ASEN 6519. Lidar Remote Sensing

HW Report #2

Please address in your report the following questions concerning physical interactions involved in lidar remote sensing:

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 levels (J = 4 and 3) in the ground state 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 MLT region: Given the conditions below, please calculate the transmission T_c (due to Na absorption) versus altitude in 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 is given by MSIS-00 data that can be downloaded at the following website:

   http://superlidar.colorado.edu/Classes/Lidar2011/HWFinalProjects/MSISE00zTPND52N102182.dat

   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.

   4) Repeat the calculations for K case: using the same laser lineshape and linewidth parameters, atmospheric winds and temperatures, but change the K layers to a Gaussian with a peak at 91.0 km, rms width of 4.7 km, and column abundance of 6×10^7 cm^{-2}. The laser central frequency is tuned to the K D1a peak whose frequency is -180 MHz away from the line center.

   Related atomic parameters can be found in the textbook "Laser Remote Sensing".