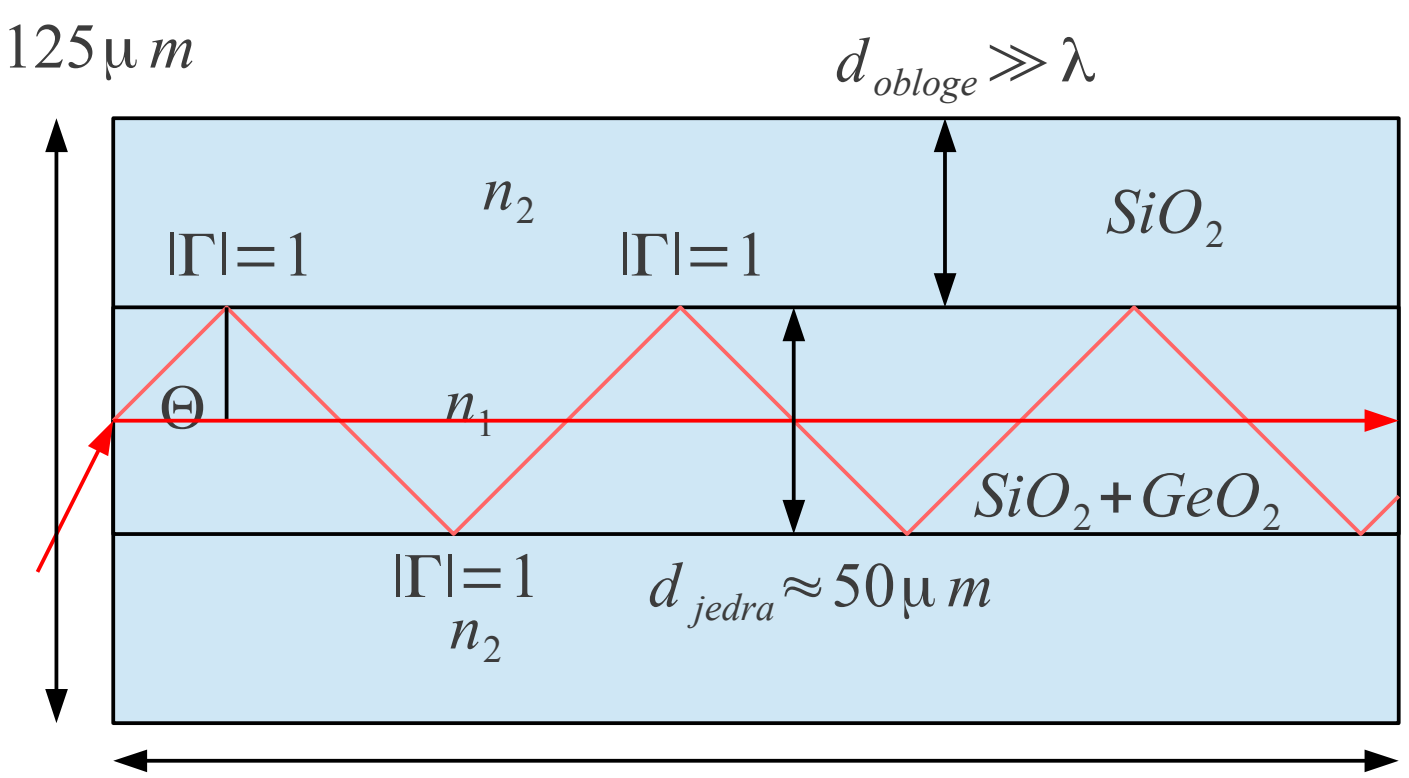
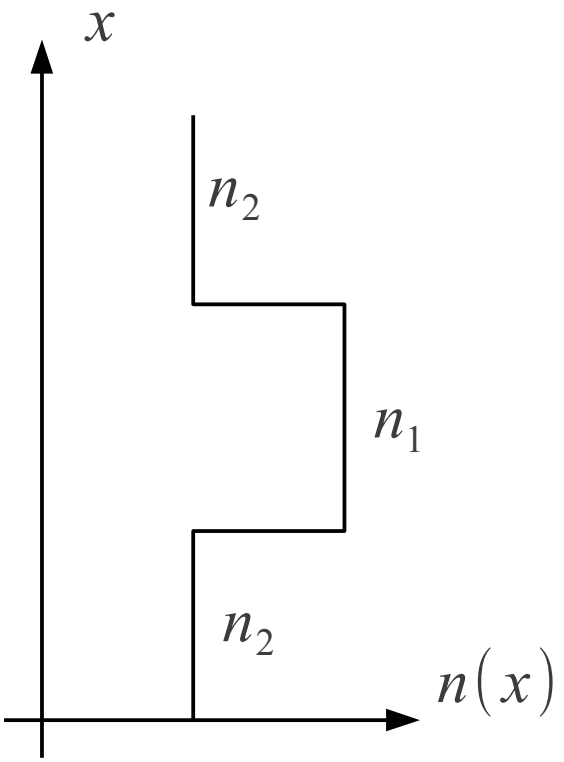
Optične komunikacije

Predavanje 4:

Rodovi v dielektričnem valovodu





$$\pi/2 > \Theta > \Theta_m = \arcsin\left(n_2/n_1\right)$$

Stopničasti lomni lik

$$\Delta = \frac{n_1 - n_2}{n_1} \approx 0.01 \ll 1$$

Step-index profile

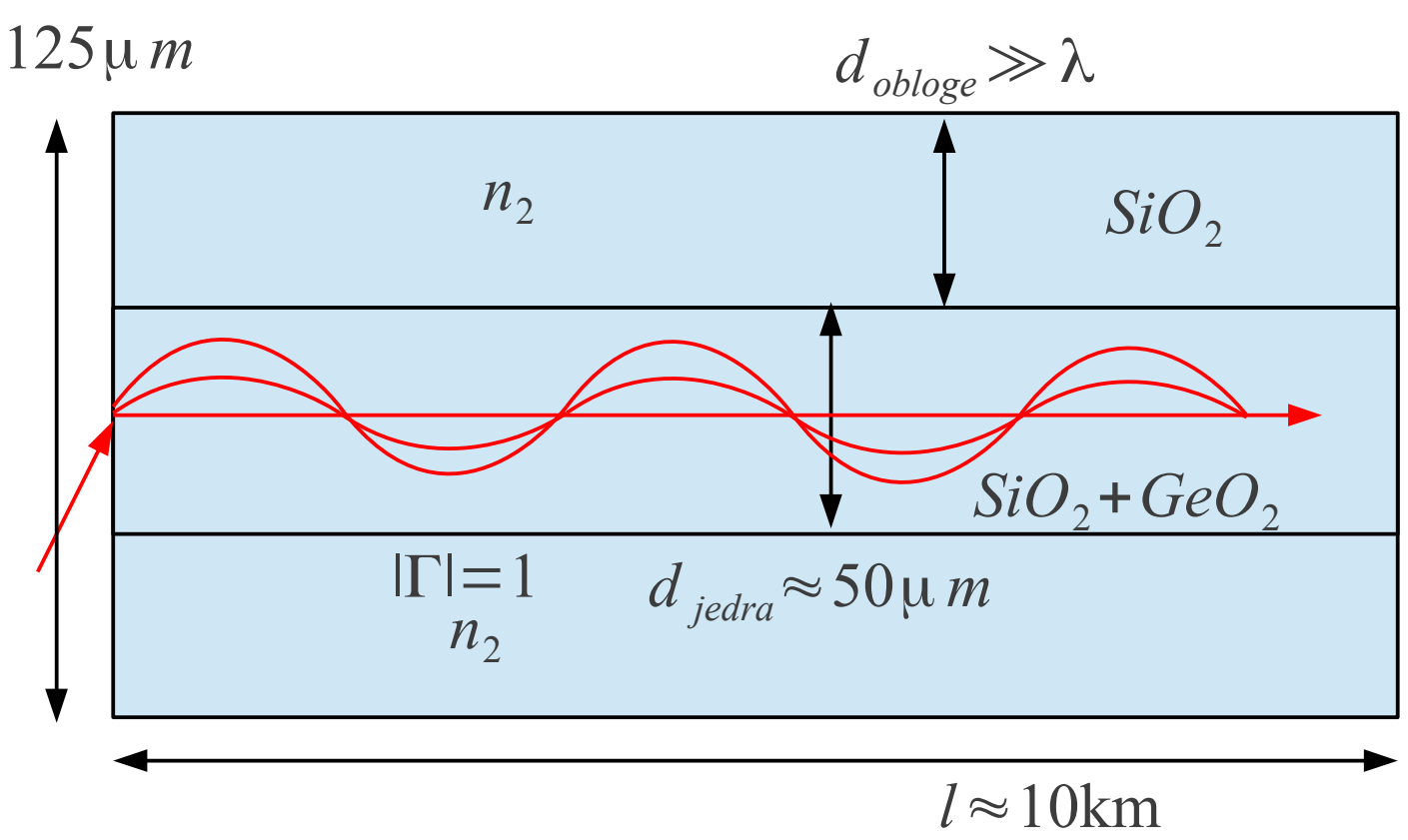
$$\Delta t \approx \frac{l}{c_0} \cdot n_1 \cdot \Delta \approx 0.5\,\mu s$$

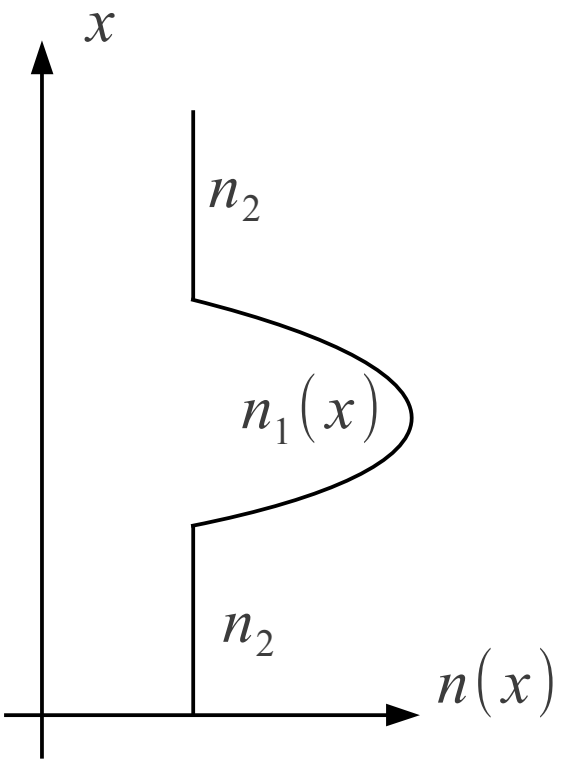
SI

$$NA = \sqrt{n_1^2 - n_2^2} \approx 0.2$$

$$NA \approx n_1 \sqrt{2\Delta}$$

$$\eta \approx \frac{NA^2}{4} \approx 0.01$$





$$\Delta = \frac{n_{1\max} - n_2}{n_{1\max}} \approx 0.01 \ll 1$$

$$NA_{max} = \sqrt{n_{1\max}^2 - n_2^2} \approx 0.2$$

$$\Delta t \approx \frac{l}{c_0} \cdot n_1 \cdot \Delta^2 \approx 0.005\,\mu s = 5\text{ns} \rightarrow C \approx 66\text{Mbit}/s$$

Gradientni lomni lik

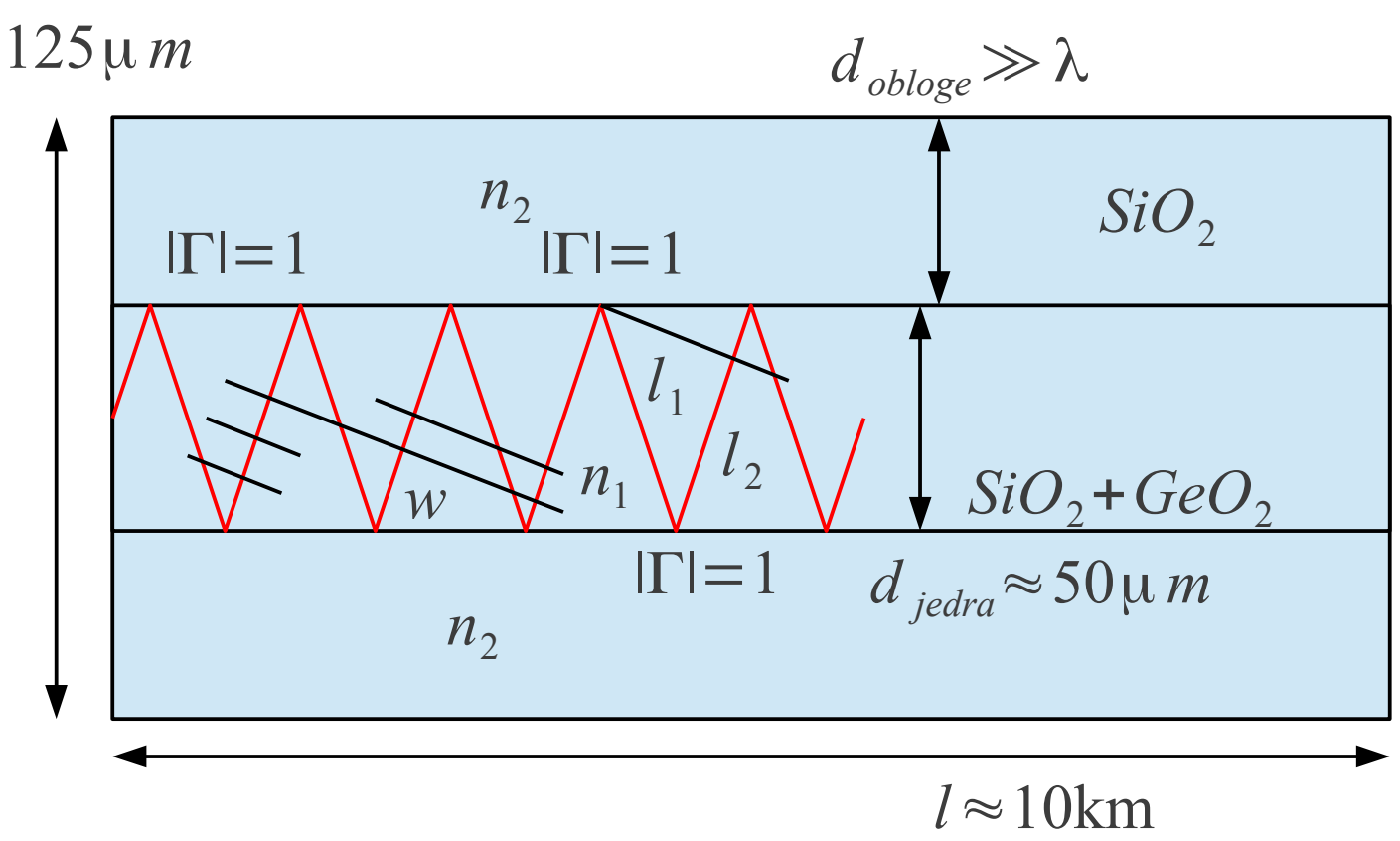
Graded-index profile

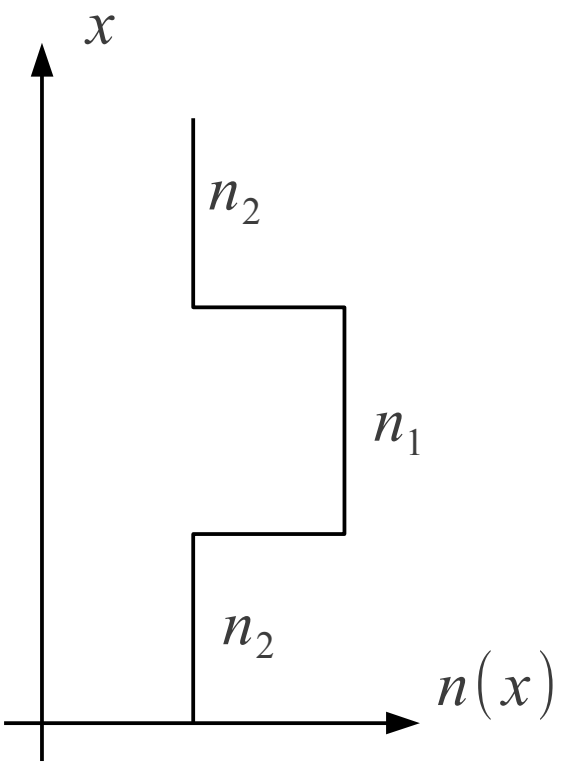
GI

ITU G.651

~1980

$\lambda_0 = 850\text{nm}$ $C \approx 34\text{Mbit}/s$





$\Theta = ?$

$\Delta\Theta \cdot w = konst.$

$w \to \infty$

$\Delta\Theta \to 0$

$$l_1 = \frac{d_{jedra}}{\cos\Theta}$$

$$l_2 = l_1 \cdot \cos 2\Theta$$

$$\Sigma l \cdot k_1 - 2\phi = m \cdot 2\pi$$

$$\Sigma l = l_1 + l_2 = \frac{d_{jedra}}{\cos\Theta}(1+\cos 2\Theta) = \frac{d_{jedra}}{\cos\Theta} \cdot 2 \cdot \cos^2\Theta = d_{jedra} \cdot 2 \cdot \cos\Theta$$

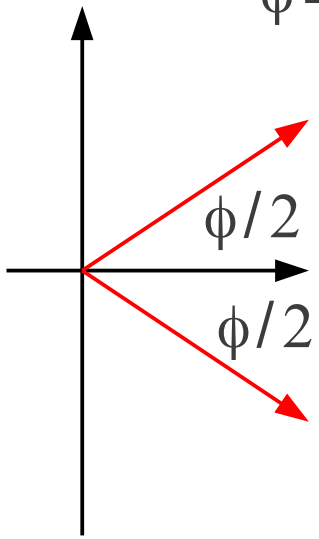
$$\textit{Popolni odboj}: \quad \Gamma = \frac{a - jb}{a + jb}$$

$$a_{TE} = \cos\Theta$$

$$a_{TM} = (n_2/n_1)^2 \cos\Theta$$

$$b = \pm\sqrt{\sin^2\Theta - (n_2/n_1)^2}$$

$$\phi = 2\arctan(b/a)$$



$$\cos\Theta_m = \sqrt{1 - \sin^2\Theta_m}$$

$$\sin\Theta_m = n_2/n_1$$

$$\Sigma l \cdot k_1 - 2\phi = m \cdot 2\pi$$

$$d_{jedra} \cdot 2 \cdot \cos\Theta \cdot k_1 - 2\phi = m \cdot 2\pi$$

$$d_{jedra} \cdot \cos\Theta \cdot k_1 - \phi = m \cdot \pi$$

$$0 < \cos\Theta < \cos\Theta_m$$

Transcendentna enačba!!!!!! $\phi(\Theta)$

$$0 < \phi(\Theta) < \pi$$

$$m = 0,1,2,3,4,5,6.... \equiv \textit{celo število}$$

$$k_1 = n_1 \cdot k_0 = \frac{n_1 \cdot \omega}{c_0} = n1 \cdot 2\frac{\pi}{\lambda_0}$$

$$V = k_0 n_1 d_{jedra} \cos\Theta_m = k_0 d_{jedra} NA$$

$n_2 = 1$

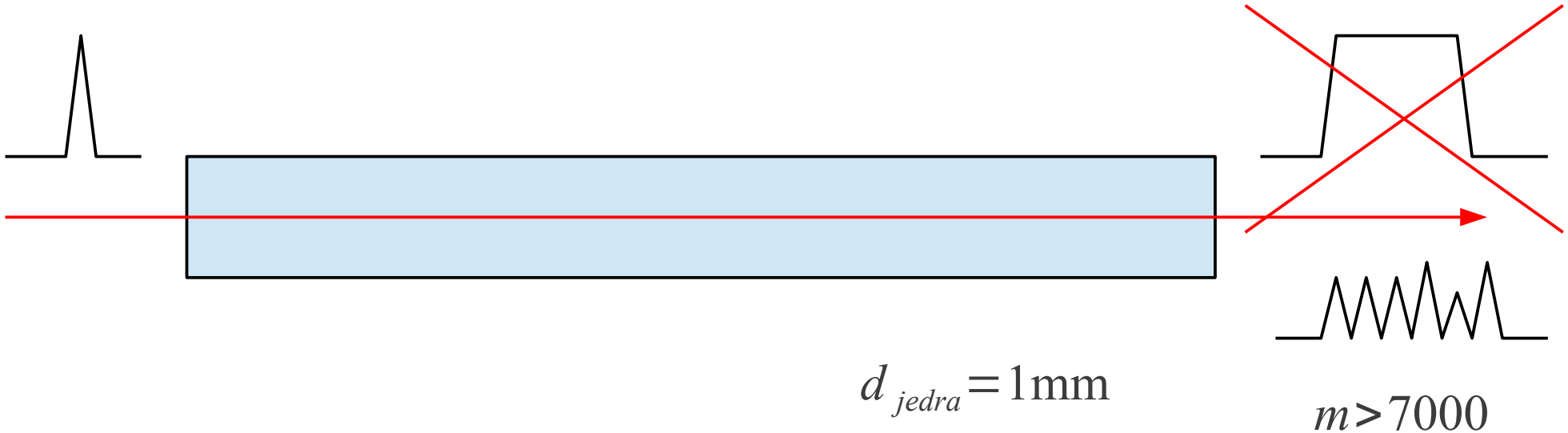
$$V = k_0 d_{jedra} NA = 2\frac{\pi}{\lambda_0} d_{jedra} NA \approx 11000$$

$\lambda_0 = 633\text{nm}$ $\quad NA = \sqrt{1.5^2 - 1}$ $\quad m < \frac{V}{\pi} \approx 3533$

$m = 0,1,2,3,4,5,6 \ldots 3533$

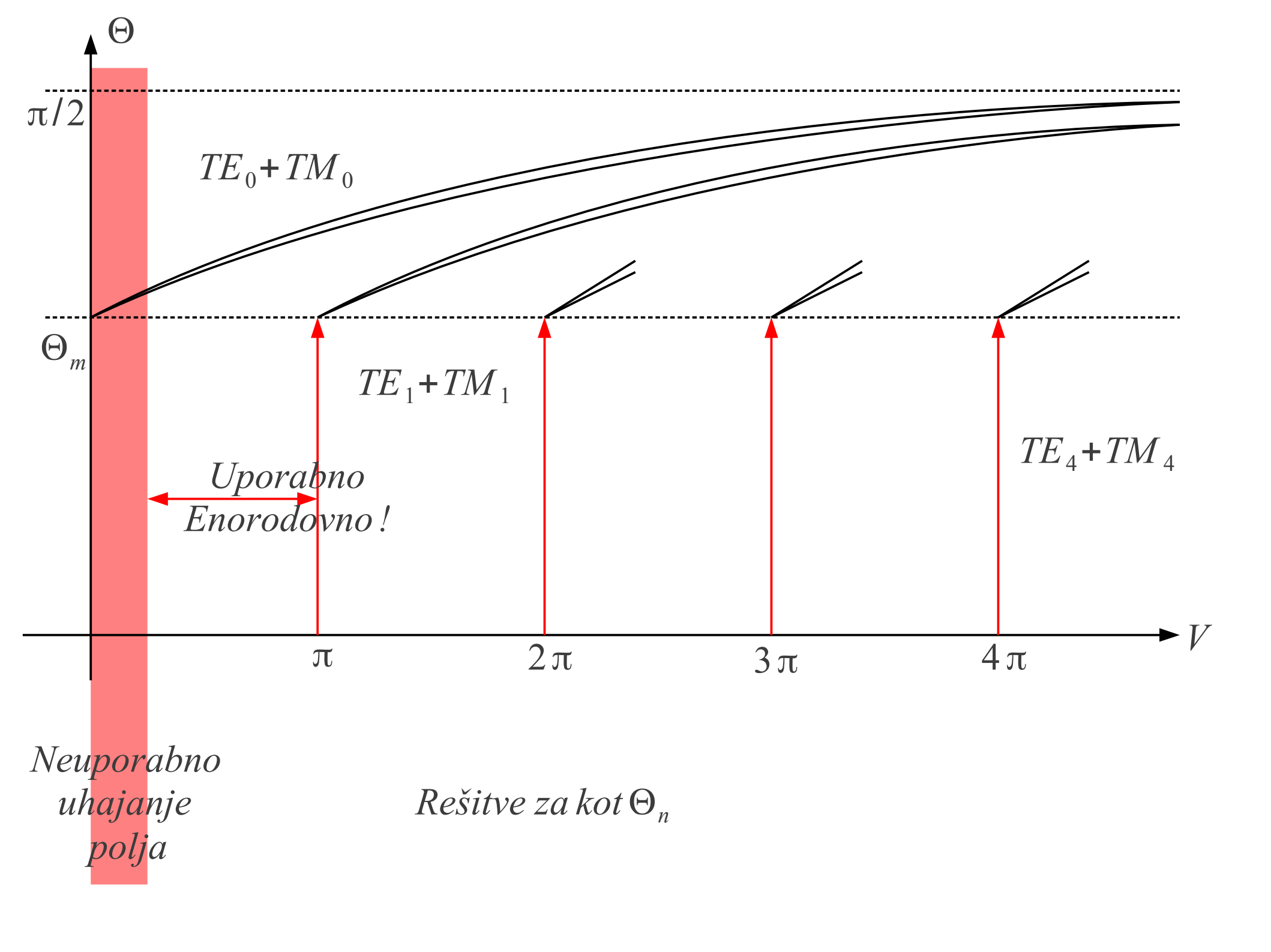
$Rešitve: \Theta_{TE0}, \Theta_{TE1}, \ldots . \Theta_{TE3533}$

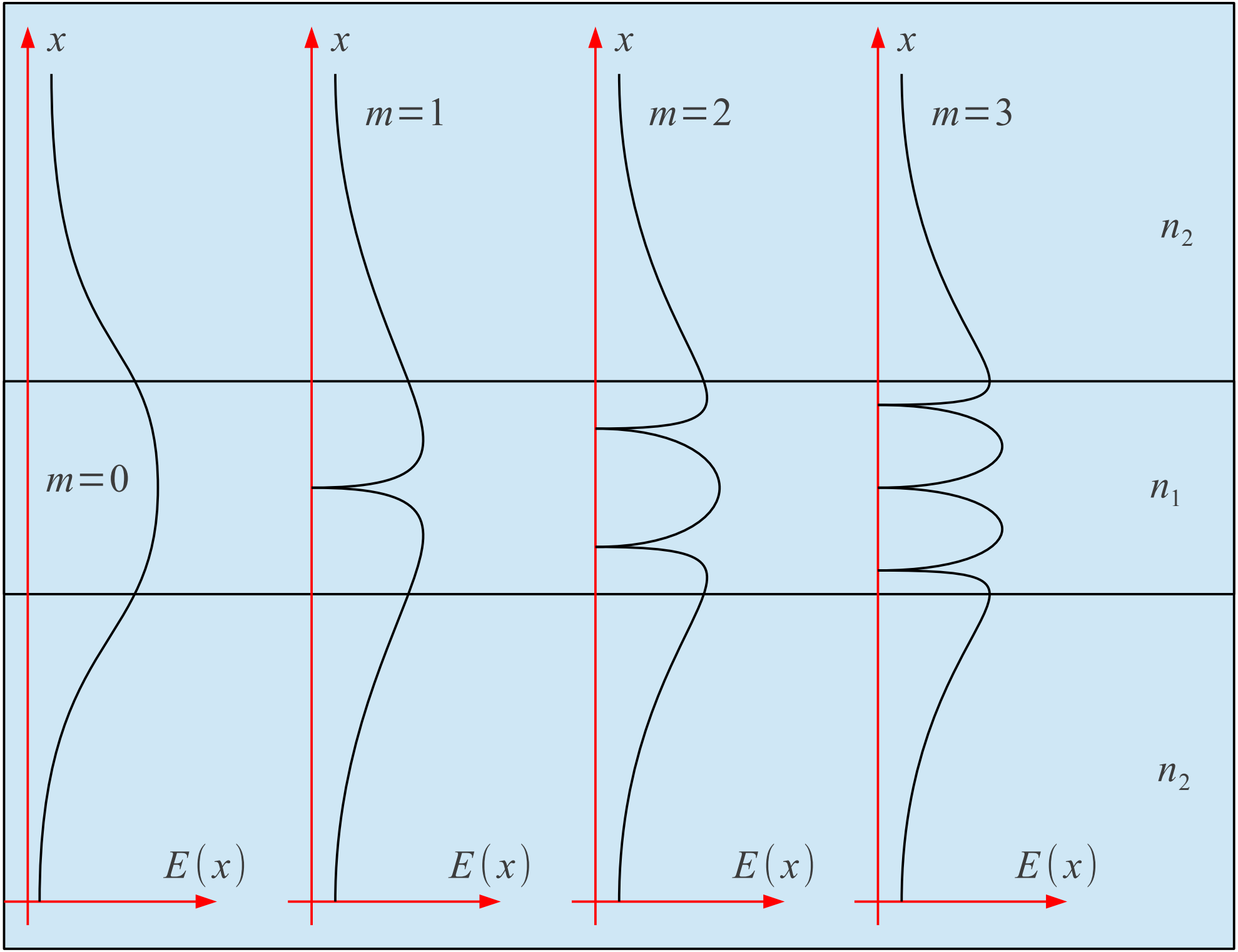
$Rešitve: \Theta_{TM0}, \Theta_{TM1}, \ldots . \Theta_{TM3533}$

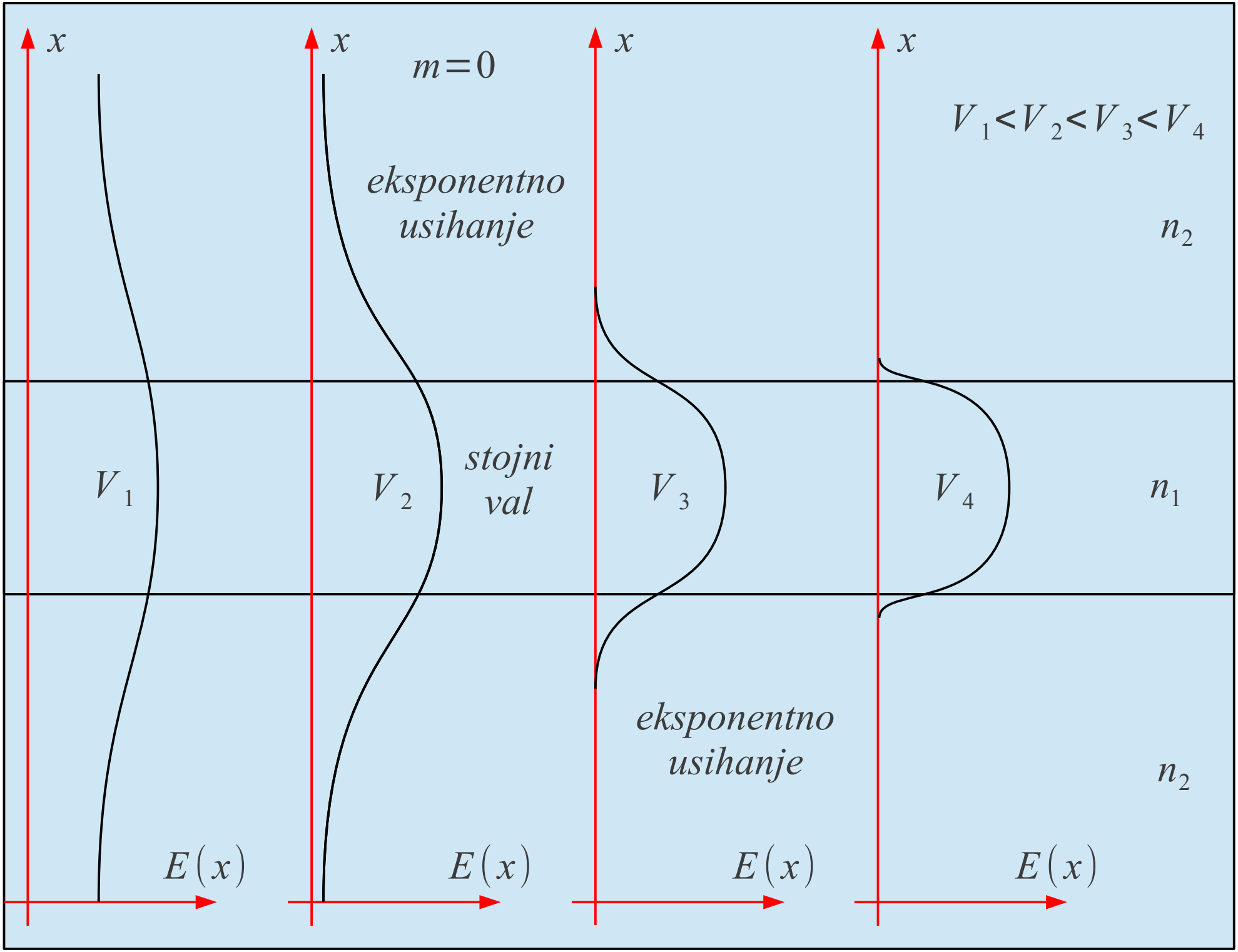


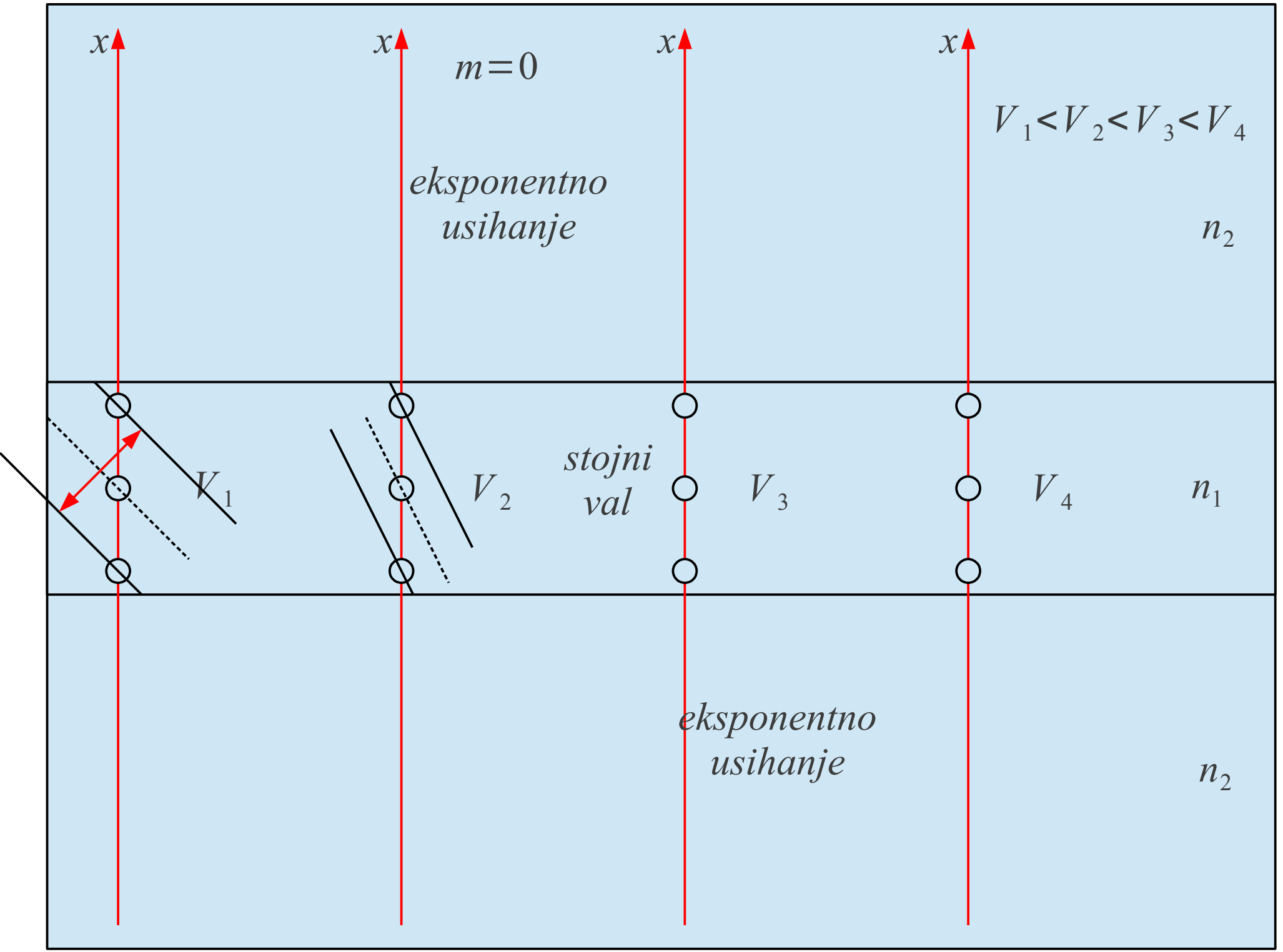
$d_{jedra} = 1\text{mm}$

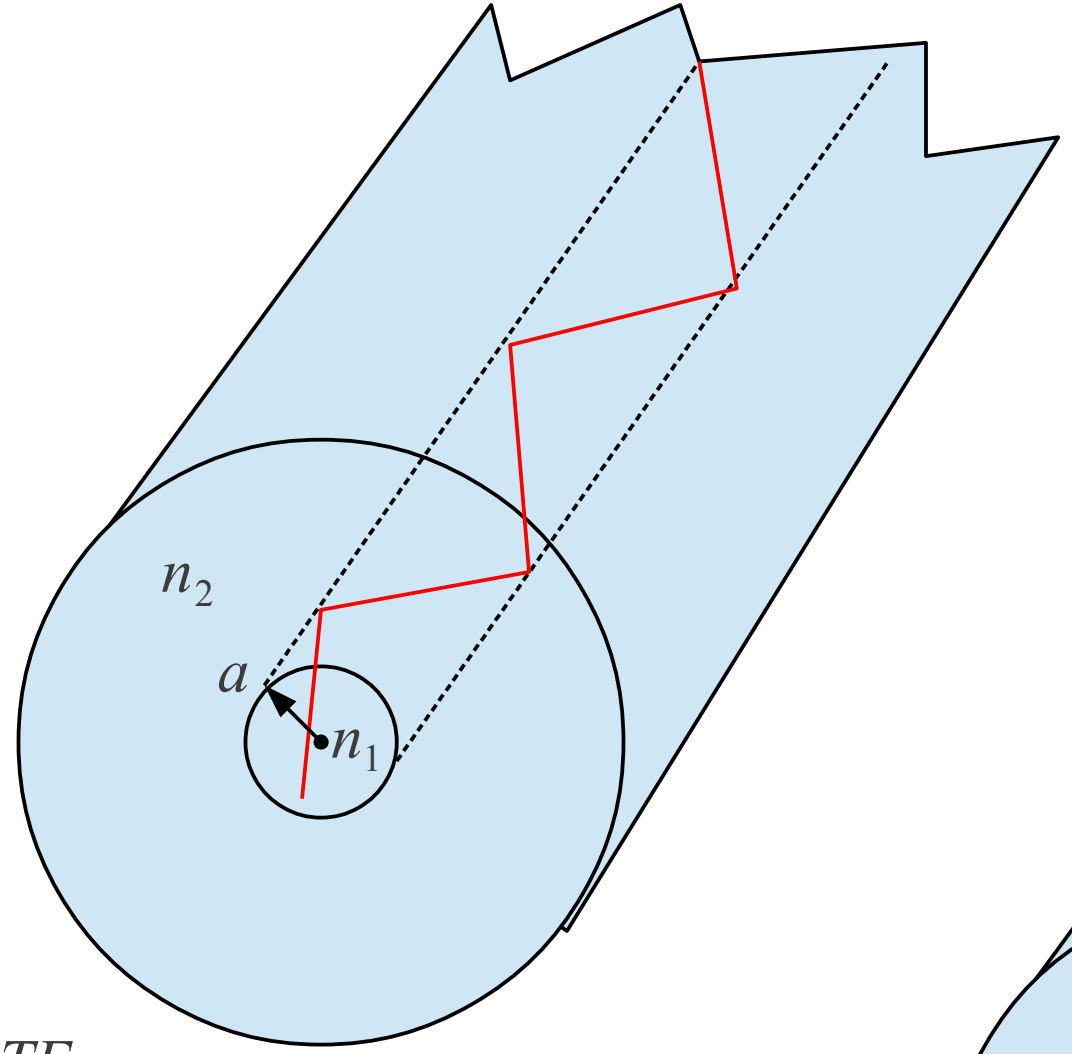
$m > 7000$


Θ
π/2
$TE_0 + TM_0$
Θ_m
$TE_1 + TM_1$
$TE_4 + TM_4$
Uporabno
Enorodovno !
π
2π
3π
4π
V
Neuporabno
uhajanje
polja
Rešitve za kot Θ_n


x
x
x
x
m=1
m=2
m=3
n2
m=0
n1
n2
E(x)
E(x)
E(x)
E(x)

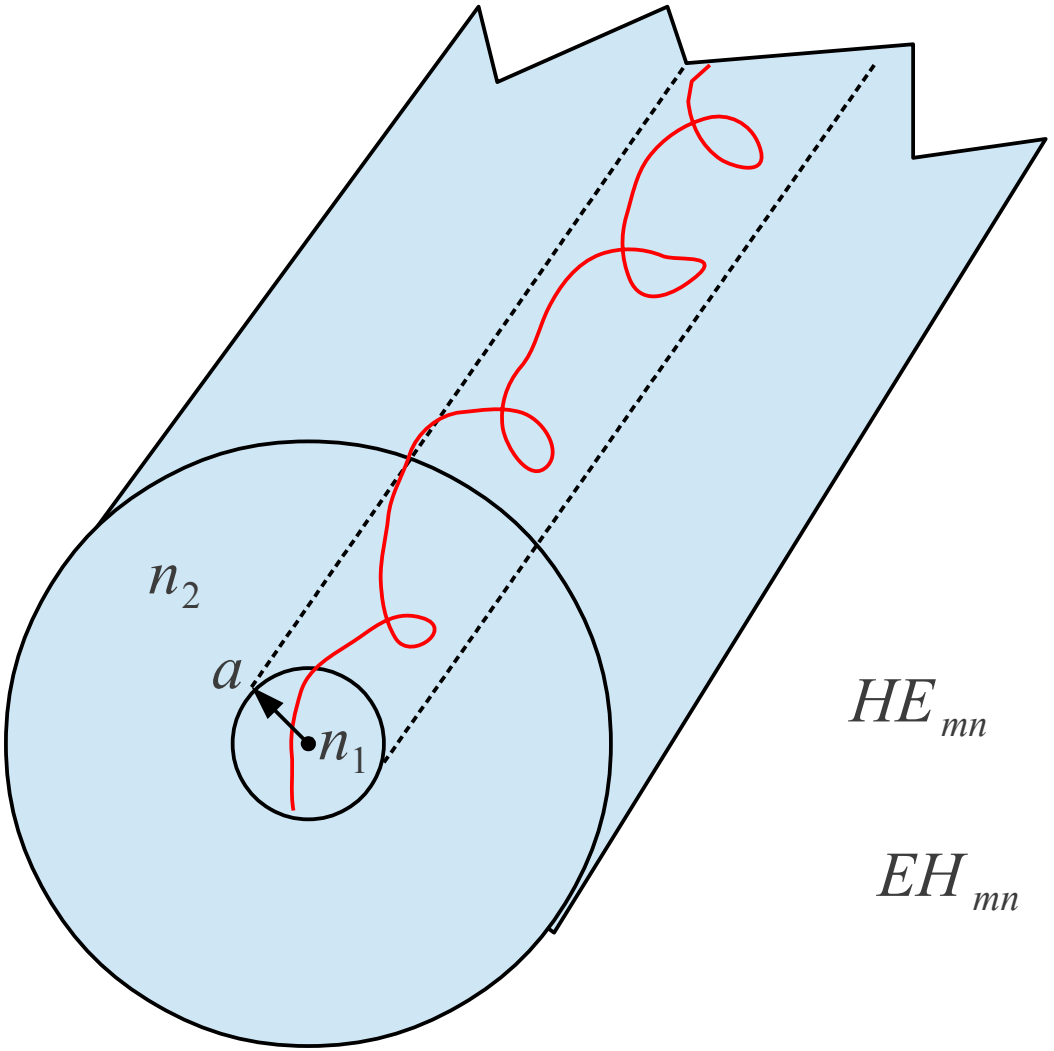

x
x
x
x
m=0
V1<V2<V3<V4
eksponentno
usihanje
n2
V1
V2
stojni
val
V3
V4
n1
eksponentno
usihanje
n2
E(x)
E(x)
E(x)
E(x)


x
x
x
x
m = 0
V1 < V2 < V3 < V4
eksponentno
usihanje
n2
V1
V2
stojni
val
V3
V4
n1
eksponentno
usihanje
n2



Normirana frekvenca

$$V = k_0 a\, NA$$



TE_{mn}

TM_{mn}

HE_{mn}

EH_{mn}

$a \equiv$ *polmer jedra !*

Valjne koordinate $(\rho, \phi, z) \rightarrow$ *Valjne funkcije !*

$$\Delta E_Z + k^2 E_Z = 0 \qquad \Delta H_Z + k^2 H_Z = 0$$

Normirana frekvenca
$V = k_0 a\, NA$

Jedro: *stojni val*

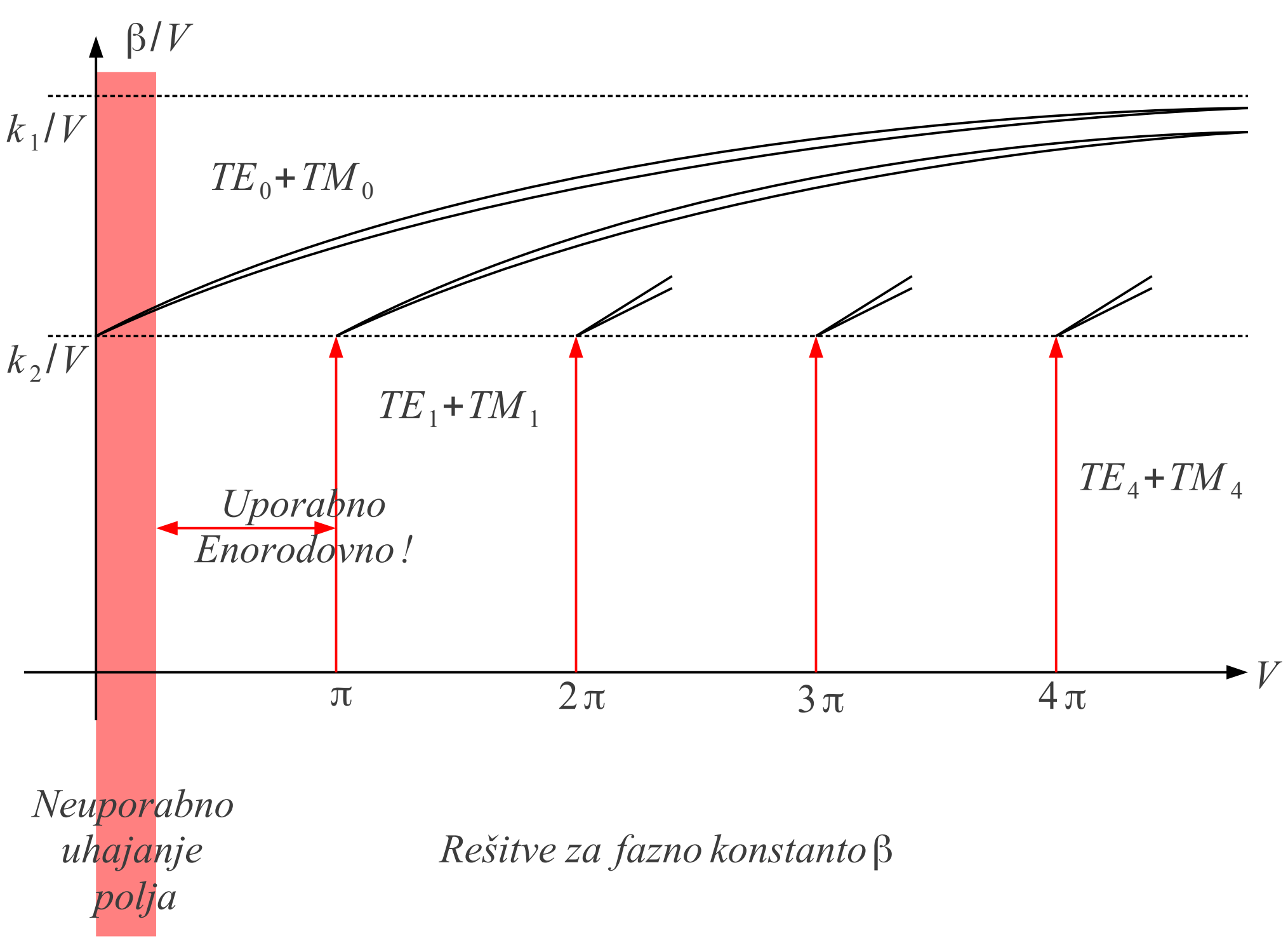
$$E_Z = C_{jedro} J_m(k_\rho \rho) \begin{bmatrix} \cos m\phi \\ \sin m\phi \end{bmatrix} e^{-j\beta z}$$

Obloga: *eksponentno usihanje*

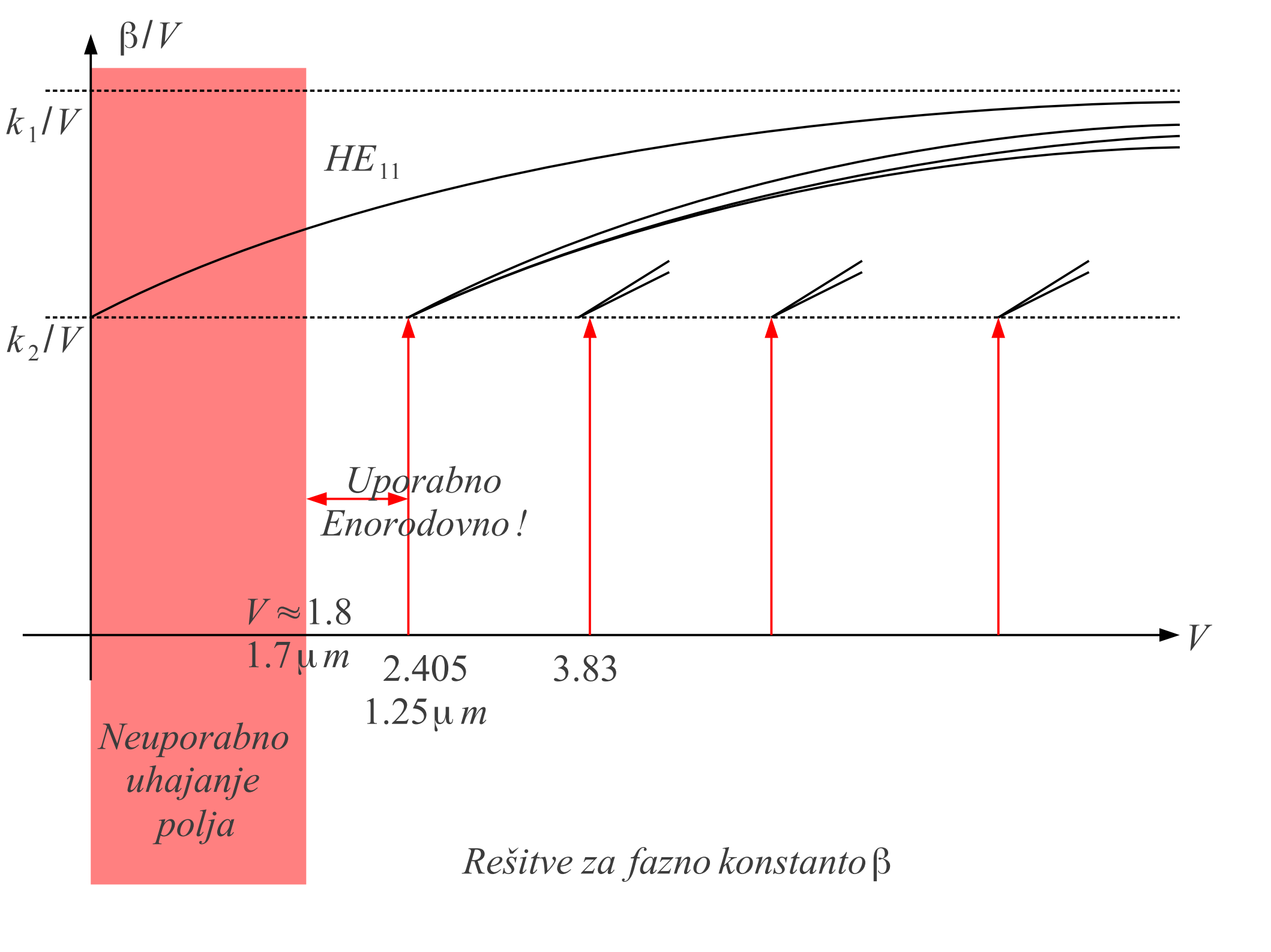
$$E_Z = C_{obloga} K_m(k_\rho \rho) \begin{bmatrix} \cos m\phi \\ \sin m\phi \end{bmatrix} e^{-j\beta z}$$

$E_Z, H_Z \rightarrow E_\rho, E_\phi, H_\rho, H_\phi$

$\beta \equiv$ *fazna konstanta*

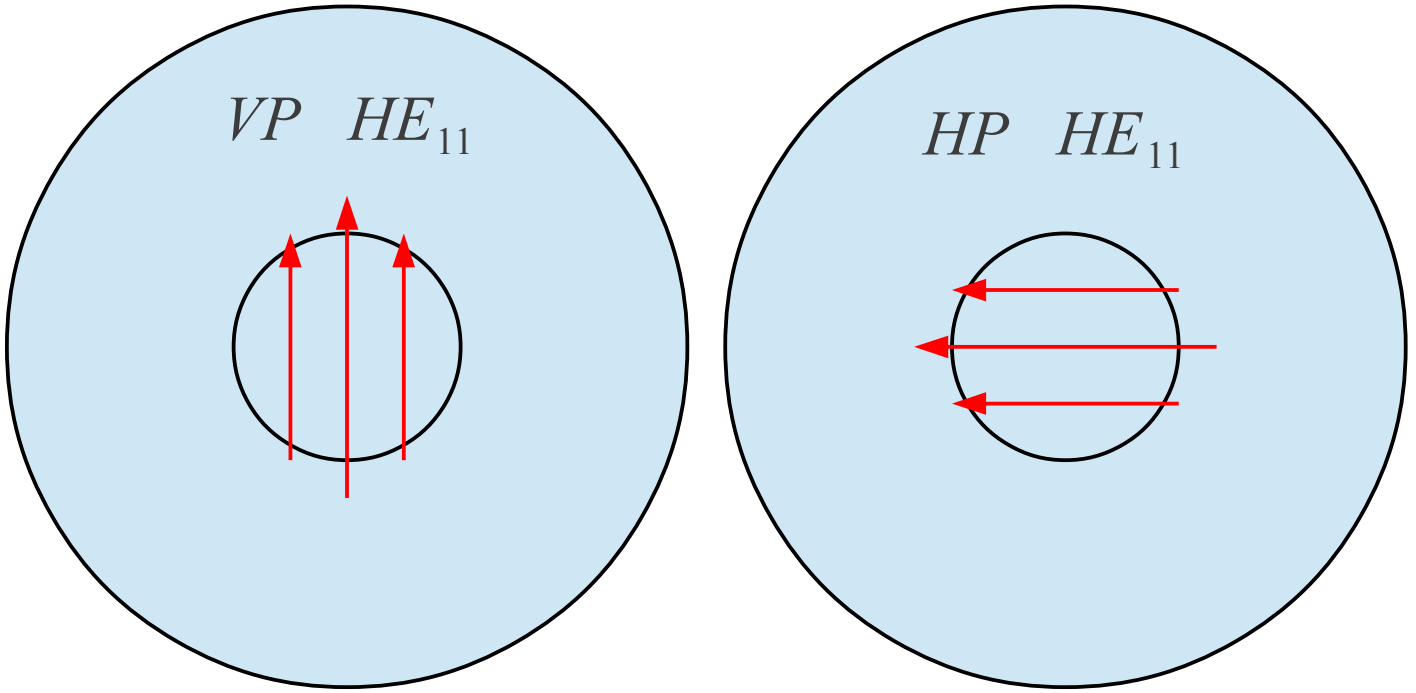


Rešitve za fazno konstanto β



Rešitve za fazno konstanto β

ITU G.652x



$NA \approx 0.1 \qquad a \approx 4.5\,\mu m$

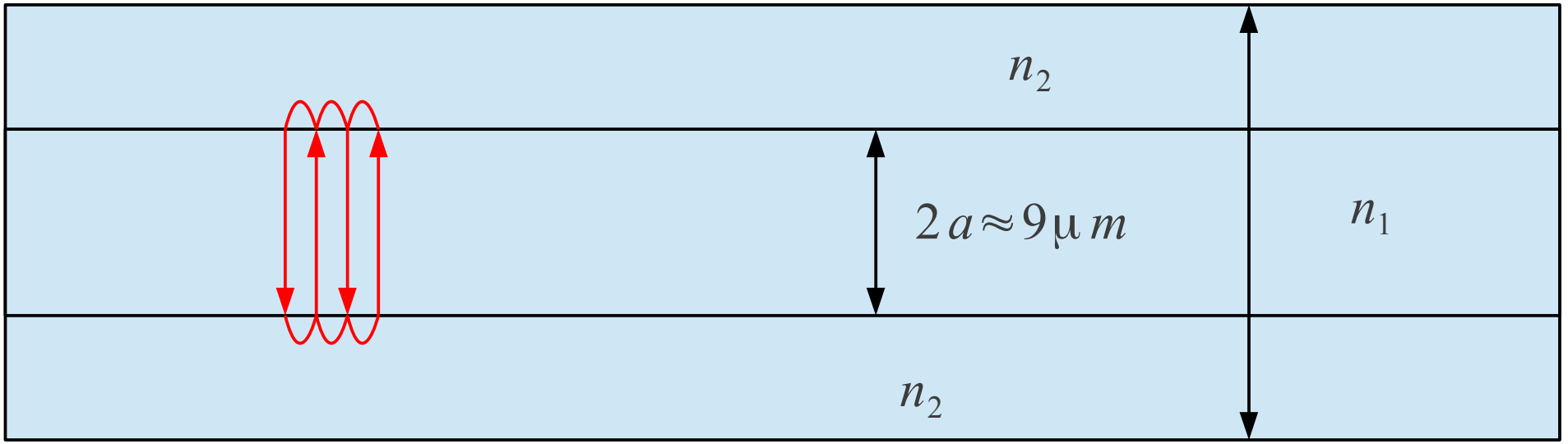
$$V = 2.405 = \frac{2\pi}{\lambda_0} a\, NA$$

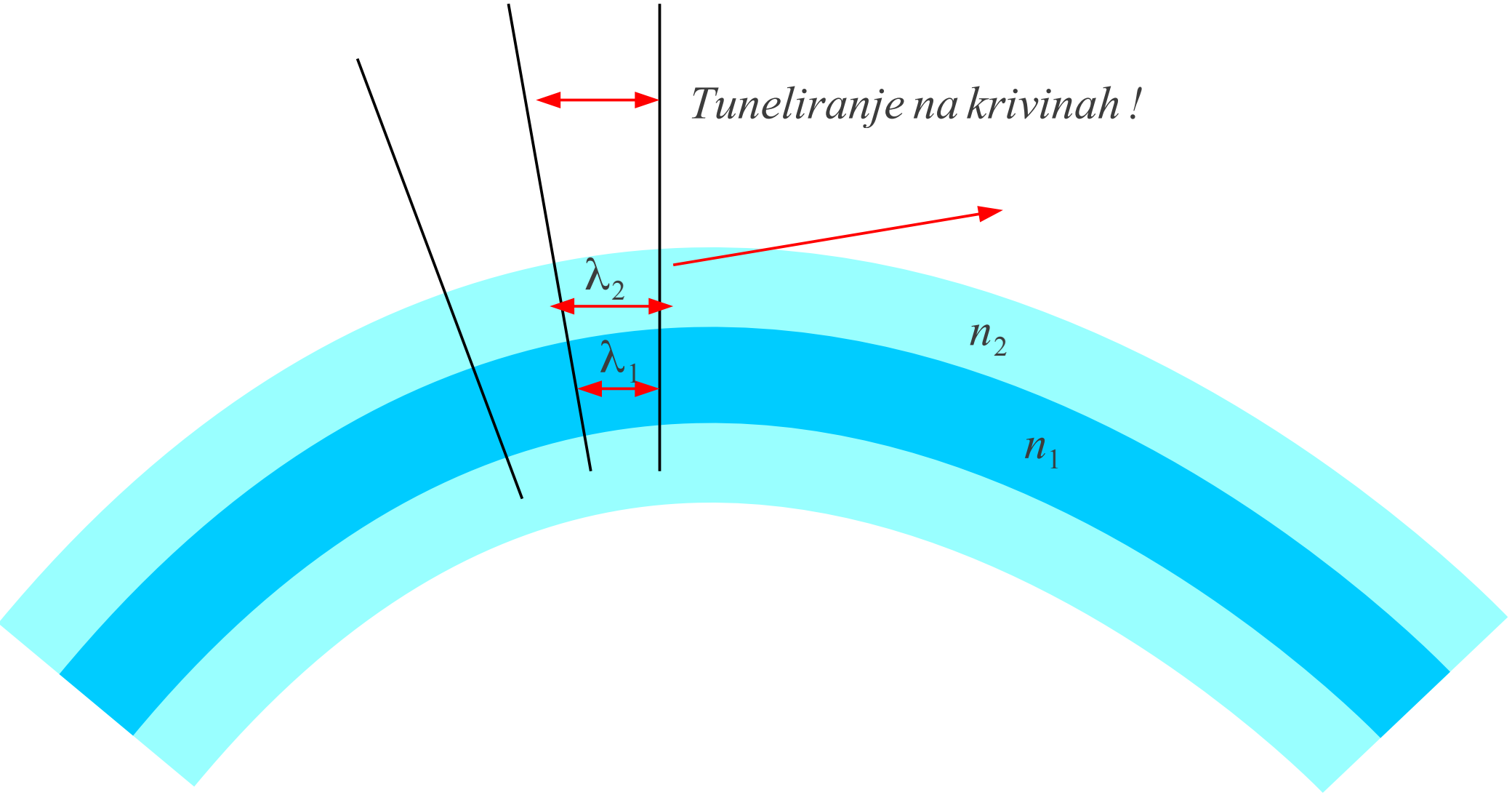
$$\lambda_0 = \frac{2\pi a\, NA}{2.405} \approx 1.2\,\mu m$$

Uporabno:
$1.3\,\mu m \ldots 1.55\,\mu m$

HE_{11} *v šibkolomnem vlaknu*

$125\,\mu m$




Tuneliranje na krivinah !
λ2
λ1
n2
n1