ELEC2350 : Lab on coherence

In this lab, we will study the coherence of light. Two types of randomness will be investigated: randomness originating from the source and randomness originating from the medium through which the light propagates.

Part 1: Partially coherent light from a light emitting diode

As seen during the lecture, the coherence of the light is intrinsically related to its ability to create interferences. Thus, a simple way to probe the coherence of the light is to use a double-slit experiment. The light is collected at two different positions and diffracted. If the two diffraction patterns overlap each others, one can look at the fringes in the overlapping zone. The visibility (or contrast) of the interference fringes is directly related to the amplitude of the complex degree of coherence of the fields at the position of the slits.

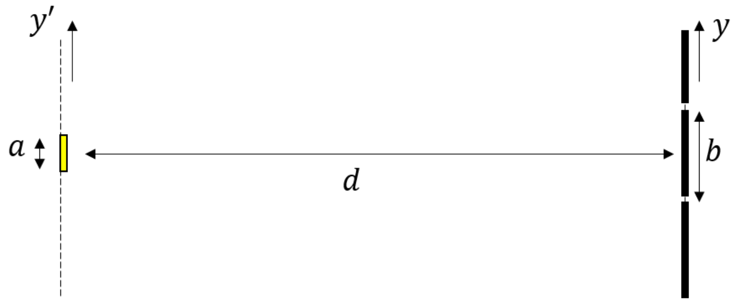
In this lab, we will measure the coherence of the light emitted by a light emitting diode (LED) as a function of the distance. From this information, we will estimate the size of the emitting zone of the LED. To do so, we will proceed in two steps. First, we will predict theoretically the coherence function as a function of the geometrical parameters of the problem. Then, comparing the model with the experiments, we will estimate the size of the emissive zone.

Theoretical model

To simplify the problem, we will work with scalar fields and a 2D space. We consider two parallel planes (which, in 2D, are parallel lines). The emissive zone of the LED is located on the first plane. The two slits are located on the second plane. The distance between the planes is noted d, the distance between the slits is noted b and the size of the emissive zone is noted a. Within the emissive zone, the correlation function of the current distribution reads

$$\langle J(y_2')J^*(y_1')\rangle = I_0\delta(y_2' - y_1') \tag{1}$$

with y_2' and y_1' the coordinate of the position in the plane of the sources.



We will consider that the slits are located in the far-field of the sources, so that the electric field generated in the plane of the slits by currents on the plane of the LED reads

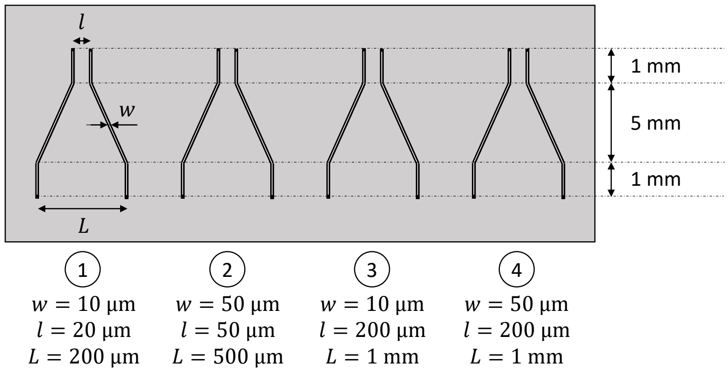
$$E(y) = -jk\eta \int \frac{\exp(-jkR)}{4\pi R} J(y') \exp(-jk\hat{u}\cdot\mathbf{r})dy' \tag{2}$$

with $R = \sqrt{d^2 + y'^2} \simeq d$, $\hat{u} = (d, -y')/|(d, -y')| \simeq (1, -y'/d)$, $\mathbf{r} = (0, y)$, k is the wavenumber and η is the free-space impedance.

- Using these hypotheses, what is the complex degree of coherence of the fields at the positions of the slits? Give you answer as a function of the parameters of the problem.
- How does this complex degree of coherence relates to the amplitude of the fringes that can be observed?

Experiments

To measure the size a of the emissive zone of the LED, one possibility is to vary the distance between the slits b or the propagation distance d and look at combinations of b and d for which the interference pattern is washed out. To check the impact of parameter b, you have access to a set of slits of varying width and separation. The system is mounted on an optical rail, so that the distance d can be easily and continuously tuned. The geometry and dimensions of the slits are illustrated below:



Using the measurement system, record the interference fringes at several distances from the LED. From your measurements, estimate the size of the emissive zone of the LED.

Part 2: Turbulences and mechanical perturbations

Now, we will study the impact of the propagation medium on the coherence of the light. To do so, we will use a Michelson interferometer and analyse the interferences generated using a Helium-Neon laser. Lasers of that kind are known for their very sharp spectrum and high coherence. The goal of this lab is be to observe the impact of random fluctuations of the path followed by the laser beam and evaluate the sensitivity of an optical interferometer to external perturbations.

- Try to align the two beams of the laser, so that interference fringes are visible. Why are the interferences so sensitive to the alignment?
- Now that the system has been aligned, try to apply different mechanical perturbations to the system. What happens to the fringes? How can this modification of the fringes be related to the concept of partial coherence?
- Last, apply a perturbation to one of the two beams by lighting the candle, creating a flow of hot air. What happens?