ASEN 6519. Lidar Remote Sensing

HWK Project #2 – Computation of Cross Section and Calibration Curves

This project is part of lidar simulation and also the beginning of lidar data processing for resonance fluorescence lidar in the middle and upper atmosphere. Only when we clearly understand and are able to calculate the interaction between photons and atoms interested, we can correctly invert the lidar photon counts into meaningful physical parameters that we are trying to measure. Such radiation-matter interaction is used in both lidar simulation and data processing procedures. Thus, this project is the step to compute the light-atom interaction used in the resonance fluorescence lidars.

This project contains three aspects –

(1) Understand the Na spectroscopy, especially the absorption cross section [Eq. (5.41)] and the effective cross section [Eq. (5.43)] for Na D_2 line.
a). Write a computer code to compute the Na absorption and effective cross sections for conditions of temperature T = 200 K and radial wind V_R = 0 m/s.
b). Plot the cross sections versus frequency offset, and give the numbers for the maximum absorption and effective cross sections in the plot.

Conditions: Table 5.1 in the textbook provides the fundamental parameters for Na spectroscopy. The frequency offset (relative to the center of the line) range is from -2500 to 2500 MHz. Assume laser line shape is a Gaussian with rms width of 60 MHz.

(2) Similar to (1) but now calculate the absorption cross section for several different conditions: a) for V_R = 0 m/s, T = 150, 200, 250 K; b) for T = 200 K, V_R = -50, 0, 50 m/s. Plot the absorption cross section versus frequency offset for a) and b), separately. This will help you to see the temperature dependence of Doppler broadening and wind dependence of Doppler shift.

(3) Compute and plot the calibration curves (R_T versus R_W) for the Na Doppler lidar with the following temperature and wind metrics:

1). $R_T = \dfrac{\sigma_{eff}(f_+)+\sigma_{eff}(f_-)}{\sigma_{eff}(f_a)}$, $R_W = \dfrac{\sigma_{eff}(f_-)}{\sigma_{eff}(f_+)}$

2). $R_T = \dfrac{\sigma_{eff}(f_+)+\sigma_{eff}(f_-)}{\sigma_{eff}(f_a)}$, $R_W = \dfrac{\sigma_{eff}(f_+)-\sigma_{eff}(f_-)}{\sigma_{eff}(f_a)}$

3). $R_T = \dfrac{\sigma_{eff}(f_+)+\sigma_{eff}(f_-)}{\sigma_{eff}(f_a)}$, $R_W = \dfrac{\ln\left[\sigma_{eff}(f_-)/\sigma_{eff}(f_+)\right]}{\ln\left[\sigma_{eff}(f_-)\times\sigma_{eff}(f_+)/\sigma_{eff}^2(f_a)\right]}$

4). $R_T = \dfrac{\sigma_{eff}(f_+)\times\sigma_{eff}(f_-)}{\sigma_{eff}^2(f_a)}$, $R_W = \dfrac{\ln\left[\sigma_{eff}(f_-)/\sigma_{eff}(f_+)\right]}{\ln\left[\sigma_{eff}(f_-)\times\sigma_{eff}(f_+)/\sigma_{eff}^2(f_a)\right]}$

where σ_{eff} is the effective cross section of Na D_2 line, frequencies f_a = -651.4 MHz, f_+ = -21.4 MHz, and f_- = -1281.4 MHz (relative to the line center).

The temperature and wind ranges are T = 100 to 300 K and V_R = -100 to +100 m/s at resolution of 10 K and 10 m/s.

(4) Repeat (1) and (2) for the K Doppler lidar. The laser line shape is a Gaussian with a linewidth of 70 MHz (FWHM). Other related K atomic parameters are (frequency in Hz unit)

```
Aki = 0.382e8;              % Einstein A coefficient for K D1 line
Kstandard = 39.0983;        % Molecular weight
KM39 = 38.9637069;          % Molecular weight
KM41 = 40.96182597;         % Molecular weight
freqiK39(1) = 310.00983e6;
freqiK39(2) = 252.84983e6;
freqiK39(3) = -151.7099e6;
freqiK39(4) = -208.8699e6;
freqiK41(1) = 405e6;
freqiK41(2) = 375e6;
freqiK41(3) = 151e6;
freqiK41(4) = 121e6;
strengthK(1) = 5;
strengthK(2) = 1;
strengthK(3) = 5;
strengthK(4) = 5;
abdnK39=0.932581;
abdnK41=0.067302;
```

Note: K has isotopes 39 and 41, while Na has only one isotope 23.

Since you will repeatedly use the absorption or effective cross section calculation in (2) and (3), you may consider making this part of computation as sub-routines or functions so that you can call these functions with different input parameters (like T, V_R, and frequency).

You are required to show your MatLab code with your computation results (numbers and figures).