

Commissioning of a prototype novel laser melting sampler for analyzing ice cores with high depth resolution and high throughput

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A new facility for analyzing ice cores is being developed jointly by the Astro-Glaciology Research Group (AGRG) of RIKEN Nishina Center and the Photonics Control Technology Team of RIKEN Center for Advanced Photonics in a room (50 m²) at Wako Campus. The mission of this facility is to analyze ice cores with high depth (temporal) resolution and high throughput to obtain concentration profiles of various isotopes such as ¹⁸O/¹⁶O and various ions such as SO₄²⁻ and NO₃⁻.

The ice cores that we study have been drilled by the Japanese Antarctic Research Expedition (JARE) around Dome Fuji (DF) station in East Antarctica, and the current JARE project to obtain the third Japanese deep ice core, which is expected to contain information up to more than a million years ago, has been approved and is in progress. We aim at investigating the long-term history of climate change from the viewpoints of the relation with solar activities and volcanic eruptions. We also seek traces of supernovae in our galaxy and its explosion rate as our final goal.

In our facility, a low-temperature (LT) room, *i.e.*, a prefabricated freezer container (3 m wide × 5 m long × 3 m high), has been installed, and its inside has been kept at -20°C. Outside the LT room, *two* sets of isotope analyzers have been equipped at room temperature; we plan to add the newest ion chromatography system here in the near future.

The application of the laser melting method on ice cores to obtain samples is the first in the world. Figure 1 depicts a schematic of the prototype laser melting sampler. The sampler consists of a continuous-wave fiber laser ($\lambda = 1.55 \mu\text{m}$), an optical fiber (core diameter = 200 μm , our originally designed nozzle (2 mm outer ϕ), a sampling buffer system with an electromagnetic valve, and a computer that controls the positions of the sampling nozzle and the motorized stage on which an ice core is placed. This system makes it possible to analyze ice cores at a high depth resolution of ~ 2 mm scale, which corresponds to a temporal resolution of ~ 1 month in the case of a DF ice core. Our system is also applicable to a 1-year resolution (~ 3 cm) when sampling is performed in the direction of core depth.

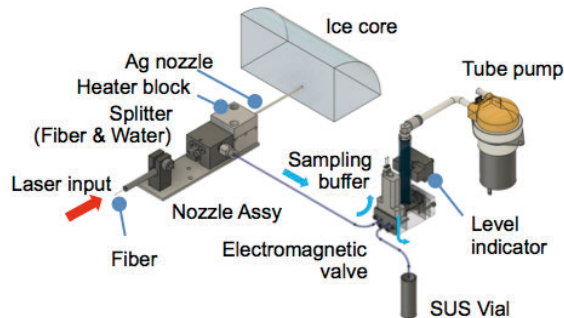


Fig. 1. Schematic of the ice-core laser melting sampling system.

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Fig. 2. Left figure shows a photo of melting ice with the nozzle intruding the dummy ice (bottom right) and the inside buffer being filled (bottom left). The right shows a filled vial.

In Fig. 1, the laser beam delivered by the optical fiber irradiates the target ice-core surface, and 1.5 mL of melted water (sufficient volume for our precision analysis) is sucked up through the nozzle and transported into our original SUS vial bottle by a peristaltic tube pump at a pressure drop of 1 atm. The nozzle and tube are kept above 0°C by the heaters installed inside the nozzle assembly.

We succeeded in continuous sampling into the vials using this prototype sampler. Figure 2 shows the result: the holes were vertically made as small as 2 mm ϕ on a dummy ice block ($\rho = 0.9 \text{ g/cc}$) by laser melting. For this purpose, a laser beam with a power of $\sim 1.3 \text{ W}$ was irradiated, and the nozzle intruding speed was set to 0.40 mm/s. The efficiency of collecting melted water was estimated to be $\sim 100\%$. As the first step, we set our target sampling time for a vial to 20 min, which was determined in concordance with the measurement time of *one* sample by *a single* isotope analyzer using the AGRG protocol developed based on our isotope measurements. By choosing optimum apparatus parameters and by using an automated *multi-nozzle* system that has already been equipped in our system, we plan to attain a higher throughput to handle many sample vials.

Our new technique has some advantages in comparison with the standard heater-melting continuous flow analysis method.¹⁾ They are as follows: 1) sampling zones are discrete to avoid mixing with each other, 2) the amount of sampling ice can be adequately minimized, and 3) fragile low-density ice cores are also applicable because the portion of a core is placed horizontally (Fig. 1). Making the most of these merits, we have started to perform our first application on Antarctic ice to study if there appear seasonal variations in the well-established temperature proxy (¹⁸O/¹⁶O) for the first time in the past ~ 30 years for direct comparison with the temperature measured in the area.

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Reference

- 1) *e.g.*, R. Dallmayr *et al.*, Bull. Glaciol. Res. **34**, 11 (2016).