Laboratory 4 - Beam Propagation Method

The Beam Propagation Method (BPM) has been the workhorse of integrated optics over the course of the last 30 years. Numerous implementations based on various approaches have been implementated and are daily used. The present laboratory introduce the BPM in its simplest form, i.e. dealing with 1-dimensional fields within the weak guidance approximation.

Up to now, we have considered only modes of translationally invariant waveguiding structures and we have focussed on the steady state of propagation. These are special conditions that are not generic enough to enable the design of integrated chips. We need to know the behaviour of light under conditions which break the translational invariance of the waveguiding structure. Example of such conditions are the presence of bends, splices, tapers, mirrors to name but a few. The BPM is the method of choice for some of these cases and the current laboratory provides an introduction to the subject.

Contents

Necessary files

Two files are required to complete this laboratory:

1. `Propagation.m` -- Propagation algorith for 1-D scalar fields
2. `Slab.m` -- Step-index slab waveguide

Beam Propagation Method

The companion document entitled *Beam Propagation Method* discusses the implementation of the propagation algorithm and provide a description of the associated MATLAB class `Propagator`. We encourage you to read this document before starting this laboratory.

Starting with your project

To get things started, we simply want to calculate and visualise the propagation of light in a straight step-index slab waveguide. The description of this specific waveguide is provided in `Slab.m` and essentially consists of a function `Slab(x,z)` returning the value of the refractive index for a given coordinate (x,z) (transverse and longitudinal positions). For example:

```
Slab(0.0, 1.0)
```

```
ans =

    1.4500
```

yields the value of the refractive index on the waveguide axis (x = 0) at position z = 1.0 along the same axis.

Since we are interested in propagation, we must specify the simulation domain *i.e.* the spans both in x and z we are interested in. For the case considered here, a domain of 60 micron width is sufficient. Furthermore, we want to propagate over distance of 5 millimeters (5,000 microns). This could be done by creating an array:

```
D = [-30, 30, 0, 5000];
```

but the BPM algorith requires also to specify a background index, which we will take as the cladding index. So, the BPM expects an array of 5 components:

```
D = [-30, 30, 0, 5000, 1.447]
```

```
D =

   1.0e+03 *

  -0.0300    0.0300         0    5.0000    0.0014
```

and this describes completely the simulation domain. In order to propagate light in our waveguide, we first create an object of class `Propagator` that specifies the simulation domain, the wavelength and the wavguide structure:

```
P = Propagator(D, 1.3, @Slab)
```

```
P =

      domain: -30.000000 30.000000 0.000000 5000.000000 1.447000
  wavelength: 1.300000
     profile: @Slab
```

Note the usage of the `@` symbol to specify the index profile. We are now ready to specify the input field for the simulation. The propagator can do that using the method `SetGaussianField`:

```
P.SetGaussianField(2.0, 6.0);
```

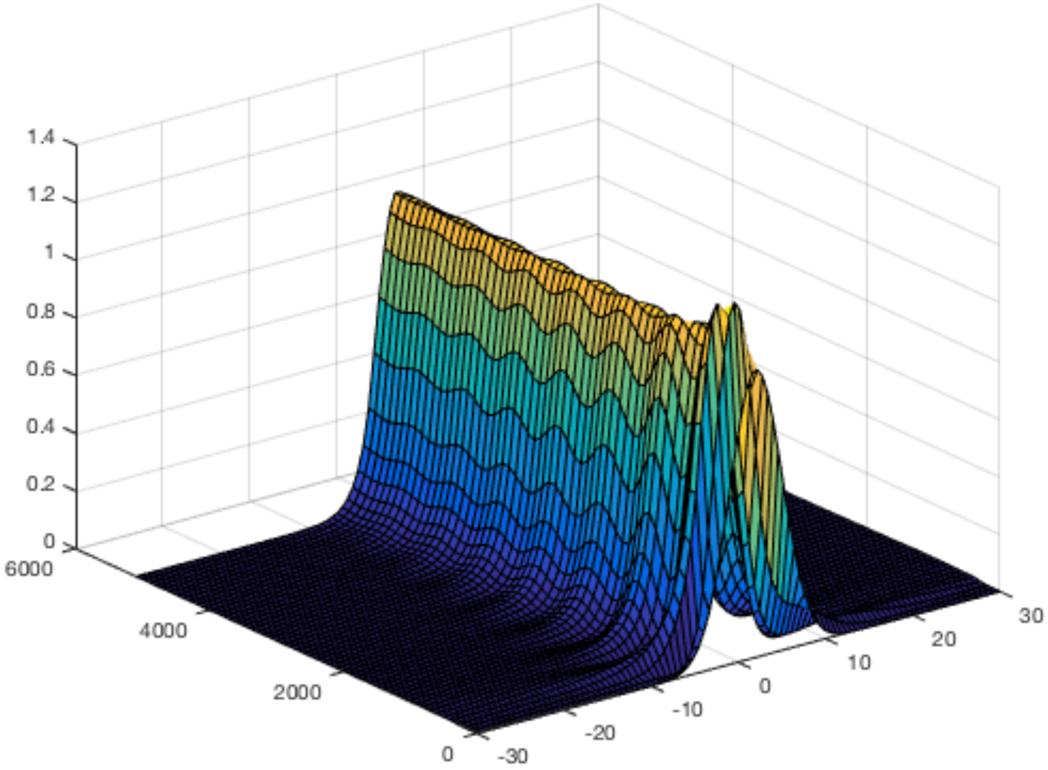
Which intialise the field to be a Gaussian centered at x = 2.0 microns and of spot-size 6.0 microns. We are now ready to run the simulation by telling the propagator to collect information along the waveguide axis periodically. Here we specify 50 points:

```
P.Run(50);
```

....

After the simulation is run, we can view the field evolution by typing

```
P.ViewIntensity;
```



Problem 1

Using the data found in Slab.m, is the waveguide used single-moded? How can this give you a clue on the field behaviour after the initial transient phase?

Problem 2

Change the half-width of the waveguide from 3 microns to 5 microns and run the simulation again. Plot both the field evolution and the power in the core. Provide an explanation for the sharp qualitative change in the behaviour of the field during propagation.

Problem 3

Write a function similar to `Slab(x,y)` that would describe a symmetric coupler with arms of half-width of 3.0 microns separated by a centre-to-centre distance of d = 12.0 microns. Inject a Gaussian beam of spot-size *s* = 5.0 micron into one of the arms. Plot the field evolution over 5 millimeters together with the fraction of power in the chosen arm. From either outputs, estimate the coupling length of this device.

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