Fiber-Loop Cavity Ring-Down Analyzer for Cryogenic Liquids

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Cryogenic liquids are used for many purposes, from freezing food to hydrogen fuel cells to MRIs. All of these applications share a common need to measure impurities in cryogenic liquids. For example, water contamination can cause filters and transfer lines to ice up, and accumulation of oxygen and hydrocarbons condensing in cryogenic liquids poses a serious risk of explosion. Nonetheless, there is currently no technology to directly measure the concentration of impurities in the liquid phase inside air separation units, cryogenic storage tanks, or filling stations. Instead, contamination is measured in the gas phase by various instruments. But, the gas phase does not necessarily have the same impurity concentrations as the liquid phase due to different boiling-point temperatures of the contaminants and the matrix. Therefore, the levels of contamination can be considerably larger in the liquid phase, allowing impurities to accumulate and yet go undetected in gas phase measurement. Combining the robustness of fiber sensors with the sensitivity of CRDS, Fiber-Loop Cavity Ring-Down Spectroscopy has been proven to be a promising alternative to gas-phase analyzers. We will present a ring-cavity formed by a strand of optical fiber bent into a loop, with one section of the fiber loop replaced by a sensing element where the light can interact with the sample. Similar to mirror-based CRDS, light is coupled into the loop and its decay time is measured. We compared the performance of several types of sensing elements: fiber tapers, side-polished fibers, and core-only fibers; and we examined their potential to reach detection limits of contaminants in the parts-per-million range. Our results indicate that Fiber-Loop Cavity Ring-Down Spectroscopy is suitable for measuring contaminants in cryogenic liquids.