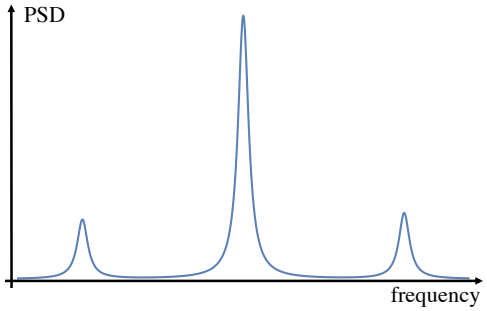
OPTI 544 **1st Midterm Exam, March 15, 2023** **Jessen**

I

An atom driven by a strong, monochromatic electro-magnetic field re-radiates light with the power spectral density (PDS) shown in the figure at right. Comment on the various features (number, location, shape, width, etc.,) of the PDS and what they tell you about the atom and the regime in which it is being driven. (15%)



II

(a) Write out the electric dipole selection rules as derived in class. Then draw a level diagram similar to those made in the Course Section on multi-level atoms, showing the magnetic sublevels present in an $F=2\rightarrow F'=2$ hyperfine transition. Indicate which transitions are allowed for σ_+, σ_-, and π (linear along the quantization axis) polarized light. Discuss how you might use optical pumping to prepare atoms in the $F=2, m=2$ ground state. (15%)

(b) Now consider an $F=2\rightarrow F'=1$ transition. Draw a level diagram similar to the one in (a). What modifications of the optical pumping scheme are needed to prepare atoms in the $F=2, m=2$ ground state? (10%)

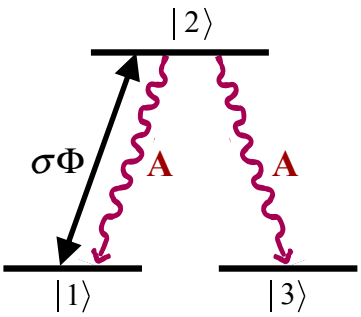
III

Alice needs to prepare a mixed state $\rho=\frac{1}{4}|1\rangle\langle 1|+\frac{3}{4}|2\rangle\langle 2|$ of a two-level system. She can prepare arbitrary coherent superpositions, do measurements that projects the system into states $|1\rangle$ or $|2\rangle$ contingent on the measurement outcome, and modulate the energy separation between $|1\rangle$ or $|2\rangle$ with a magnetic field. The whole process can be run manually, or by a computer that stores measurement outcomes in memory. This makes it possible to efficiently produce many copies of any given coherent superposition. She also has a graduate student Bob who can do these things for her.

(a) Describe **3 and only 3** ways Alice can prepare the state ρ, with or without help from Bob. (20%)

IV

Consider a 3-level atom as shown at right, with ground states $|1\rangle$ and $|3\rangle$ and a shared excited state $|2\rangle$. The system is strongly collision broadened and can be described by a rate equation model. Stimulated processes drive the $|1\rangle\rightarrow|2\rangle$ transition only and occur at a rate $\sigma\Phi$. Spontaneous decay of state $|2\rangle$ occurs at equal rates A into the ground states.



(a) Using physical arguments similar to those for a two-level system, write out a set of Rate Equations for the populations ρ_{11}, ρ_{22}, and ρ_{33}. Perform whatever checks you can think of to confirm you got it right. (20%)

(b) Without solving the Rate Equations, what do you expect will be the steady state. (5%)

(c) Assuming the atom starts in state $|1\rangle$, use your intuition to make a rough sketch of the time dependent populations from $t=0$ until steady state is reached. Use the same units on the time and population axes for all 3 plots. Do not attempt to formally solve the Rate Equations (15%)