Session 7

Exercise 1: MATLAB exercise: Scalar Beam Propagation Method

Use the Scalar Beam Propagation Method (BPM) to simulate the following scenarios. An electric field with amplitude $E_0 = 1\ V/m$, a wavelength $\lambda = 1.3\mu m$ in an aperture $A = 8\lambda$ over a distance $z = 8\lambda$.

a) The electric field is part of a plane wave which propagates through vacuum at 0 degrees and 5 degrees. Plot the spatial field distribution (real part of $E(x, z)$), the spectrum of the incident field as well as the x- and z-part of the propagation constant over the angle of propagation. What are the spatial frequencies f_0 and f_5?

b) The electric field is part of a Gaussian beam with a waist of $W_0 = A/8$, propagating through vacuum at vertical incidence. Plot the spatial field distribution (real part of $E(x, z)$) and the spectrum of the incident field. What are the spatial frequencies f_0 and f_5?

c) The Gaussian Beam in b), which propagates through a waveguide with a diameter of 2λ and an index contrast $n_{core}/n_{clad} = 1.5$. Plot the waveguide, the absolute of the propagating electric field and its contour.

d) A plane wave with unit amplitude propagates through a lens with a focal length $R_l = 10\lambda$ and $R_r = -5\lambda$. Plot the absolute of the electric field and verify the focal distance with the Lensmaker's equation.

e) A plane wave with unit amplitude and wavelength $\lambda = 1.5\ nm$ propagates through a single slit with diameter $d = 2\lambda$ and a refractive index $n = 1.5+i2$ (high absorbing!). Verify the position of the diffraction maxima and minima with the results from theory.

Hints:

Get the algorithm for the BPM from the course material. Write the program for a two-dimensional scene (xz-plane) only.

Use the function `fft2()` and `ifft2()` to perform the forward and inverse Fourier transformation. The spatial frequencies of `fft2()` are sorted `index_fx = [0:nx/2-1 -nx/2:-1]`. A reasonable space index is `index_x = -nx/2:nx/2-1`. Express the aperture, sampling rate f_s and the propagation distance per layer dz in terms of the wavelength `lambda = 1.3e-6`, `ax=8*lambda`, `az = 8*lambda`, `dz = lambda/10` and `fs = 8/lambda`.

Exercise 2: Matlab exercise: Scalar Wave Propagation Method

Use the Scalar Wave Propagation Method (WPM) to simulate the following scenarios.An electric field with amplitude $E_0 = 1\ V/m$, a wavelength $\lambda =$

$1.3\mu m$ in an aperture $A = 8\lambda$ over a distance $z = 8\lambda$.

a) The electric field is part of a plane wave which propagates through vacuum at 0 degrees and 5 degrees. Plot the spatial field distribution (real part of $E(x, z)$), the spectrum of the incident field as well as the x- and z-part of the propagation constant over the angle of propagation. What are the spatial frequencies f_0 and f_5?

b) The electric field is part of a Gaussian beam with a waist of $W_0 = A/8$, propagating through vacuum at vertical incidence. Plot the spatial field distribution (real part of $E(x, z)$) and the spectrum of the incident field. What are the spatial frequencies f_0 and f_5?

c) The Gaussian Beam in b), which propagates through a waveguide with a diameter of 2λ and an index contrast $n_{core}/n_{clad} = 1.5$. Plot the waveguide, the absolute of the propagating electric field and its contour.

d) A plane wave with unit amplitude propagates through a lens with a focal length $R_l = 10\lambda$ and $R_r = -5\lambda$. Plot the absolute of the electric field and verify the focal distance with the Lensmaker's equation.

e) A plane wave with unit amplitude and wavelength $\lambda = 1.5\ nm$ propagates through a single slit with diameter 2λ and a refractive index $n = 1.5 + i2$ (high absorbing!). Verify the position of the diffraction maxima and minima with the results from theory.

Hints:

Get the algorithm for the BPM from the course material. Write the program for a two-dimensional scene (xz-plane) only.

Use the function `fft2()` to perform the forward Fourier transformation. The spatial frequencies of `fft2()` are sorted `index_fx = [0:nx/2-1 -nx/2:-1]`. A reasonable space index is `index_x = -nx/2:nx/2-1`. Express the aperture, sampling rate f_s and the propagation distance per layer dz in terms of the wavelength `lambda = 1.3e-6`, `ax=8*lambda`, `az = 8*lambda`, `dz = lambda/10` and `fs = 8/lambda`.

Exercise 3: Matlab exercise: Simulation of a refracted gaussian beam

A gaussian beam of unit amplitude and passes a tilted interface under an angle of incidence $\theta_{i,1} = 3°$ and $\theta_{i,2} = 30°$. The refractive index before the interface is $n_i = 1$ and behind the interface $n_t = 1,5$. The beam propagates a distance of 5λ after being refracted by the interface.

a) Derive the position of the gaussian beam at the given distance behind the interface from theory.

b) Simulate the scenario with the Scalar Beam Propagation Method and calculate the deviation to the results from theory.

c) Simulate the scenario with the Scalar Wave Propagation Method and calculate the deviation to the results from theory.

d) Discuss the results.