in parallel to the development of slow RI beam generators, such as PALIS (Parasitic RI-beam production by Laser Ion-Source) and other gas cell type ion stoppers.[1] The beamline will transport singly charged RI ions, which are separated and slowed by PALIS at the F2 chamber of BigRIPS, from F2 to the experimental area E11. It consists of four sector dipole magnets, two focal plane chambers, 62 electrostatic quadrupole singlets, and 11 electrostatic quadrupole quartets. Fourteen 450 L/s turbo molecular pumps evacuate the beamline, which is divided into nine sections (two of them are focal plane chambers) delimited by gate valves. The beamline was installed two years ago.

In contrast to the case of usual fast accelerator beams, it is very important to keep the beamline in a good vacuum since the collisional electron capture cross sections of ions with residual gas molecules are large for slow ions.[2] In some cases, the cross section reaches $\approx 1 \times 10^{-15}$ cm^2 at approximately 10 keV.[3] Assuming this value for the cross section, we estimated the beam fraction surviving after 60 m flight for some vacuum pressures at a temperature of 25℃. The results showed that beam fractions of 48.2%, 93.0%, and 99.3% survive through pressures of 5×10^{-4}, 5×10^{-5} and 5×10^{-6} Pa, respectively. Therefore, a vacuum of the order of 10^{-6} Pa should be sufficient. In order to realize such a good vacuum, the beamline was baked with wire heaters coiling the ducts at 120℃ for about 10 months.

Figure 1 shows a typical vacuum change of the beamline during the baking. Before baking, the vacuum pressure was about 1×10^{-4} Pa. When the heaters were turned on in the middle of October 2015, the pressure temporarily increased up to 3.3×10^{-4} Pa and then decreased gradually. Some dips of pressure appearing in Fig. 1 correspond to the days in which heaters were off because of Christmas holidays, RIKEN Open Day, and so on. Many of the beamline vacuum ducts (and electrostatic quadrupoles inside them) were previously used at other facilities and had been stored for about 15 years. Therefore many molecules were supposed to be stuck on their inside surfaces. Especially, it was considered that the Kapton (polyimide) insulators inside the ducts had adsorbed a considerable amount of H_2O molecules. It took almost 10 months to reach the range of 10^{-6} Pa. The heaters were turned off on August 10, 2016, when the vacuum was about 9×10^{-6} Pa, and then the vacuum became about 5×10^{-6} Pa. Some spikes (sudden rise of pressure) after baking were caused by the stoppage of evacuation pumps due to power outage and maintenance. Once water molecules stuck tight on the surface have been baked out, the vacuum can reach the range of 10^{-6} Pa easily even after ventilation of the beamline with dry nitrogen gas.

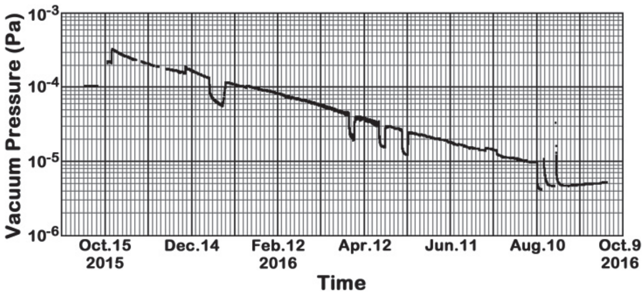

Fig. 1. Typical vacuum change of the beamline during baking. The dips correspond to the days in which baking heaters were turned off (see text).

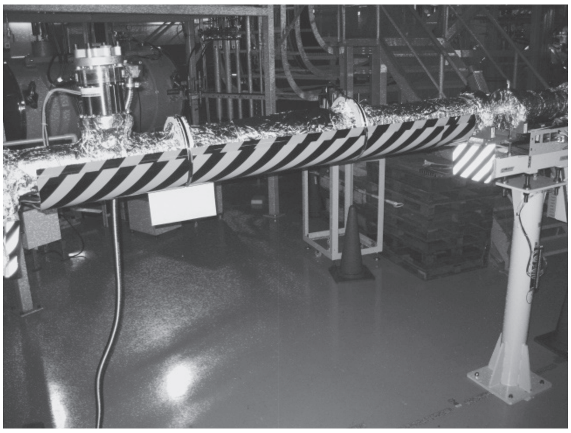

Fig. 2. Protector shell (zebra patterned) covering the beamline ducts over the passage.

Since the baking period was long, for the safety of experimental workers and tour visitors who pass under the beamline, the ducts over the passage were covered with a protector shell (see Fig. 2). The protector is made of aluminum and thermally insulated with thick glass wool rings. The surface of the protector is covered with zebra cushions to minimize physical damages if someone bumped his/her head against it.

In the next year, we will install a conventional ion source and beam profile monitors, following which beam transportation will be tested with some ions.

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References

1) M. Wada et al., RIKEN Acc. Prog. Rep. **47**, 203 (2014).
2) E. W. McDaniel, J. B. A. Mitchell, M. Eugene Rudd: Atomic Collisions: Heavy Particle Projectiles (John Wiley & Sons, New York, 1993).
3) See, for example, data in the following Web Data Base:
CMOL (http://dbshino.nifs.ac.jp/nifsdb/cmol/top)
CHART (http://dbshino.nifs.ac.jp/nifsdb/chart/top)