Radiation resistivity test of an optical fiber for laser cooling of francium atoms

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Francium is an alkali element in the 7th period, and all its isotopes are radioactive with half-lives of up to 20 min. The application of francium atoms to high-precision spectroscopy for testing fundamental symmetries has been implemented on a vertical beam line of the E7 room at the RI Beam Factory. Francium is produced in the $^{197}\mathrm{Au}(^{18}\mathrm{O}, xn)^{215-x}\mathrm{Fr}$ reaction and finally supplied as laser-cooled atoms into the spectroscopic region. For Fr production, a 7 MeV/nucleon $^{18}\mathrm{O}^{6+}$ beam (target current 18 $e\mu$A) propagating through two beryllium foils and helium gas flow is injected into a gold target positioned at the end of the beam line. However, the optical experimental region for spectroscopy is exposed to high radiation from the target, which is placed a few meters away. Therefore, the optical experimental devices should be evaluated for radiation resistivity.

Laser sources were placed in the laser spectroscopy room in the basement of the RIBF building. A titanium-sapphire laser and external cavity diode lasers supplied 718 nm light beams for the laser cooling of Fr atoms. These light beams will be transported to the E7 room via 400 m of optical fiber. The optical fiber consists of a polarization-maintaining optical fiber (Fujikura SM63-PS-U25D) covered by a stainless flexible tube and flame-retardant polyvinyl chloride (Nippon Steel Welding & Enginering PICOFLEC). One of the concerns is radiation damage caused by boron, which has a large capture cross section of neutrons, contained in stress-applied parts of this optical fiber.[1)] We expected the radiation damage to cause two behaviors: transmission power drifting and degradation of light polarizability.

To evaluate the radiation resistivity, we performed a light transmission monitoring test using 40 m of the same model optical fiber wired inside the E7 room, during the Fr production beam time (maximum 7.9 $e\mu$A). A part of the optical fiber (4.5 m) was stuck with plastic masking tape on the vertical flat surface of a steel rack approximately 1.2 m away from the vertical beam line. The ends of the optical fiber were connected to an optical monitoring system set downstairs of the E7 room, where the radiation level is low. A 685 nm, 1 mW light beam from a diode laser was used for the monitoring system. The output light power of the diode laser, and each s- and p-polarized light power from the optical fiber were monitored using power meters. We determined the transmittance T by the power of the s-polarized output light from the optical fiber normalized by the value of the input power monitor. In addition, the radiation dose to the optical fiber was estimated using data from the E7 room monitoring posts. The peak value of the neutron dose rate was 3.7 mSv/hr, and the integrated neutron dose at the monitoring posts over the beam time was 21.6 mSv. Considering only the distance from the target, the expected dose of the optical fiber was several times larger than the dose estimated at the monitoring post.

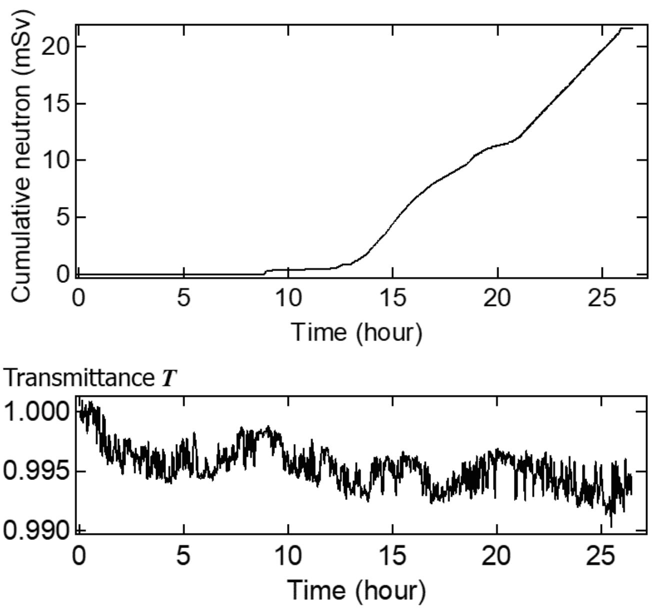

Fig. 1. The upper figure shows the integrated neutron dose at the E7 room monitoring post from the beginning of measurement, and the lower figure shows the optical-fiber transmittance.

The data obtained during the beam time are shown in Fig. 1. Although it is clear that the cumulative neutron dose and the fluctuation of T in Fig. 1 did not correlate, T gradually reduced by less than 1% during 27 h. In order to identify whether this was caused by the irradiation, we carried out followup tests with a low radiation background condition. By checking the optics used in the monitoring system, we found that the coupling efficiency on the fiber couplers may have caused a similar drift. In conclusion, a significant change beyond the measurement accuracy of the transmitted light power and light polarization due to the irradiation was not observed with the current experimental setup. Additional checks using a higher radiation dose are necessary to ensure that this optical fiber can be used for a longer beam time.

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Reference
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