FIBER LASER PUMPED DIFFERENCE FREQUENCY BASED MID-IR SOURCE FOR AMMONIA DETECTION

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1. Abstract

Sensitive, selective and on line ammonia detection is of interest in various application such as in De-NO_x process monitoring of power plants. In this work we report direct laser absorption spectroscopy of NH_3 absorption lines at ~ 3 μm. The 3 μm radiation is generated by difference frequency mixing a high power cw Yb-fiber amplified fiber laser at 1038 nm and a fiber pigtailed 1577 nm DFB diode laser in a 20 mm long periodically poled lithium niobate (PPLN) crystal . A NH_3 absorption line at 3295.4 cm^{-1} was detected in a single pass gas cell (L=10cm, p=3, 0.2Torr) from which we estimate a NH_3 detection sensitivity of ~40 ppm·m.

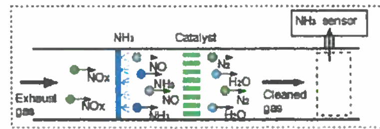
2. Motivation

- Monitoring NH_3 concentration after De-NO_x process of exhaust pipes in a power station
- Pollutant gas monitoring
- Atmospheric chemistry
- Space craft related gas monitoring
- Semiconductor Processing
- Medical diagnostics (kidney)

3. De NO_x Process

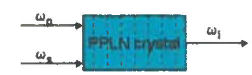
- Process principle
  - NO_x gases in the exhaust are removed using NH_3 with a catalyst to non-harmful N_2 and H_2O

$$4NO + 4NH_3 + O_2 \longrightarrow 4N_2 + 6H_2O$$
$$6NO_2 + 8NH_3 \longrightarrow 7N_2 + 12H_2O$$



- Requirements for the NH_3 sensor :
  - 1 - 2 ppm (Minimal concentration)
  - Real time detection

4. Difference Frequency Generation



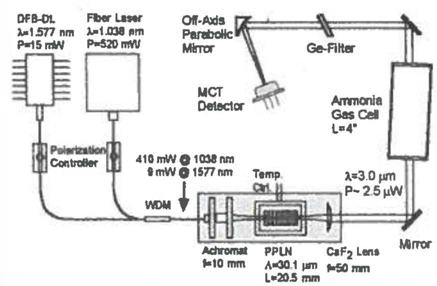
- Conservation of Energy: $\omega_i = \omega_p - \omega_s$
- Conservation of Momentum: $n_i/\lambda_i = n_p/\lambda_p - n_s/\lambda_s - 1/\Lambda$
- Predicted power: $P_i = C\,L\,P_p\,P_s$

ω, frequency ; λ, wavelength; n, refractive index; Λ, grating period; P, power; C, figure of merit; L, crystal length.

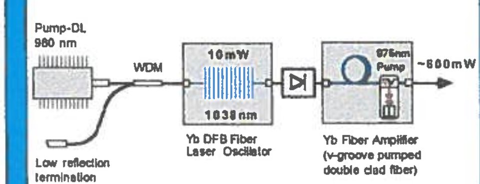
5. Merit of fiber laser-DFG based sensor

- Easy fiber optic alignment and robust
- Real time measurements (2-20 s)
- High resolution (< 30 MHz) spectroscopic source (vs. FTIR: ~3GHz)
- Strong, relative interference free absorption line (vs. 5 times weaker overtone line at ~1.53 μm)
- Compact and portable device

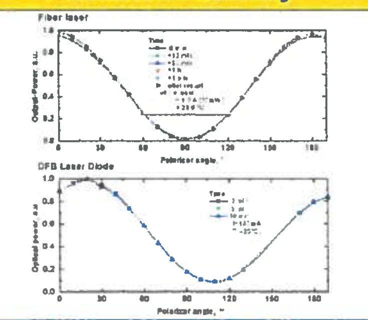
6. Schematic of NH_3 Gas Sensor



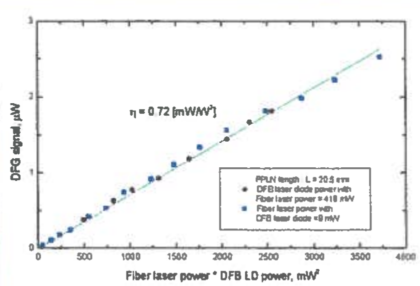
7. Schematic of Fiber Laser



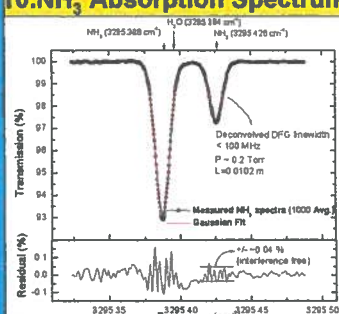
8. Polarization Stability



9. DFG Slope Efficiency

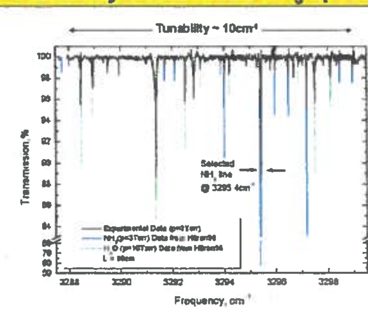


10. NH_3 Absorption Spectrum @ 3 μm



- Measured Doppler limited spectrum
- DFG linewidth < 100MHz
- Absorption sensitivity: +/- 4x10⁻⁴ (0.2Torr) ➔ Detection limit 40ppm m (p>100Torr)

11. Tunability:Continuous NH_3 spectrum



12. Summary

- Demonstration of a fiber laser pumped DFG based spectroscopic source @ 3 μm
- Mid-infrared power ~2.5 μW
- Spectral linewidth < 100MHz
- High resolution spectrum of NH_3 @ 3295.4 cm^{-1}
- Demonstrated minimum detectable absorption: 4×10^{-4} @ 0.2Torr ➔ 40ppm m @ p>100Torr