Sensitivity Improvements in a Cavity Ring-Down Spectrometer for Radiocarbon Analysis in Biomedical Samples

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While most detection methods for radioisotopes focus on measuring their activity or decay products, long lived emitters with low abundance often require alternative techniques. For detection of the radioisotope ^{14}C high sensitivity techniques such as Accelerator Mass spectrometry (AMS) are commonly used. In the environment, its abundance is typically at the ppt level, however in medical samples, where it is used as tracer isotope to study the metabolism of subjects or other biological processes, the abundance can be significantly higher. Detection may then be performed by application of optical methods such as Cavity Ring-Down Spectroscopy (CRDS) [1], thus providing a more compact and inexpensive solution as well as possibilities for in-field measurements.

An overview and status of our current system for CRDS of $^{14}CO_2$ in the Mid-IR wavelength range will be given. Our optical cavity is directly coupled to a CHNS elemental analyzer by a computer controlled valve system, allowing quick sample analysis [2]. A liquid nitrogen cold trap can be employed to separate the CO_2 sample from the helium buffer gas stream of the analyzer, improving concentration especially for small samples. Attaining high sensitivity requires careful control of environmental variables and contaminants. Thermo-electric cooling of the cavity is applied to suppress interference by absorption of other close-lying molecular transitions. Remaining contaminants vary depending on sample type, but can be estimated from a wide range spectral scan. The sensitivity and linearity of our current ^{14}C determination procedure is estimated. Wavelength calibration is performed using combination of N_2O absorption cell and a solid silicon etalon, however first attempts to reference the system to a Mid-IR frequency comb have been made [3].

Oscillations and drifts in the Ring-Down spectrum baseline are a further issue, severely limiting the sensitivity of the system. A significant fraction of these effects is caused by spurious etalons from partially reflective surfaces along the beam-path. While these may be partially suppressed by optical isolation, an active pathlength modulation [4] has shown promise as well.

References

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