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 λ , ω and ν ; 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 σ 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.

Saturation fluence, saturation intensity

- 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
- Saturated gain: $G(I)=\dfrac{G_0}{1+I/I_s}$, G_0 and the saturation intensity I_s in general depend on the frequency difference $\omega-\omega_{21}$
- Understand that saturation is physically necessary because it is impossible to extract more energy or power from the medium than what it pumped into it.

Beam interference

- How to calculate a two-beam interference pattern, starting with the complex expressions for the electric field