Finite Element Anisotropic Beam propagation method (FEAB) - User documentation -

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Terms of Use

This document describes the use of FEAB, the compiled version of the Finite Element Anisotropic Beam propagation method presented in Optics Express, vol. 17 (12). This version is intended for educational and academic purposes only. Commercial use, including commercial research, is strictly prohibited. This evaluation version is limited to homogeneous material layers and the number of elements is restricted to 400 elements. Contact us if commercial use or additional program functionality (e.g. more elements, other input optical fields, inhomogeneous or bianisotropic material layers) is desired.

NOTE: Please cite our paper in Optics Express vol. 17 (12) in your future publication when reporting on results that have been (partly) obtained by using FEAB.

1 Prerequisite: Matlab Component Runtime (MCR)

FEAB is written in Matlab to take advantage of the efficient built-in operations on sparse matrices and advanced plotting options. The present version of FEAB is compiled and can be run without having to purchase Matlab. However, it still requires a few Matlab components (mainly libraries), which are made available by the Matlab Component Runtime (MCR). The drawback is that this component is heavy (175 MB), but it can be freely distributed in a non profit perspective for academic use. You do not need to install the MCR on your machine if your machine has both Matlab (version 7.6) and Matlab Compiler or if MCR version 7.8 is already installed. Therefore, two versions of FEAB are available for download:

- FEAB_vs_MCR: the MCR version 7.8 is included as a self-extracting package for Windows and can be directly installed from the command line.
- FEAB_vs_noMCR: the MCR is not included for users who have the MCR version already installed.

To install the MCR version 7.8 first download FEAB_vs_MRC.zip, unzip the archive and run FEAB_vs_pkg.exe. Answer yes (y) to the four questions and follow the procedure to install the MCR on your machine. The MCR version 7.8 is also available for other operating systems on the official Mathworks website.

2 Running FEAB

To start FEAB, run FEAB_vs.exe from the command line from the directory where you have unzipped the archive. First you will be prompted for a mesh file of your structure. A uniform 10μm by 10μm mesh file 'iso10_090.txt' (254 elements) is included in the archive for testing purposes. It is described in section 3 how a user-defined mesh file can be created. The resulting mesh file should be placed in the same directory as the FEAB executable. If you have entered an appropriate mesh file, the meshed structure will be shown in a popup figure. Next, you will be prompted for following input parameters:

- *Input beam parameters*: in this section the input optical field is defined.
  - Wavelength (um).
  - Amplitude Ex: the amplitude of E_x, the first component of the electrical field of the considered input optical field.
  - Amplitude Ey: the amplitude of E_y, the second component of the electrical field of the considered input optical field.
  - Consider plane wave (0) or gaussian beam (1)?
    - Choose '0' to consider a plane wave. Note that in the current version perfectly matched layers (PML) with absorbing boundary conditions are implemented. Because of these absorbing boundary conditions, the plane waves will be absorbed and distorted at the edges of the computational window and they will lose their 'plane wave' character. Therefore, it is a better choice to opt for an input optical field with a gaussian profile (option '1').
    - Choose '1' to consider an input optical field with gaussian field amplitudes:

$$E_{x \text{ or } y} = \text{Amplitude}_{E_x \text{ or } E_y} \exp\left[-\frac{(x-x_0)^2}{\sigma_x^2} - \frac{(y-y_0)^2}{\sigma_y^2}\right].$$

  - define x_0, y_0, σ_x and σ_y.

- *Beam propagation parameters*: in this section the parameters for the beam propagation are defined.
  - Propagation step (um): Δz.
  - Propagation distance (um).
  - Effective index: the reference refractive index n_o as defined in Eq.(2) on page 3 in the paper (choose a value close to the refractive index of the medium).

- *Plot parameters*: define the plot options.
  - Use surface plots (0) or contour plots (1)?
  - Number of plots (1-2-4-6): choose how you want to plot the evolution of the optical field (in combination with 'Plot option' in the next prompt if Number of plots = 1 or 2):
    - Number of plots = 1:
      - Plot option = 1: show E_x only.
      - Plot option = 2: show E_y only.
    - Number of plots = 2:
      - Plot option = 1: plot E_x and E_z in separate subplots.
      - Plot option = 2: plot E_y and E_z in separate subplots.
      - Plot option = 3: plot E_x and E_y in separate subplots.
    - Number of plots = 4: Plot the transverse field polarization, E_x, E_y and E_z in separate subplots.
    - Number of plots = 6: Plot the transverse field polarization, E_x, E_y, E_z and the phase of E_x & E_y in separate subplots.

  - Plot option.
  - Convert plot sequence to movie (0/1)?
    * Choose '1' to convert the plot sequence to a movie 'bpm_movie.avi' stored in the same folder as the executable.

- *Material parameters*: define the material properties of the homogeneous layers defined in the mesh file.
  - Enter n_o for layer nr.X: ordinary refractive index.
  - Enter n_e for layer nr.X: extra-ordinary refractive index.
  - (when $n_o \neq n_e$) Enter theta_epsilon for layer nr.X: enter the inclination θ of the crystalline c-axis relative to the y-axis (see Fig. 4(b) on page 9 of the paper).
  - (when $n_o \neq n_e$) Enter phi_epsilon for layer nr.X: enter the azimuth ϕ of the crystalline c-axis relative to the x-axis in the xz-plane (see Fig. 4(b) on page 9 of the paper).

3 Preparing the mesh file

The mesh file has to be generated outside FEAB with an external problem such as GiD (`http://gid.cimne.upc.es`). A trial version of this program limited to 1000 elements is freely available online. The professional version of GiD removes this limit, and is reasonably priced. To create the geometry and mesh file, we refer to the extensive documentation of GiD.
The 2D rectangular structure must be defined in the xz-plane. First the points, lines and surfaces of the geometry are created in consecutive order. Next, a material number is assigned to the different lines and surfaces. For this purpose, a problem type file has to be downloaded. Unzip the following archive 'problem.zip' (`http://www.ee.ucl.ac.uk/~rjames/downloads/problem.zip`) and copy it into the GiD problemtypes directory.
One of the surfaces must be Domain1 (material number 4), while the other surfaces must be Dielectric# (material number 36, 40, 44, etc.). After that you must force the mesh criteria 'Mesh->Mesh Criteria->Mesh->Lines' and select all the lines (the same holds also for the surfaces). At this moment the mesh file can be generated and exported to a file with extension *.msh and renamed afterwards to a *.txt. This file is then used for input in FEAB. Some tips on how to create structures with GiD can be found on the website of our colleagues at University College London:

- `http://www.ee.ucl.ac.uk/~rjames/modelling/constant-order/gid/`
- `http://www.ee.ucl.ac.uk/~rjames/modelling/constant-order/gid/gidtips.htm`

4 A short demonstration

To calculate the polarization rotation of a horizontally polarized gaussian beam with wavelength $\lambda = 1\mu$m in an uniaxial medium with $n_o = 1.5$ and $n_e = 1.6$ ($\theta = \pi/4, \phi = 0$) as an example and make a movie of the beam propagation afterwards, the program can be run as follows:

Command Prompt - FEAB_vs14052009.exe

```
*************************************************************************
*                              F-E-A-B                                  *
*          Finite Element Anisotropic Beam propagation method          *
*                    Optics Express, vol. 17 (11)                       *
*                      Compiled on 14 May 2009                          *
*                                                                       *
*    (C) Liquid Crystals and Photonics group, Ghent University, Belgium *
*                 www.elis.ugent.be/ELISgroups/lcd                      *
*                                                                       *
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*                   Pieter.Vanbrabant@elis.ugent.be                     *
*************************************************************************

Enter mesh file: iso10_090

 Input field parameters
========================
        *Wavelength (um): 1
        *Amplitude Ex: 1
        *Amplitude Ey: 0
        *Consider plane wave (0) or gaussian beam (1)? 1
                -beam center x0: 5
                -beam center y0: 5
                -beam width sigma_x: 1.25
                -beam width sigma_y: 1.25

 Beam propagation parameters
=============================
        *Propagation step (um): 0.25
        *Propagation distance (um): 5
        *Effective index: 1.5

 Plot parameters
=================
        *Use surface plots (0) or contour plots (1)? 0
        *Number of plots (1-2-4-6): 4
        *Convert plot sequence to movie (0/1)? 1

 Material parameters
=====================
        *Enter n_o for layer nr.4:1.5
        *Enter n_e for layer nr.4:1.6
        *Enter theta_epsilon for layer nr.4:pi/4
        *Enter phi_epsilon for layer nr.4:0

 System calculations
=====================
        *Start assembling matrices
        *Calculating beam profile
                =>Elapsed time is 2.083705 seconds.
        *Calculating paraxial propagator
                        -calculating A_bpm
                        -calculating B_bpm
                        -calculating propagator
                =>Elapsed time is 20.523246 seconds.
        *Calculating inhomogeneous wide angle propagator
                        -calculating A
                        -calculating B
                        -calculating A_bpm
                        -calculating B_bpm
                        -calculating propagator
                =>Elapsed time is 107.158640 seconds.

 Beam propagation
==================
0um     0.25um  0.5um   0.75um  1um     1.25um  1.5um   1.75um  2um     2.25um
2.5um   2.75um  3um     3.25um  3.5um   3.75um  4um     4.25um  4.5um   4.75um
5um
                =>Elapsed time is 27.779640 seconds.


 Plotting beam propagation
===========================
0um     0.25um  0.5um   0.75um  1um     1.25um  1.5um   1.75um  2um     2.25um
2.5um   2.75um  3um     3.25um  3.5um   3.75um  4um     4.25um  4.5um   4.75um
5um

***Calculations finished***
```