Cavity ring down Faraday rotation spectroscopy for oxygen detection

Motivation

- Medical diagnostics
- Respiration
- Environmental applications
  - Oxidative ratio (O₂/CO₂)
  - High sensitivity (1 ppm)
- Semiconductor manufacturing processes
- Combustion characterization
- Food packaging

Experimental methods and procedures

Cavity ring down spectroscopy

- Measure intensity decay as a function of laser frequency.
- Long interaction length due to cavity enhancement.
- Insensitive to intensity noise.
- Off-resonance or empty cavity calibration required.

Absolute measurement of absorption:

\[ \text{Absorption} = \frac{\text{Intensity at zero delay}}{\text{Intensity at maximum delay}} \]

Respiration

Insensitive to intensity noise.

Long interaction length \( \propto (b) \)

Combustion characterization

Long interaction length

Magnetic field

Differential measurement

Measure \( t \)

Semiconductor manufacturing

and two photodetectors

180° of pressure.

Of pressure.

\( t_I = \frac{1}{2} - \frac{1}{2t_0} \)

Medical diagnostics

Faraday rotation accumulates

Line locking (no need for off noise. This uncovers the shot fluctuations of empty cavity ring down measurements. The ring down times for the s

Introduction to Faraday rotation

- Magnetic field \( \leftrightarrow \text{Circular birefringence} \leftrightarrow \text{Faraday rotation} \)
- Rotation converts linearly polarized light to circularly polarized light.
- No interference from diamagnetic species (e.g. CO, H₂, etc.)

Results

- Strong absorption
- Weak absorption

Absorption measurements of oxygen for the two orthogonal polarization directions measured at 8 Torr of pressure.

\( T = \frac{\text{Intensity at zero delay}}{\text{Intensity at maximum delay}} \)

\( 180° \)

Conclusions

- Differential cavity ring down spectroscopy.
- Polarization rotation measurement.
- No interfering species (CO₂, H₂O, etc.).
- Suppression of \( T \) fluctuations.
- Both detectors measure the same ring down event.
- White noise limited performance for more than 1000 s.
- No \( T \), measurement required.
- \( O₂ \) detection limit \( \sim 60 \) ppb @ 100 s.

Future work

- Improve coil/cell assembly.
- Line locking (no need for off-resonance measurement).
- Duty cycle increase.

Acknowledgments

- No empty cavity measurement required!