Study guide for Laser Physics in-class midterm.

You may bring in one sheet of paper with anything on it that you want. You should bring a calculator.

Basic knowledge:

- Converting among $\lambda$ , $\omega$ and $\nu$ ; converting among widths $\Delta\lambda$ , $\Delta\omega$ and $\Delta\nu$
- Making simple approximations: $(1+\varepsilon)^n \approx 1+n\varepsilon$ , small argument sin( ), cos( ), exp( ).
- How to calculate intensity, e.g. from energy, beam area and pulse duration

Interaction of light with atoms

Cavity modes and blackbody radiation

- Simple 1-D cavity/resonator: how to derive discrete allowed k's,
- Resonance frequencies for a linear cavity, longitudinal mode spacing
- Boltzmann distribution: relative excitation density of two states under thermal equilibrium: $\frac{N_2}{N_1} = \frac{g_2}{g_1} \exp\left( -\frac{E_2 - E_1}{k_B T} \right)$

Einstein A and B coefficients

- Relation of $B_{12}$ to $B_{21}$, and $A_{21}$ to $B_{21}$.
- How to know when spontaneous emission is more likely than emission stimulated by blackbody radiation.
- Constructing and working with simple rate equations that include spontaneous emission, absorption, stimulated emission and external pumping rates (using A, B coeff or using cross-sections). Finding relations under steady-state conditions.

Line broadening, line shapes

- Normalized Lorentzian and Doppler (Gaussian) lineshapes.
- Which mechanisms lead to which lineshapes; qualitative difference between homogeneous and inhomogeneous broadening.
- Natural broadening: linkage of exponential damping with Lorentzian lineshape, damping rate with linewidth.
- Decay rate from a single level is the sum of all rates out to destination levels

Cross-sections: gain and absorption

- cross-section $\sigma$ is particular to a given process: the cross-section will depend on initial and final states, as well as whether it is for absorption or stimulated emission.
- The absorption or gain coefficient is $N\sigma$, where $N$ is the number density of the species involved (e.g. inversion density for gain, where $N = N^*$).
- Definition of inversion density

- Exponential behavior of light growth or decay as light propagates in a gain or absorbing medium.
- Role of upper state lifetime as the storage time for gain.
- Calculation of stored, extractable energy (# excited atoms/volume)*(lasing photon energy).
- Calculation of small signal gain by various methods: inversion density, cross-section and length; stored energy fluence and saturation fluence (both energy/area).
- How spectral dependence of the cross-section affects gain or absorption. For gain, this leads to spectral or spatial gain narrowing.
- steady-state (CW) gain:
  small signal, spectrally-dependent gain $G_0(\omega-\omega_0)=\exp\left[\alpha(\omega-\omega_0)z\right]$
- gain coefficient: $\alpha(\omega-\omega_{21})=N^*\sigma_{21}(\omega-\omega_{21})$, where the cross-section includes the appropriate lineshape and broadening

Beam propagation, interference

- Calculation of focal spot radius of a Gaussian beam given input beam radius, wavelength, focal length
- Simple telescope design, using negative or positive lens
- Geometric imaging formula: image distance from object distance and focal length
- How to calculate a two-beam interference pattern, starting with the complex expressions for the electric field
- Paraxial expression for diverging spherical wave