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Advances in deuterium dioxide concentration measurement

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HIGHLIGHTS

- Heavy water (D_2O) with a high purity level is necessary for nuclear fusion application.
- D_2O purity is analyzed using Fourier Transform infrared (FT-IR) spectroscopy and newly introduced off-axis integrated cavity output spectroscopy (OA-ICOS).
- OA-ICOS has advantages in terms of analysis of D_2O vapor.
- OA-ICOS is expected that it can be used for accurate isotopic analyses in the future.

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ABSTRACT

The deuterium–tritium (D–T) reaction has been identified as the most efficient reaction for fusion devices. Deuterium can be obtained by heavy water electrolysis. Heavy water (D_2O) with a high purity level is necessary for nuclear fusion application. A D_2O isotopic analysis is thus very important. A system for a heavy water analysis was built and a newly designed isotopic analysis experiment was carried out. We tried to analyze the D_2O purity using Fourier Transform infrared (FT-IR) spectroscopy and newly introduced off-axis integrated cavity output spectroscopy (OA-ICOS). We found that the OA-ICOS based on measurement via laser absorption spectroscopy shows very high sensitivity. We ameliorated the sensitivity by an order of magnitude of more than 10^3–10^5. We could make the apparatus smaller by employing very tiny diode laser and fiber optics elements of a DFB (Distributed Feedback) type. Consequently, our device has advantages in terms of maintainability and mobility even in a radioactive environment. This new method could be used for an accurate isotopic analysis in the future.

1. Introduction

Deuterium or heavy water (D_2O) is used for fusion devices or as coolant/moderator/reflector in some research reactors and CANDU reactors. Especially, heavy water (D_2O) with a high purity level is necessary for nuclear fusion application because the deuterium–tritium (D–T) reaction has been identified as the most efficient reaction for fusion devices and deuterium can be supplied by heavy water electrolysis. To control the electrolysis process, analysis of D_2O (liquid and vapor) is essential. The purity of heavy water is usually analyzed by FT-IR. FT-IR is useful to analyze liquid D_2O to measure the purity of heavy water without chemical reagents and it is easy to monitor the results [1,2,3]. But it has a limitation in analyzing D_2O vapor. Especially, in the field of fusion engineering, analysis of D_2O vapor is important as well as that of liquid D_2O because liquid D_2O is a raw material of electrolysis to supply the D_2 gas for fusion reaction and D_2O vapor is generated during electrolysis. Nevertheless, a method to analyze the D_2O vapor has not been developed until now. Therefore we present a liquid D_2O isotopic analysis experience based on the conventional FT-IR and a D_2O vapor isotopic analysis using a new OA-ICOS.

Off-axis integrated cavity output spectroscopy (OA-ICOS) is considered to be very promising and has several advantages including simple alignment and mechanical stability. Since the OA-ICOS adopts time integrated measurement, the device makes real measurement more convenient than devices using other techniques [2].

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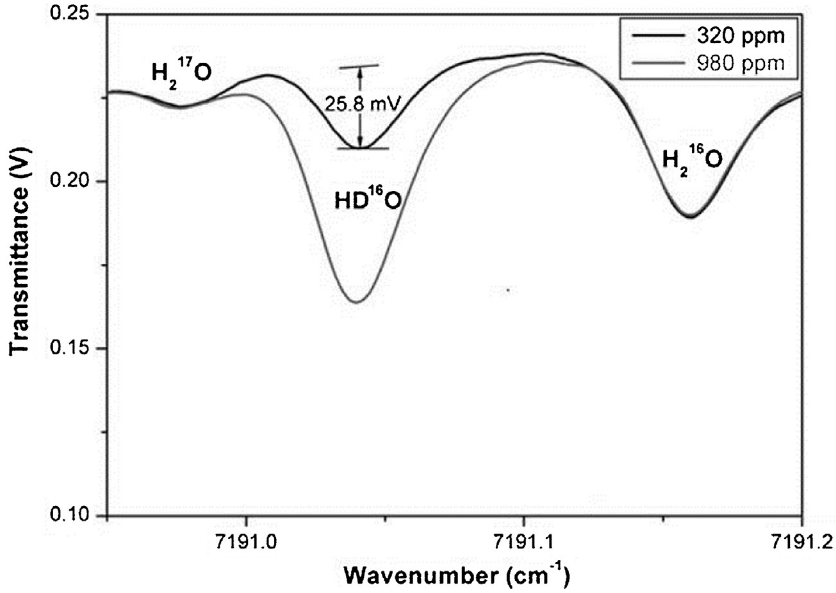

Fig. 1. Absorption spectra corresponding to H_2O and HDO molecules for the case of heavy water [2].

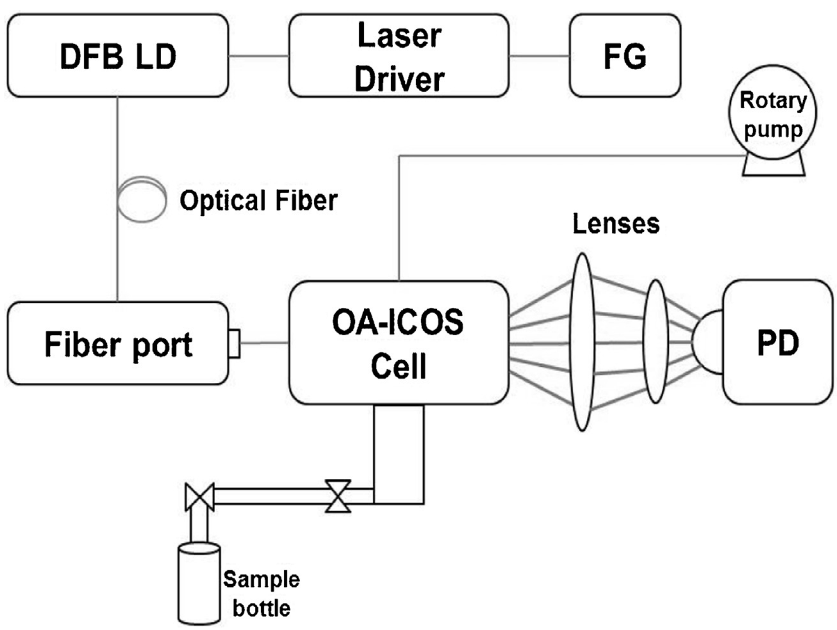

Fig. 2. Schematic diagram of experimental setup (DFB: Distributed Feedback, FG: Function Generator, PD: Photodiode) [2].

We found that the OA-ICOS based on laser absorption spectroscopy provides very high sensitivity. We ameliorated the sensitivity by an order of magnitude of more than 10^3–10^5. We made the apparatus smaller by employing a very tiny diode laser and fiber optics elements of a DFB (Distributed Feedback) type. Consequently our device offers advantages in terms of maintainability and mobility even in a radioactive environment.

2. Experimental

2.1. Preparation of standard solutions

Standard solutions of 99.10, 99.30, 99.50, 99.70 and 99.90 wt.% D_2O in heavy water were prepared by adding H_2O to 99.91 wt.% D_2O, respectively.

2.2. Preparation of samples

Two samples were respectively taken from the reflector system containing heavy water at the High-flux Advanced Neutron Application Reactor (HANARO). One was sampled from a pipe (sample A) and the other was sampled from the tank (sample B).

2.3. FT-IR spectroscopy

To measure the spectra of the prepared standard solutions, the solutions were introduced by using a syringe into the spectrum kit, which was loaded on a FT-IR spectroscope. The spectrum of each sample was obtained by the same procedure. The FT-IR spectroscopy specifications used in this experiment are shown in Table 1.

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