Laser heterodyne radiometer for sensitive detection of CO_2 and CH_4

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We propose to develop an inexpensive, miniaturized, passive laser heterodyne radiometer (LHR) using commercially available telecommunications laser components to measure two significant carbon cycle gases in the atmospheric column: carbon dioxide (CO_2) and methane (CH_4). This instrument would operate in tandem with the passive aerosol sensor currently used in AERONET (an established network of more than 450 ground aerosol monitoring instruments worldwide). Because aerosols induce a radiative effect that influences terrestrial carbon exchange, simultaneous detection of aerosols with these key carbon cycle gases offers a uniquely comprehensive measurement approach that supports the Decadal Survey.

Laser heterodyne radiometry is a technique for detecting weak signals that was adapted from radio receiver technology. In a radio receiver, a weak input signal from a radio antenna is mixed with a stronger local oscillator signal. The mixed signal (beat note, or intermediate frequency) has a frequency equal to the difference between the input signal and the local oscillator. The intermediate frequency is amplified and sent to a detector that extracts the audio from the signal. In a laser heterodyne radiometer, the weak input signal is light that has undergone absorption by a trace gas. The local oscillator is a laser at a near-by frequency - in this case a low-cost distributed feedback (DFB) telecommunications laser. These two light waves are superimposed in either a beamsplitter or in a fiber coupler (as is the case in this design). The signals are mixed in the detector, and the RF beat frequency is extracted. Changes in concentration of the trace gas are realized through analyzing changes in the beat frequency amplitude.

A schematic of the progression of the LHR development project is shown in the figure below. At the center (within the dashed line), light from the local oscillator is superimposed upon light that has undergone absorption by a trace gas, in a single mode fiber coupler. Superimposed light is mixed in a fast photoreceiver, and the beat signal is analyzed for changes in absorption. The left portion of the figure depicts a progression of light sources that pass through the trace gas, increasing in complexity in the downward direction. On the right side of the figure, RF signal processing progresses from a commercially available spectrum analyzer to a RF receiver, and finally to an RF filter bank to deconvolute portions of the beat frequency more heavily weighted for different altitudes.