Long term operation of low charge state laser ion source†

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In March 2014, a laser ion source (LIS) that delivers high-brightness low charge state heavy ions for the hadron accelerator complex in Brookhaven National Laboratory (BNL) was comissioned. Since then, the LIS has provided many heavy ion species successfully. The induced low-charge-state (mostly singly charged) beams are injected to the electron beam ion Source (EBIS),[1)] where ions are heavily ionized, e.g., Au^{32+}, to fit to the ensuring accelerator's Q/M acceptance. To provide various species[2)] to NASA space radiation laboratory (NSRL), more than ten materials are installed in the laser irradiation chamber, and the target can be changed in a few seconds. In 2015, we installed another laser and an additional disk-shaped target to provide a gold beam to the relativistic heavy ion collider (RHIC). Now the LIS provides beams to two user facilities simultaneously.

Although the LIS was a newly conceptualized ion source and we encountered many minor difficulties as expected, we could provide various heavy-ion beams with almost no down time during the past runs. Table 1 shows the operation days. Run 17 has already started, and the LIS is providing beams to the following accelerators now.

Table 1: Total days of operation.

		Li	B	C	O	Al	Ca	Si	Ti	Fe	Ta	Au
Run14 (since March 25, 2014)	NSRL (days)			2				11	1	18	1	3
	RHIC (days)											33
Run15	NSRL (days)	1		2			1	18	4	30		6
	RHIC (days)					14						42
Run16	NSRL (days)		1	5	9			13	5	33	4	1
	RHIC (days)											198

We have experienced many types of the failures. Initially, we planned to rotate the gold disk target with a constant velocity. However, the continuous revolution of the mechanical shafts destroyed some bearings since they are in a vacuum condition. Therefore, we employed the step scanning of the rotating target. By applying an intermittent rest condition, accumulated heat can be conducted from bearings. We also replaced some ceramic ball bearings to Vespel bushings.

In 2016, we found heavy accumulation on the gold target. An enlarged photo of the accumulation is shown in Fig. 1. The shown build-up was formed from evaporated material, since we had operated the beam or almost two hundred days continuously. Unfortunately, some chunks of gold were stuck on the target surface and caused unstable beam condition. For the next run, we modified the target cover and installed a carbon fiber brush to scrape off the accumulations.

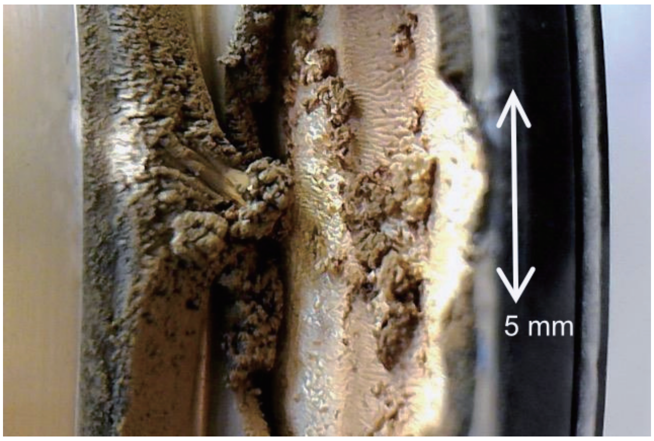

Fig. 1. Accumulation caused by vaporized gold.

The vacuum window for the laser path is one of the vulnerable parts in a laser ion source. The window is 1.8 m away from the target at an angle of 30° from the plasma expanding axis. Since the plasma expands within about 20°. the off-set position of the window helps to reduce direct exposure from the dense plasma. Even under this condition, after one season's exposure, the window was darkened. The outside surface has AR coating, but the inner surface has no coating since a slight accumulation could easily dirupt the AR condition. On the laser path, the deposited laser energy helps to keep clean the inner surface of the window. The laser transmission on the laser spot reduced to 4 %, the remaining area absorbs 9 % of the laser energy.

We also experienced an energy drop in one of the laser systems. The laser had been in standby mode for a month at a steady temperature of 38 °C. This warm water condition could cultivate algae in the water circulation system and degrade the reflectors installed around the laser flash lamps. Now, we avoid a long standby mode and apply UV sanitization when the cooling water is replaced.

The LIS has operated successfully since 2014. Although we had some failures, those experiences help us improve the overall reliability of the LIS.

References

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