جامعة الملك سعود
كلية العلوم
قسم الفيزياء

الأسم .... الرقم الجامعي

الاختبارالنهائي لمقرر ٥٣١ فيز (الفصل الدراسي الثاني ١٤٢٣/١٤٢٤ هـ)

OPEN BOOK

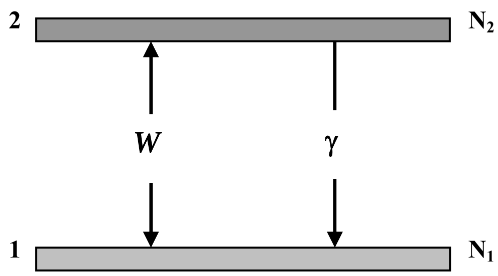
1. Consider a collection of free sodium atoms in thermal equilibrium with an electromagnetic field (i.e. with a blackbody radiation field).

(a) Calculate the ratio of stimulated and spontaneous emissions at room temperature for the sodium D-line (λ=589 nm).

(b) What should the temperature be so that the stimulated emission would dominate?

(c) For which wavelength the rates of stimulated and spontaneous emissions are equal at room temperature?

2. Consider the two-level atomic system shown; γ is the spontaneous emission rate out of level 2 and W is the stimulated transition rate between levels 1 and 2. The total electron density is $N=N_1+N_2$.



(a) What is the ratio N_2/N_1 in thermal equilibrium? At room temperature (T=300 K), what is the maximum transition wavelength between 2 and 1 such that the population N_2 is less than 1% of the total population?

(b) Write down rate equations for N_2 and N_1.

(c) Find the steady-state inversion $\Delta N=N_2-N_1$.

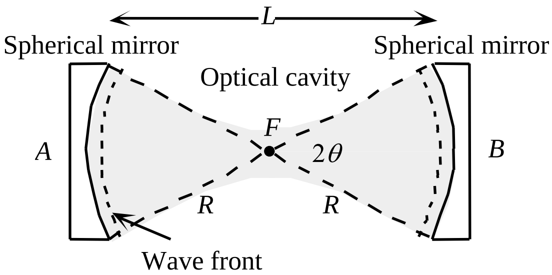
3. Consider a two-level system, non-degenerate, homogeneously broadened system of atoms with line-shape function $g(\nu)$ and energy levels E_1 and E_2. This system is pumped in a steady-state by monochromatic radiation with intensity I_ν and frequency $\nu = (E_2-E_1)/h$.

(a) give stimulated transtion rate W_{21} in terms of the pump intensity I_v and other atomic parameters.

(b) Derive a steady-state expression for $(N_1-N_2)/(N_1+N_2)$ of this system in terms of W_{12}, W_{21} and A_{21}. N_1 and N_2 are the population density for the lower and upper state respectively; A_{21} is the spontaneous emmision rate.

(c) Can acheieve population inversion for this system? If so, what is the necessary pump intensity I_v?

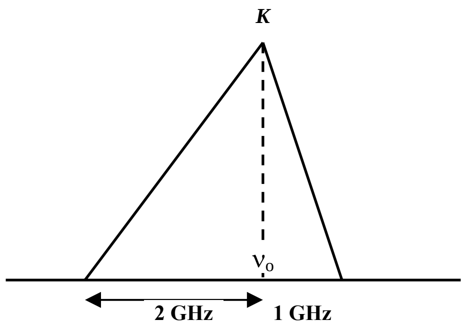
4. (a) In the confocal cavity shown, the light beam in the cavity is a Gaussian beam. If *R* =25 cm, and the mirrors are of diameter 2.5 cm, estimate the divergence of the beam and its spot size (minimum waist) for light of wavelength 500 nm.



(b) For inhomogeneous line shape function shown of the laser with;

$\lambda = 8\times10^{-5}$ cm , $A_{21} = 2.5\times10^{6}$ s^{-1} , $\eta = 2.75$

Calculate the stimulated emission cross section.

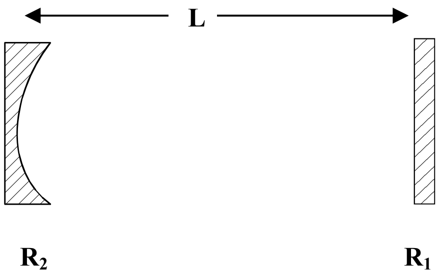


5. A He-Ne laser (λ = 0.63 μm) operating in the fundamental transverse mode has mirrors separation by L =1 m. The Doppler width is $\Delta\nu_D$ =1.5 GHz, and the effective refractive index is η = 1. The output mirror is flat, and the other mirror is spherical with radius of curvature 16 m.

(a). What is the frequency difference between longitudinal modes in the resonator?

(b). Show that the resonator is stable.

(c). What would the Doppler width become if the temperature of the laser medium were doubled?



(d). What is the spot size at the flat mirror?

(e). If the output is taken from the flat mirror, what is the spot size 16 km away?

6. Consider a 4 mW, TEM_{00} He-Ne laser (λ =632.8 nm) with cavity dimensions given below. The left mirror (R_1 = 2 m) is 100% reflecting. The right mirror ($R_2 \rightarrow \infty$) is partially reflecting plain through which 4 mW output beam passes. The beam waist in the laser cavity (L = 1 m) occurs at the plane mirror, where the reference plane $z = 0$ was chosen.

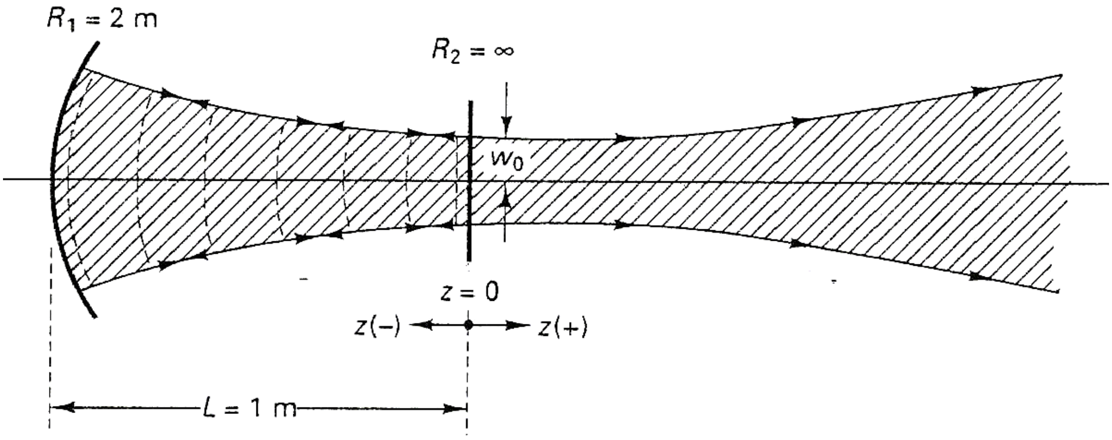
(a) Determine the spot size w_0 at the beam waist.

(b) Determine the laser beam spot size on the rear laser mirror.

(c) Determine the complex radius of curvature $\tilde{q}(z)$ at z = -1 m and z = 0.

(d) Determine the location z_{FF} of the far field from the beam waist (z = 0).

(e) What is the half angle beam divergence θ_{FF} for this laser in the far field?



7. (a) The quantum yield of $S_1 \rightarrow S_0$ transition for Rhodamine 6G is 0.87, and the corresponding lifetime is ≈ 5 ns. Calculate the radiative and nonradiative lifetimes (τ_{sp} and τ_{nr}, respectively) of the S_1 level (assume η=1.36 for ethanol).

(b) From a knowledge of the radiative life time τ_{sp} of Rhoamine 6G (from part a),

(i) Calculate the corresponding $|\mu|$, where λ =0.59 μm at the maximum of the emission curve.

(ii) Calculate the effective atomic dimension, a.

PHYSICAL CONSTANTS

Rest mass of electron	m	$= 9.110 \times 10^{-31}$ kg
Charge of electron	e	$= 1.602 \times 10^{-19}$ C
Avogadro's constant	N_A	$= 6.022 \times 10^{23}$ mol^{-1}
Planck's constant	h	$= 6.626 \times 10^{-34}$ J s
Boltzmann's constant	k	$= 1.381 \times 10^{-23}$ J K^{-1}
Speed of light (vacuum)	c	$= 2.998 \times 10^{8}$ m s^{-1}
Stefan-Boltzmann constant	σ_{SB}	$= 5.670 \times 10^{-8}$ W m^{-1} K^{-4}

مع تمنياتي لكم بالتوفيق والنجاح