Helicopter-mounted device measures methane in ship exhaust

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Researchers have developed a new gas sensor that is compact and lightweight enough to monitor emissions in ship exhaust from an airborne vehicle. The device uses mid-infrared supercontinuum gas spectrometry to simultaneously monitor the methane and water vapor concentration in the exhaust of moving ships in real time.

S. Chin from the Swiss Center for Electronics and Microtechnology (CSEM) will present the research at the virtual OSA Imaging and Applied Optics Congress and Optical Sensors and Sensing Congress to be held 19-23 July. Chin's presentation is scheduled for Thursday, 22 July at 11:45 PDT.

Today, over 80% percent of global trade is carried across the world's oceans, and the volume of exchanged goods is steadily growing. Ships run on fossil fuels thus contributing significantly to climate change by releasing carbon dioxide and methane as well as a handful of other pollutants that are potentially harmful to human health.

"The sensor developed by the center relies on a novel spatially coherent mid-IR light source, in a region of the electromagnetic spectrum where several of these pollutants can be detected by absorption spectroscopy," said Chin. "Our system can measure several gases simultaneously, but for this demonstration, we particularly looked at methane emission from different sources."

Methane is a potent greenhouse gas. The global maritime and shipping industry accounts for a growing share of total greenhouse gas emissions, and methane emissions from ships have risen particularly sharply in recent years as liquified natural gas has become more prominent as a fuel source. Better monitoring of methane in ship exhaust can help governments and industry understand the scope of methane pollution from ships and potentially inform new approaches to reduce these emissions.

Spectrometers measure the chemical composition of gases or objects by applying a light source and measuring how the light interacts with what is being measured. For this new work, researchers took advantage of recent advances in broadband high-brightness light sources to develop a spectrometer that can efficiently measure the chemical fingerprint of methane and other gases in air. This efficiency gives the new spectrometer a high level of sensitivity, allowing it to reliably differentiate between methane and other components and to measure methane at concentrations below the normal background level of less than 2 parts per million (ppm).

The spectrometer uses an external chopper to modulate the intensity of a supercontinuum light source, eliminating the intrinsic system noise. The light then goes through a multipass cell that involves 40 passes over a length of 30 centimeters, resulting in a total optical path 12 meters long. The beam is then directed to a diffraction grating and then expanded by a cylindrical lens before entering a camera that captures the transmission profile of the light, generating a gas fingerprint. A single shot measurement covers the spectral range of 34cm-1 with 0.7cm-1 resolution. The grating which is used to spectrally disperse the light is mounted on a rotating platform and can scan across the full emission spectrum of the supercontinuum.

"The most exciting part about this technology is the broadband supercontinuum light source," said Chin. "Due to its spatial coherence properties, it is possible to have a very long interaction length with the sample gas mixture and thus lower the limit of detection to trace amounts. Moreover, its large spectral coverage allows us to simultaneously detect several gas species in a single device, and to avoid measurement artifacts by checking the measured absorbance spectrum. The refresh rate, on the order of 1 second, makes it a fast detector compatible with airborne applications. It is like having a Swiss army knife: it replaces a series of single component gas detectors in one device."

To test the use of the spectrometer in an airborne vehicle, the researchers first mounted the device aboard a Zeppelin airship and flew it in the vicinity of a simulated methane leak from a pole-mounted bottle 4 meters off the ground. The spectrometer detected a rise in methane when the Zeppelin flew near the methane source and recorded a drop to background levels when it flew away from the leak.

The researchers then mounted the spectrometer aboard a helicopter which was flown behind ships cruising along the Kattegat channel between Denmark and Sweden. In this test, the device successfully and reproducibly measured emission levels of methane at approximately 20 ppm from several vessels, all of which were powered by liquefied natural gas. The measurements from the sensor aligned well with those from a commercial methane sensor used as a reference.

The center is now working toward increasing the spectral coverage of the supercontinuum up to 10 µm in order to expand the list of gases that can be measured by the system. One of the challenges there is to ruggedize the light source. The researchers are also designing a compact Fourier Transform Spectrometer that is a better match for the larger spectral coverage. They plan on increasing the SNR of the system by developing an ad hoc balanced detector system. They are also implementing machine learning algorithms for the identification and monitoring of gas species. These improvements allow them to identify other use cases, such as e.g., industrial plant monitoring. Those activities are being carried out in the frame of the TRIAGE project.

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