Cavity-Enhanced Faraday Rotation Spectroscopy for Oxygen Detection

Jonas Westberg[1], Brian Brumfield[2], Gerard Wysocki[1]
[1]*Princeton University, Princeton, New Jersey*
[2]*Pacific Northwest National Laboratory, Richland, Washington*

Indirect spectroscopic techniques such as photoacoustic spectroscopy or laser induced fluorescence (LIF) are known to benefit from increased optical power that directly affects the measured signal and improves the sensitivity. This is rarely the case for direct methods that rely on transmitted radiation through the sample. In this category, Faraday rotation spectroscopy (FRS), is one of the few techniques, in which the signal is directly proportional to the optical power, and hence benefits from large intra-cavity power build-ups. In this work we investigate the application of high-finesse cavities to effectively build up intra-cavity optical power to perform cavity enhanced FRS (CE-FRS). FRS utilizes an external magnetic field to induce a rotation of light polarization in the proximity of a magnetically sensitive molecular transition. The rotation angle is proportional to the sample concentration, which can be detected using a conventional polarimetric setup. Since FRS is sensitive only to paramagnetic species, unwanted interferences from diamagnetic molecules, such as CO_2 and H_2O, are largely suppressed. In recent years, this technique has been thoroughly investigated and several system have reached shot-noise limited performance. In order to perform CE-FRS, we propose a polarized cavity containing an intra-cavity polarization selector (e.g. a Brewster window). In this configuration, Faraday rotation results in an out-coupling of non-resonant polarization on every round-trip. Optical feedback with active laser-frequency locking and heterodyne detection are implemented for measurement of the out-coupled signal, and efficient suppression of background birefringence is obtained through a sinusoidal modulation of the magnetic field followed by lock-in detection. We will demonstrate an experimental setup with possible cavity build-up powers of up to several hundreds of mW, or even W, and theoretical modeling with prospects for obtaining enhanced FRS detection limits.