UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualification:-

M.Sci.

Physics 4421: Atom and Photon Physics

COURSE CODE	:	**PHYS4421**
UNIT VALUE	:	**0.50**
DATE	:	**20-MAY-03**
TIME	:	**10.00**
TIME ALLOWED	:	**2 Hours 30 Minutes**

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TURN OVER

Answer any THREE questions.

The numbers in square brackets in the right-hand margin indicate the provisional allocation of maximum marks per sub-section of a question.

Planck's constant h = 6.63×10^{-34} Js

1. Using helium as an example draw an energy level diagram and denote Electric Dipole, Magnetic Dipole and Auto Ionizing transitions. In each case give typical lifetime values.

   In hydrogen the $2^2S_{\frac{1}{2}}$ level has two single photon decay routes and one two-photon decay route. Denote them on an energy level diagram. In each case give typical lifetime values. [5]

   In the two-photon decay of $2^2S_{\frac{1}{2}}$ estimate the lifetime of the virtual state. [4]

   Describe the electron-photon coincidence method used to measure the lifetime of the $2^1P \rightarrow 1^1S$ transition in helium. [5]

   Assuming the hydrogenic nature of sodium determine the lifetime of the 60 ^2P level if the lifetime of the 10 ^2P is 10 μs. Assume a common lower level. [2]

   A single atom of lifetime τ and transition frequency _ is placed in a cavity. Explain, without proof, how the tuning of the cavity affects the lifetime τ. [4]

2. A single point source, S, emits quasi monochromatic light along two paths 1 and 2 defined by co-planar apertures P_1 and P_2. The light signal is observed at Q. The axis SQ is perpendicular to the plane containing P_1 and P_2.

Show that the light intensity I at Q is given by

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\ \text{Re}\ \gamma_{12}\ (\tau)$$

where $\gamma_{12}\ (\tau)$ is the complex degree of Partial Coherence and τ is the time difference for propagation along the paths SP_1Q and SP_2Q. I_1 and I_2 are the intensities observed at Q along the sperate paths SP_1Q and SP_2Q respectively. [12]

Explain how $\gamma_{12}\ (\tau)$ can be measured experimentally and show that the fringe visibility is given by $|\gamma_{12}\ (\tau)|$ for $I_1 = I_2$. [8]

3. Explain the physical origins of Natural, Pressure and Doppler broadening. Give typical values for the bandwidth in each case. [3]

Explain how Hole Burning and Two Photon Spectroscopy reduce or remove the bandwidth. [8]

Using these spectroscopic techniques describe how the Lamb Shift of the ground state of hydrogen can be measured. [9]

4. Two interacting light beams with space time coordinates (r_1,t_1) and (r_2,t_2) and electric fields $\boldsymbol{E}$ have a correlation function

$$\langle \boldsymbol{E}(r_1,t_1)\boldsymbol{E}(r_2,t_2)\rangle = \frac{2\bar{I}}{\varepsilon_0 c} \exp(i\omega\tau - \gamma|\tau|)$$

where the symbols have the usual meanings.

Write down the expression for the First Order Correlation Function (g_{12}) and derive g_{12} for a chaotic light field of bandwidth γ. [4]

How does the coherence time, τ_c, of the light influence fringe visibility in a Young's slit experiment? Estimate the coherence time and coherence length for a Doppler broadened light source. [7]

In what way does the "interference" in a Young experiment differ from that in a Hanbury-Brown-Twiss experiment? [3]

Describe the Hanbury-Brown-Twiss experiment and show how the Second Order Correlation function is obtained. [6]

5. Explain what is meant by Optical Pumping. [2]

Using the $5^2S \rightarrow 5^2P$ transition in Rb explain how the atoms become orientated using σ^+ light in Zeeman pumping. Neglect the hyperfine structure. [5]

What happens to the magnetization of the rubidium vapour when σ^- light is used? [1]

In atomic molasses cooling using laser beams the laser wavelength must be chirped. Explain why! [2]

Describe the trapping process in a Zeeman trap. [4]

In Sisyphus cooling a polarization gradient is employed. Explain how this is established and the role of Light Shifts in the cooling process. [6]

END OF PAPER