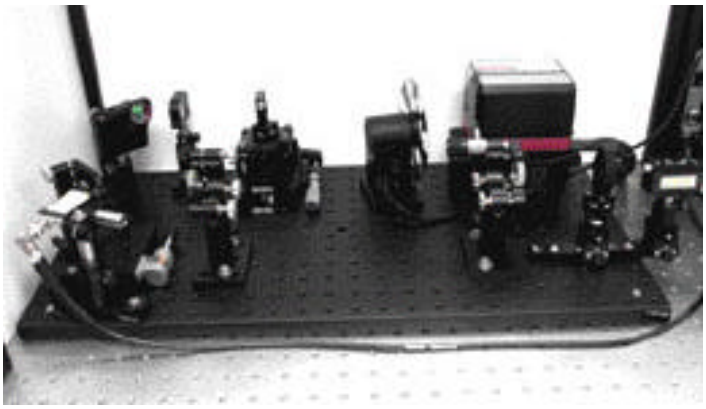
An ORNL State Partnerships Program Success Story

ICOS Can Measure Exhaust Emissions in Real Time on Real Vehicles

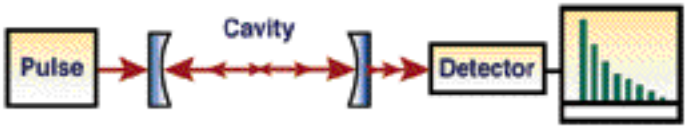
Researchers at ORNL's Advanced Propulsion Technology Center have developed a new diagnostic instrument that probably won't stay in the lab. Proof-of-principle testing has been demonstrated for an instrument that can measure trace amounts of gaseous pollutants in engine exhaust in real time, aboard a moving vehicle. The development resulted from research conducted in collaboration with the University of Minnesota's Center for Diesel Research and the Minnesota State Energy Programs Office, through ORNL's State Partnerships Program (SPP).



ICOS, developed by ORNL's Advanced Propulsion Technology Center, can measure trace amounts of specific compounds in engine exhaust precisely and quickly.

The instrument is called ICOS, or integrated cavity output spectroscopy. ICOS is based on a technique called cavity ringdown laser absorption spectroscopy (CRLAS). Whereas most conventional measurement systems measure direct absorption, CRLAS measures the rate of absorption in a closed cavity.

In CRLAS, a gas sample is introduced into a cavity formed by a pair of highly reflective mirrors. A laser system injects a short-duration pulse of light (less than 10 microseconds) into the cavity. To measure CO_2, for example, the laser output is scanned over the narrow band of wavelengths that are absorbed by CO_2 but not by other species present in the sample. The light pulse fraction of the pulse intensity is absorbed by the sample during each round-trip pass through the cavity. The intensity of the light pulses leaking out of the cavity demonstrates a simple decay profile. The time required for the pulse intensity to decay to a specified proportion of the initial intensity is called ringdown time. The ringdown time can consist of thousands of round-trip absorption events. Because a ringdown profile and measured ringdown time is generated for each laser pulse, fluctuations in laser pulse energies from shot to shot do not affect the accuracy of the measurement. The ringdown time indicates the concentration of the specified gas in the sample.



Schematic of the CRLAS process.

ICOS translates the CRLAS concept into a small, robust, relatively inexpensive package. In the preliminary tests, ICOS measured CO_2 concentrations of as low as about 400 parts per million (ppm)—only about 20 ppm above background levels of CO_2 in air. The instrument needs less than 10 microseconds to make measurements that are accurate to 0.1 ppm. ICOS can also measure concentrations of other gases; one of the next steps is to use it to measure carbon monoxide emissions. The Advanced Propulsion Technology Center has been successful in continuing the work, landing a 2-year contract to extend the range of gas species measured, reduce the signal-to-noise ratio, and provide technical assistance in the design and engineering of a spruced-up package.

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