Cavity mode-width spectroscopy with widely tunable ultra narrow laser

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We demonstrate very promising, high dynamic range cavity enhanced spectroscopy technique in which an absorption spectrum of investigated gas can be determined from the dependence of a high finesse cavity TEM_{00} mode widths on the absorption coefficient. Similarly to the Cavity Ring-Down Spectroscopy (CRDS) the idea of the Cavity Mode-Width Spectroscopy (CMWS) is based on variation of interaction time of the laser light with the optical cavity. While this interaction time can be measured directly from the ring-down decay time constant it has also influence on spectral width of the cavity resonant modes and their shift due to dispersion. With decreasing interaction time, due to absorption by intracavity medium the mode width increases. Measurement of the mode half width allows to retrieve the information about the absorption coefficient for given frequency. Recently built in our laboratory [1], high spectral-resolution laser system (linewidth below 8Hz) with wide tunability within 20 GHz, was used to probe a P7Q6 O_2 line from the B-band (689 nm). To our knowledge this is the first absorption spectrum recorded by the CMWS technique.

We also discuss features of CMWS in comparison with the very actual, high senistive and precise CRDS methods. It seems that precision of the determined absorption coefficient α in CMWS should not decrease with increasing α as fast as in CRDS. While in CRDS both the amplitude and the decay time of the ring-down signal decrease with increasing α in the CMWS decrease of signal amplitude is partially compensated by larger mode width, which can be measured with higher accuracy. Moreover, CMWS does not require fast light detectors and therefore detectors with very high gain can be used and if necessary their gain can be varied during spectrum measurement to increase dynamic range of absorption measurement. It was demonstrated that in CRDS experiments extremely high precision can be obtained [2] and spectra of molecular transitions can be measured in milliseconds [3]. On the other hand it is challenging to avoid systematic errors associated with linearity of optical detector and data acquisition card [4], and fast switching off the laser beam [5]. A natural limitation for precise cavity ring-down time measurement is that it must be significantly longer than the laser beam switching off time. In this context the CMWS seems to be complementary method to CRDS, allowing to measure this part of absorption spectrum at which absorption is too high for precise ring-down time measurements.

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[1] D. Lisak, et al., *Acta Phys. Pol. A* **2012**, *121*, 614.
[2] A. Cygan, et al., *Phys. Rev. A* **2012**, *85*, 022508.
[3] G.-W. Truong, et al., *Nature Photonics* **2013**, *7*, 532.
[4] S. Wójtewicz, et al., *Phys. Rev. A* **2011**, *84*, 032511.
[5] D. A. Long, et al., *Proc. SPIE* **2013**, *8726*, 07260O-1.