Statistical Optics and Image Formation

Homework Set 2 Due: December 2, 2020

1. **<u>Degree of Coherence for a Gaussian source</u> (20%)**
A circularly symmetric light source has an intensity distribution $I(a) = I_0 e^{-a^2/(2a_0^2)}$, where *a* is the radius measured from the optic axis. Compute the degree of spatial coherence.
1a) What is the lateral coherence length?
1b) What happens to the degree of spatial coherence if the source is displaced from the optic axis by *d*?
1c) Consider that you are performing a double-slit interference experiment with the light source, what happens to the interference pattern if the source is displaced from the optic axis by *d*?

2. **<u>Power spectrum of Doppler-shifted Signal</u> (20%)**
A harmonic electromagnetic wave signal $exp(-j\omega_0 t)$ was observed by a stationary observer standing at distance r_0. The oscillation frequency ω_0 is a deterministic constant. The signal source moves with constant but random velocity V (relative to the observer) with a probability density function $p_V(v)$, thus the observer will receive a Doppler-shifted signal of $S(t) = a\exp\{j\omega_0[t - (r_0 + Vt)/c]\}$.
1a) What is the power spectrum of this received signal?
1b) What do you conclude about the power spectrum of the light if it was produced by a collection of gas molecules moving at random and emitting at identical frequencies?
1c) What is an appropriate probability density function $p_V(v)$ for V for this case?

3. **<u>Wiener filter for deblurring and denoising images</u>** (30%)
Wiener-Helstrom filter can be used to deblur and remove noise from a degraded image as demonstrated in the workshop 2 at the course website. However, the original algorithm of Wiener-Helstrom optimum filter requires users to have the knowledge on the statistics of both signal and noise. Design a Wiener-Helstrom filter to circumvent this obstacle. Use your m-script to recover this degraded image of cell (cell1.tif). Do you beat the performance of the m-script demonstrated in workshop 2? Verify your achievement by quantifying the error of your recovered image (compare to this original image cell0.tif).

4. **<u>Young's double-slit experiments with Partially Coherent Light</u>** (30%)
Use the m-scripts (MutualIntensityPropagation.m) demonstrated on Workshop 4 for a partially coherent light emitted from an LED system. Use the script to prepare a file of the complex coherent factor at the collimated output plane of the optical system. Explore the double-slit experiment by assuming the LED to be quasi-monochromatic with λ0=650 nm and having a circular area (*d*=1 mm). Compare your results of a pinhole diameter of 0.1 mm and 0.3 mm in the optical system.
Summarize your results with a concluding remark.