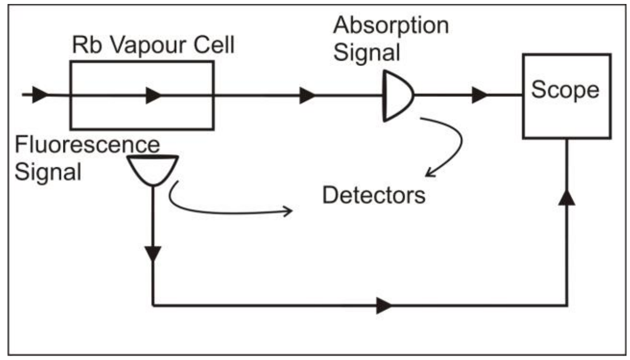
Phys 4061/5061 – Tutorial Two

Details Pertaining to laboratory experiments covered in this tutorial can be found in the lab manual under the following sections

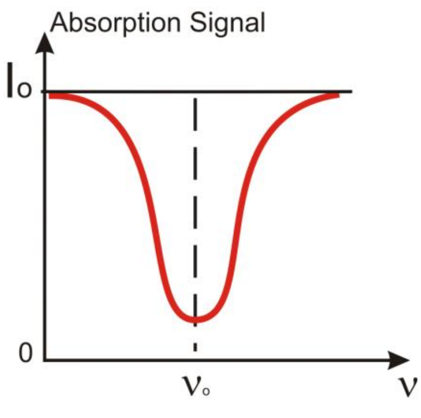
1. Absorption/Emission Spectroscopy/EOM
2. Lockin
3. Zeeman Shift

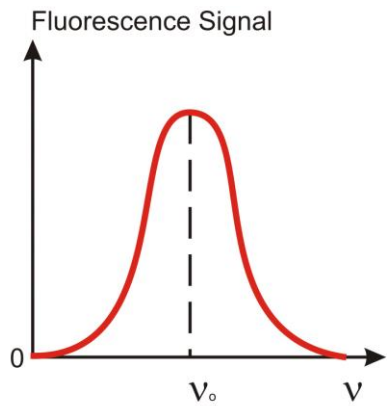
Spectroscopy

- fluorescence
  - strong probe
- absorption
  - weak probe

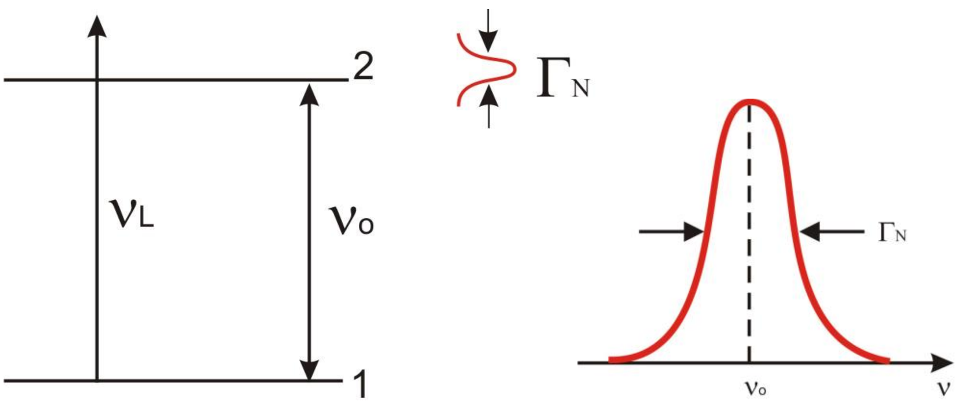


For both fluorescence and absorption, the atomic line shape will be Gaussian with a FWHM of about 500MHz





Natural Linewidth



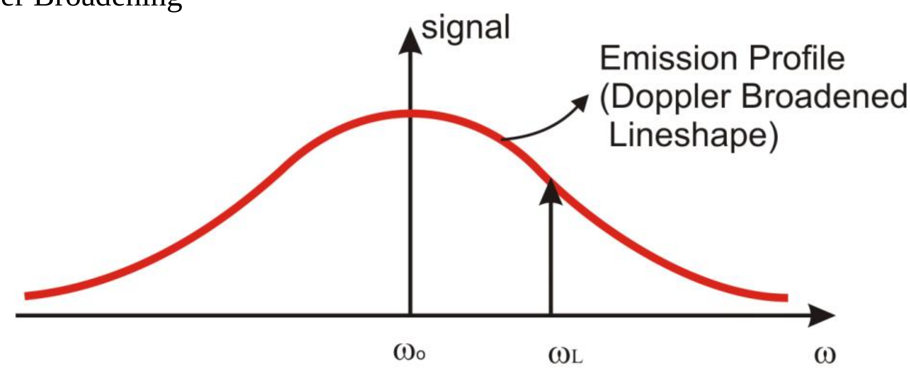
$\tau_2 \sim 27$ns (radiative lifetime)
$\Gamma_{21} = A_{21} = 1/\tau_2 = 3.7 \times 10^7\ s^{-1}$ (radiative rate)
$\Gamma_N = \Gamma/2\pi = 5.9$ MHz (natural linewidth)

Note: $2\pi\nu_o = \omega_o$

Γ_N is the intrinsic atomic line width defined by the uncertainty principle.
Goal: Use ECDL with linewidth $\Delta\nu_L \sim 1$MHz to do Doppler Free Spectroscopy, ie. measure intrinsic atomic

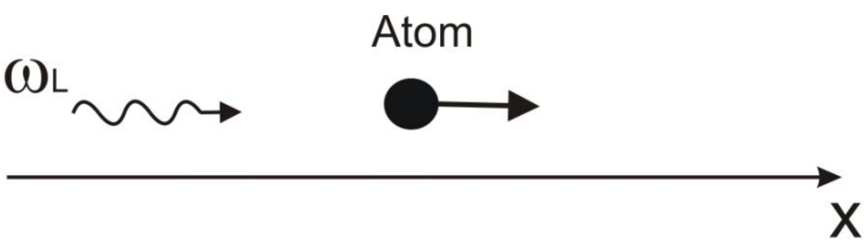
linewidth

Doppler Broadening



Atoms absorb or emit light over a wide range of frequencies because of the Maxwell Boltzmann velocity distribution that describes thermal motion.

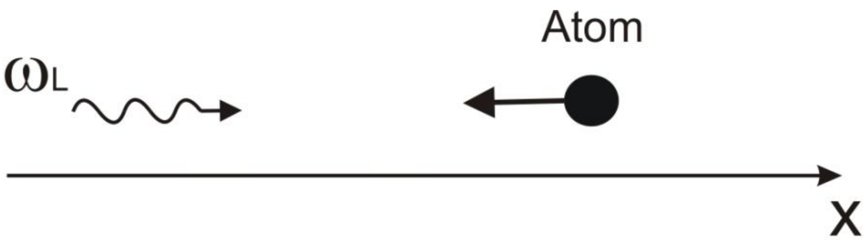
A. Consider the case where $\omega_L > \omega_o$



- Atoms moving along +x with certain velocity will see ω_L redshifted onto resonance
- Because of Maxwell Boltzmann velocity distribution atoms with appropriate velocity will absorb/emit light

$\upsilon` - \upsilon_o = \pm(v_x/c)\upsilon_o$ whee $\delta\nu = \nu` - \nu_o$ is the Doppler shift and ν_o is the natural (resonant) frequency
$\Delta = \omega_L - \omega_o$ is the detuning of the laser
$\delta\upsilon/\upsilon_o = \pm(v_x/c)$ is the fractional Doppler Shift
$\delta\omega = \pm k v_x$ where $k = 2\pi/\lambda$

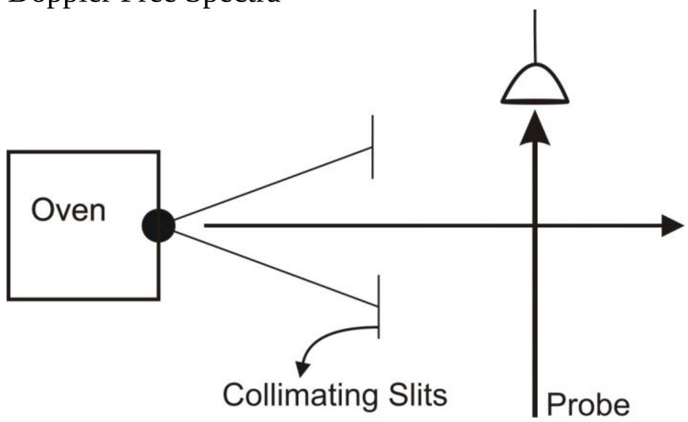
B. Consider the case where $\omega_L < \omega_o$



- atom along -x will see laser blue shifted into resonance

If |Δ| is the same, the velocity class in A) and B) correspond to atoms with same speed moving in opposite direction

Doppler Free Spectra



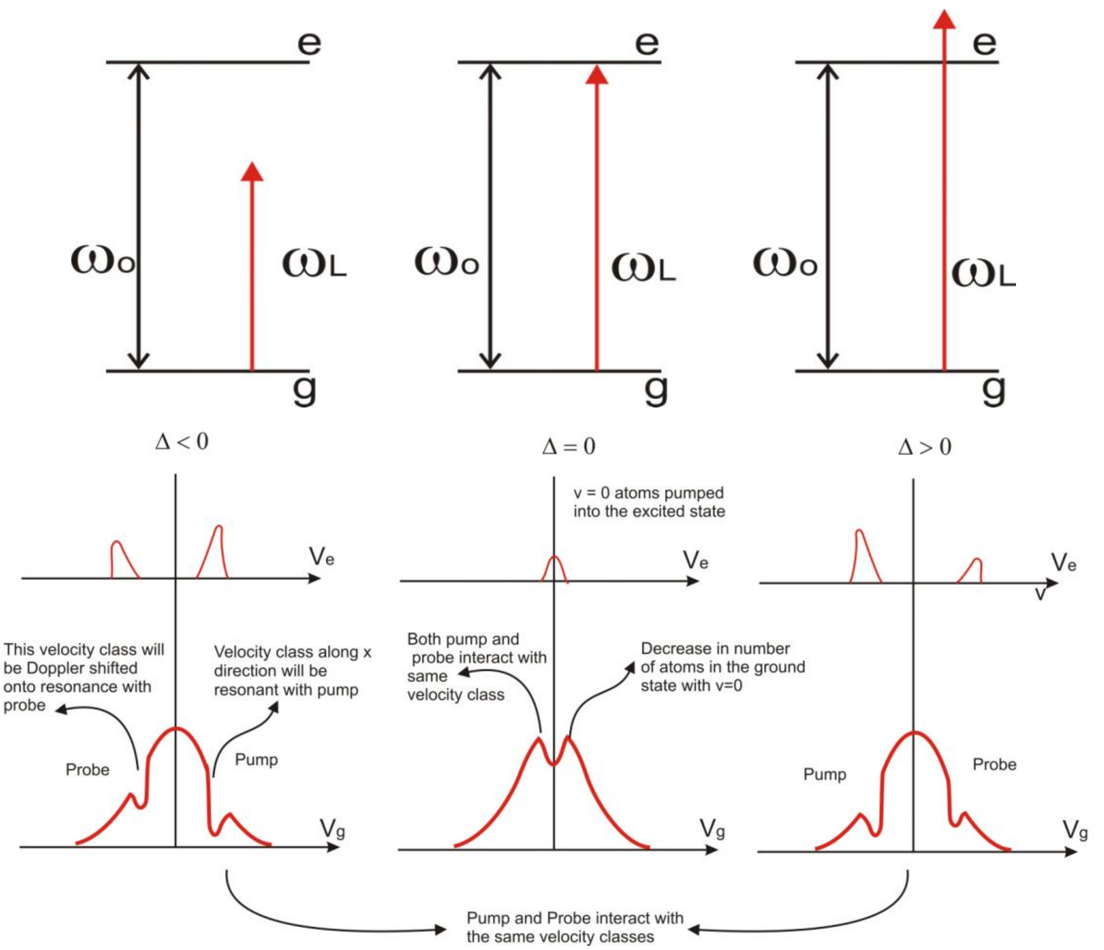
- collimate atomic beam
- measure probe absorption – spectrum is Doppler free transverse to atomic beam
- note that such a system is not compact or easy to maintain

Alternative Techniques

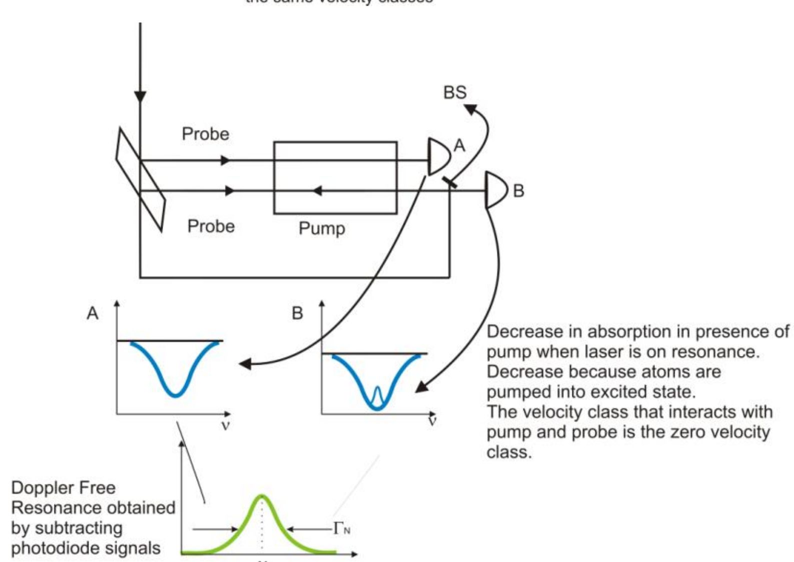
- use saturated absorption spectroscopy in vapour cell
- atoms have Maxwell Boltzmann velocity distribution
- obtain Doppler free resonances ~ Γ_N in width
- pump and probe derived from the same laser

Saturated Absorption

- Pump and probe derived from the same laser



Note: the velocity axis can be considered as the frequency axis so v = 0 corresponds to ν = 0



Experimental Arrangement for Saturated Absorption