ASEN 6519. Lidar Remote Sensing

HW #2 – Fundamental Physical Processes in Lidar

Please address in your report the following questions concerning physical interactions involved in lidar remote sensing: (mainly based on Lectures 5−7, 10 and the textbook Chapter 5)

1. **Doppler shift and Doppler broadening**: in the atmospheric region free of aerosol and fluorescence, we send a lidar beam (532 nm) to detect the pure Rayleigh scattering from air molecules. (1) If the laser is assumed to be single frequency (no linewidth), then how much is the full-width-at-half-maximum (FWHM) of the scattered Rayleigh signal spectrum at 280 K? (2) If the laser has a Gaussian lineshape with rms width of 100 MHz, how much is the FWHM of the scattered Rayleigh signal at 280 K? How about if the laser's FWHM is 1 GHz?

2. **Boltzmann distribution**: for Fe-56 isotope, the energy difference between the two lowest energy levels (J = 4 and 3) is 415.932 cm^{-1}. Please compute the population ratio P1/P2, where P1 and P2 are respectively the populations on the levels of J = 4 and J = 3, for three temperatures T = 150, 250, and 300 K.

3. **Raman scattering**: if a 532-nm transmitted photon is shifted to 607 nm by the vibrational-rotational (VR) Raman scattering of atmospheric molecule N_2, then what wavelength should you detect for N_2 VR Raman scattering if the transmitted photon is changed to 355 nm or 372 nm? Please show your calculation procedure and explain your basis.

4. **Extinction caused by constituent absorption** in the mesosphere and lower thermosphere (MLT) region: Given the conditions below, please calculate the transmission T_c (due to Na absorption) versus altitude in the MLT region, and then give the overall extinction for the round trip of the photons going through the Na layers (i.e., the integrated extinction).

   1) Assume the Na layers in MLT region has a Gaussian distribution with a peak at 91.5 km, rms width of 4.6 km and the column abundance of 4×10^9 cm^{-2}.

   2) Assume vertical wind V_R = 0 m/s, and the MLT temperature = 180 K.

   3) Laser frequency is tuned to the Na D2a peak, and the laser has a Gaussian line-shape with a rms width of 60 MHz.

   Related atomic parameters can be found in Chapter 5 of "Laser Remote Sensing".

5. **Light transmission through the atmosphere**: The Rayleigh scattering by air molecules contributes to the light attenuation when light propagates through the atmosphere. Let us calculate the light transmission through the atmosphere from ground (0 km) to 150 km for a 589-nm laser beam if only Rayleigh scattering induced extinction is considered. Empirical formula of total Rayleigh scattering cross section and atmospheric density provided by an empirical model (MSISE-00) should be used in the calculation.

   In your solution, please provide the equations you used to derive and calculate the light transmission, and then show the result as a figure of transmission versus altitude. The transmission at 0 km is set to unity 1. The altitude step can be 0.5 km or 0.1 km, but no larger than 1 km. (You may try such calculation for various wavelengths, such as 532, 770, 372, and 355 nm.)

   Note: The MSIS atmospheric density can be calculated using a MatLab built-in MSISE-00 model "atmosnrlmsise00.m" for the following conditions: year = 2012; month = 5; day = 23; time = 12; latitude = -77.83 deg; longitude = 166.67 deg; and default solar flux and geomagnetic index. Code is available from the instructor. You can also take the MSIS data from the following file (obtained at different geographic conditions):

   http://superlidar.colorado.edu/Classes/Lidar2014/HWFinalProjects/MSISE00zTPND.dat

HW #2 is due on (Wed) February 10, 2016 in class.