Physics 640
October 9, 2007

Project 3 options (all with animations)

1) Direct extension of FDTD 1D to 2D, surface waves, with ABC (Team 1)
How many time instants we will need to initialize? 2, 4, 6?
Please discuss this in your report

2) FDTD1D for EM waves with ABC and implement a least two media, should see reflection and transmission (FDTD can handle any number of media we may have) (Team 3)
3) Use existing FDTD2D with Mur ABC but implement a correct mode for waveguide coupling. You can implement two parallel waveguides into the FDTD code, then feed in a correct mode (Team 2)

What is the waveguide?
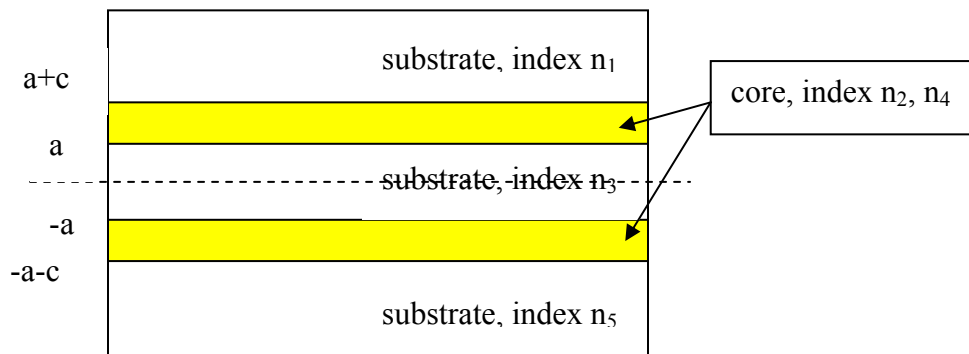
Physics requires only certain modes to exist within the two core layers (continuity of Maxwell equations at the separations). These modes can be solved using Mathematica to simplify a symbolic equation, or we can provide you with the numbers. Once you have the mode, the FDTD2D example code will propagate it properly within the core layers.

$$x > a+c \quad E_y = A_1 e^{-\gamma_1(x-a-c)}$$

$$a < x \le a+c \quad E_y = A_2 \cos k_2\left(x-a-\frac{c}{2}\right) + A_3 \sin k_2\left(x-a-\frac{c}{2}\right)$$

$$-a < x < a \quad E_y = A_4 e^{-\gamma_3 x} + A_5 e^{\gamma_3 x}$$

$$-a-c \le x \le -a \quad E_y = A_6 \cos k_4\left(x+a+\frac{c}{2}\right) + A_3 \sin k_4\left(x+a+\frac{c}{2}\right)$$

$$x < -a-c \quad E_y = A_8 e^{-\gamma_5(x+a+c)}$$

$$\gamma_i = \sqrt{\beta^2 - n_i^2 k_o^2}, \quad (i = 1,3,5)$$
$$k_j = \sqrt{n_j^2 k_o^2 - \beta^2}; \quad (j = 2,4)$$

From the continuity of the fields and its derivatives at the boundaries the following values for the propagation constant along z can be obtained: β_a=7.27e6 and β_s=7.95e6, for the antisymmetric and symmetric modes, respectively. Then the following amplitudes can be obtained (see table below), using these data:

```
freq=3e14;
speedc=3e8;
rk0=2*pi*freq/speedc;
sizex=2.5e-8;
n1=1;
n2=1.5;
```

The width of each waveguide is 10 cells, the separation between them is 10 cells, the substrate is 35 cells each side.

| Antisymmetric β_a=7.27e6	Symmetric β_s=7.95e6
a1 =1	a1 =1
a2 =1.1474	a2 = 1.3754
a3 = -0.2352	a3 = 0.1846
a4 = 0.6990	a4 = 0.5192
a5 =-0.7103	a5 = 0.4850
a6 =-1.1474	a6 = 1.3754
a7 =-0.2352	a7 = -0.1846
a8 = -1	a8 = 1
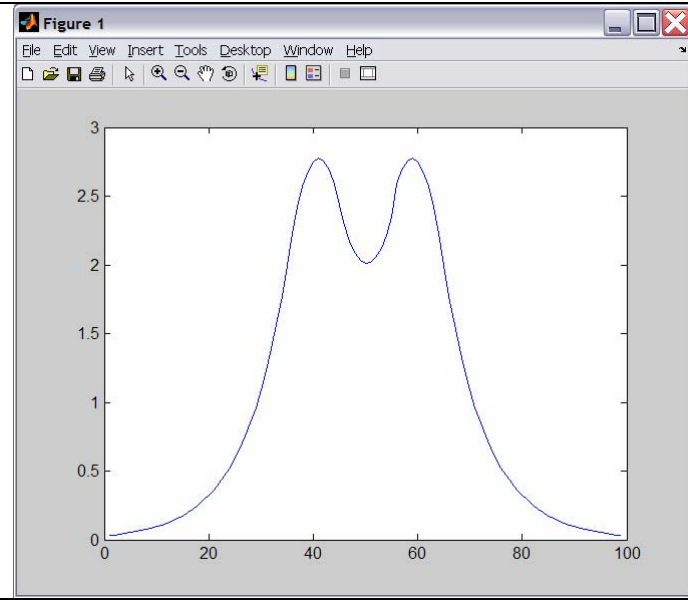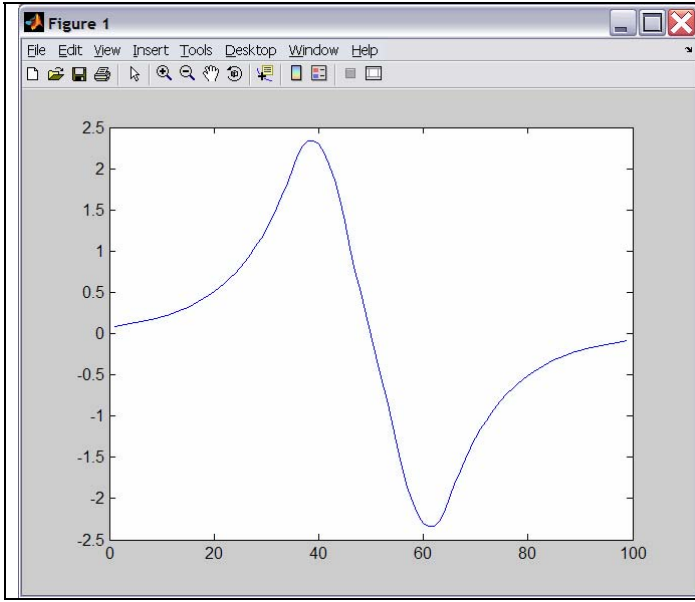
Something like this can be used to define the sum these modes:

```
i1=1:1:35;
ey1=a1*exp(gamma5s*(i1-35).*sizex)+a1a*exp(gamma5a*(i1-35).*sizex);
i2=36:45;
ey2=a2*cos(rk2s*(i2-40).*sizex)+ a3*sin(rk2s*(i2-
40).*sizex)+a2a*cos(rk2a*(i2-40).*sizex)+a3a*sin(rk2a*(i2-40).*sizex);
i3=46:55;
ey3=a4*exp(-gamma5s*(i3-50).*sizex)+ a5*exp(gamma5s*(i3-
50).*sizex)+a4a*exp(-gamma5a*(i3-50).*sizex)+ a5a*exp(gamma5a*(i3-
50).*sizex);
i4=56:65;
ey4=a6*cos(rk2s*(i4-60).*sizex)+a7*sin(rk2s*(i4-
60).*sizex)+a6a*cos(rk2a*(i4-60).*sizex)+a7a*sin(rk2a*(i4-60).*sizex);
i5=66:99;
ey5=a8*exp(-gamma5s*(i5-65).*sizex)+a8a*exp(-gamma5a*(i5-65).*sizex);
i=[i1 i2 i3 i4 i5];
ey=[ey1 ey2 ey3 ey4 ey5];
```
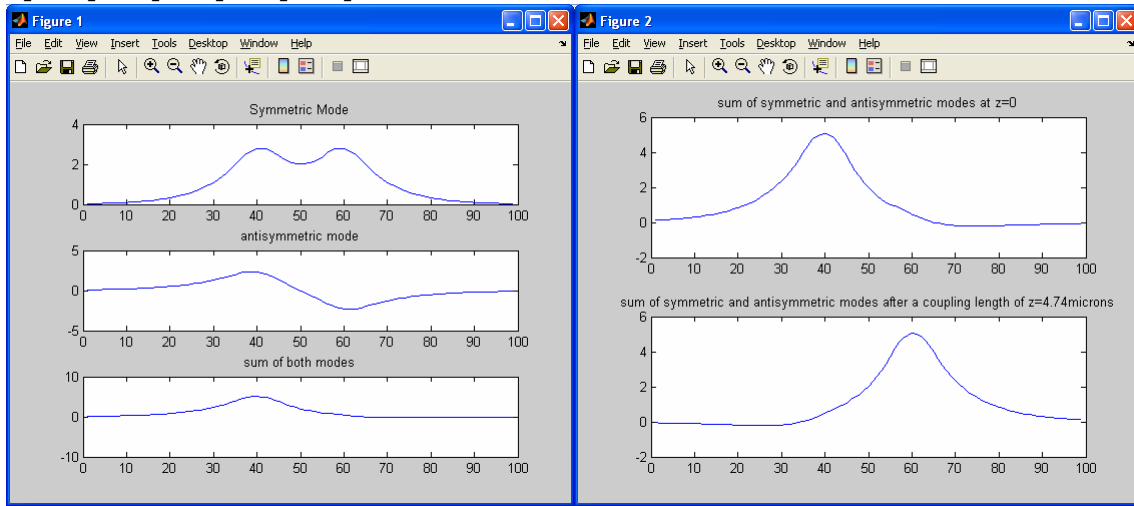
After a coupling length of z=4.74microns, the sum mode is coupled into the other waveguide as seen in the figure above.