Infrared laser spectroscopy of molecular hydrogen

V.L. Kasiutsich[1], E.D. Mcnaghten[2], P.A. Martin[1]

[1]*School of Chemical Engineering and Analytical Science, University of Manchester, Manchester, M13 9JP, UK*
E-mail: philip.martin@manchester.ac.uk
[2]*AWE, Aldermaston, Reading, RG7 4PR, UK*

Off-axis cavity-enhanced absorption spectroscopy has been used to measure the S(1) quadrupole band of the fundamental 1 – 0 vibrational band of molecular hydrogen for applications in plasma catalysis.

1. Introduction

Plasma catalysis is one approach to produce molecular hydrogen from CH_4 for a range of applications in the energy sectors such as fuel cells. In order to study these processes in detail a direct optical method for quantitatively measuring hydrogen is required. Infrared laser spectroscopy is often used for measuring low concentrations of trace gases but hydrogen does not exhibit electric dipole moment transitions in the infrared spectral region. However it does possess a weak quadrupole moment which can be used if long optical absorption pathlengths are employed. This work describes an off-axis cavity-enhanced absorption experiment to measure hydrogen around 2.1 μm.

2. Methodology

2.1. Theory

Quadrupole transitions have the rotational selection rule $\Delta J = 0, \pm 2$ which gives rise to a Q branch as well as S and O branches. The quadrupole moment spectrum of H_2 was first measured by Herzberg in 1949 [1] and later by Fink et al. [2]. The S(1) line of the fundamental vibrational quadrupole band has a linestrength of 3.36×10^{-26} cm/molecule at 298 K.

2.2. Experimental

A cw-DFB diode laser producing around 5 mW at 2122 nm was used to illuminate a high finesse optical cavity of length 19.4 cm in an off-axis alignment. The laser light emerging from the cavity was focused onto an extended InGaAs photodetector. Difficulties were encountered due to amplified spontaneous emission of the laser passing through the cavity onto the detector.

Hydrogen gas (99.99%) was introduced into the optical cavity using a gas sample bag and the infrared spectrum at several different pressures was measured.

3. Results and Conclusions

Figure 1 shows an example of the spectra obtained with the off-axis cavity enhanced absorption technique. The very low laser power detected at exit of the cavity limited the detection limit to 0.16% hydrogen for 200 scan averages within 2 s. This was limited by detector noise. Higher laser power and a longer effective pathlength should enable detection limits lower than ppm levels.

In conclusion, we have demonstrated that off-axis cavity enhanced absorption spectroscopy can be used to quantitatively measure molecular hydrogen in the infrared spectral range. The technique can now be incorporated into the atmospheric pressure plasma catalysis reactor to study the formation of hydrogen.

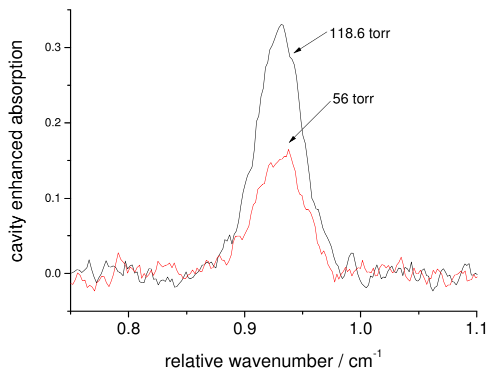

Fig. 1: *Cavity-enhanced absorption spectrum of the S(1) quadrupole transition 1 – 0 on H_2 at 4712.89 cm^{-1} (2122 nm) for different pressures of H_2.*

References

[1] G.Herzberg: Can.J.Phys. A28 (1950), 144.

[2] U. Fink, T.A.Wiggins, D.H.Rank: J.Mol. Spec 18, (1965) 384.