Cavity Ring-Down Spectroscopy for ^{14}C Isotope Analysis of Biomedical samples

Nagoya Univ. [1], ADME & Tox. Research Inst., Sekisui Medical, Tokai, Ibaraki [2], ○ Volker Sonnenschein[1], Ryohei Terabayashi[1], Hideki Tomita[1], Noriyoshi Hayashi[1], Shusuke Kato[1], Lei Jin[1], Masahito Yamanaka[1], Norihiko Nishizawa[1], Atsushi Sato[2], Kohei Nozawa[2], Kenta Hashizume[2], Toshinari Oh-hara[2], and Tetsuo Iguchi[1]

E-mail: volker@nagoya-u.jp

High sensitivity techniques such as Accelerator Mass spectrometry are commonly used for detection of the radioisotope 14C. 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), 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. The optical ring-down cavity is directly coupled to a CHNS elemental analyzer by a computer controlled valve system, allowing quick sample analysis. The analyzer combusts the organic samples and separates the extracted gases using a column in a buffer gas flow of helium. While this already produces a relatively pure sample gas of CO2, thermo-electric cooling is applied to the ring-down cavity to further suppress interference by absorption of other close-lying molecular transitions. The impact of remaining contaminants in biomedical samples on the ^{14}C detection limit and linearity are estimated.

The employed laser is a distributed feedback quantum cascade laser (DFB-QCL) with a single mode output power of >20mW. It is passed through an optical system containing a collimation telescope, optical isolator and an acousto-optic modulator (AOM), which is used for fast switching of the laser source. It is then coupled into a single-mode optical fiber and is mode-matched to the cavity mode of the ring-down gas cell. Frequency calibration of the QCL is performed either by current calibration, or by a newly developed low Finesse Fabry-Pérot interferometer (FPI). Since the QCL frequency drifts depending on environmental factors the temperature stabilized FPI provides a reliable reference signal, which can be used for compensation.

Further improvements to the system are a new quasi-locking concept, that keeps the piezo position of the ring-down cavity close to resonance, so that a higher acquisition speed of ring-down events is possible with loss of signal strength and a passive optical feedback system, which reduces high frequency noise of the laser source.