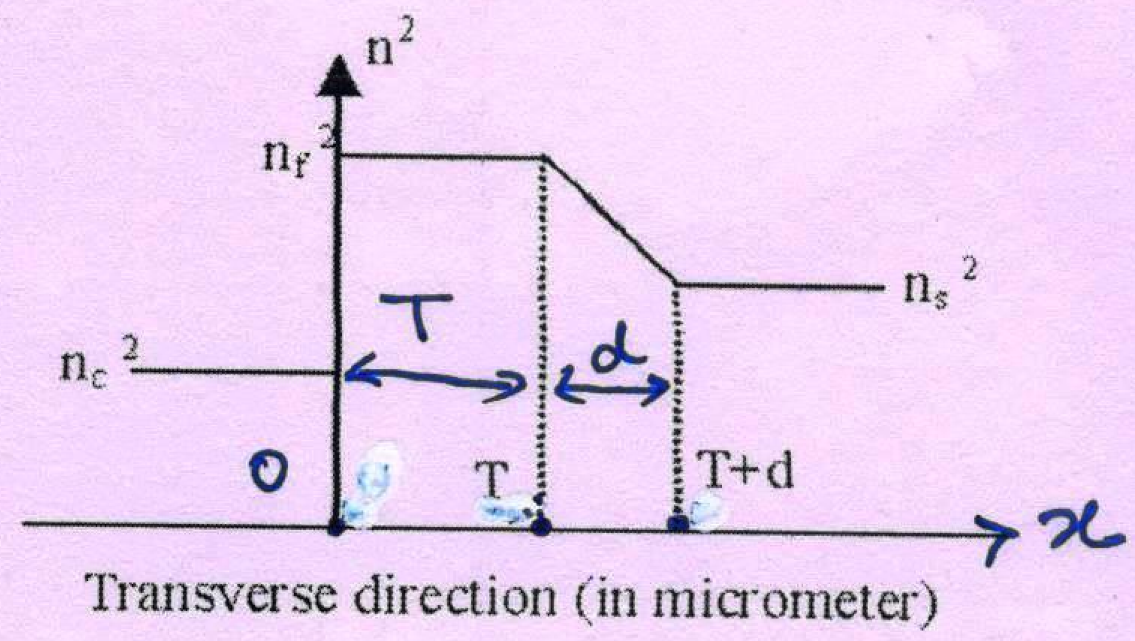
Four-layer asymmetric linearly-graded index planar waveguide

Next, we consider a multilayered planar waveguide with linearly varying RI in each layer which is in general asymmetric in nature. Such waveguides find use in guiding beams from CO_2 laser having wavelength ~10.6 μm. Using our mode-calculation algorithm, we also determine the guided modes of this waveguide and compare the results with the reported one.

$$
\begin{aligned}
n^2(x) &= n_c^2 && x \le 0 \\
&= n_f^2 && 0 \le x \le T \\
&= n_f^2\left(1-2\Delta\frac{x-T}{d}\right) \quad \Delta=\frac{n_f^2-n_s^2}{2n_f^2} && T \le x \le T+d \\
&= n_s^2 && x \ge T+d
\end{aligned}
$$



The RI distribution of asymmetric multilayered planar waveguide

Following the usual notations, we express the refractive index profile of the structure as,

The corresponding RI profile is plotted in Fig 6. In [6], three distinct parameters were introduced, we have intentionally kept these parameters unchanged for straight comparison and those are given as:

$$
a_E=\frac{n_s^2-n_c^2}{n_f^2-n_s^2} \qquad V=k_0(T+d)\sqrt{(n_f^2-n_s^2)} \qquad b=\frac{\beta^2-k_0^2 n_s^2}{k_0^2(n_f^2-n_s^2)}
$$

The physical solution of the scalar Helmholtz equation for different layers of such a waveguide can be expressed as

$$
\begin{aligned}
\psi(x) &= A e^{\gamma_c x} && x \le 0 \\
&= B\cos ux + C\sin ux && 0 \le x \le T \\
&= E\,A_i(P) + F\,B_i(P) && T \le x \le T+d \\
&= G e^{-\gamma_s x} && x \ge T+d
\end{aligned}
$$

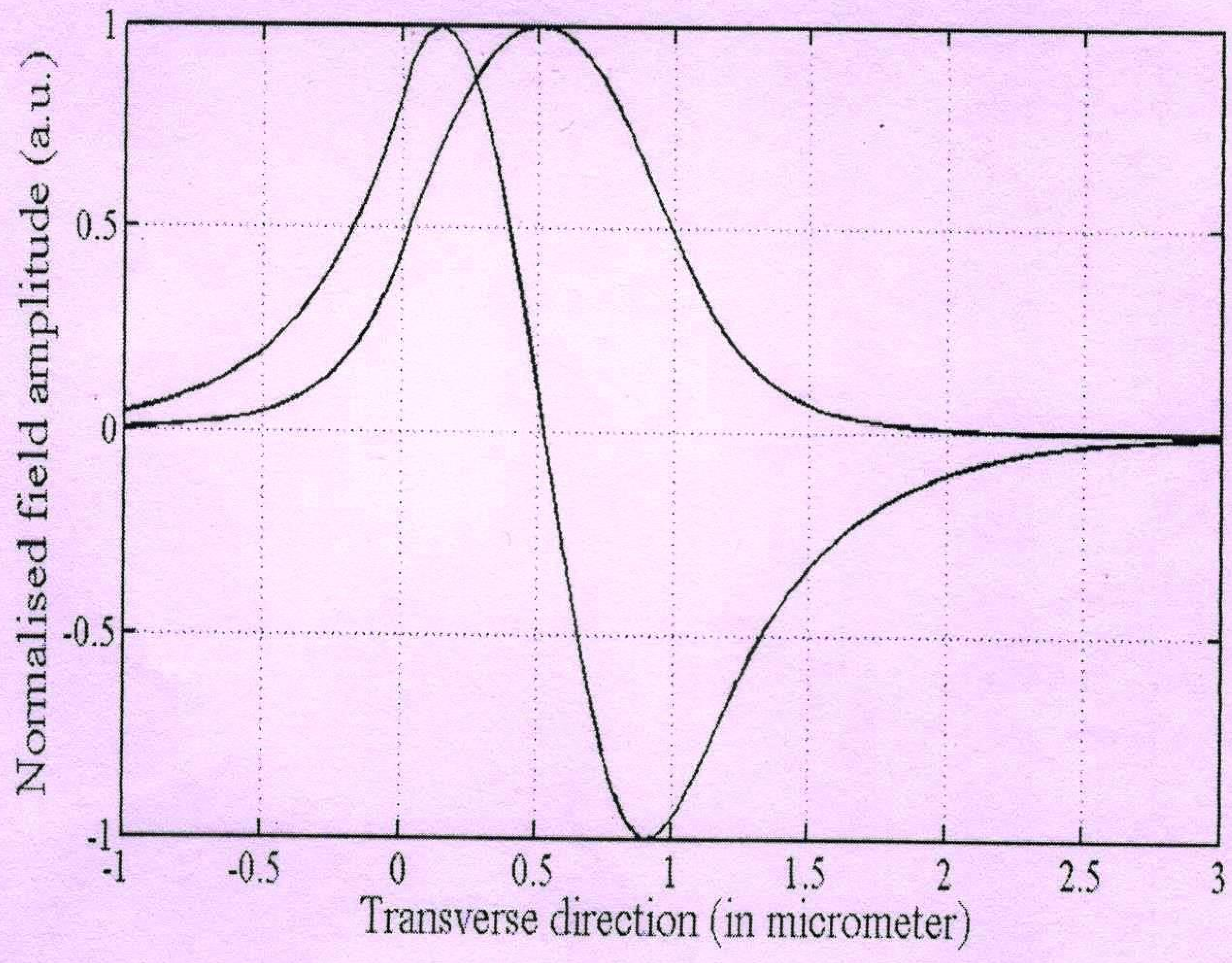
$$
\text{where} \quad \gamma_c^2=\beta^2-k_0^2 n_c^2,\ u^2=k_0^2 n_c^2-\beta^2, D=\left(2k_0^2 n_f^2\frac{\Delta}{d}\right)^{2/3}, C^2=k_0^2 n_f^2-\beta^2+2k_0^2 n_f^2\Delta\frac{T}{d}
$$

$$
\gamma_s^2=\beta^2-k_0^2 n_s^2,\ P=\frac{D^{3/2}x-C^2}{D}
$$

Now, to represent a mode, we consider the electric field and its normal derivative to be continuous across every interface of the waveguide. By putting all these continuity conditions, we have obtained a co-efficient matrix. For mode solution, the determinant of this matrix must be zero, *i.e.*

$$
\begin{vmatrix}
1 & -1 & 0 & 0 & 0 & 0 \\
\gamma_c & 0 & -u & 0 & 0 & 0 \\
0 & \cos(uT) & \sin(uT) & -A_i(P)_{=T} & -B_i(P)_{=T} & 0 \\
0 & -u\sin(uT) & u\cos(uT) & -A_i'(P)_{=T} & -B_i'(P)_{=T} & 0 \\
0 & 0 & 0 & A_i(P)_{=T+d} & B_i(P)_{=T+d} & -e^{-\gamma_s(T+d)} \\
0 & 0 & 0 & A_i'(P)_{=T+d} & B_i'(P)_{=T+d} & \gamma_s e^{-\gamma_s(T+d)}
\end{vmatrix} = 0
$$

The modal field distribution for this type of waveguides for the first two modes (*m=0* and *m=1*), using two different values of a_E and λ, have been plotted and are shown in the **Figure** below.



Field distribution of asymmetric planar waveguides for d/T=0.5, λ=10.6μm and a_E=0.125