This project is to illustrate how BPM techniques can be used in modeling semiconductor lasers. The particular type considered here is the vertical external cavity semiconductor laser, or VECSEL.

For our purposes the resonator cavity consists of a flat, optically pumped active mirror and a curved out-coupling mirror. The active mirror contains a set of quantum wells backed by a Bragg mirror. For the laser light, and in the presence of optical pumping beam, the active mirror has respective reflectances higher or lower than unity within and outside of the spot pumped by the optical pump. The light reflected off the active mirror is thus amplified in the center, and partially absorbed outside of the pumped spot (which is typically tens to hundreds of microns in diameter). The gain the beam experiences upon reflection from the active mirror is balanced by the losses in the out-coupling mirror (which are typically a few percent).

The task:

- Implement a wide-angle BPM-based Fox-Li method to calculate modes in a simple optical resonator of a semiconductor disc laser.
- Research the literature to find a suitable parameters to model the laser cavity; dimensions and properties of the out-coupling mirror as well as the properties of the active mirror, typical size of the pumped spot, etc.
- You may choose to simplify the geometry further by imposing an axial symmetry, and then use DHT based BPM. (Note than in reality the pumped spot is either not a perfect circle, or the cavity is more complex)
- Assume that we want to find the laser mode on which it will start to lase, given certain pumped spot size and geometry. At this level, we will neglect that the lasing light will eventually modify (decrease) the gain in the active mirror — assume that the gain profile is "frozen," and use the Fox-Li BPM method to calculate the spatial profile of the lasing mode. In what is a crude assumption, we assume that the lasing starts in the mode which experiences the largest gain — this is the mode we need to calculate.
- Illustrate the properties of the highest-gain mode, in particular how it overlaps with the size of the pumped spot on the active mirror. This overlap is one of the important issues that affect the ultimate performance in VECSELs.

Notes:

We have neglected one aspect of semiconductor lasers that is very important for how such lasers operate. It is the fact that in a semiconductor, gain is always strongly coupled to, or accompanied by a change in the refractive index. What this means is that the active mirror not only modifies the amplitude of the incident beam, but it also imposes a phase perturbation. The amplitude of the latter is a complex function of many variables, including the operating temperature, pump spot, pump power etc. All these effects should and can be included in a sophisticated model. However, the BPM part of the model would be very much similar to the simple concept this project aims to illustrate.

Optional:

Research the so-called alpha factor (or the linewidth enhancement factor) as a simple way to relate (changes in) gain and refractive index, and introduce this effect into your model. Make an illustration of the impact on the lasing mode.

Potentially useful sources:

Exercise package on fractal resonator modes.