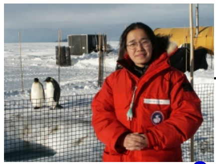
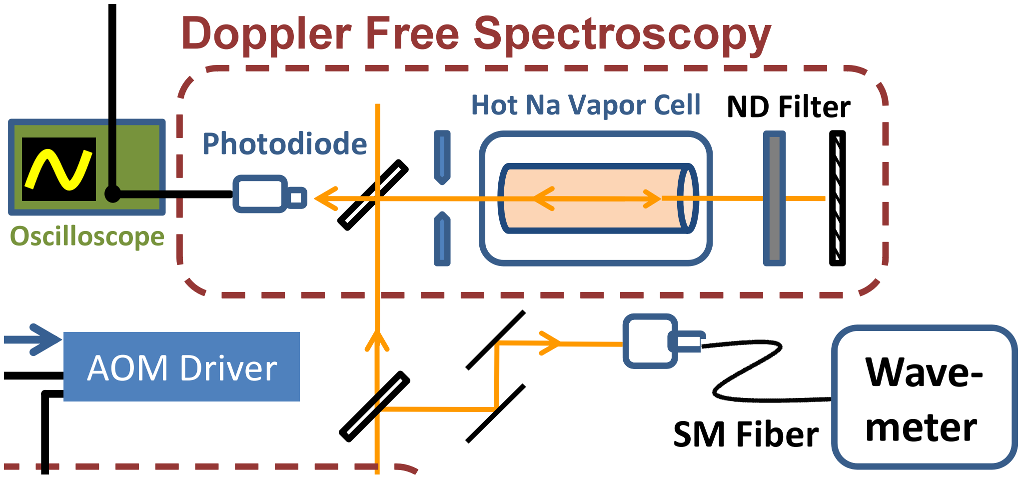


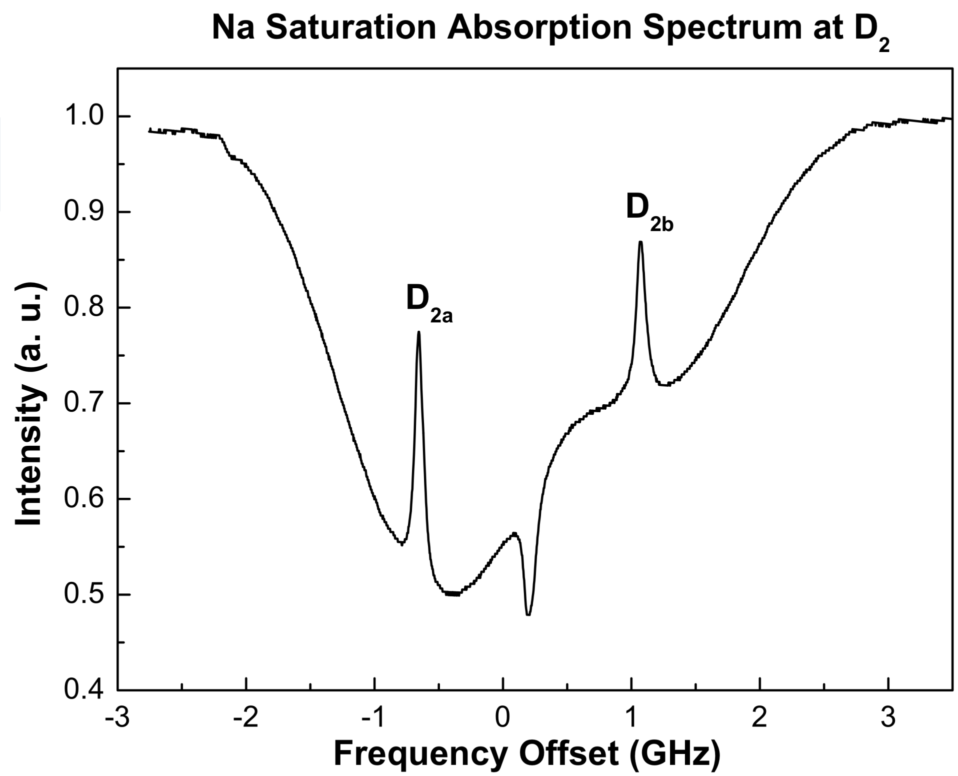
Lecture 20. Two Applications of Atomic Spectroscopy in Lidar

- Doppler-free saturation spectroscopy
  - Saturation-absorption
  - Saturation-fluorescence
- Faraday filter for daytime measurements
  - Na Faraday filter
  - K Faraday filter (dual-channel)
- Review several concepts and their calculations
  - Transmission vs. Extinction and Extinction coefficient
  - Doppler broadening
  - Absorption and effective cross section

Doppler-Free Na Spectroscopy Saturation-Absorption

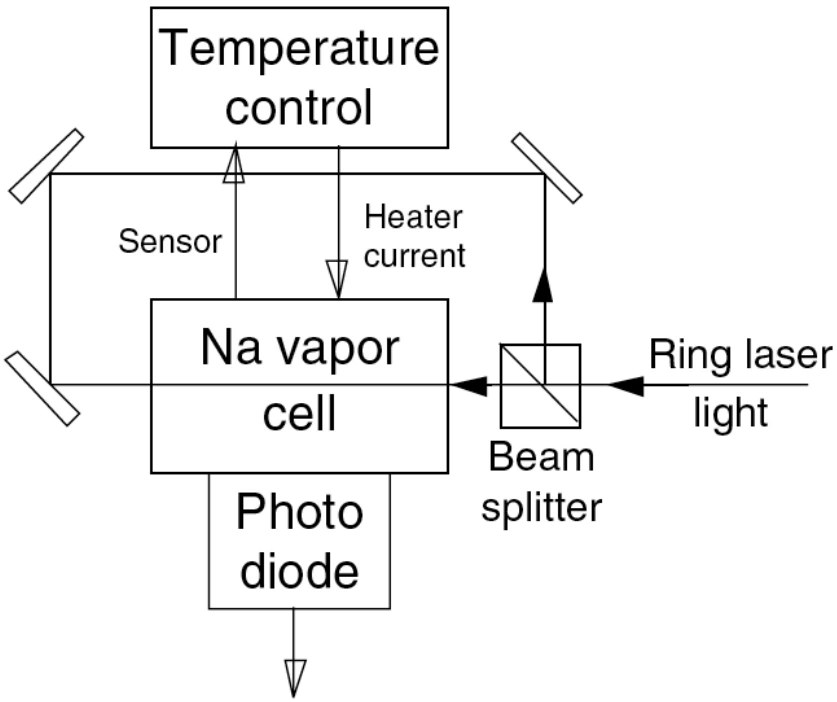


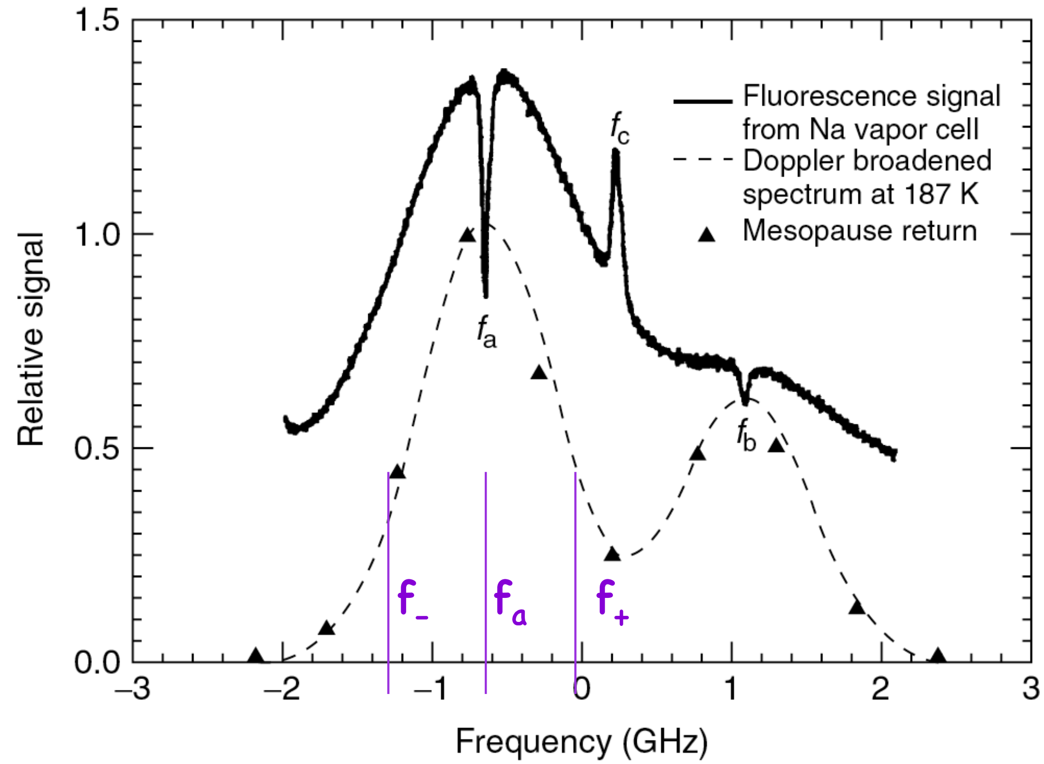
[Smith et al.]



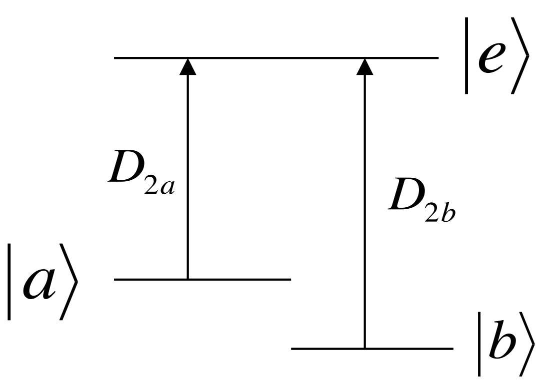
[Chu et al., ILRC, 2008]

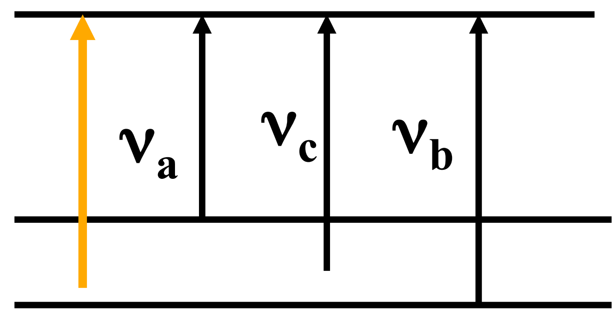
Doppler-Free Na Spectroscopy Saturation-Fluorescence



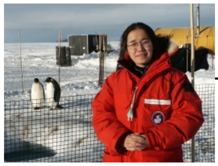


3-Level Explanation

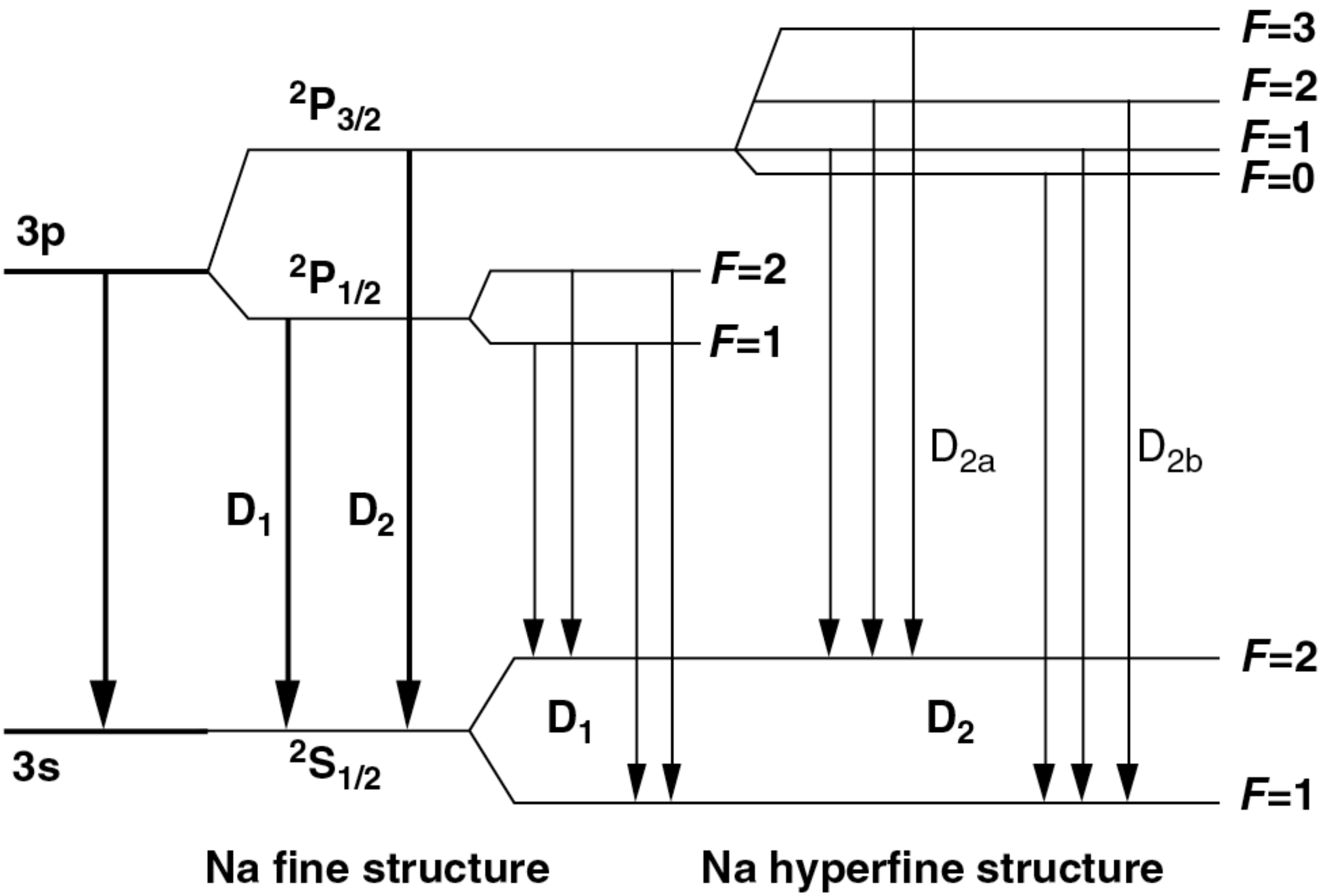




$$\nu_c = (\nu_a + \nu_b)/2$$

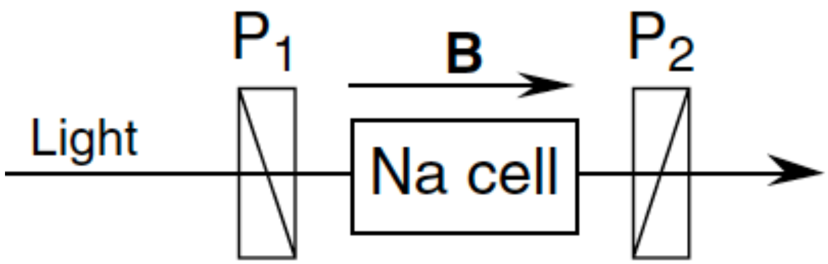


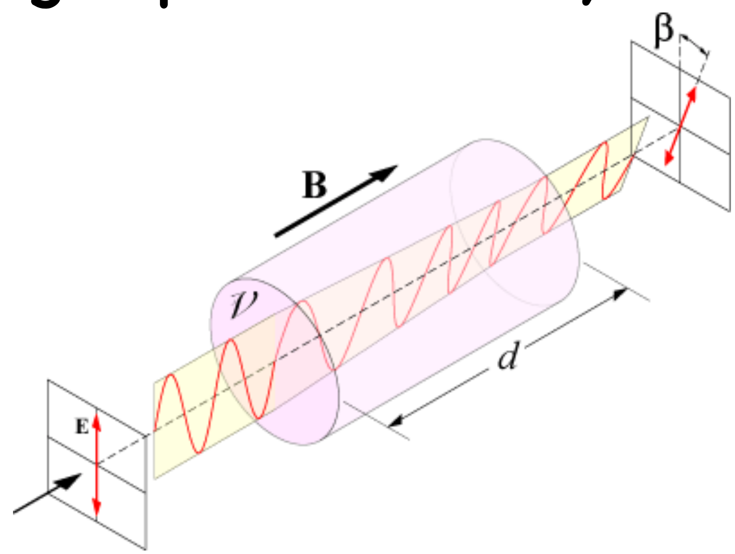
Na Atomic Energy Levels



Daytime Capability: Faraday Filter

- Faraday effect is the rotation of light polarization by some media under magnetic field.





- Refraction index n of dilute Na vapor

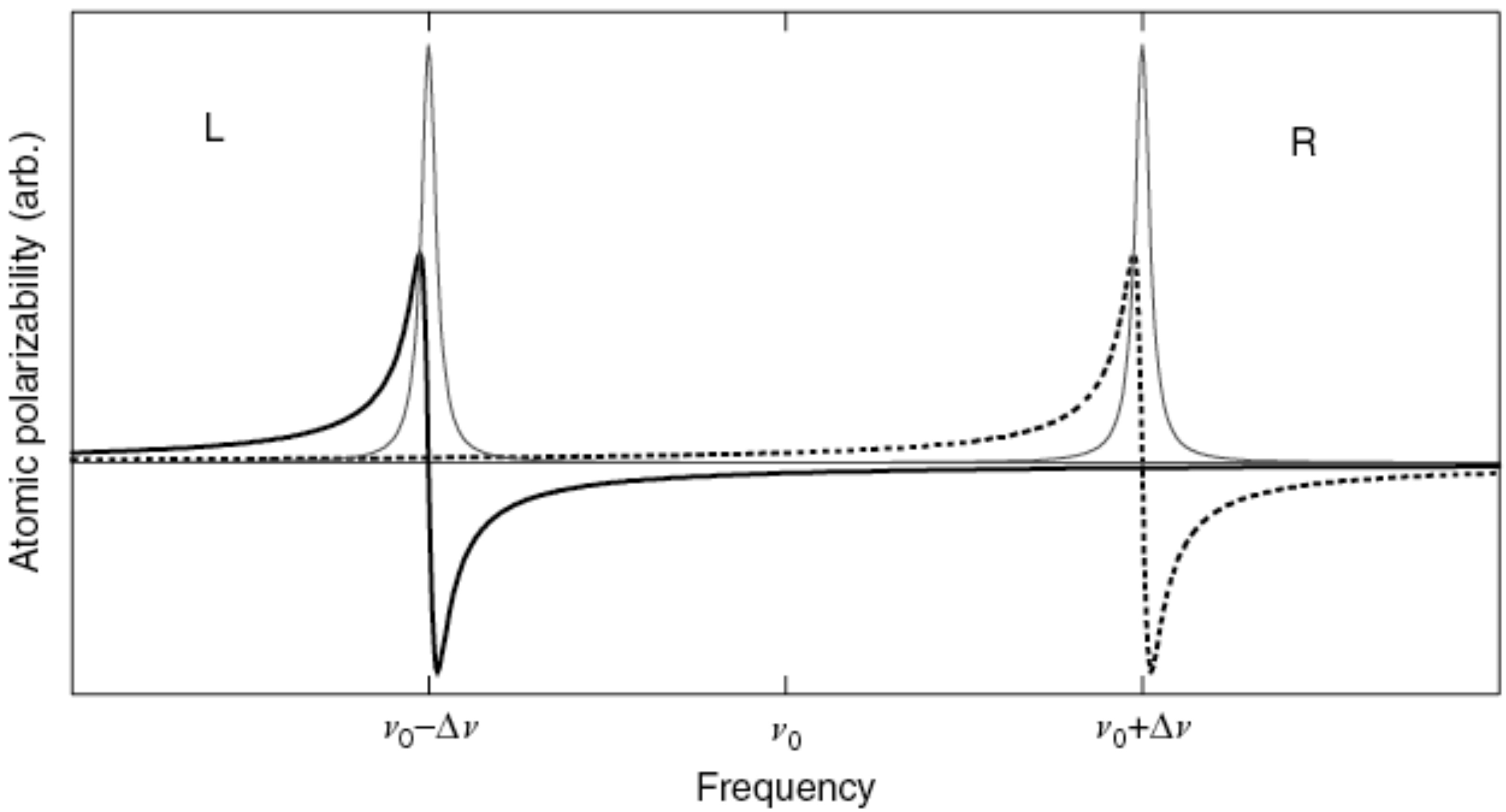
$$n = \sqrt{1+\chi} \cong 1 + \frac{1}{2}\chi = 1 + \frac{1}{2}\chi' - i\frac{1}{2}\chi'' \qquad (5.74)$$

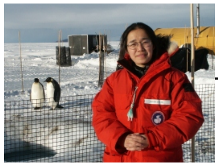
χ is the electric susceptibility of Na vapor

Faraday Filter

$$\chi' = \frac{Ne^2 f}{2m\omega\epsilon_0} \frac{\omega_0 - \omega}{(\omega_0 - \omega)^2 + (\gamma/2)^2}$$ Dispersion

$$\chi'' = \frac{Ne^2 f}{2m\omega\epsilon_0} \frac{\gamma/2}{(\omega_0 - \omega)^2 + (\gamma/2)^2}$$ Resonance absorption

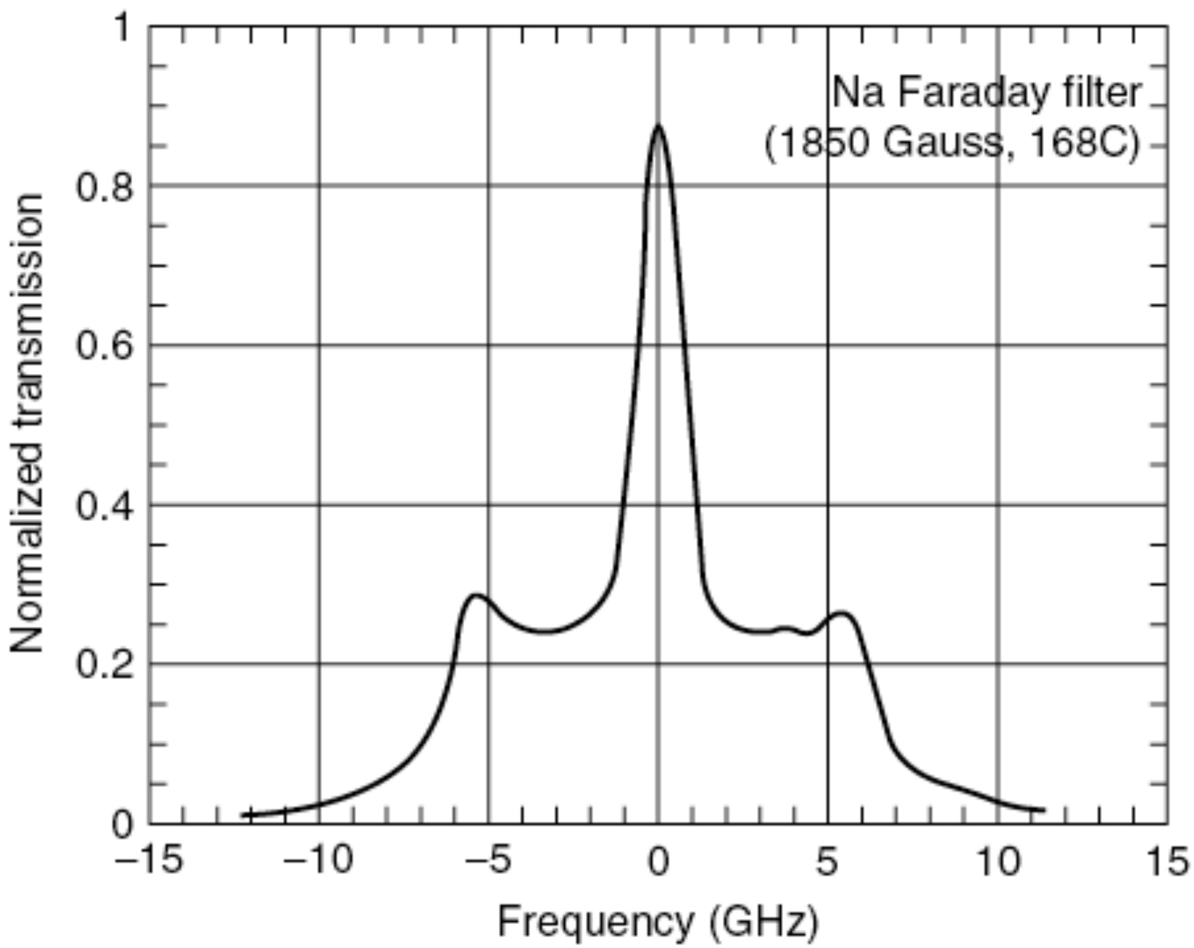




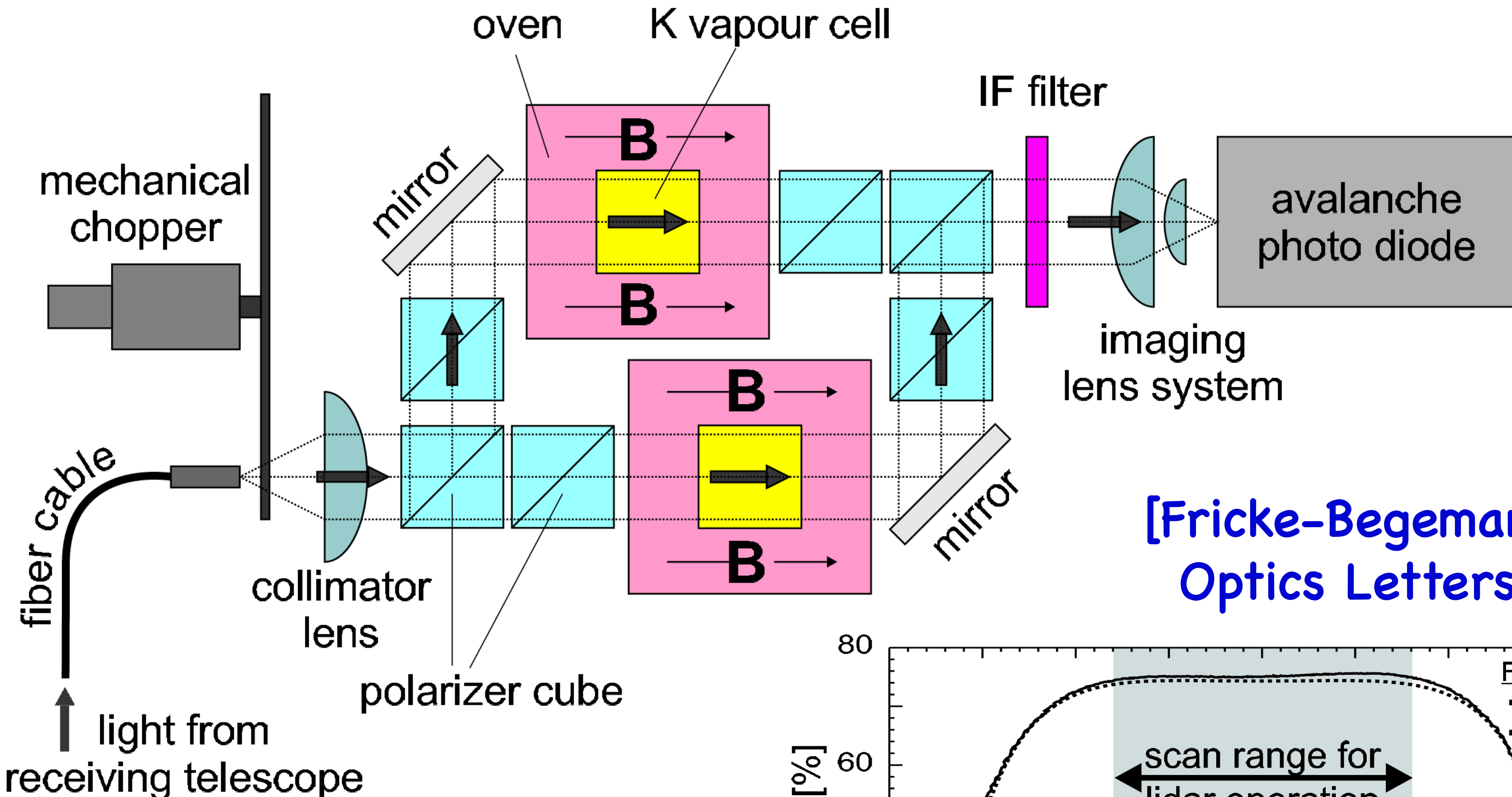
Faraday Filter

- Phase shift between two circular polarizations

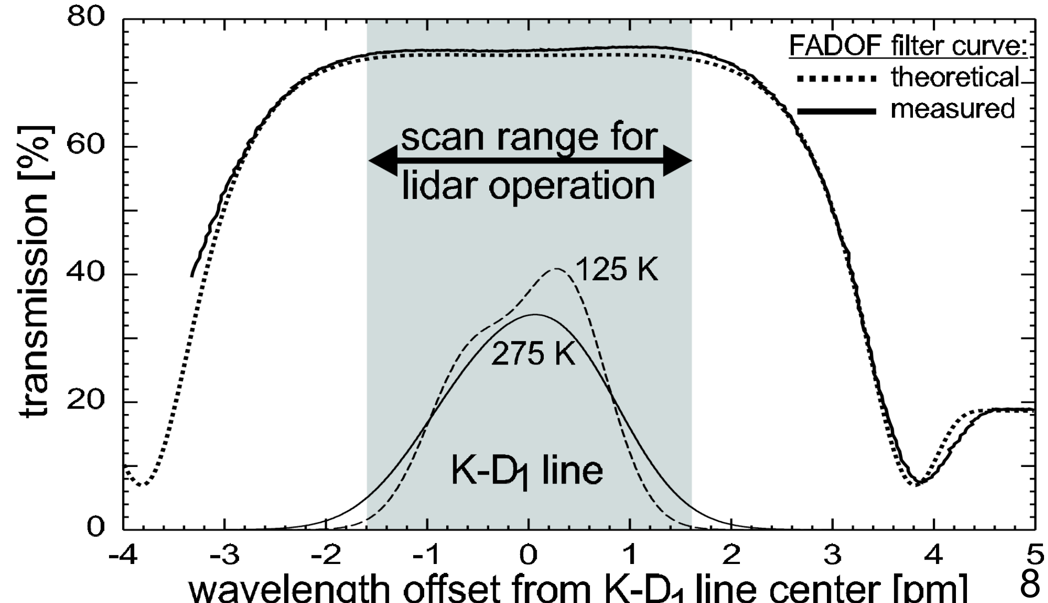
$$\Delta\varphi = 2\pi \frac{l\Delta n}{\lambda}$$



Dual K-Faraday Filter



[Fricke-Begemann et al., Optics Letters, 2002]

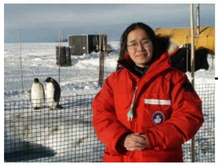


- Due to closer spacing of D_{1a} and D_{1b}, the K Faraday filter can be made nearly flat in the range we care.

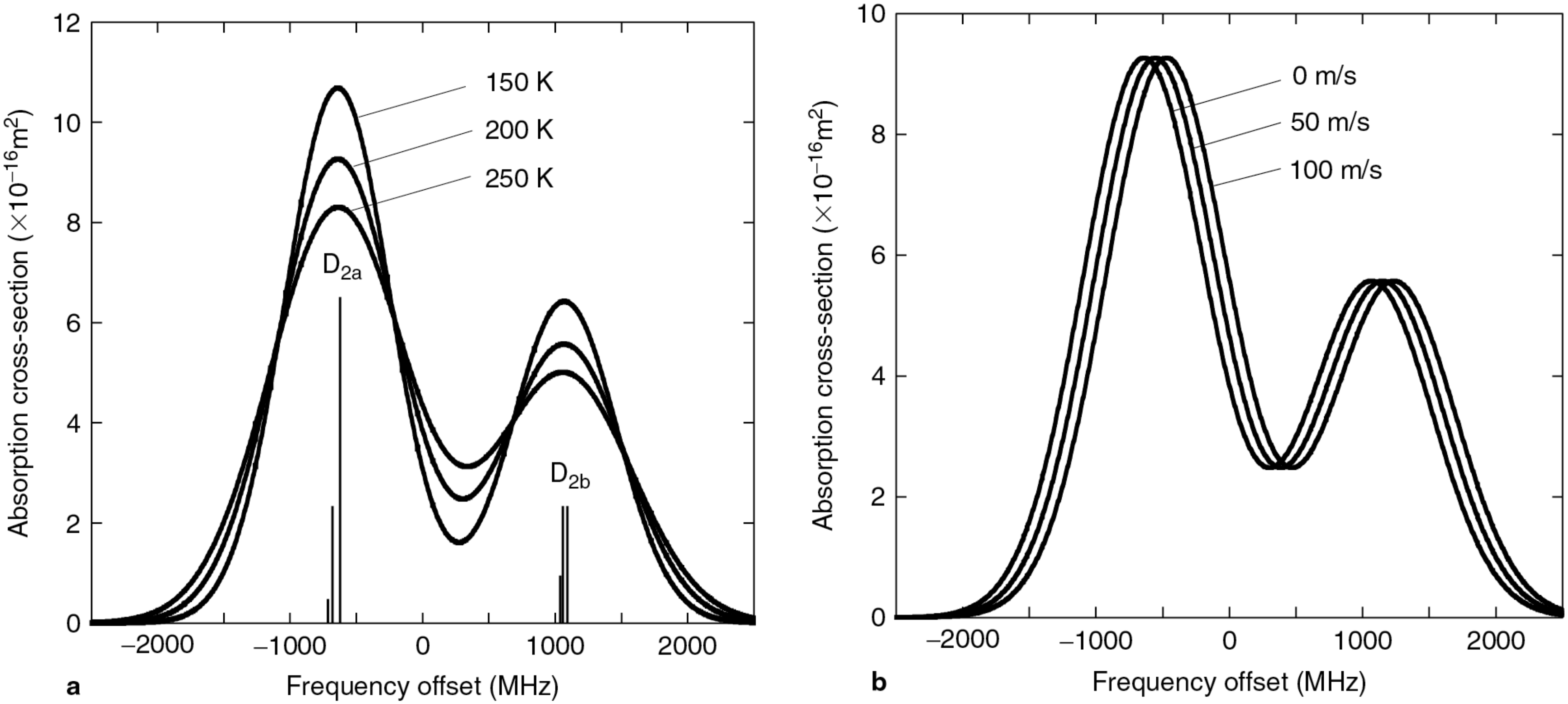
Several Concepts and Terms

- Correction to the book regarding "E" – it should be T_c – the transmission through the constituent layer.

- Extinction (absorption) coefficient α
- Transmission
- Extinction
- Doppler broadening
- Absorption and effective cross sections



Doppler Effect in Na D_2 Line Resonance Fluorescence



Na D_2 absorption linewidth is temperature dependent

Na D_2 absorption peak freq is wind dependent

Na Atomic Parameters

Table 5.1 Parameters of the Na D_1 and D_2 Transition Lines

Transition Line	Central Wavelength (nm)	Transition Probability ($10^8\,s^{-1}$)	Radiative Lifetime (nsec)	Oscillator Strength f_{ik}
D_1 ($^2P_{1/2} \rightarrow {}^2S_{1/2}$)	589.7558	0.614	16.29	0.320
D_2 ($^2P_{3/2} \rightarrow {}^2S_{1/2}$)	589.1583	0.616	16.23	0.641

Group	$^2S_{1/2}$	$^2P_{3/2}$	Offset (GHz)	Relative Line Strength[a]
D_{2b}	$F=1$	$F=2$	1.0911	5/32
		$F=1$	1.0566	5/32
		$F=0$	1.0408	2/32
D_{2a}	$F=2$	$F=3$	−0.6216	14/32
		$F=2$	−0.6806	5/32
		$F=1$	−0.7150	1/32

Doppler-Free Saturation–Absorption Features of the Na D_2 Line

f_a (MHz)	f_c (MHz)	f_b (MHz)	f_+ (MHz)	f_- (MHz)
−651.4	187.8	1067.8	−21.4	−1281.4

[a]Relative line strengths are in the absence of a magnetic field or the spatial average. When Hanle effect is considered in the atmosphere, the relative line strengths will be modified depending on the geomagnetic field and the laser polarization.