1. Gain vs Loss: The transition between two energy levels exhibits a Lorentzian lineshape of central frequency $\nu 0 = 5 \times 10^{14}$ with a linewidth $\delta\nu = 10^{12}$ Hz. The population is inverted so that the maximum gain coefficient is 0.1 cm^{-1}. The medium has an additional loss coefficient at 0.05 cm^{-1}, which is independent of ν. Calculate in which spectral range the light will be amplified in the material.

2.

Threshold Population Difference for an Ar^+-Ion Laser. An Ar^+-ion laser has a 1-m-long resonator with 98% and 100% mirror reflectances. Other loss mechanisms are negligible. The atomic transition has a central wavelength $\lambda_o = 515$ nm, spontaneous lifetime $t_{sp} = 10$ ns, and linewidth $\Delta\lambda = 0.003$ nm. The lower energy level has a very short lifetime and hence zero population. The diameter of the oscillating mode is 1 mm. Determine (a) the photon lifetime and (b) the threshold population difference for laser action.

3.

14.2-7 **Transmittance of a Laser Resonator.** Monochromatic light from a tunable optical source is transmitted through the optical resonator of an unpumped gas laser. The observed transmittance, as a function of frequency, is shown in Fig. P14.2-7.

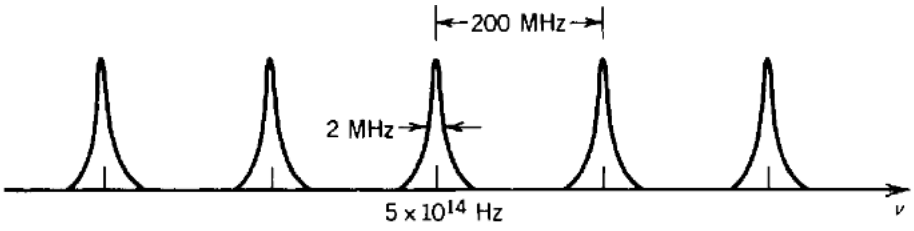

Figure P14.2-7 Transmittance of a laser resonator.

(a) Determine the resonator length, the photon lifetime, and the threshold gain coefficient of the laser. Assume that the refractive index $n = 1$.
(b) Assuming that the central frequency of the laser transition is 5×10^{14} Hz, sketch the transmittance versus frequency if the laser is now pumped but the pumping is not sufficient for laser oscillation to occur.

4.

Threshold of a Ruby Laser

(a) At the line center of the $\lambda_o = 694.3$-nm transition, the absorption coefficient of ruby in thermal equilibrium (i.e., without pumping) at $T = 300$ K is $\alpha(\nu_0) \equiv -\gamma(\nu_0) \approx 0.2\ \text{cm}^{-1}$. If the concentration of Cr^{3+} ions responsible for the transition is $N_a = 1.58 \times 10^{19}\ \text{cm}^{-3}$, determine the transition cross section $\sigma_0 = \sigma(\nu_0)$.

(b) A ruby laser makes use of a 10-cm-long ruby rod (refractive index $n = 1.76$) of cross-sectional area 1 cm^2 and operates on this transition at $\lambda_o = 694.3$ nm. Both of its ends are polished and coated so that each has a reflectance of 80%. Assuming that there are no scattering or other extraneous losses, determine the resonator loss coefficient α_r and the resonator photon lifetime τ_p.

(c) As the laser is pumped, $\gamma(\nu_0)$ increases from its initial thermal equilibrium value of $-0.2\ \text{cm}^{-1}$ and changes sign, thereby providing gain. Determine the threshold population difference N_t for laser oscillation.