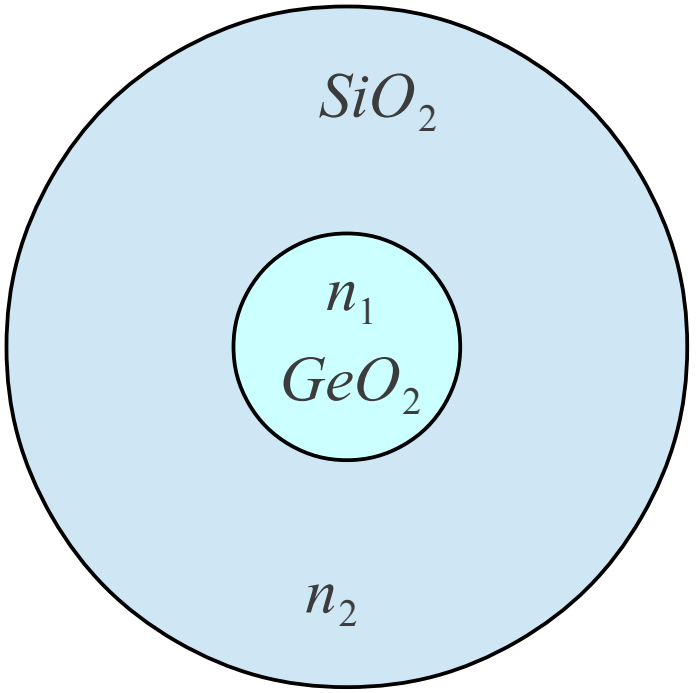
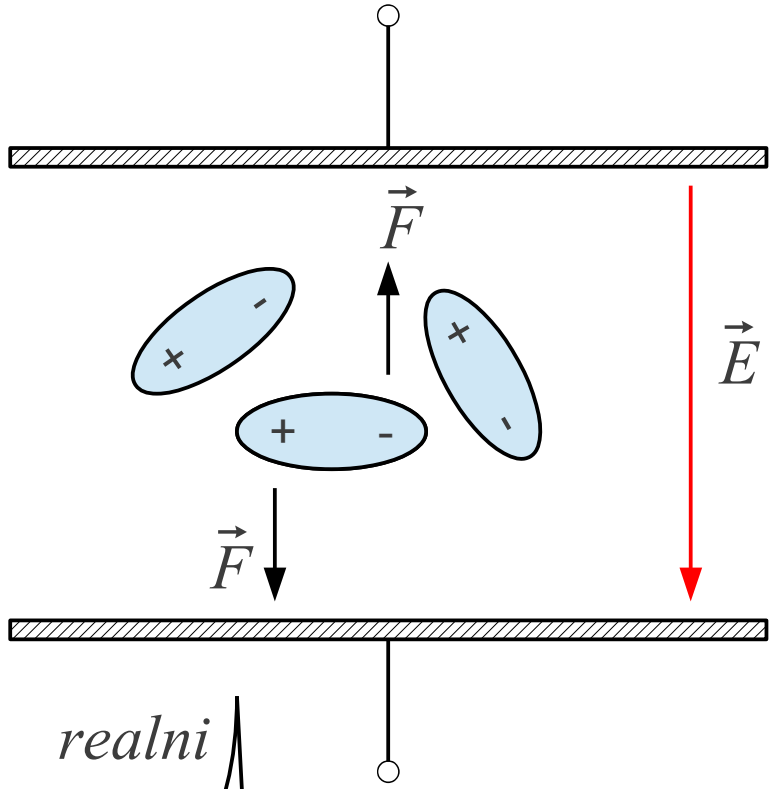
Optične komunikacije

Predavanje 6:

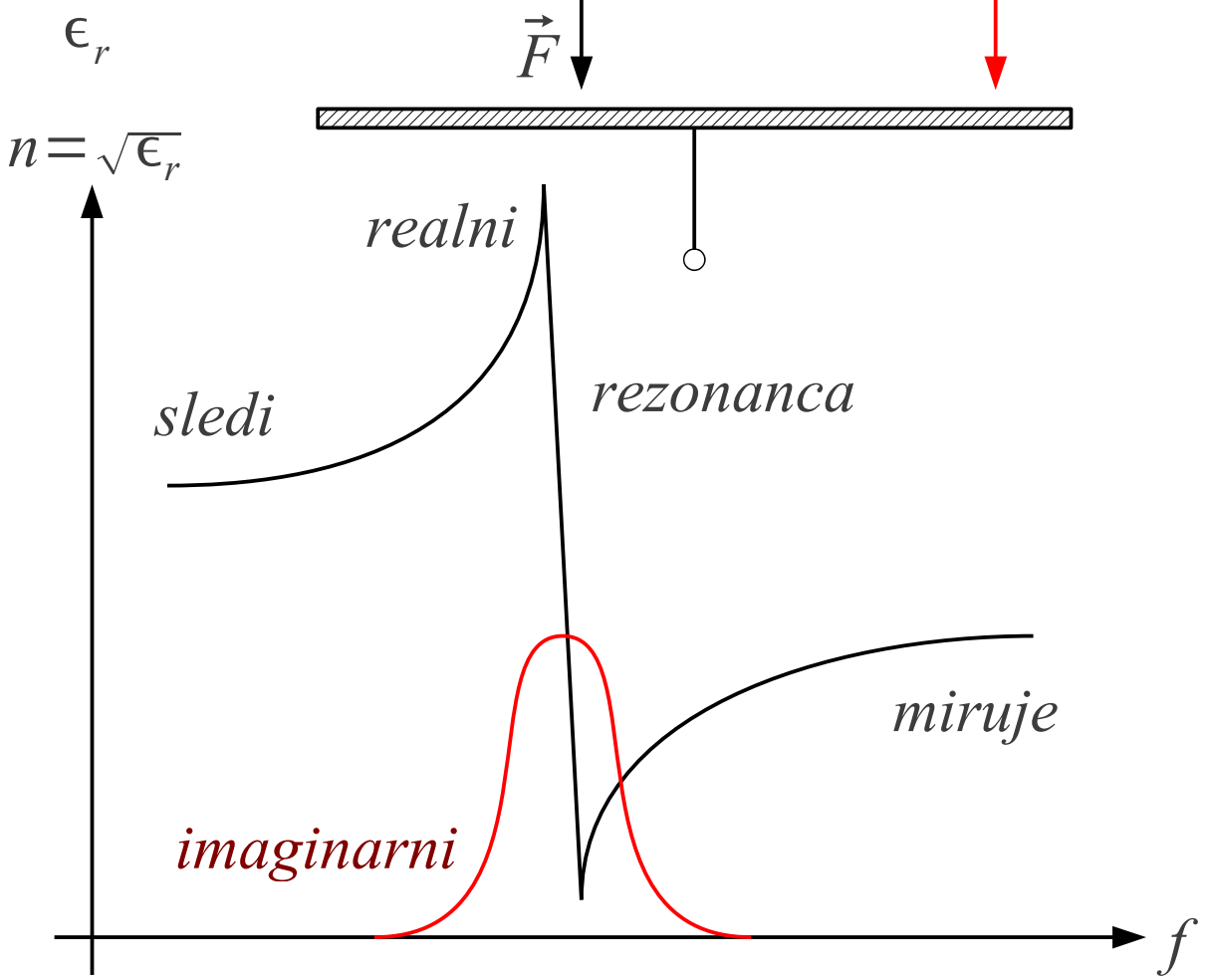
Linearne lastnosti svetlobnega vlakna

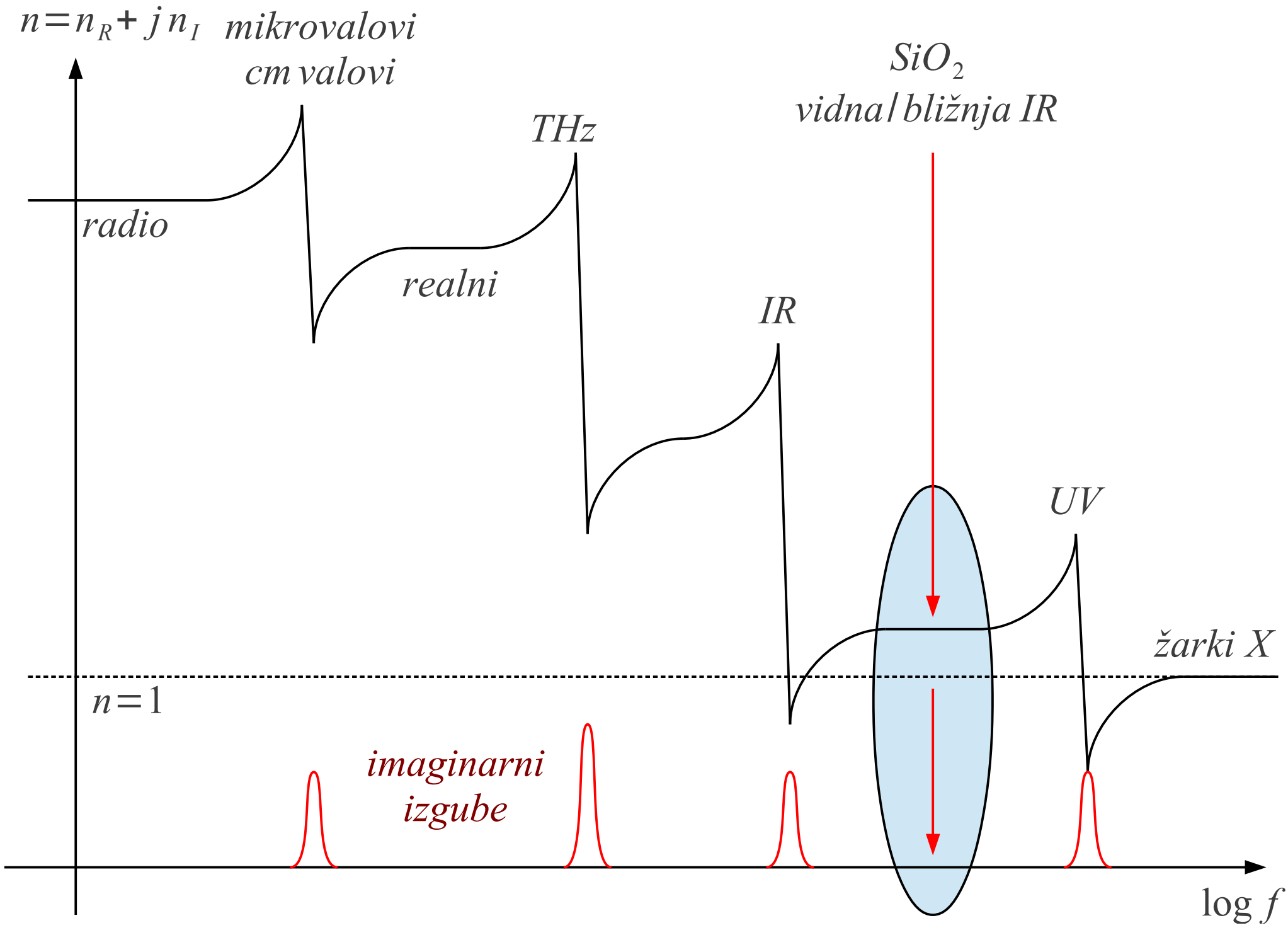


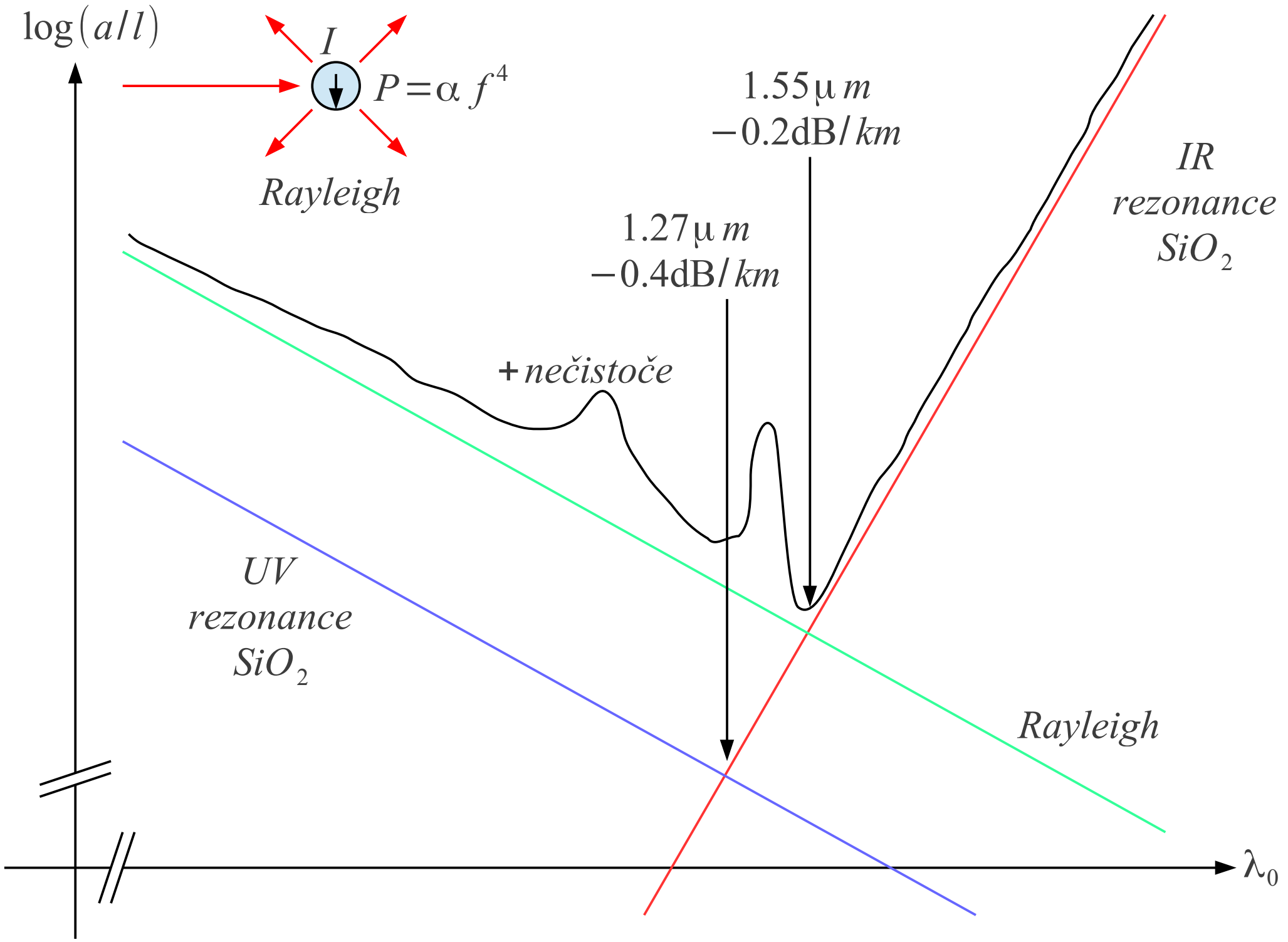


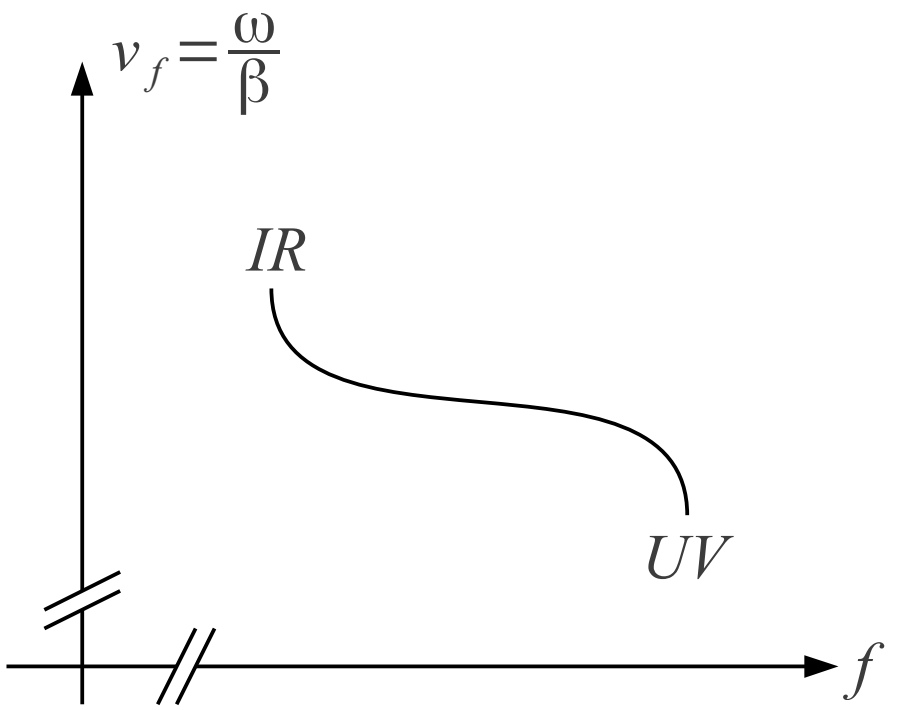
$$\epsilon_r = \epsilon_r' + j\,\epsilon_r''$$

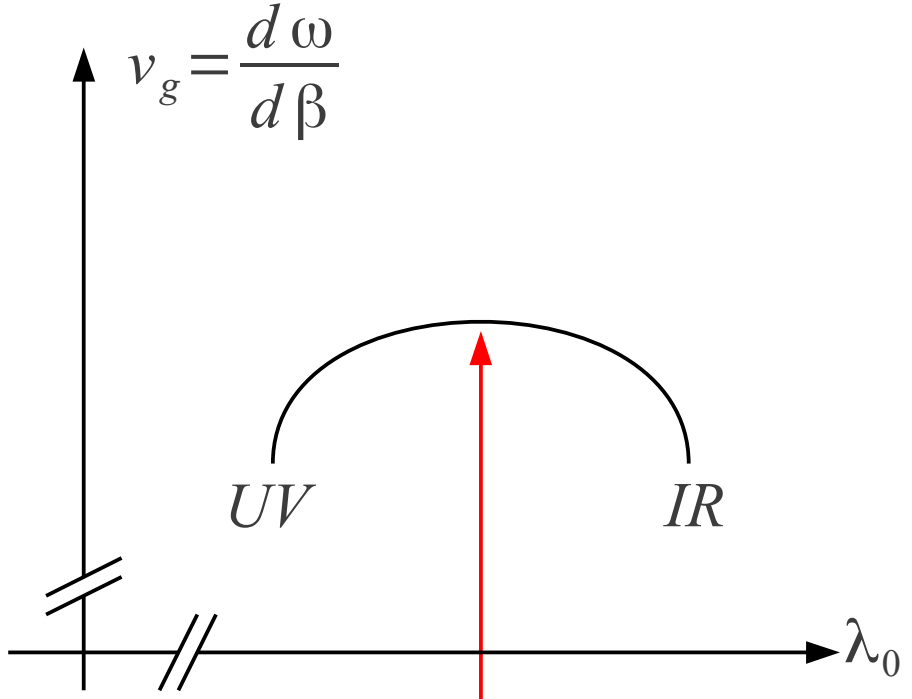
$$n = n_R + j\,n_I$$

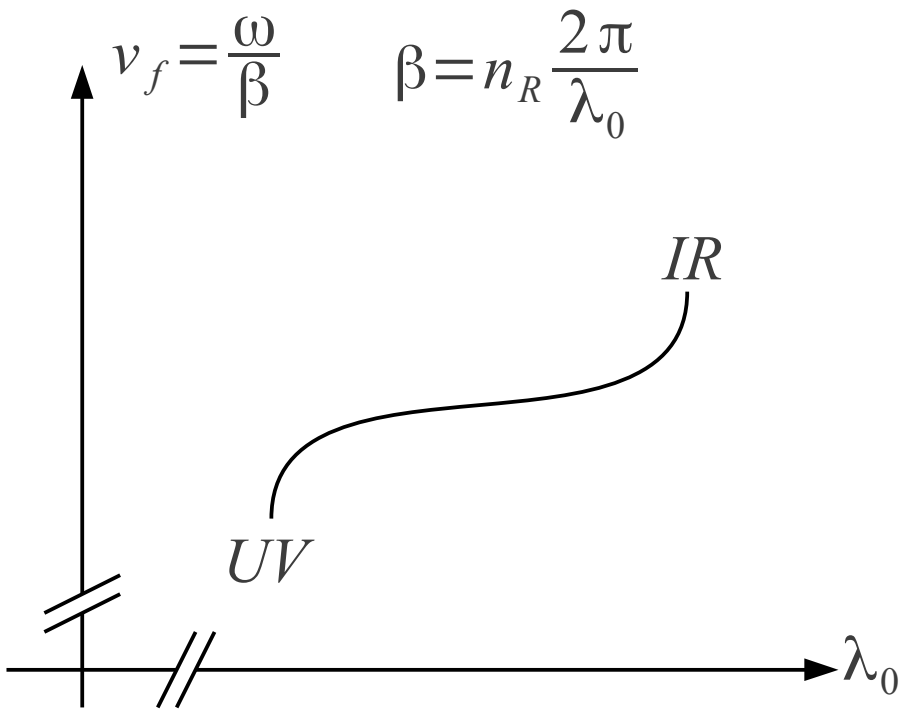


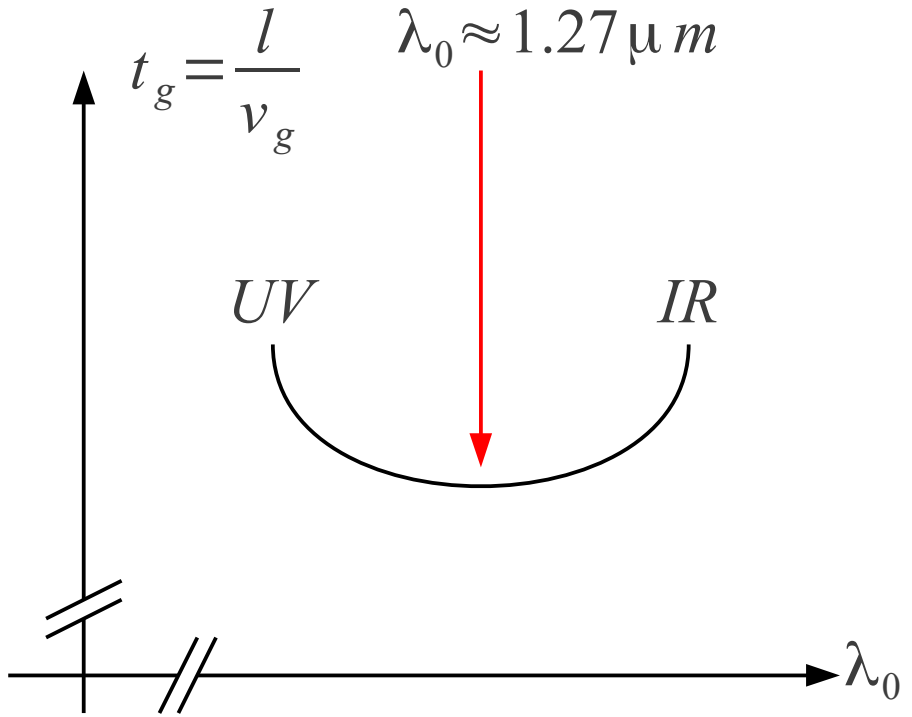

$n = n_R + j\,n_I$
mikrovalovi
cm valovi
radio
realni
THz
IR
SiO_2
vidna / bližnja IR
UV
žarki X
$n = 1$
imaginarni
izgube
log f


log(a/l)
I
P = α f^4
Rayleigh
1.55 μm
−0.2dB/km
1.27 μm
−0.4dB/km
IR
rezonance
SiO2
+nečistoče
UV
rezonance
SiO2
Rayleigh
λ0

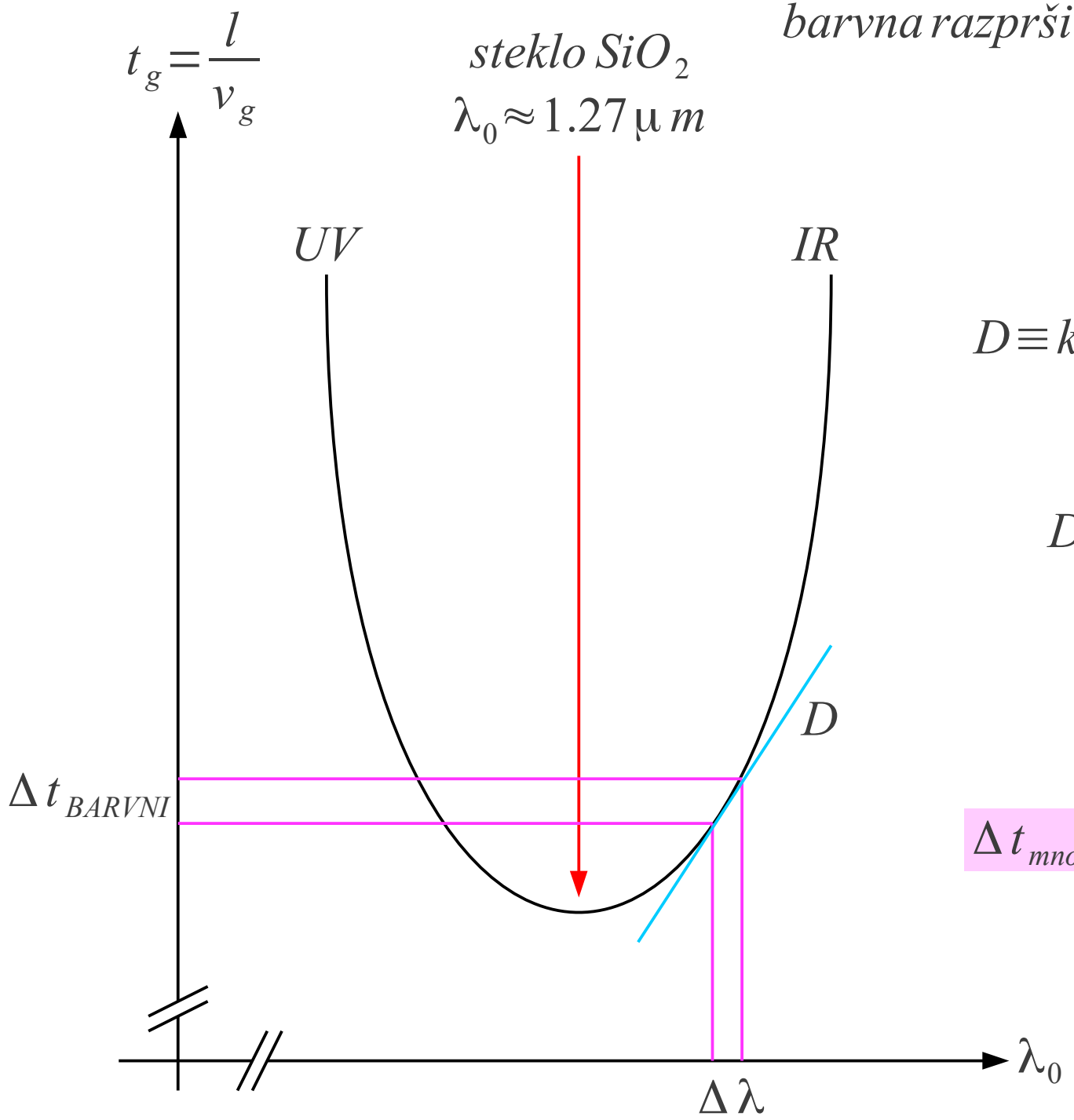

$v_f = \frac{\omega}{\beta}$
IR
UV
f


$v_g = \frac{d\omega}{d\beta}$
UV
IR
λ_0


$v_f = \frac{\omega}{\beta}$
$\beta = n_R \frac{2\pi}{\lambda_0}$
IR
UV
λ_0


$t_g = \frac{l}{v_g}$
$\lambda_0 \approx 1.27\,\mu m$
UV
IR
UV
IR
λ_0

barvna razpršitev (chromatic dispersion)

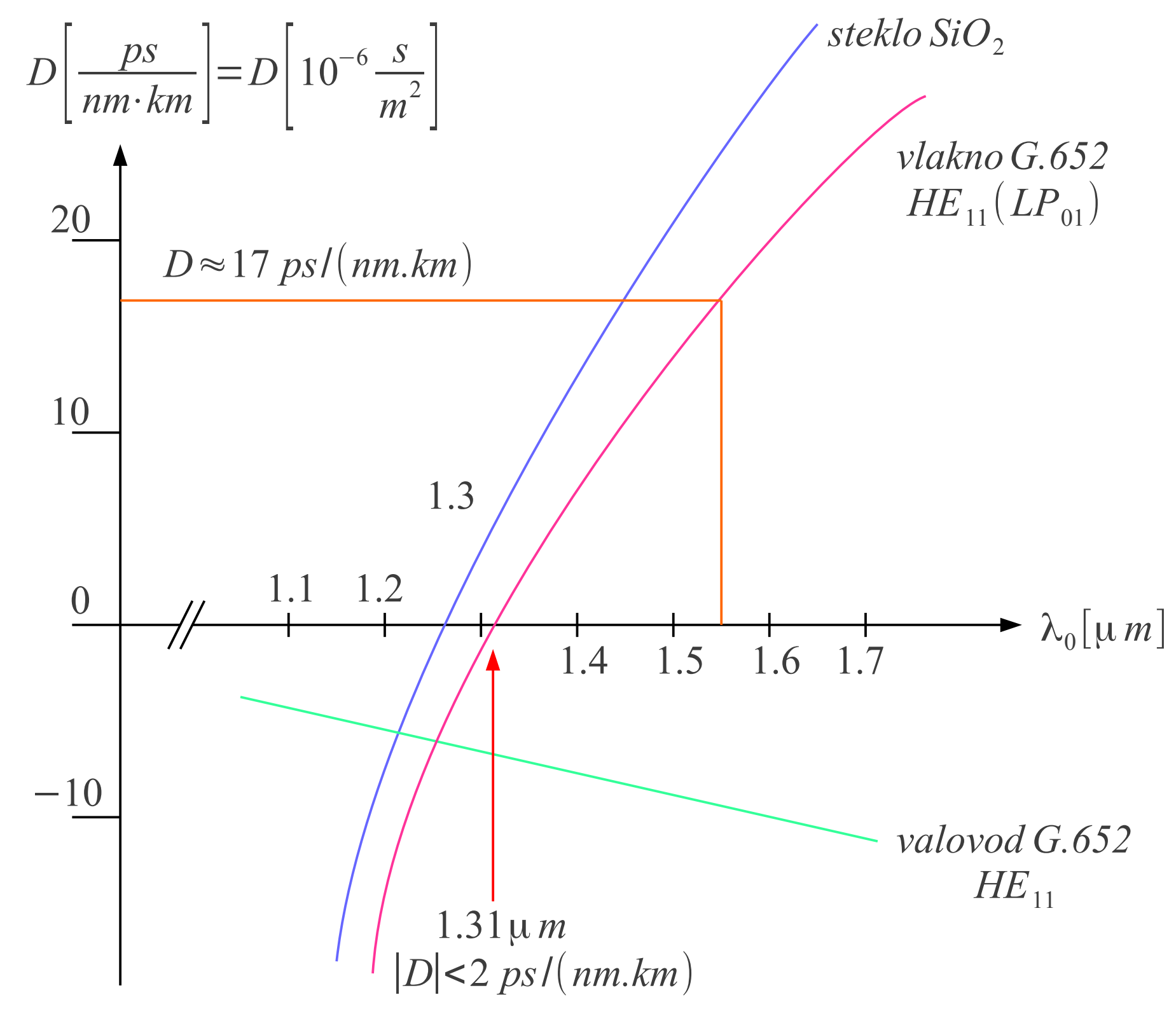


$$\Delta t_{BARVNI} = D \cdot l \cdot \Delta\lambda$$

$D \equiv$ koeficient barvne razpršitve

$$D\left[\frac{ps}{nm \cdot km}\right] = D\left[10^{-6}\frac{s}{m^2}\right]$$

$$\Delta t_{mnogorodovni} \gg \Delta t_{BARVNI} > \Delta t_{PMD}$$


$D\left[\frac{ps}{nm\cdot km}\right]=D\left[10^{-6}\frac{s}{m^2}\right]$
steklo SiO_2
vlakno G.652
$HE_{11}(LP_{01})$
20
$D\approx 17\ ps/(nm.km)$
10
1.3
0
1.1
1.2
1.4
1.5
1.6
1.7
$\lambda_0[\mu m]$
−10
valovod G.652
HE_{11}
$1.31\,\mu m$
$|D|<2\ ps/(nm.km)$

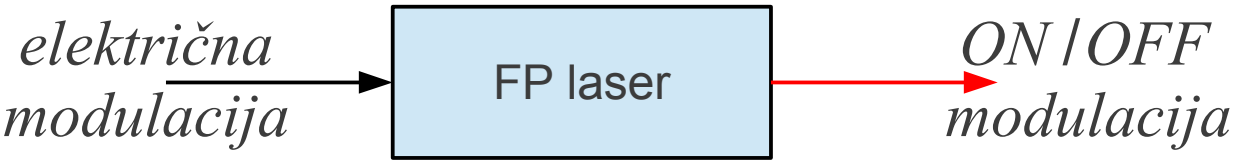
$FP\ laser\ (cenen!)$

$\lambda_0 = 1.31\,\mu m\ (II\ okno)$

$\Delta\lambda = 3\text{nm}$

$l = 50\ km$

$|D| < 2\ ps/(nm.km)$



$\Delta t = 2 \cdot 50 \cdot 3\ ps = 300\text{ps}$

$a_{1.3} \approx -20\text{dB}$

$$C = \frac{1}{3\,\Delta t} = 1.1\ Gbit/s > 622\ Mbit/s$$

$\lambda_0 = 1.55\,\mu m\ (III\ okno)$

$D \approx 17\ ps/(nm.km)$

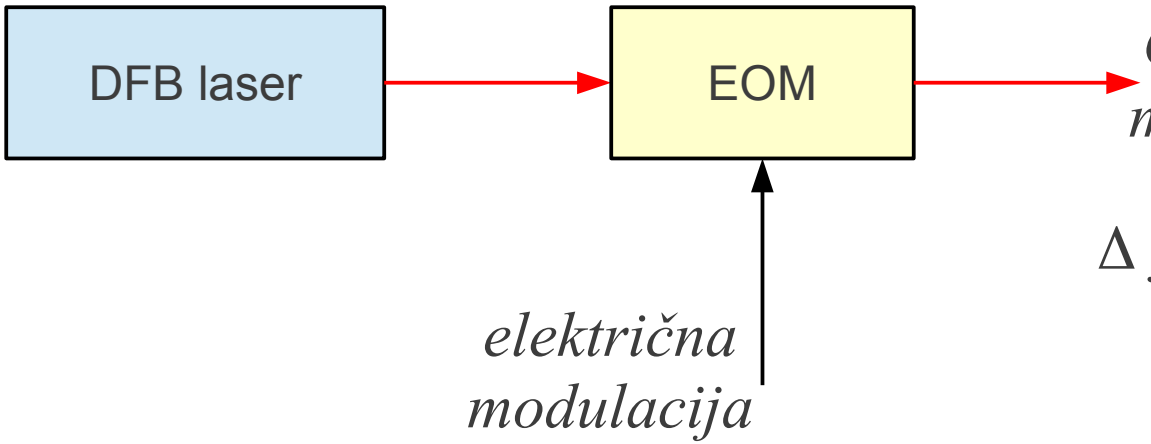
$vse\ ostalo\ isto!$

$\Delta t = 17 \cdot 50 \cdot 3\ ps = 2550\text{ps}$

$a_{1.55} \approx -10\text{dB}$

$$C = \frac{1}{3\,\Delta t} = 130\ Mbit/s$$

$\Delta f_{laser} < 10\text{MHz}$



$$\Delta f \approx C \gg \Delta f_{laser}$$

$$\lambda_0 = \frac{c_0}{f}$$

$$\frac{d\lambda}{df} = -\frac{c_0}{f^2}$$

$$\Delta\lambda = \frac{\lambda_0^2}{c_0}\Delta f = \frac{\lambda_0^2}{c_0} C$$

$$\Delta t = D \cdot l \cdot \Delta\lambda = \frac{D \cdot l \cdot \lambda_0^2}{c_0} C \approx \frac{1}{C}$$

$$C = \frac{1}{\Delta t} \left(manj\ stroga\ zahteva \right)$$

$$l = 50\,km \qquad D \approx 17\ ps/(nm.km)$$

$$\lambda_0 = 1.55\,\mu m \left(III\ okno \right)$$

$$C = \sqrt{\frac{c_0}{D \cdot l \cdot \lambda_0^2}} \approx 12\text{Gbit}/s$$

$\lambda_0 = 1.55\,\mu m\,(III\ okno)$

$D \approx 17\ ps/(nm.km)$

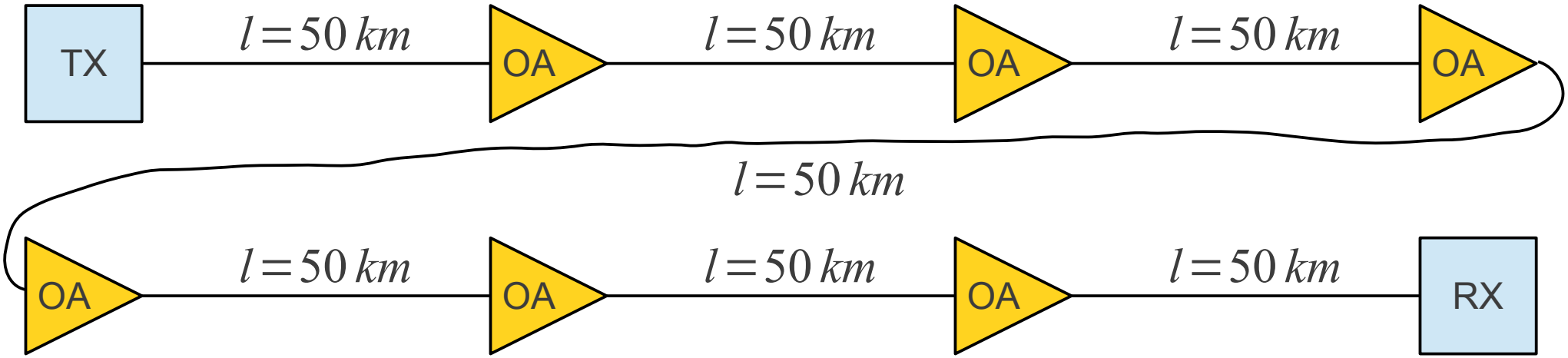
$$l = \frac{c_0}{D \cdot C^2 \cdot \lambda_0^2}$$

$C = 2.5\text{Gbit}/s \rightarrow l \approx 1200\text{km}$

$C = 10\text{Gbit}/s \rightarrow l \approx 73\text{km}$

$C = 40\text{Gbit}/s \rightarrow l \approx 4.5\text{km}$

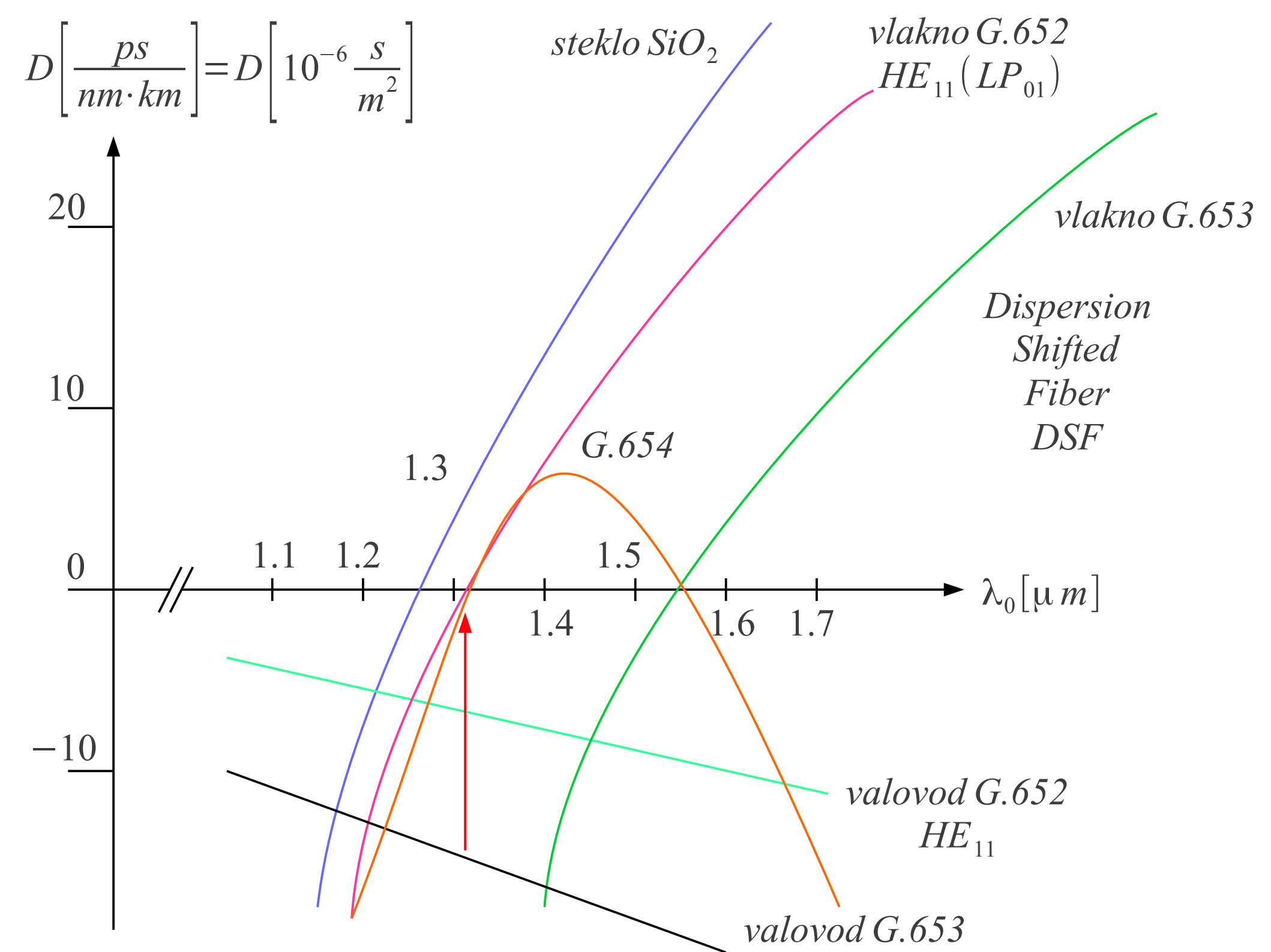
Protiukrep : analogni FDM → WDM (Wavelength Division Mux)

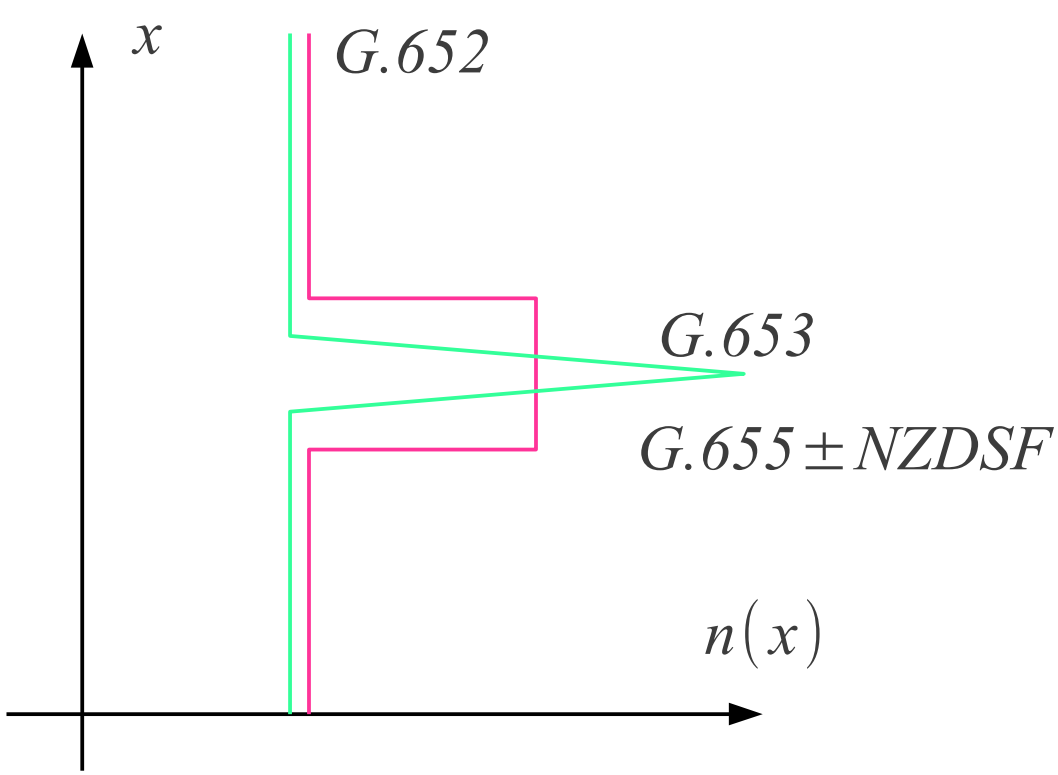


$\Sigma l = N \cdot l_{odseka} = 5000\ km$

$C = 1.2\text{Gbit}/s\ ???$

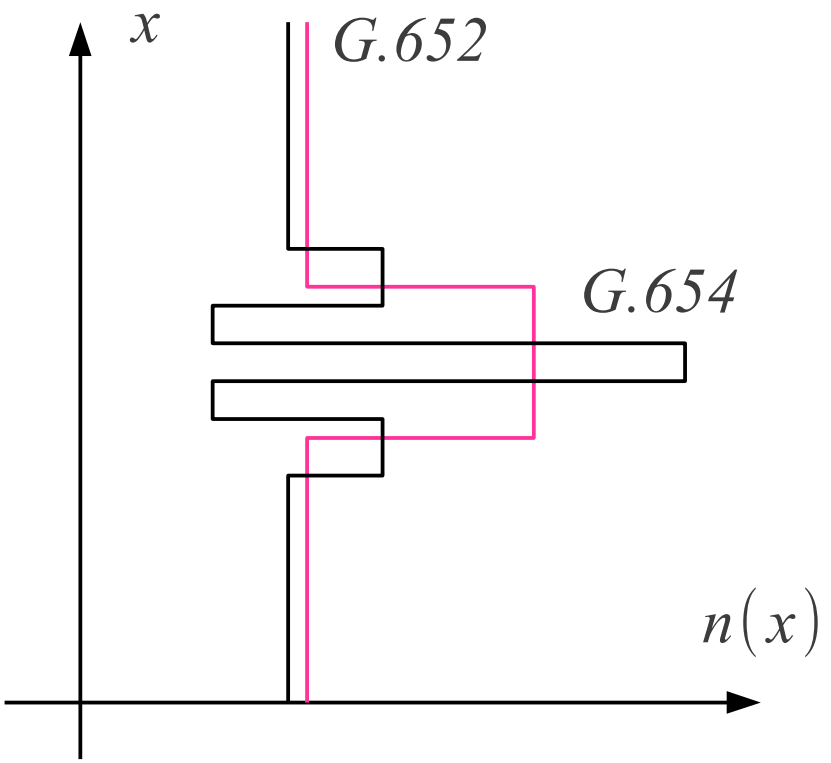
Rešitev 1990
vlakno G.653 ???

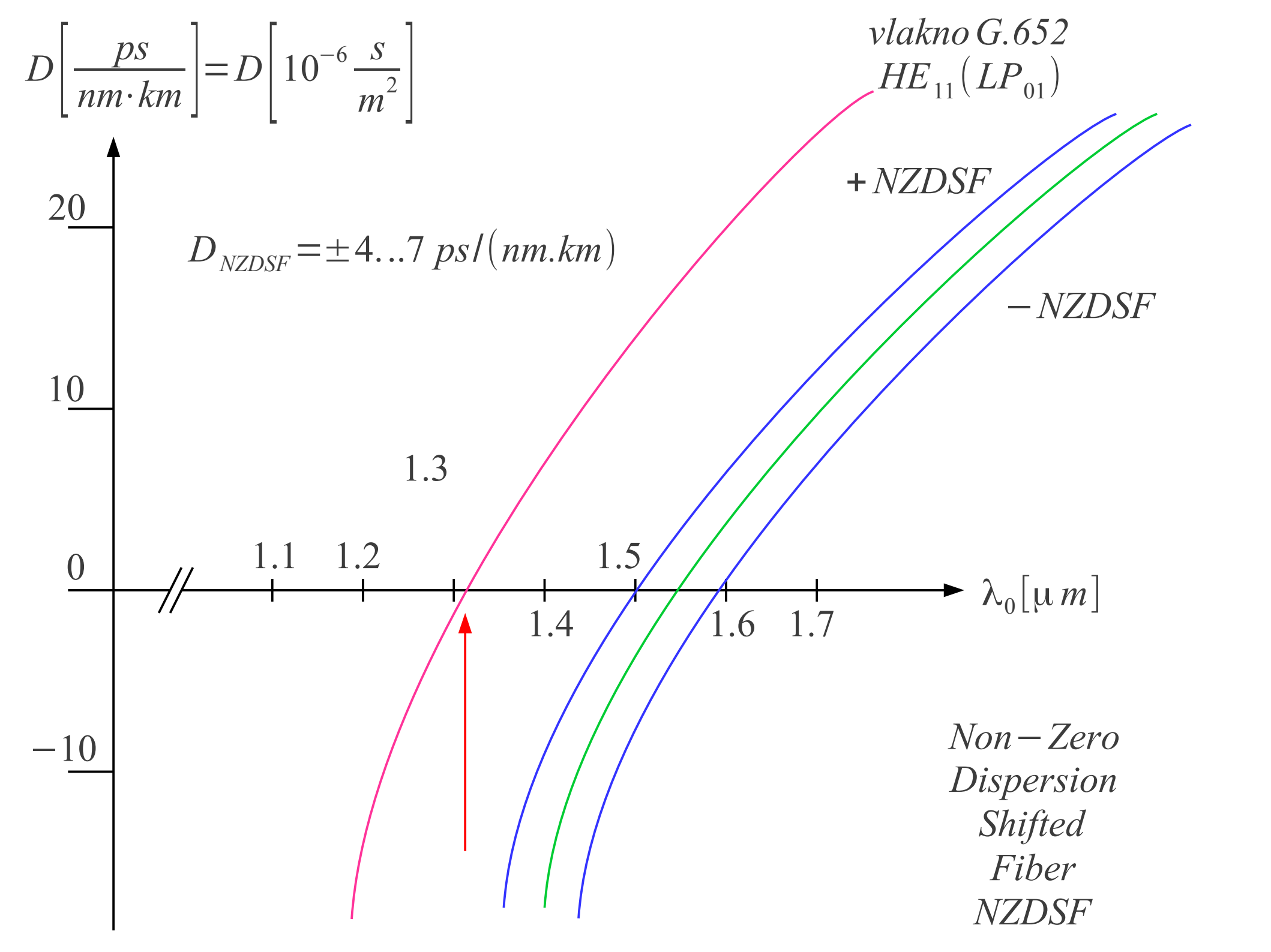

$D\left[\frac{ps}{nm\cdot km}\right]=D\left[10^{-6}\frac{s}{m^2}\right]$
steklo SiO_2
vlakno G.652
$HE_{11}(LP_{01})$
vlakno G.653
Dispersion
Shifted
Fiber
DSF
G.654
20
10
0
−10
1.1
1.2
1.3
1.4
1.5
1.6
1.7
$\lambda_0[\mu m]$
valovod G.652
HE_{11}
valovod G.653

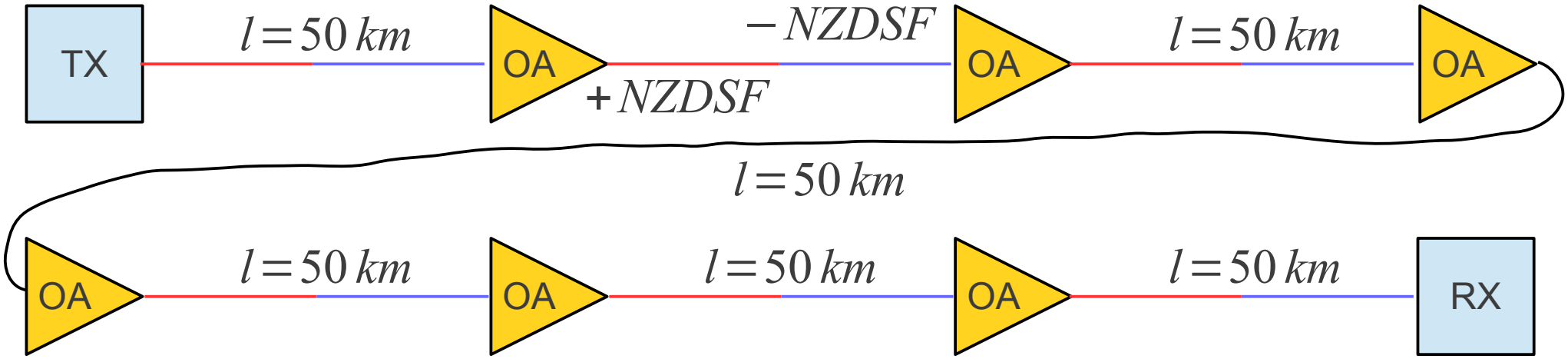


Dispersion
Shifted
Fiber
DSF
nelinearni pojavi !

Dispersion
Flattened
Fiber
W
G.654
občutljivo na ukrivljanje !




$D\left[\frac{ps}{nm\cdot km}\right]=D\left[10^{-6}\frac{s}{m^2}\right]$
vlakno G.652
$HE_{11}(LP_{01})$
+ NZDSF
− NZDSF
$D_{NZDSF}=\pm 4...7\ ps/(nm.km)$
20
10
0
−10
1.3
1.1
1.2
1.4
1.5
1.6
1.7
$\lambda_0[\mu m]$
Non − Zero
Dispersion
Shifted
Fiber
NZDSF



$D \approx 17\ ps/(nm.km)$

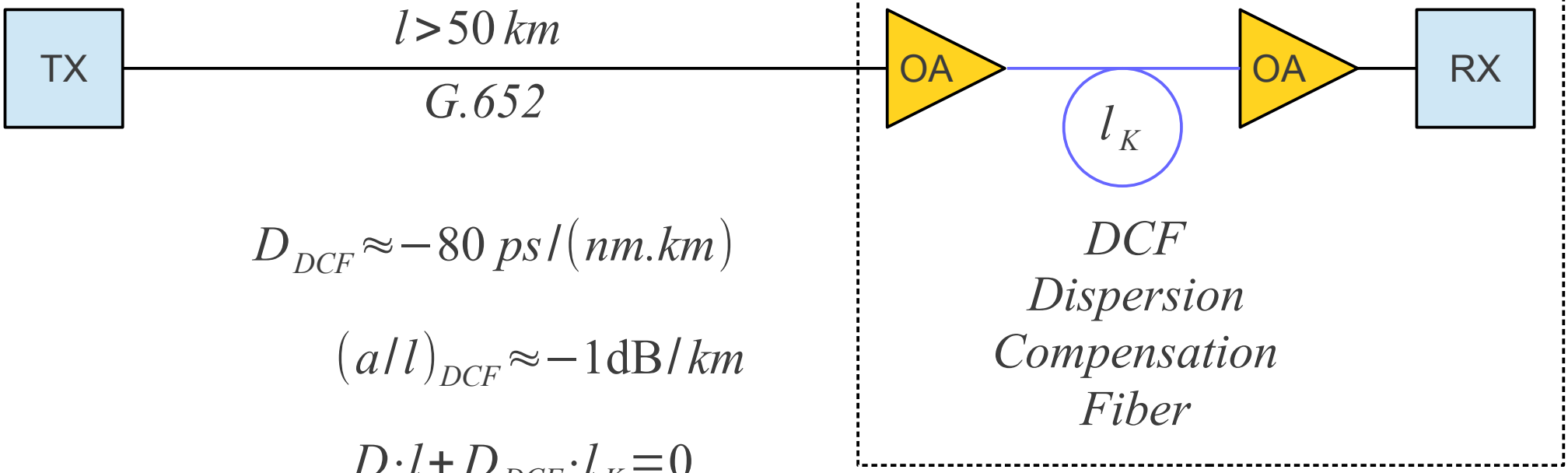
$l > 50\ km$

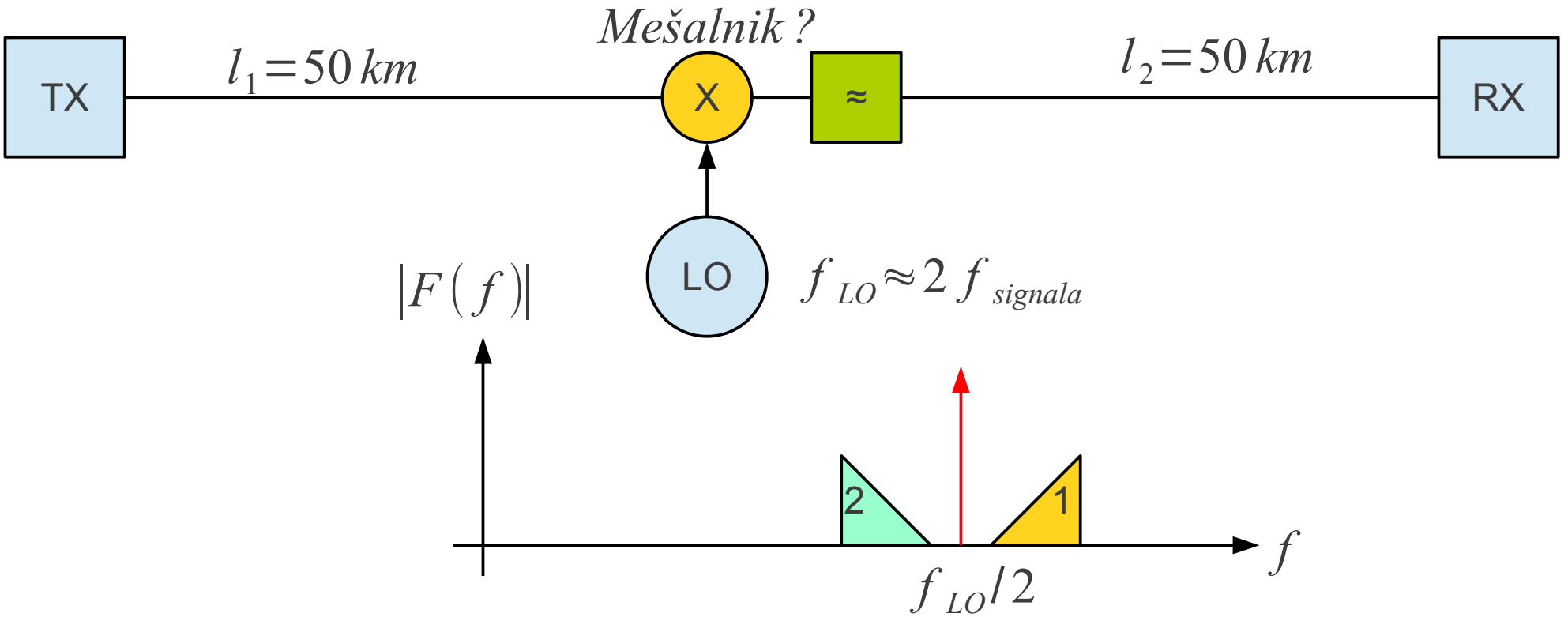
$G.652$

$D_{DCF} \approx -80\ ps/(nm.km)$

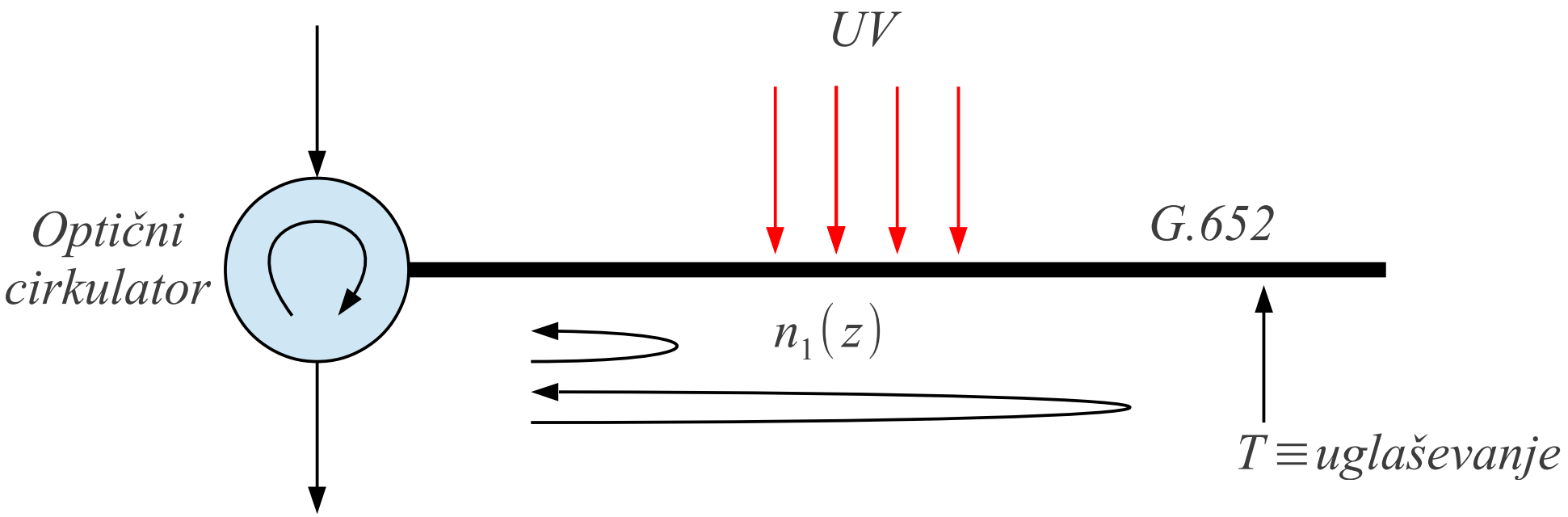
$(a/l)_{DCF} \approx -1\text{dB}/km$

$D \cdot l + D_{DCF} \cdot l_K = 0$



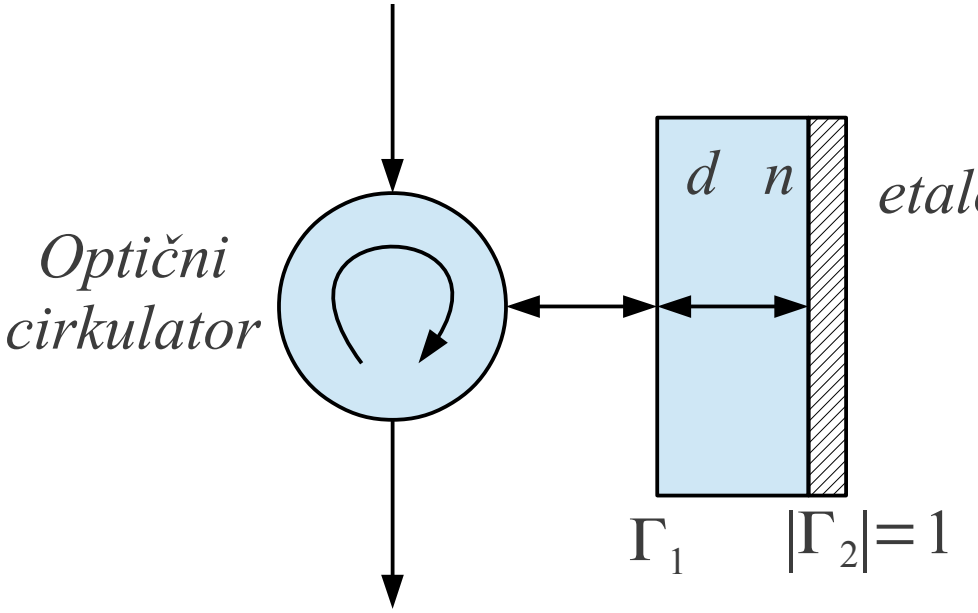


Mid – Point Spectral Inversion



Kompenzacija barvne razpršitve z uklonsko mrežico

$TDCM \equiv Tunable\ Dispersion\ Compensation\ Module$



$etalon\ Gires - Tournois\ (uporaben\ v\ WDM\ !)$