Optical feedback in a distributed feedback quantum cascade laser and linewidth reduction for cavity ring-down spectroscopy

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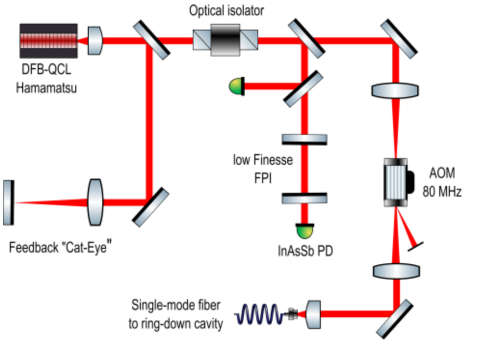
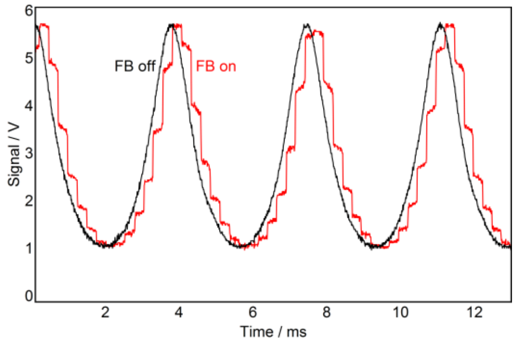
Cavity ring-down spectroscopy (CRDS) is a high sensitivity technique, allowing the spectroscopy of very weak optical transitions in atoms and molecules, or the study of very rare species. Our goal is the quantification of the radiotracer 14C in biomedical samples [1], using the strong absorption of the CO2 molecule at a wavelength of 4.5µm. In this wavelength range quantum cascade lasers (QCL) are a cost effective and powerful solution. Maximal transmission through a high finesse optical cavity, as used in CRDS, is only achieved if the linewidth of the exciting laser is at least as narrow as the transmission peak given by the Airy function. For our system a linewidth of less than 50kHz would be required, which is not generally achieved using standard commercial distributed feedback (DFB) or external cavity QCL lasers, which typically feature a linewidth of more than 1MHz.

Optical feedback, also known as self-injection, is known to reduce the short-term linewidth of lasers and has been applied in several designs, such as the well-established external cavity diode lasers. Compared to diode lasers little experimental information on optical feedback in DFB QCL systems is available, yet a few impressive results have been published, such as the use of Rayleigh backscattering from a CaF2 whispering gallery resonator [2]. This type of filtered optical feedback can show impressive reduction of the linewidth to the kHz level.

A





B

We are pursuing a simpler approach, similar to the one detailed in [3] and shown in Figure A. Our first experimental results demonstrate the effect of feedback on the wavelength tuning behavior of the laser as well as first indications of linewidth narrowing. Measurements were carried out both with a low finesse FPI (Figure B) as well as by monitoring the output of the high finesse cavity used for ring-down spectroscopy.

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[3] L. Jumpertz, M. Carras, K. Schires, and F. Grillot, Applied Physics Letters 105, 131112 (2014)