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continuous assessment 2011-12

Subject PHYSICS SPECIALITY
Title of paper LASERS AND QUANTUM OPTICS
Time allowed 14 Days

Instructions to candidates

Candidates should hand in answers to all questions.

The marking scheme for each question is indicated by the numbers in square brackets on the right-hand side of the question.

Answers to questions should be handed in to the teaching office. Marked answers will be returned and solutions discussed in the lectures.

The deadline for the submission of questions is 12:00 2nd December 2011

1. A laser beam of continuous power 1 mW and wavelength 633 nm is right-hand circular polarized.

What is the rate of transfer of angular momentum in the beam? [3]

The same beam is reflected from a perfect mirror at normal incidence. What is the polarization of the reflected beam? [1]

What force does the mirror experience? [3]
2. X-rays of wavelength 1.24 nm are absorbed in a thin gold film 10 by 10 μm square and 0.1 μm thick. What is the increase in the temperature of the film when 1 photon is absorbed assuming that the gold is thermally insulated from the surroundings? The density of gold is 19300 kg m^{-3} and the specific heat of gold is 132 $\text{J kg}^{-1} \text{K}^{-1}$. [3]
3. In a Young's slits experiment the fringes are measured as the separation between the slits is changed. As the fringes get closer together their visibility drops such that the smallest fringe separation which can be seen is 200 μm . If the wavelength of the light is 545 nm and the distance from slits to screen is 1 m estimate the lateral coherence length in the beam incident on the slits. [3]

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4. Estimate the coherence length for the following light sources:

A filament lamp that produces white light over the wavelength range 400-700 nm. [2]

A CW Nd-YAG laser operating in a single mode with line width 30 kHz. [2]

A He-Ne laser with cavity length 30 cm in which 3 longitudinal modes are excited. [2]

5. What is the longitudinal mode separation in the cavity of a He-Ne laser, $\lambda = 633$ nm, if the cavity length is 0.2 m? [2]

If the gain curve has a width of 3×10^9 Hz approximately how many longitudinal modes will be excited? [2]

6. The atomic mass of Ar is 40. Estimate the Doppler broadening expected in an Argon ion laser if the effective ion temperature is 5000 K and the emission wavelength is 488 nm. [4]

7. A ruby laser produces $\lambda = 694$ nm. The spontaneous lifetime of the upper laser level is 3 ms, the linewidth of the transition is 150 GHz and the refractive index of the ruby is 1.78. If the cavity is 5 cm long and has reflectivities of 1.0 and 0.96 at the ends what is threshold small signal gain needed for laser operation? [8]

What is the minimum population inversion required to achieve this gain? [4]

8. In an optics experiment laser pulses of wavelength $1.455 \mu\text{m}$ are produced at a rate of 100 MHz. The pulses are injected into a single-mode optical fibre with a mode field (core) diameter of $9 \mu\text{m}$ and core refractive index $n_o = 1.5$. On leaving the fibre the pulses are found to have a duration of 1.5 ps and a mean energy of 12 pJ. The pulses are detected using a photodiode and the noise on the pulses (fluctuations in intensity from pulse to pulse) is measured using a stable reference pulse.

Estimate the number of photons in each pulse. [2]

What is the expected level of rms fluctuations (shot noise) in the detected energy of the pulses? [2]

Estimate the number of SiO_2 molecules contained within the pulse. [3]

3.

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Estimate the maximum electric field produced by the pulses in the fibre core.

[4]