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## Non-Dispersive Raman Spectroscopy for Hydrogen Detection below 100 ppm using 532 nm and 450 nm Excitation Sources

Hydrogen is considered a key energy carrier for decarbonized energy systems, with applications ranging from industrial processes and gas-grid blending to storage, transport, and safety-critical environments. Its reliable detection is therefore essential, but conventional sensing technologies may suffer from aging, cross-sensitivity, consumable requirements, or direct gas-transducer interaction. Raman spectroscopy is particularly attractive for hydrogen because  $H_2$  is a homonuclear molecule with weak direct absorption signatures, while its vibrational Raman band around  $4156\text{ cm}^{-1}$  is intense, spectrally isolated, and suitable for selective optical detection. In this work, two compact non-dispersive Raman systems were developed and experimentally compared for hydrogen sensing. The systems use continuous-wave excitation sources at 532 nm and 450 nm, delivering approximately 1.5 W and 1.9 W of optical power, respectively. In both configurations, the laser beam is focused inside a gas cell and the Raman-scattered radiation is collected at  $90^\circ$  and imaged onto an uncooled industrial CMOS camera. The hydrogen Raman emission is isolated by commercially available band-pass filters centered at approximately 680 nm for 532 nm excitation and 550 nm for 450 nm excitation. Measurements were performed using a certified gas mixture containing 2%  $H_2$  in  $N_2/O_2$  at 1 bar pressure, with camera integration times of 2, 5 and 10 s. Detection limits were estimated using a  $3\sigma$  criterion based on vacuum-background acquisitions. The 532 nm system achieved  $H_2$  limits of detection of 400 ppm, 135 ppm, and 125 ppm for integration times of 2, 5 and 10 s, respectively, while the 450 nm diode-based system achieved improved values of 260 ppm, 75 ppm, and 60 ppm. The comparison highlights the trade-off between Raman scattering efficiency and excitation-beam quality: although the blue diode source provides higher Raman efficiency due to the  $\lambda^{-4}$  dependence, its larger divergence leads to a broader focal waist compared with the DPSS source. Nevertheless, the diode-based configuration demonstrated better overall detection performance. These results show that non-dispersive Raman spectroscopy can provide compact, contactless, and fast hydrogen detection with limits of detection below 300 ppm in 2 s at 1 bar, making the approach suitable for safety-oriented and field-deployable monitoring applications.

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### References

- [1] Fabio Melison, Lorenzo Cocola, Luca Poletto "Nondispersive Raman spectroscopy for hydrogen detection", Proc. SPIE 14086, Optical Sensing and Detection IX, 140861Z (29 May 2026); <https://doi.org/10.1117/12.3097612>
- [2] Melison, F.; Cocola, L.; Poletto, L. Raman Gas Sensor for Hydrogen Detection via Non-Dispersive and Dispersive Approaches. *Sensors* **2025**, 25, 4190. <https://doi.org/10.3390/s25134190> Authors, Journal, Issue