Indian Institute of Technology, Delhi
Minor 2: PHL 755 Statistical and Quantum Optics
Instructor: Kedar Khare Date: October 10, 2015

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1. (a) State the relation between the cross spectral density $W(\vec{r}_1, \vec{r}_2, \nu)$ and the degree of coherence $\Gamma(\vec{r}_1, \vec{r}_2, \tau)$. **(3 points)**
(b) If a partially coherent field described by $\Gamma(\vec{r}_1, \vec{r}_2, \tau)$ is incident on two pinholes in a Young's double slit arrangement, show that the spectral density $S(\vec{r}, \nu)$ at the observation screen follows the spectral interference law given by:
$$S(\vec{r}, \nu) = S^{(1)}(\vec{r}, \nu) + S^{(2)}(\vec{r}, \nu) + 2\sqrt{S^{(1)}(\vec{r}, \nu)S^{(2)}(\vec{r}, \nu)}Re[\mu(\vec{r}_1, \vec{r}_2, \nu)e^{-i2\pi\nu(R_1-R_2)/c}],$$
where all the symbols have the usual meaning. **(7 points)**
(c) Two independent laser beams with fields described by $X(t)$ and $Y(t)$ are combined using a 50:50 beamsplitter and the two outputs of the beamsplitter are then used for illuminating the slits in a Young's double slit experiment.
(i) Show that the spectrum of light at each of the pinholes is identical.
(ii) Calculate $W(\vec{r}_1, \vec{r}_2, \nu)$ and $\mu(\vec{r}_1, \vec{r}_2, \nu)$ in terms of the spectral densities $S_X(\nu)$ and $S_Y(\nu)$ of the two laser beams, where $\vec{r}_1, 2$ denote the position of the two pinholes.
(iii) Use your result in (b) to calculate the spectral density observed at the mid-point $R_1 = R_2$ on the observation screen. **(2+3+5=10 points)**

2. (a) A unit amplitude random phase screen is illuminated by a laser (wavelength λ) spot of diameter D. Find the average speckle size in a transverse plane at distance z from the phase screen which may be assumed to be in the far zone. **(5 points)**
(b) The random phase screen is an input to a linear space invariant imaging system with coherent impulse response $h(x, y)$. When plane wave illumination with wavelength λ is used along the optic axis of the system, find the speckle size in the image plane. **(5 points)**

3. (a) A light source with constant intensity $I(t)$ (in photon number units) falls on a detector with quantum efficiency η. State the probability distribution for number of photon counts n observed in a counting time T. **(5 points)**
(b) How does this distribution change if the intensity $I(t)$ is a random process? **(5 points)**
(c) Find the photon counting probability when polarized thermal light is incident on a pinhole and detector combination and the detector counting time is much smaller than coherence time. **(5 points)**
(d) How will you modify your calculation for the photon counting distribution if the thermal light is unpolarized? **(5 points)**