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A feasibility study of Atmospheric Methane DIAL measurements at 1.65 micron spectral region

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A feasibility study of atmospheric methane measurements using the Differential Absorption Lidar (DIAL) technique is presented. The study was conducted in the 1.65 micron spectral region, taking advantage of an existing receiver system with custom designed 16" all metal telescope with 70% efficiency and a commercially available, high performance InGaAs avalanche photodiode (APD) detector with 75% and 2.5 quantum efficiency and excess noise factor, respectively. The study focused on a direct detection system with a tunable pulsed laser operating in the 1.65 micron region. The laser can switch between on- and off-line wavelengths of the methane absorption feature, assuming 50 Hz repetition rate at 5 mJ pulse energy. Sensitivity calculations were conducted to provide optimum differential absorption cross-section with low temperature dependence for methane measurements, and with low interference from water vapor and carbon dioxide absorption features. We derived the composite spectra of methane, water vapor and carbon dioxide using line parameters in the neighborhood of the operating wavelength from the HITRAN data base assuming the Voigt line profile. As a result, the methane R3 line, at 1645.5612 nm, was selected for DIAL operation. The computation of methane optical depth included the influence of all neighboring lines.

System performance studies were conducted using methodology developed earlier for range resolved (for ground-based azimuthal scan to 2.5 km range) and column and boundary layer methane (for aircraft system at an altitude of 7 km). Both vegetation and ocean reflected signals were included in the calculations. The study assumes a mid-latitude summer model atmosphere, mid-day background solar irradiance level of 5×10^{-3} W/(m2•nm•str), and methane concentrations of 1.7 ppm. The top of the atmospheric boundary layer was assumed at 1.5 km with nominal backscattering of 2.9×10^{-6} m-1sr-1. For the air-borne study, the calculated signals from the boundary layer top and either vegetation or ocean ground reflection were stronger than either the detector dark current or the day background (assuming a 1-nm day background filter). Systematic errors influencing these measurements were included in the performance estimates. For example, column methane measurements can be made from single shots (@ 50 Hz, or 4 m apart), over 400 m distances over the boundary layer from aircraft; and up to 2.5 km over 2 s time intervals with less than 0.3% error from the ground-based system. Furthermore, lidar data could be averaged to trade precision, resolution (or time interval), and range. This performance study showed that high precision methane measurements can be made in the 1.65 micron region using this system from the ground and aircraft.