MINIATURIZED LASER POINT SENSOR FOR NATURAL GAS

Updated: November 20, 2017

TITLE: Autonomous, High Accuracy Natural Gas Leak Detection System

PROGRAM: Methane Observation Networks with Innovative Technology to Obtain Reductions (MONITOR)

AWARD: $2,494,131

TEAM: Aeris Technologies, Inc. (Lead), Los Alamos National Laboratory, Rice University

TERM: March 2015 – August 2018

PRINCIPAL INVESTIGATOR (PI): James Scherer

MOTIVATION

The United States has leveraged its shale resources to become the world's largest natural gas producer. However, an average of about 2% of natural gas (primarily methane) is emitted inadvertently. Industry and environmentalists are increasingly focused on reducing methane leaks from the gas supply chain to reduce the loss of valuable product, improve safety, and mitigate methane's environmental impact. Low cost and effective methane monitoring technologies that can be widely deployed to promptly detect leaks and quantify flow rate will improve the efficiency and safety of natural gas production while minimizing environmental impact.

TECHNICAL OPPORTUNITY

Most existing methane detection devices are point sensors, carried by onsite personnel or vehicles to locate natural gas emissions. The most precise, high-sensitivity point sensors typically use laser-based absorption techniques. The state of the art can be mostly classified into two approaches: 1) cell-based detectors, with laser path lengths of a few meters and 2) cavity-based approaches, which use precisely aligned, highly reflective mirrors to obtain path lengths 100 times greater in the same sample volume. Cell-based approaches are limited in sensitivity, while cavity-based approaches can have reliability issues. Both use a wavelength in the near-infrared because of the low cost of detectors and lasers available. In the mid-infrared range, the absorption of methane is over 200 times stronger than in the near-infrared but lasers and detectors in the mid-infrared range have been expensive. However, as larger markets for these devices emerge, more companies are interested in producing the appropriate components, thereby decreasing the cost and creating an opportunity to utilize mid-infrared wavelengths in point sensors. Additionally, recent advances in machine learning such as deep neural networks have enabled more sophisticated modeling of leakage and location. The combination of highly sensitive point sensors and advanced leak characterization algorithms presents an opportunity to detect leaks reliably and cost-effectively.

INNOVATION DEMONSTRATION

The Aeris team set out to develop a natural gas leak detection system consisting of a sensitive and compact laser sensor and an embedded artificial neural network characterization algorithm for the location and quantification of natural gas leaks. Point sensors have been used to perform measurements attached to mobile units but have not been coupled with inversion approaches in such a way that a single point sensor can measure leak flow rate and location. This is precisely the problem that Aeris aims to solve.

At the heart of Aeris' system is a cell-based sensor using mid-infrared laser sources that have no moving parts and can be mass produced. Because methane is emitted from both natural gas leaks and biogenic sources, the

detection concentration alone is not sufficient evidence. Conversely, because ethane is not biogenic and comprises 2-15% of natural gas, the correlated detection of both methane and ethane clearly identifies a gas leak. As such, Aeris' mid-infrared sensor is unique in its ability to discriminate between methane from biological sources and methane from leaks in the natural gas supply chain. Aeris was also able to build a sensor at a much lower cost than the current state of the art for this sensitivity. A key performance benchmark for cell-based detectors is path-length-to-volume ratio. A detector with a high path-length-to-volume ratio is desirable due to its sensitivity and compactness. The team designed a cell that obtains a 13-meter path length in a 60 cm3 volume, a greater path-length-to-volume ratio than other cells, and near the theoretical limit for an optimized mid-infrared cell. With the use of mid-infrared wavelengths and optimized cell design, the produced sensor is compact, highly reliable, and has detection sensitivity on the few parts-per-billion level.

Additionally, Aeris has integrated an artificial neural network inversion approach to enable the laser-based point detector to automatically measure, locate, and quantify methane emissions. In contrast to previous inversion approaches that relied on driving a vehicle around an area and performing quantification and localization offline, this system leverages a network of sampling ports to provide information about concentrations at specific areas on the site. The artificial neural network will then, in real time, provide information on local methane emissions.

These advances have resulted in the Aeris PICO system (Figure 1). The core sensing part of the Aeris PICO system contains a 13-meter path length wrapped into a hand-sized cell. The whole unit fits in a standard protective case shown with a coffee mug for perspective. Aeris will then integrate this sensor into a multi-point sampling system.

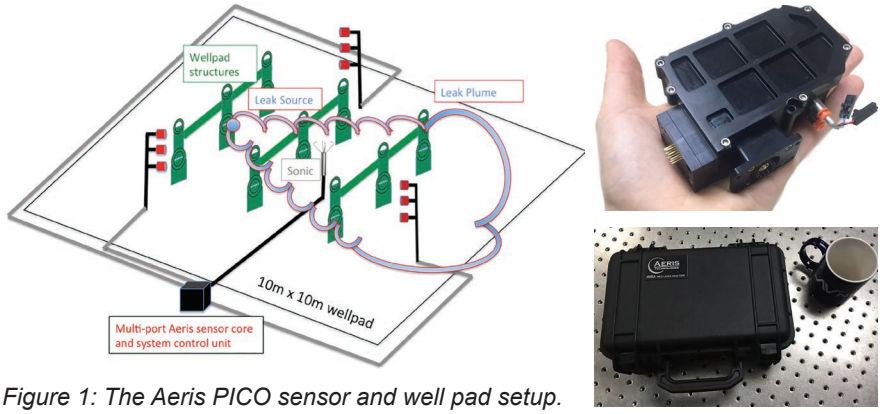

Figure 1: The Aeris PICO sensor and well pad setup.

IMPACT PATHWAY

The Aeris team is currently selling beta units of the sensor. The team started taking orders in December 2016. The team plans to sell the miniature portable unit, the PICO, as well as a temperature-controlled rack-mounted unit, the ULTRA, which enables single digit part-per-billion sensitivity. The team is also taking orders from university researchers and professionals in the oil and gas industry.

LONG-TERM IMPACT

In the long term, the technology developed could help reduce methane emissions across the natural gas supply chain, reducing costs, improving operational efficiency, and enhancing workplace safety. The portable sensor technology can help gas producers minimize the time and costs associated with sending crews to individual sites—and therefore identify unintentional emissions more quickly. If this project succeeds, the resulting system will enable cost-effective, 24/7 natural gas leak detection at well pads and in the distribution systems.

INTELLECTUAL PROPERTY AND PUBLICATIONS

As of November 2017, the Aeris project has generated one invention disclosure to ARPA-E. The Aeris project team has presented its work at conference proceedings worldwide.