Quantum Cascade Laser Spectroscopy for Radiocarbon Detection

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An instrument based on mid-infrared laser spectroscopy and a quantum cascade laser for the detection of radiocarbon is presented. The measurement is based on cavity ring-down spectroscopy, and a high sensitivity is achieved with a simple setup[1]. By using a tunable narrow-linewidth continuous-wave laser, and by selecting a suitable mid-infrared absorption line of radiocarbon dioxide at 4527 nm, it is possible to minimize spectral interference from other isotopes of carbon dioxide. In addition, issues related to optical feedback and interference fringes have been considered in order to achieve high sensitivity. The instrument was tested using a standardized sample containing elevated levels of radiocarbon. Radiocarbon dioxide could be detected from samples with an isotopic ratio $^{14}C/C$ as low as 50 parts-per-trillion, corresponding to an activity of 5 kBq/m3 in pure carbon dioxide, or 2 Bq/m3 in air after extraction of the carbon dioxide from an air sample. While radiocarbon has a natural abundance of 1.2 parts-per-trillion relative to the total amount of carbon, much higher levels are present in nuclear power environment. Radiocarbon is present in all parts of nuclear power plants and is mostly released in the form of carbon dioxide. This instrument is therefore aimed at the monitoring of radioactive gaseous emissions, during the operation and decommissioning of nuclear power plants. Its high sensitivity also makes it the ideal tool for the detection of leaks in radioactive waste repositories, where radiocarbon is present at high abundance and released as radiocarbon dioxide through biodegradation. The instrument is simple, compact, and robust, making it the ideal tool for on-site measurements.

References

[1] G. Genoud, M. Vainio, H. Phillips, J. Dean and M. Merimaa, "Radiocarbon Dioxide detection based on Cavity Ring-Down Spectroscopy and a Quantum Cascade Laser", Optics Letters 40, 1342 (2015)