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Lidar Measurements of Methane and Applications for Aircraft and Spacecraft

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Atmospheric methane levels have remained relatively constant over the last decade around 1.78 parts per million (ppm) but observations since 2007 show that levels may be increasing. This trend may be caused by increased fossil fuel production, rice farming, livestock and landfills, but the underlying causes are quite uncertain. One hypothesis is that reservoirs of carbon trapped in the permafrost regions of northern Canada, Europe, and Siberia thaw as global temperatures rise and are releasing increasing amounts of methane. Another hypothesis points to increased production of methane by microbes as the permafrost warms. Currently most observations of greenhouse gases are limited to in-situ (surface and tower sites) and limited airborne in-situ measurements. Space column density measurements are starting to become available from the GOSAT mission. Although methane survives for a shorter time in the atmosphere than CO2, its impact on climate change per molecule is about 23 times than that of CO2. Accurate global observations of several greenhouse gases, including methane, are urgently needed in order to better understand climate change processes and to reduce the uncertainty in the carbon budget.

Differential absorption lidar is a well-established technique to measure atmospheric gases, and methane has optical absorption bands near 1.65, 2.2, 3.4 and 7.8 μm. The near infrared overtones lines of CH4 near 1650 nm are relatively free of interference from other species. There are absorption lines near 1651 nm which are both temperature insensitive and have line strengths well suited for lidar measurements. We have developed a laser and demonstrated lidar measurements of CH4 using lines in this band. Our laser uses a narrow linewidth 1064 nm laser pulse passing through a nonlinear crystal. We generate the tunable laser signals near 1651 nm by using the optical parametric amplification (OPA) process. Inside the crystal the 1064 nm beam overlaps with an injection seed laser near 1651 nm from a wavelength tunable diode laser. Incident photons from the pump laser pulse are converted into two photons, with one at the wavelength of the injection seeder. The wavelength of the OPA output is tuned via the wavelength of diode laser. Our laser is tunable, operates near 1651 nm and generates $\sim$4 uJ/pulse at 6 KHz. We vary the emission wavelengths within this band by tuning the diode laser's wavelength.

We have used this OPA transmitter to make measurements of CH4 at various pressures in a gas cell and over open outdoor horizontal paths. We have measured the lineshape of methane in a 6 cm long cell at various energy levels with this transmitter, with excellent agreement with the lineshape calculated by HITRAN. We have also measured the absorption lineshape of atmospheric methane in an open 3 km outdoor path. The agreement between the measurements and HITRAN, for 1746 ppb and 760 Torr was quite good. We have also made pulsed two wavelength lidar measurements of methane line absorption in the column to a tower at 1.5 km range. These used on- and off-line wavelengths of 1650.957 nm, and 1651.072 nm, and a 20 cm diameter receiver telescope with an infrared PMT detector. The absorption of the on-line photons was 30%. The methane column absorption was estimated via HITRAN, and was in good agreement with the expected methane absorption for a concentration of 1750 ppm. Finally we have calculated the measurement performance of an airborne methane lidar using this transmitter, as well as the energy and telescope scaling needed for a lidar for space. These results, and more details of our experiments will be described in the presentation.