A prototype novel laser-melting sampler for analyzing ice cores with high depth resolution and high throughput

M. Maruyama,[*1] M. Yumoto,[*1] K. Kase,[*1] K. Takahashi,[*2] Y. Nakai,[*2] S. Wada,[*1] Y. Yano,[*2] and Y. Motizuki[*2]

A new facility for analyzing ice cores is being prepared jointly by the RIKEN Nishina Center Astro-Glaciology Research Group (AGG) and the RIKEN Center for Advanced Photonics in Room B35 (50 m^2) in the main research building at Wako. The mission of the facility is to analyze ice cores with high depth (temporal) resolution and high throughput to obtain concentration profiles of various isotopes such as $^{18}O/^{16}O$ and various ions such as $SO_4{}^{2-}$ and $NO_3{}^{-}$. The ice cores that we study have been drilled by the Japanese Antarctic Research Expedition (JARE) at Dome Fuji station in East Antarctica. From the data obtained, one can elucidate the long-term history of climate changes, and even the history of solar activities and possible supernova explosions in our galaxy. Such astro-related research was initiated by the AGG and their activity so far was summarized in the RIKEN APR special issue.[1)]

One of the major components of our facility is a newly installed prefabricated freezer container (3 m wide $\times$ 5 m long $\times$ 3 m high). The temperature in the container is controlled at $-20°$C. The inside of this container is partitioned into two areas: a storage area where valuable ice cores are kept clean and frozen, and an ice core sampling area where a new system (under development) for applying the laser-melting technique will be installed. The other components are isotope analyzers and ion chromatography systems for measuring the concentrations of isotopes and ions in the samples collected automatically as described below. They will be placed outside the container at room temperature.

Figure 1 depicts the schematic diagram of a prototype laser-melting sampler. The sampler consists of a continuous wave fiber laser (λ =1.55 μm), optical switching devices, optical fibers (0.25 mm ϕ), needles (0.7 mm ϕ), and a computer that controls the positions of the sampling nozzles and the motorized stage on which an ice core is placed. The laser beam delivered by the optical fiber is radiated on the target ice core surface, and the melted water of 1 mL (enough volume for precision analysis) thereby obtained is sucked up through the needle and transported into a vial bottle by a peristaltic tube pump at a pressure drop of 1 atm. The needle and the tube are kept over 0°C by the heater windings.

We conducted several performance tests for this prototype. Figure 2 shows one of the results: holes as small as 2 mm ϕ were made on ice 5 mm apart by laser-melting. For this performance test, a laser beam with a power of 1 W was irradiated, and the sampling speed was measured to be 26 min/mL. We are optimizing the irradiation conditions via such performance tests. In addition,

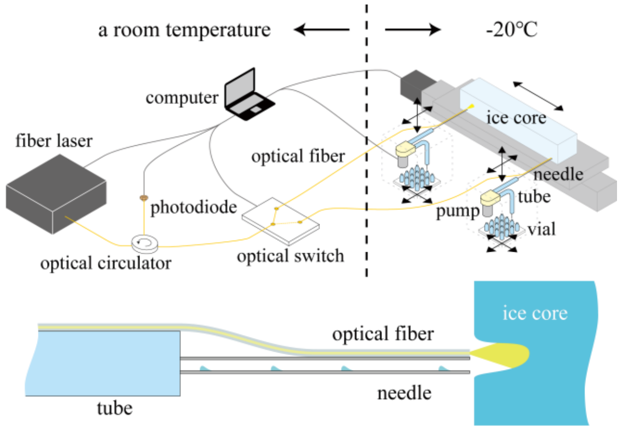

Fig. 1. A schematic view of the ice-core laser-melting sampler. The bottom image shows a sampling nozzle.

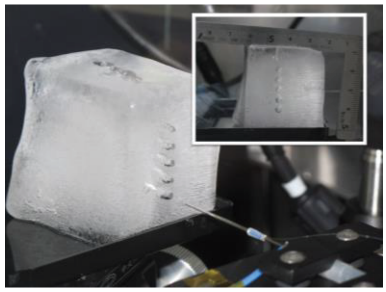

Fig. 2. Photos of a performance test.

we are developing an automated multi-nozzle system to realize high throughput, which is the mission of our facility.

The new system obviously has advantages over our previous work on ice core sampling, which was performed manually using electric band saw machines and ceramic knifes. Our new technique is different from the heater-melting continuous flow analysis method[2)] for the following reasons: 1) sampling zones, either holes or horizontal planes, are discrete to avoid mixing with each other, and 2) the amount of sampling ice is adequately minimized for precision analysis.

This system will make it possible to analyze ice cores at a high depth resolution of 1 mm scale, which corresponds to the temporal resolution of $\sim$1 month in the case of a Dome Fuji ice core. Since the new JARE ice core drilling project has been approved and is in progress, it will become possible to study the correlations between climate and solar activity, and the galactic supernova rate of the past 1,000,000 years. We thank K. Eto and M. Kawada of Tokyo Denki Univ. for helping us with our measurements.

References
1) Y. Motizuki, RIKEN Accel. Prog. Rep. **50**, S-80 (2017).
2) *e.g.*, R. Dallmayr *et al.*, Bulletin of Glac. Res. **34**, 11 (2016).

*1 RIKEN Center for Advanced Photonics
*2 RIKEN Nishina Center