Visualizing and Quantifying Methane and Natural Gas Emissions using Lasers and Small Semi-Autonomous Drones

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Abstract: We describe man-portable and aerial near-IR laser sensor platforms which spatially scan a laser beam to create quantitative plume images. These tools locate, visualize, and deduce natural gas (methane) emission rates at small infrastructure sources.

1. Introduction

Methane emissions from natural gas leakage costs customers the price of lost gas, poses safety hazards and contributes to greenhouse gas loads. This paper describes lightweight handheld and aerial sensor tools that detect, image, and quantify natural gas (methane) emissions into the atmosphere from infrastructure and storage site leaks.

Annual natural gas leakage is estimated ~250 billion cubic feet. Maintaining the security and integrity of the natural gas system is a regulated continual process of searching for, locating, and repairing leaks. Thousands of leak detection tools and devices are currently deployed worldwide to protect against potentially explosive leaks. However, despite industry motivation and desire to prioritize leak repairs based on emission rate, there are no convenient cost-effective portable leak survey tools currently available to reliably perform this function at small infrastructure sources, e.g. valves, meters, etc. Identifying and repairing the larger leaks as ranked by use of this new technology is expected to mitigate approximately 90% of the loss.

2. Technology

The sensors are a novel marriage of: a) active near-infrared Backscatter Tunable Diode Laser Absorption Spectroscopy (b-TDLAS, Figure 1) scanned over an area of interest, b) passive visible imaging, and c) advanced processing algorithms. We adapted our widely-used b-TDLAS sensors (the Heath Remote Methane Leak Detector, RMLD®) [1] to platforms that spatially scan the laser beam to create methane emission plume images with high sensitivity, spatial resolution, and temporal resolution. These platforms provide rapid (~10m^2/min) detection and quantitative imaging of emissions as small as ~ 1 scfh. They measure gas concentration integrated along the path from the laser beam source to a passive topographic surface illuminated by the beam. The fundamental TDLAS technology measures the amount of target gas along the laser beam path, uninfluenced by background characteristics, ambient light, other ambient gases or environmental effects. Our active "Quantitative Gas Imaging" (QGI) devices overlay the scanned b-TDLAS upon passive visible images to provide a scene of the leak. Advanced algorithms process the information in the plume images to identify emission source locations and calculate emission rates.

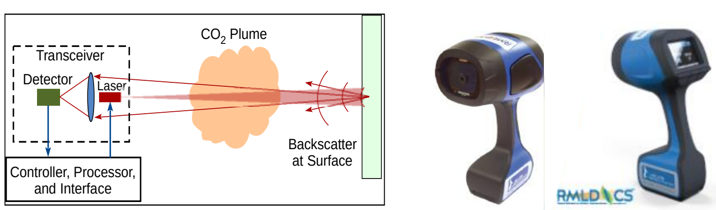

Fig. 1 - Backscatter TDLAS, underlying the Remote Methane Leak Detector (RMLD®), measures methane column density.

3. Deployments

Early QGI prototypes have been deployed: 1) in a man-portable configuration (Figure 2) for fine imaging of areas ~1m^2, suitable for infrastructure component or municipal leak inspection; and 2) aboard small (24") semi-autonomous unmanned aerial vehicles (i.e. drones, Figure 3) for coarse imaging of areas ~100 – 1000 m^2, suitable for survey at wellheads, compressor stations, storage sites (both above and underground), and pipelines.

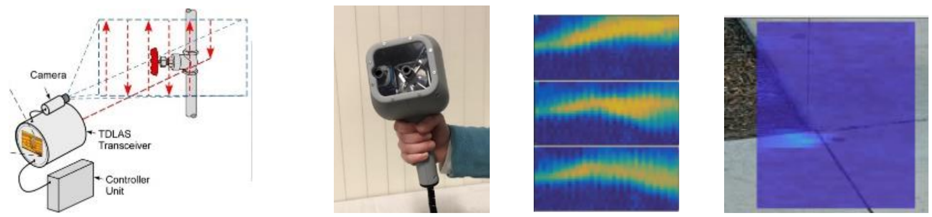

Figure 2 – QGI Concept; Prototype Handheld Transceiver; Successive 1second images of a 15 scfh methane plume at 3 m distance; Small leak emanating from a sidewalk.

Fig. 3 – Small (24”) UAV with b-TDLAS payload aimed at ground; Raster-scan flight pattern and plume image

The man-portable configuration combines miniature laser scanners with b-TDLAS technology to create a grid of TDLAS measurement pixels. The UAV variant flies a raster pattern and interpolates between measurement points to create a similar pixel grid over a larger area. The resulting 2D data reconstructions show the path-integrated methane concentration images depicting methane plumes overlain on visible camera imagery. From these images, emission rates are deduced using a mass-balance approach: Pixels forming a perimeter encompassing the leak source are selected for analysis. Emission flux is calculated as the integral over the perimeter of the vector product of the TDLAS data (ppm-m) and the local wind velocity vector (m/s). Wind is determined by: (a) user input from a known current wind value, (b) recorded from a local portable anemometer, or (c) deduced from the image data itself.

4. Conclusion

Active laser-based QGI is more sensitive than passive thermal infrared Optical Gas Imagers, quantitative, and independent of ambient conditions. These measurement virtues enable estimating emission rates (flux) thus providing the information needed by operators to prioritize repairs.

5. References

[1] Heath Consultants Inc., Houston, TX www.heathus.com/rmld

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