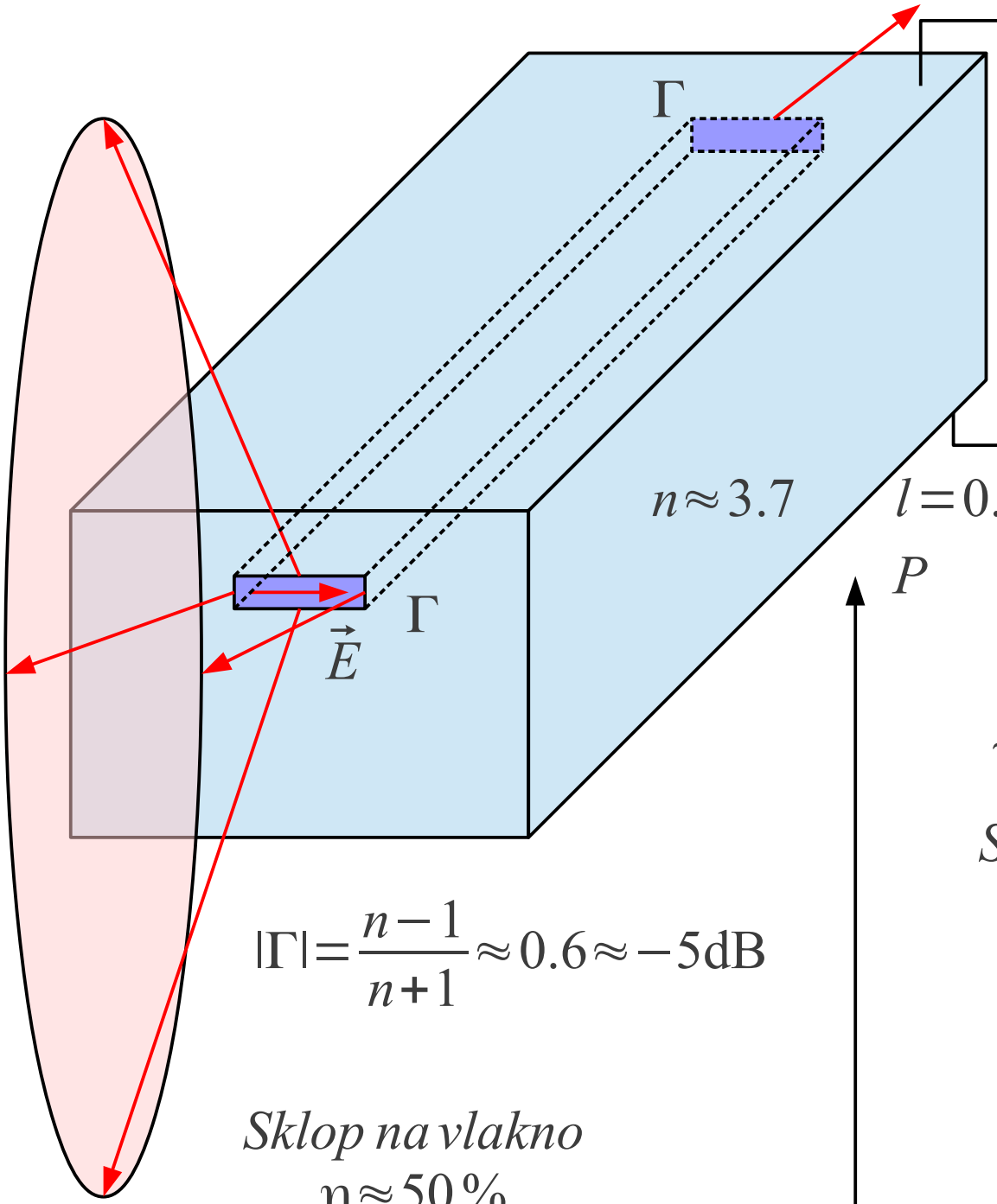
Optične komunikacije

Predavanje 11:

Izvedbe komunikacijskih laserjev



$G/l \approx 2 \cdot 10^4\ dB/m$

$G \approx 6\text{dB}$

I

$n \approx 3.7$

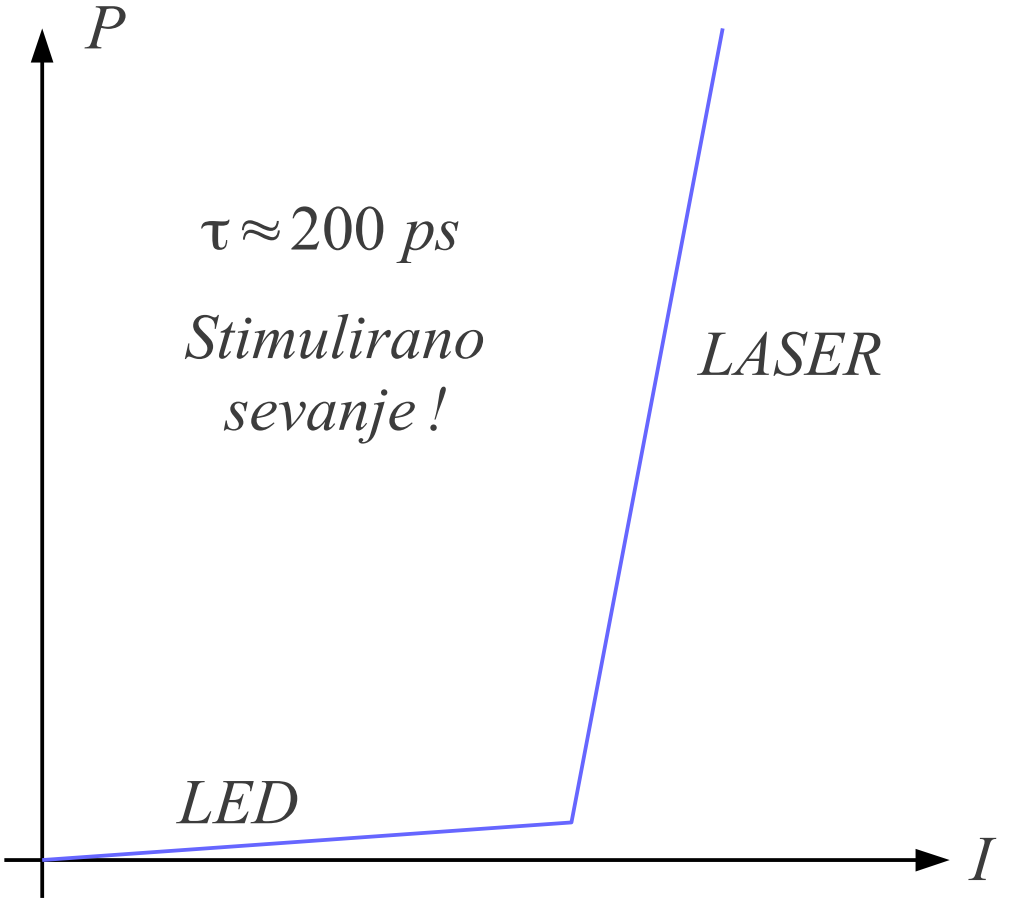
$l = 0.3\text{mm}$

$$|\Gamma| = \frac{n-1}{n+1} \approx 0.6 \approx -5\text{dB}$$

Sklop na vlakno

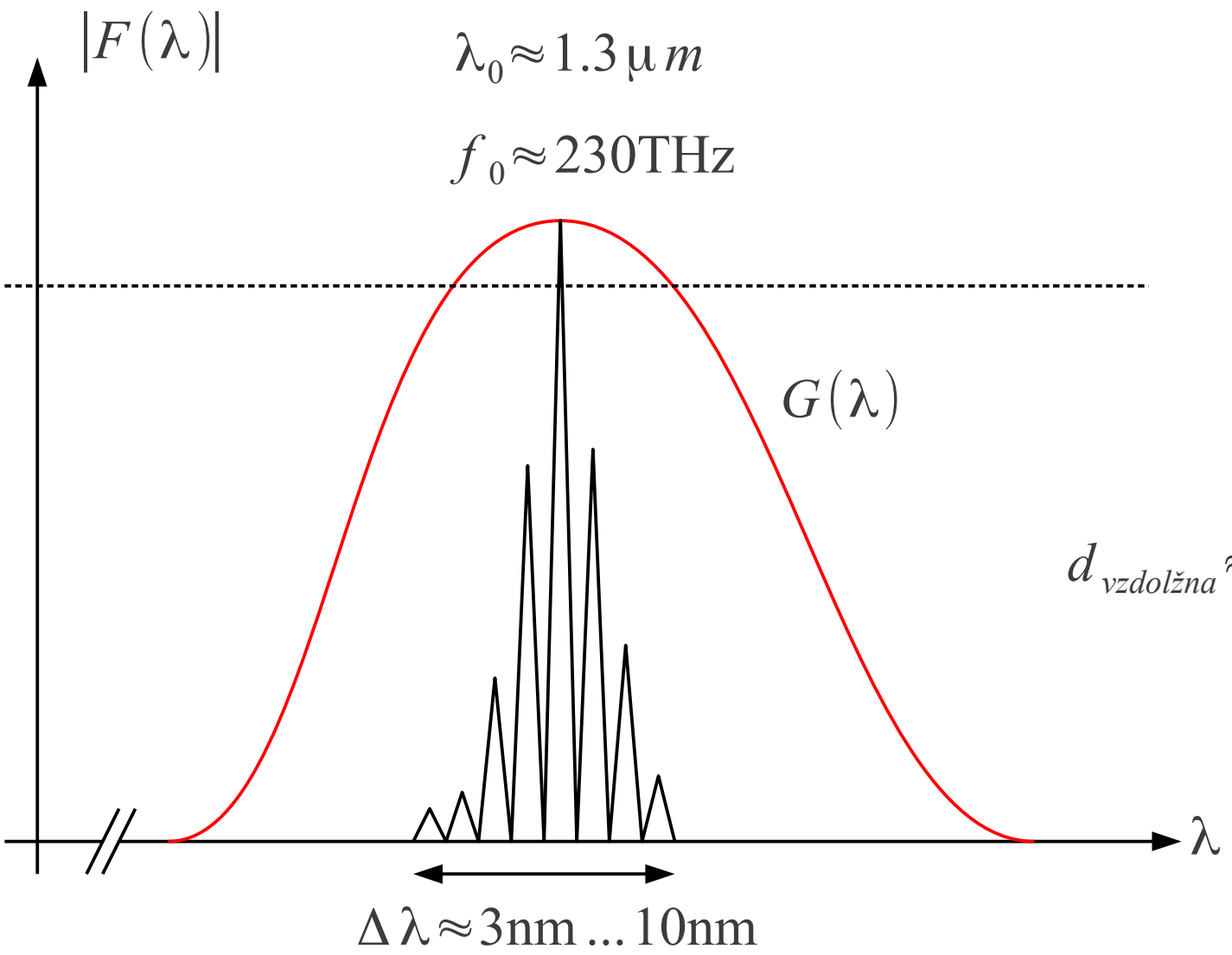
$\eta \approx 50\,\%$

$P_{vlakno} \approx 10\text{mW}$



$\tau \approx 200\ ps$

Stimulirano sevanje !



$d_{vzdolžna} \approx 0.2\text{mm} \ldots 0.6\text{mm}$

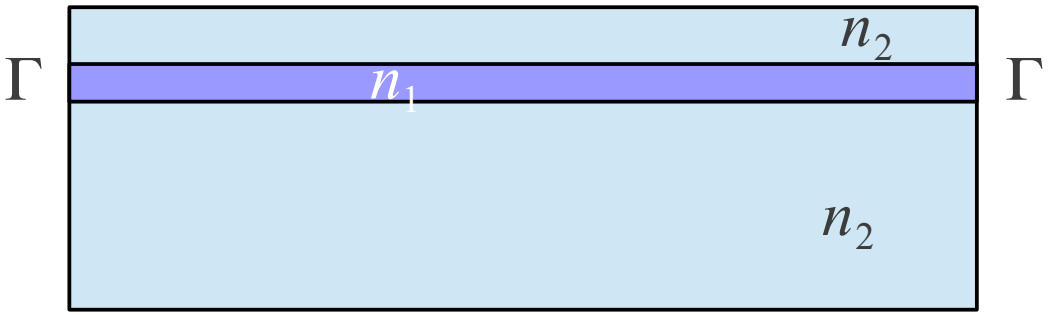
$$f_N = N\frac{c_0}{2\,l\,n}$$

$4 \ldots 13$ *vzdolžnih rodov*

preskakovanje med rodovi → velik šum ! ! !

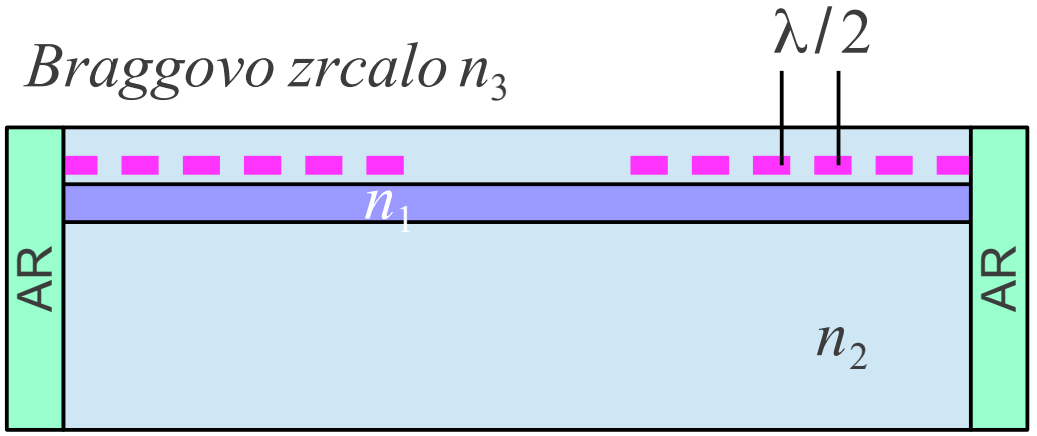
$$\Delta f = \frac{c_0}{2\,l\,n} \approx 135\text{GHz}$$

rezonator Fabry – Perot



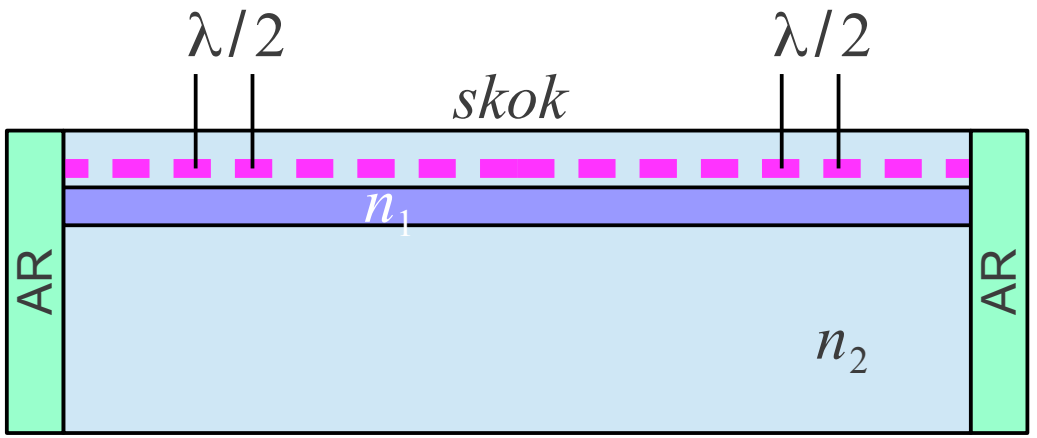
FP

Braggovo zrcalo n_3



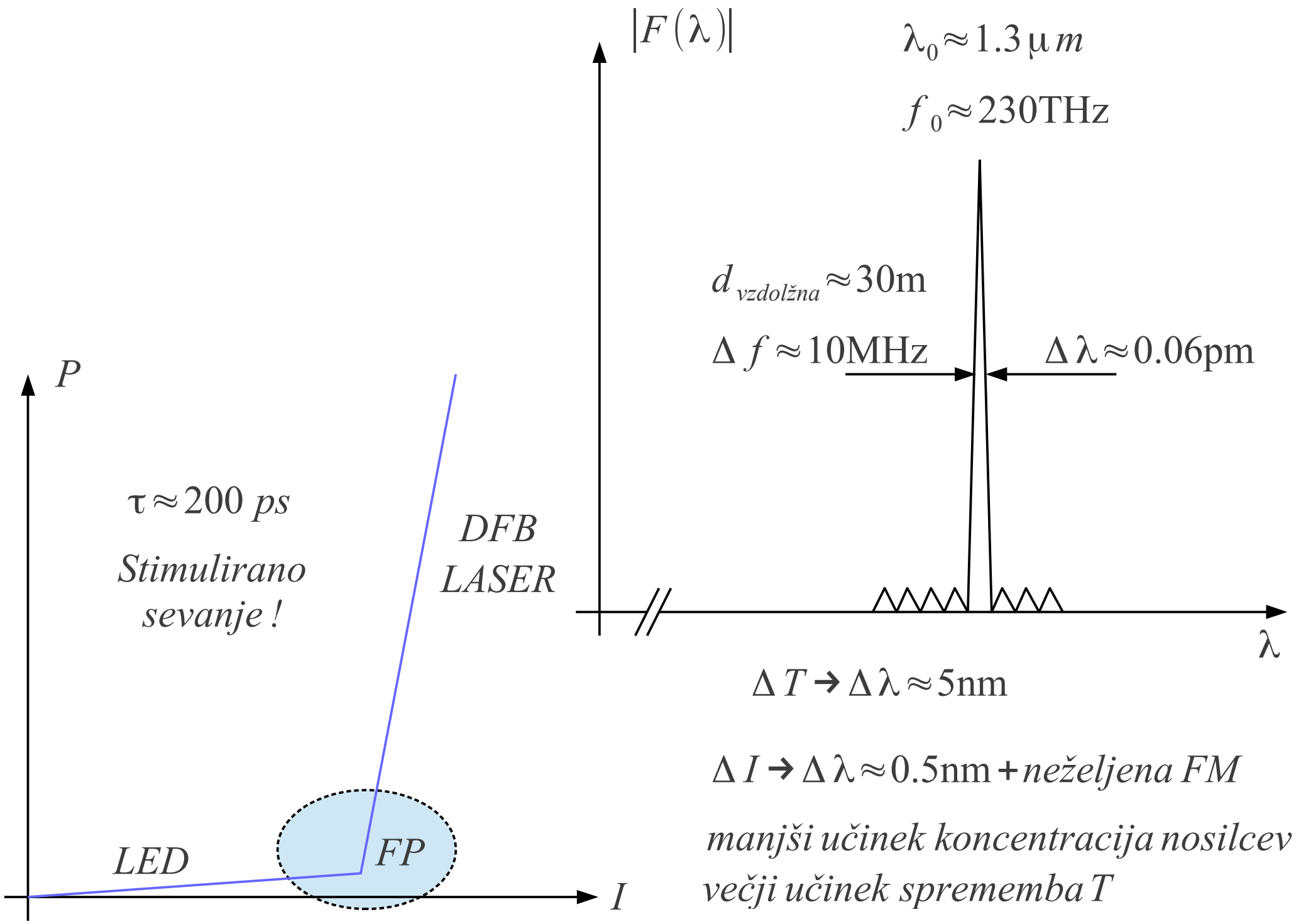
DBR ≡ *Distributed Bragg Reflector*

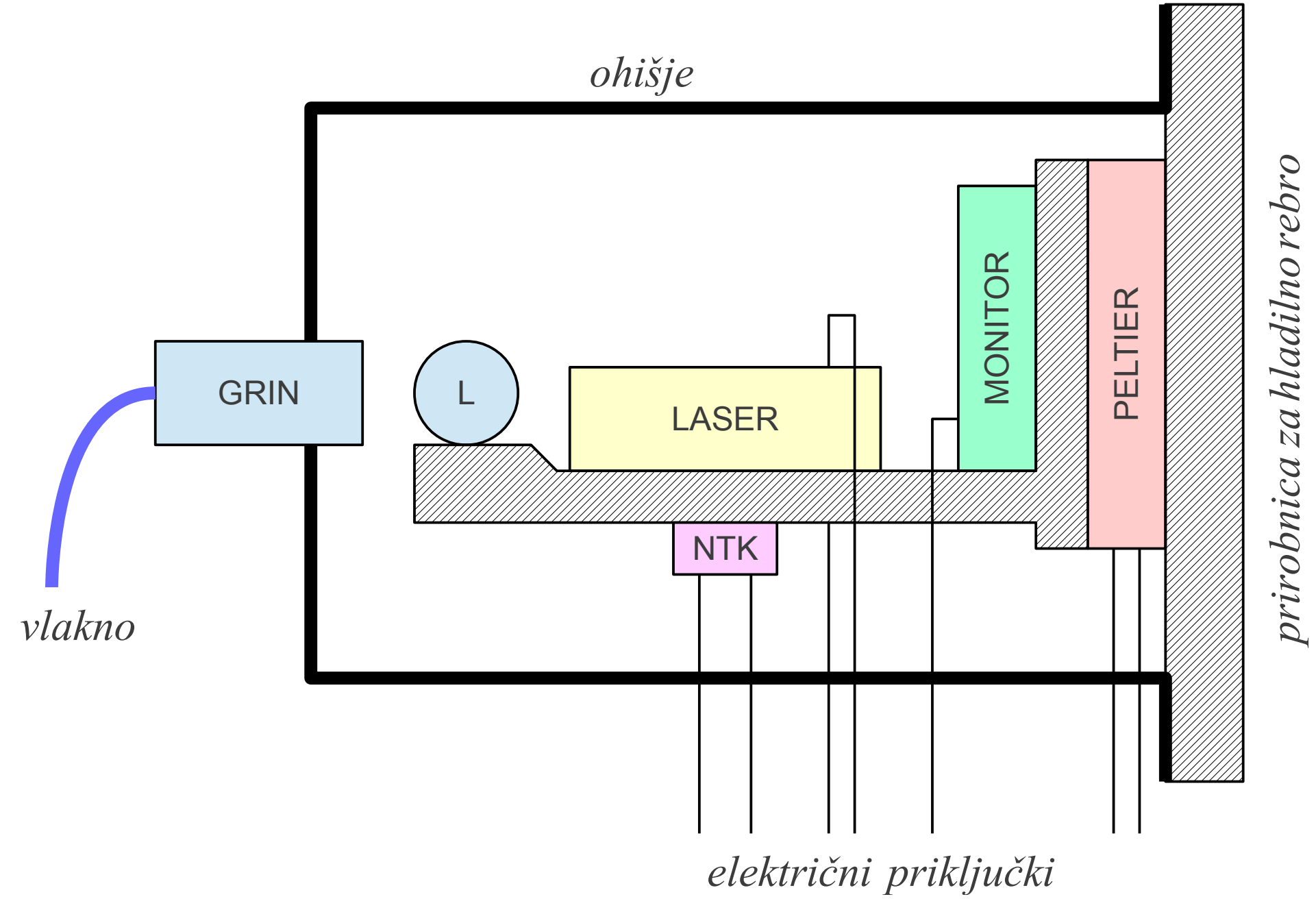
$$\lambda = \frac{\lambda_0}{n} = \frac{1.3\,\mu m}{3.7} = 0.35\,\mu m$$



$$\lambda/4 = \frac{\lambda_0}{4\,n} = 87\text{nm}$$

DFB ≡ *Distributed Feed Back*


$|F(\lambda)|$
$\lambda_0 \approx 1.3\,\mu m$
$f_0 \approx 230\text{THz}$
$d_{vzdolžna} \approx 30\text{m}$
$\Delta f \approx 10\text{MHz}$
$\Delta\lambda \approx 0.06\text{pm}$
λ
$\Delta T \rightarrow \Delta\lambda \approx 5\text{nm}$
$\Delta I \rightarrow \Delta\lambda \approx 0.5\text{nm} + neželjena\ FM$
manjši učinek koncentracija nosilcev
večji učinek sprememba T
P
$\tau \approx 200\ ps$
Stimulirano sevanje !
DFB LASER
LED
FP
I



Ločitev od bremena → nerecipročni gradnik

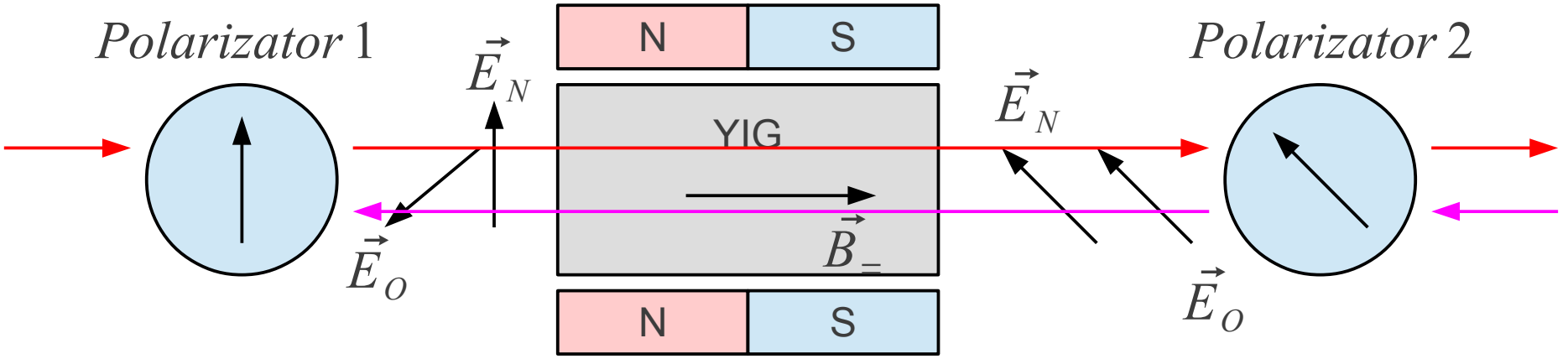
Nerecipročna snov → ferit !

Yttrium Iron Garnet

$\lambda \approx 1.3 \ldots 1.55 \mu m$

$Y_3 Fe_5 O_{12} \equiv YIG$

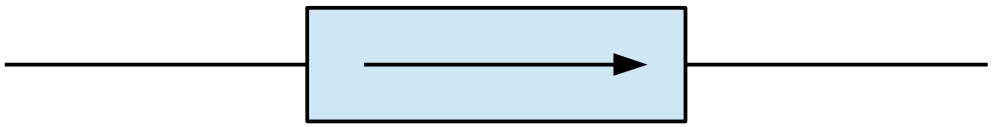
$$[\mu] = \begin{bmatrix} \mu_1 & j\mu_2 & 0 \\ -j\mu_2 & \mu_1 & 0 \\ 0 & 0 & \mu_3 \end{bmatrix}$$

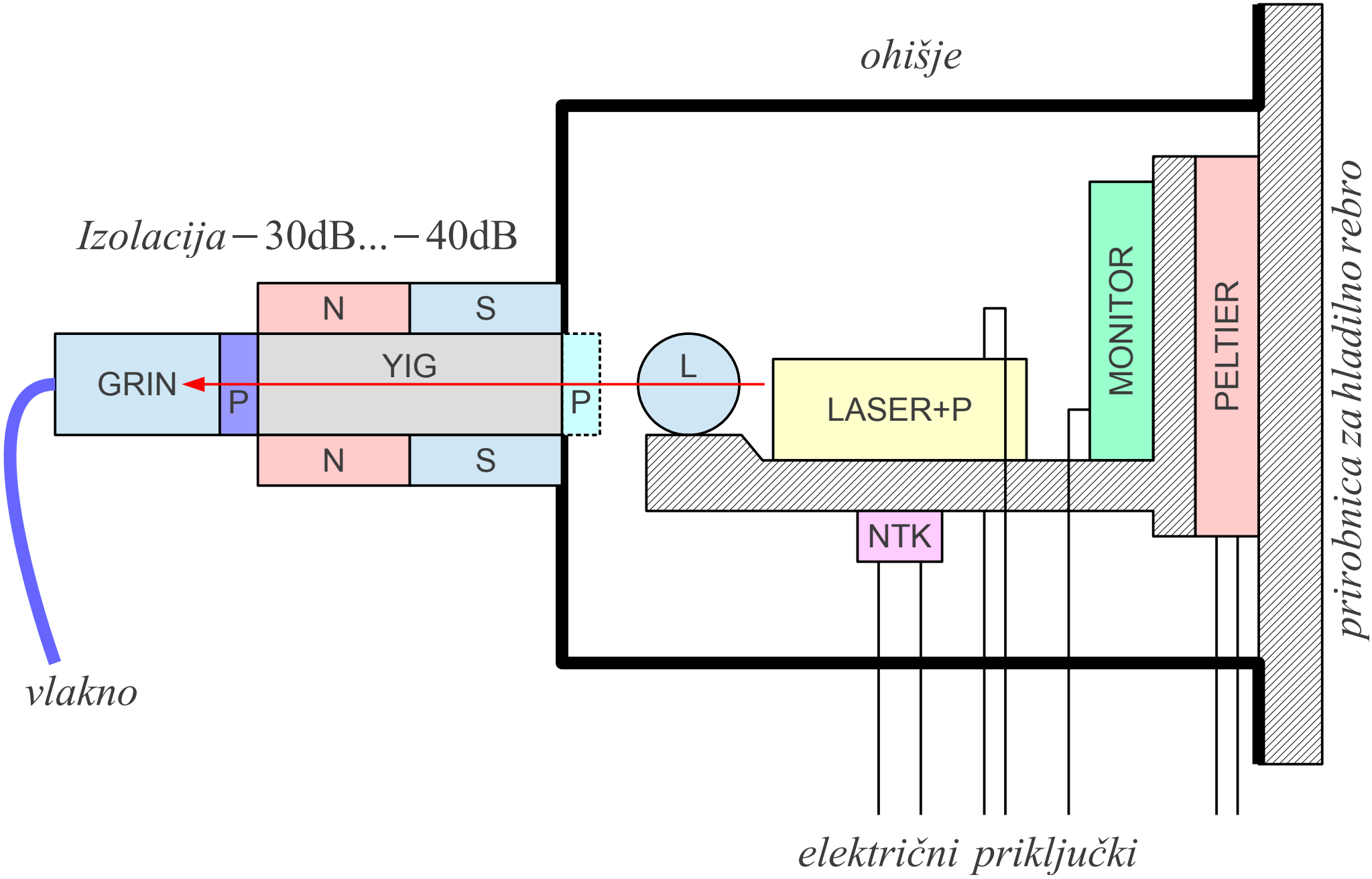


$n_{RHCP} \neq n_{LHCP}$

Faradayevo sukanje polarizacije $\phi = 45^0$

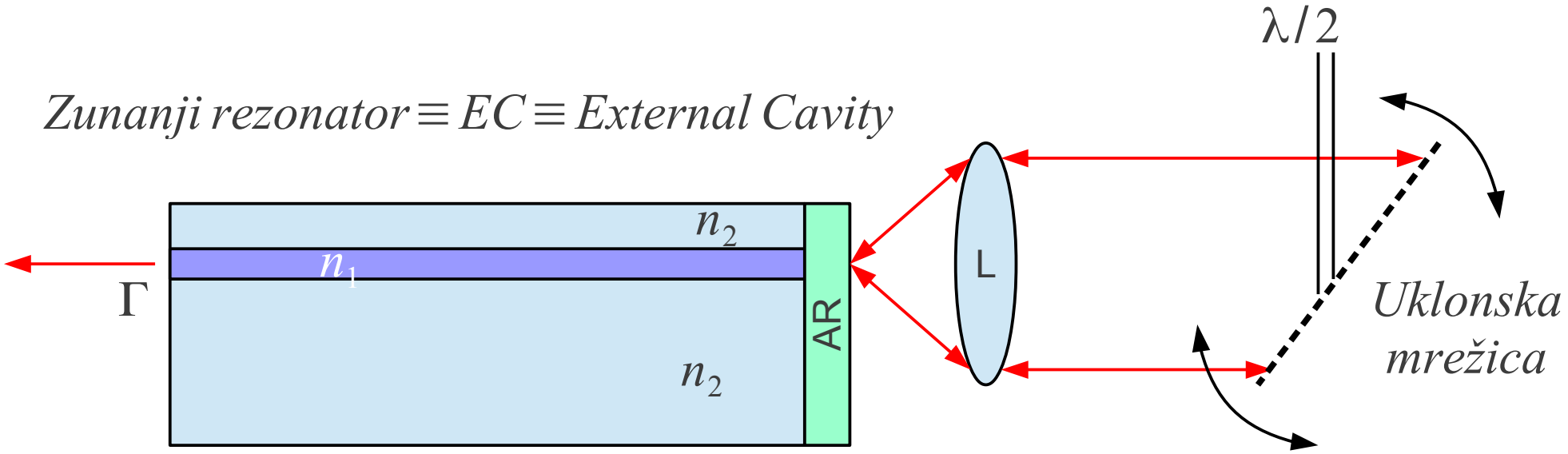
Enopolarizacijski svetlobni izolator





Ločitev od bremena → nerecipročni gradnik feritni YIG izolator

Zunanji rezonator ≡ EC ≡ External Cavity



Uglaševanje s sukanjem mrežice !

$d_{vzdolžna} \approx 3\text{km}$

$\Delta\lambda > 100\text{nm}$

$\Delta f \approx 100\text{kHz}$

$\Delta\lambda \approx 0.0008\text{pm} \,@\, \lambda_0 \approx 1550\text{nm}$

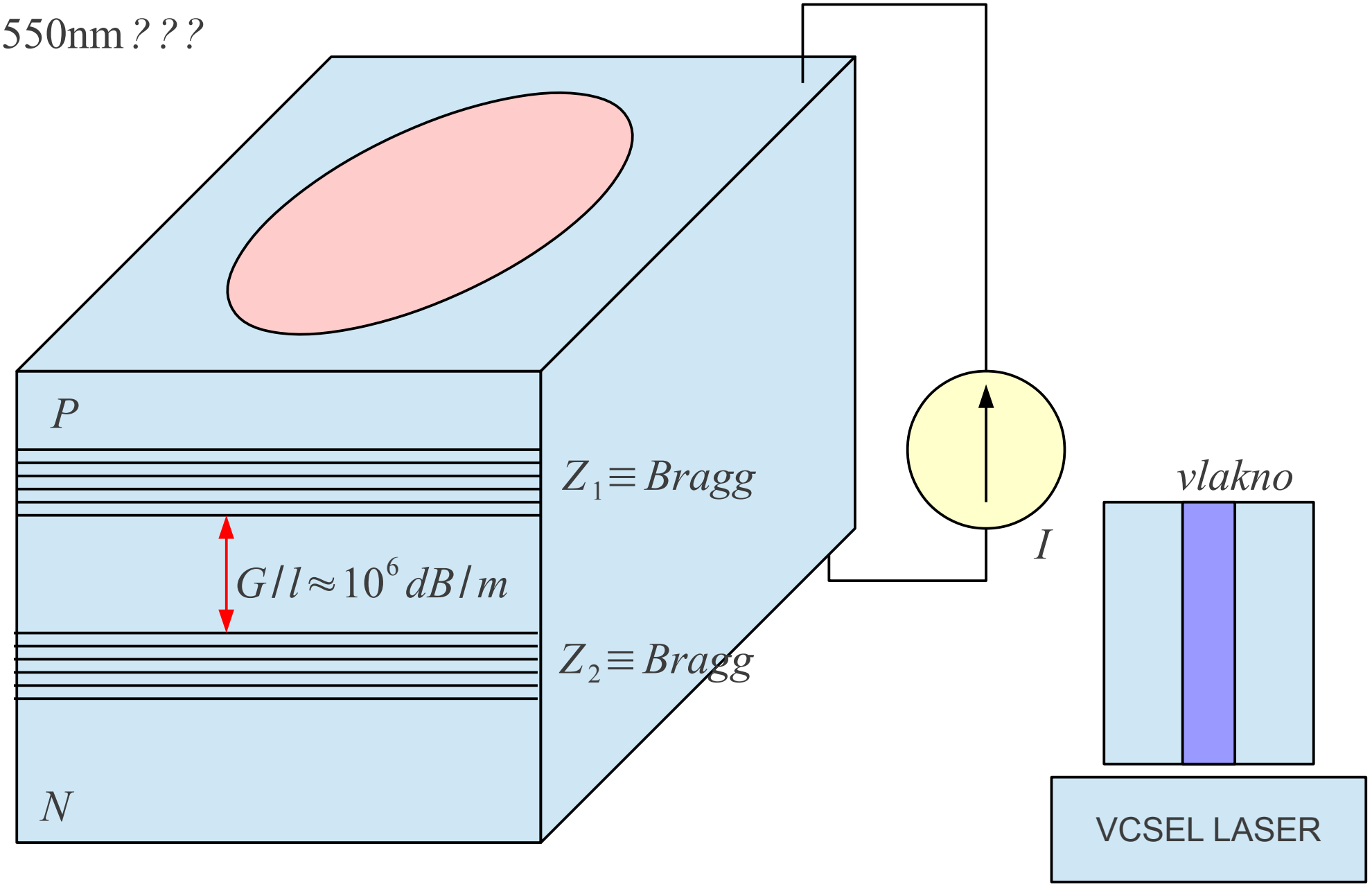
Draga mehanika ! ! ! !

Cenejše uglaševanje s tekočimi kristali...

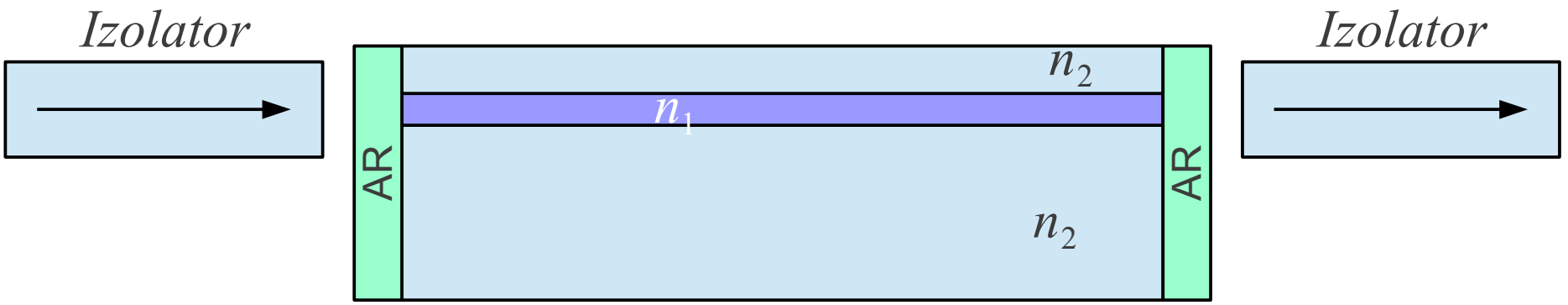
VCSEL ≡ Vertical Cavity Surface Emitting LASER

Večinoma 850nm *enorodovni !*

1550nm ? ? ?



Polprevodniški laserski ojačevalnik



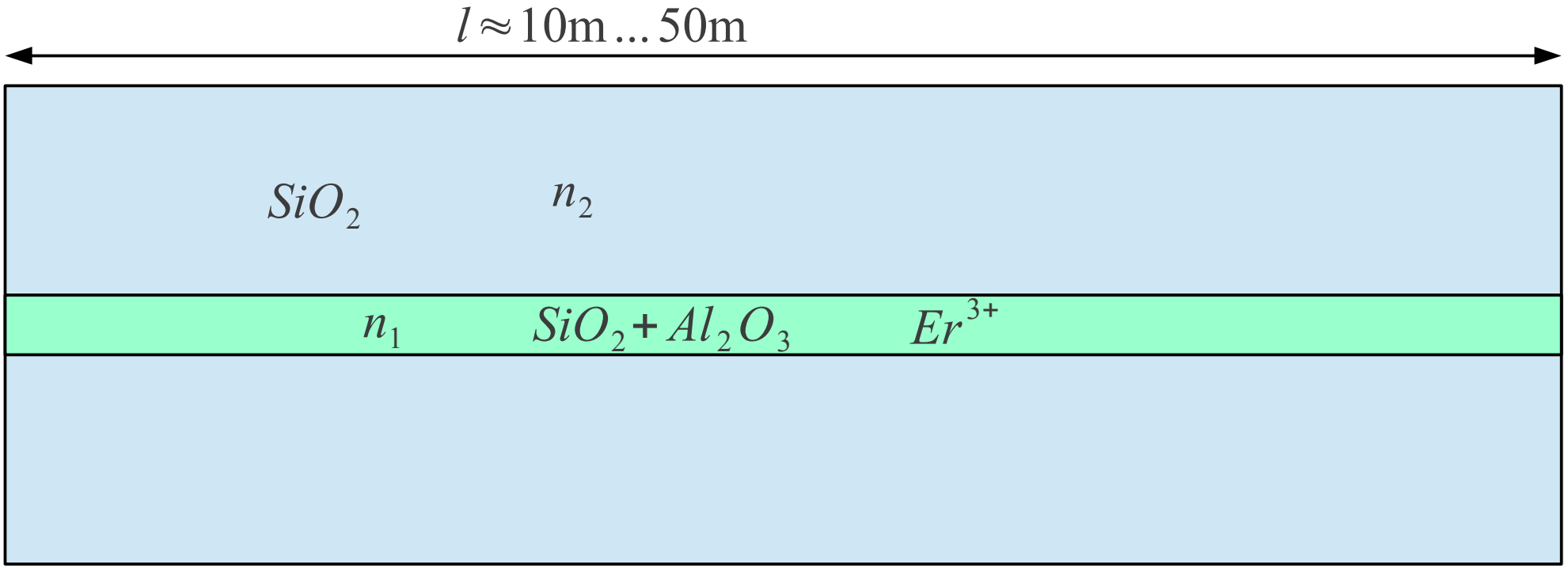
$G \approx 15\text{dB} \ldots 20\text{dB} \leftarrow (\textit{omejitev odboji na AR})$

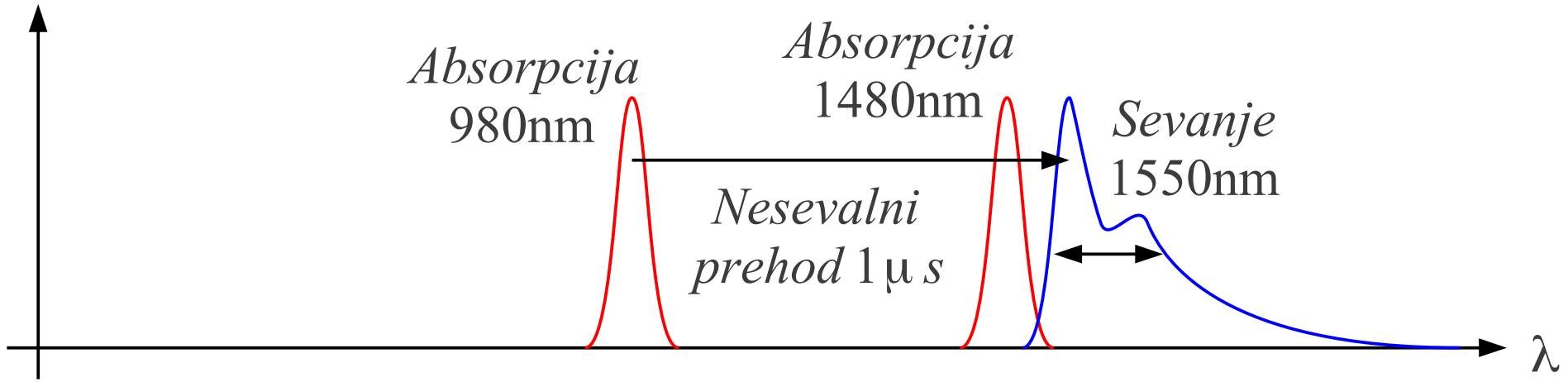
$\Delta\lambda > 100\text{nm}$

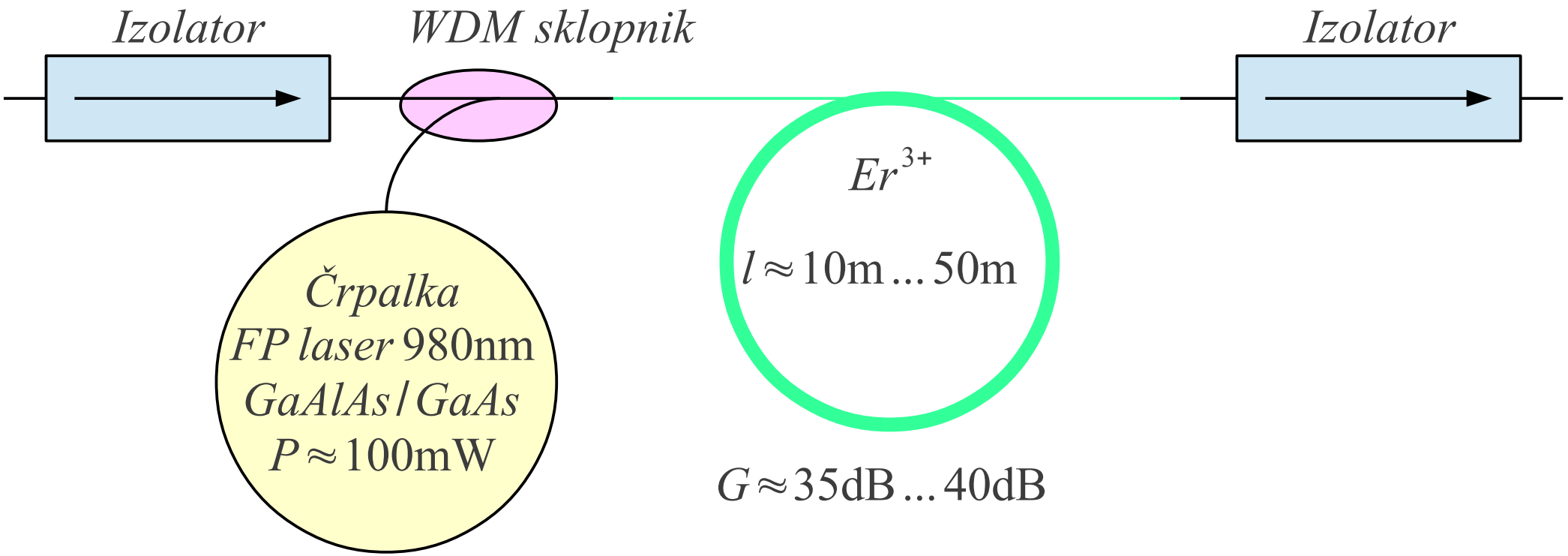
$\tau \approx 200\ ps \rightarrow$ *popačenje oziroma križna modulacija*

$Lantanidi\,(La): Nd\,,\ Er\,,\ Pr\,,\ Yb\,,\ Tm....$

$1964 \ldots Nd^{3+}$	$LASER$	$Nd-YAG$	$\lambda = 1064\text{nm}$	$\tau \approx 1\text{ms}$
$1988 \ldots Er^{3+}$	$vgradnja\ v\ steklo\ SiO_2$		$\lambda \approx 1550\text{nm}$	$\tau \approx 10\text{ms}$







$G \approx 35\text{dB} \ldots 40\text{dB}$

$\Delta\lambda \approx 30\text{nm}$

$\tau \approx 10\text{ms} \rightarrow$ *brez popačenja niti križne modulacije*

ASE ≡ Amplified Spontaneous Emission = ojačeno spontano sevanje

$$P_{ASE} = \mu \cdot (G-1) \cdot h \cdot f \cdot \Delta f$$

$$\mu = \frac{N_2}{N_2 - N_1}$$

$G \approx 40\text{dB} = 10000$

$h = 6.626 \cdot 10^{-34}\ Js$

$f \approx 194\text{THz}$

$\Delta f \approx 4\text{THz}$

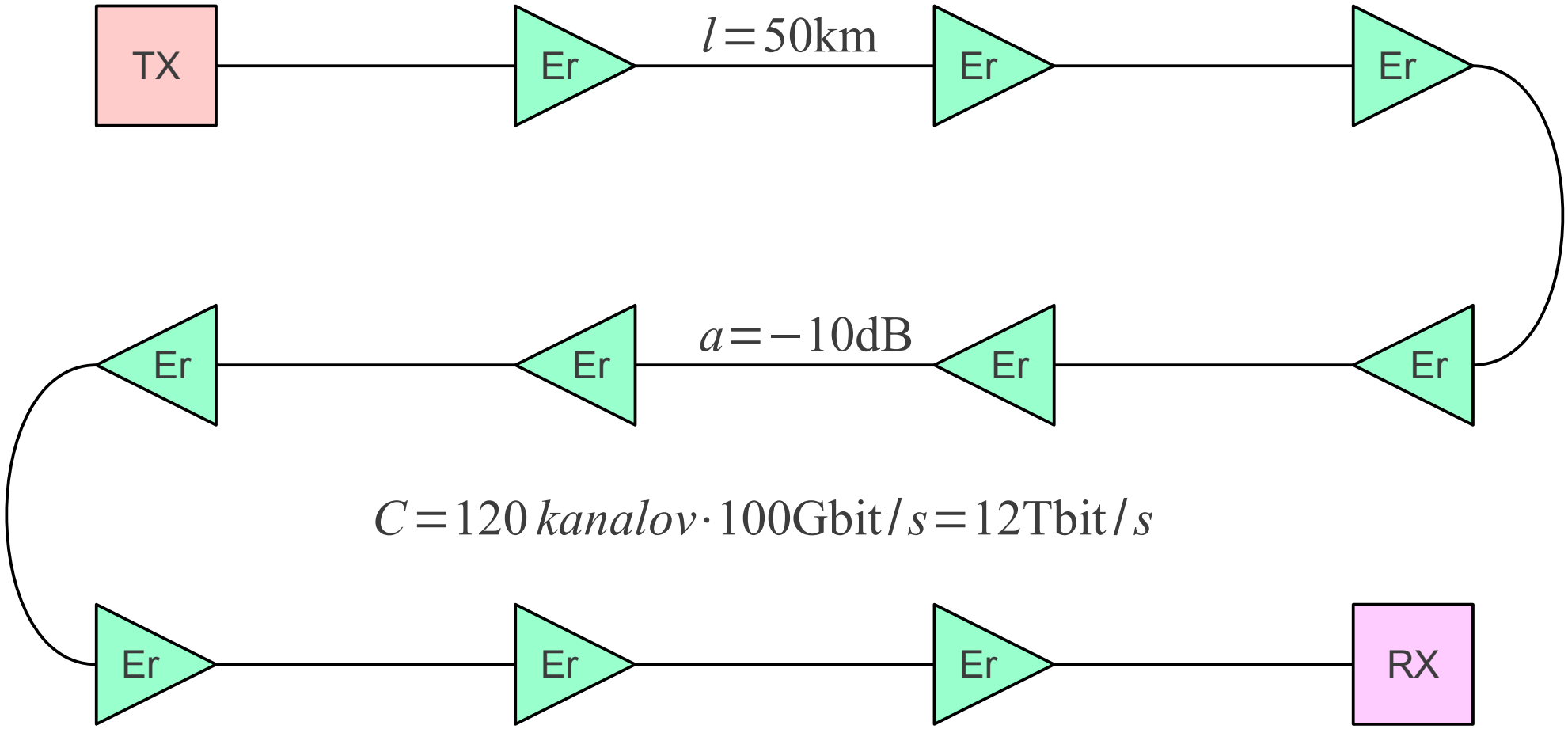
$\lambda_č = 980\text{nm} \rightarrow \mu \approx 1$

$\lambda_č = 1480\text{nm} \rightarrow \mu > 1$

$P_{ASE} = 5.1\text{mW}$ *za vsak rod posebej !*

$VP + HP$ *napredujoči + odbiti*

$\Sigma P_{ASE} = 20.6\text{mW}$ *za vse rodove*



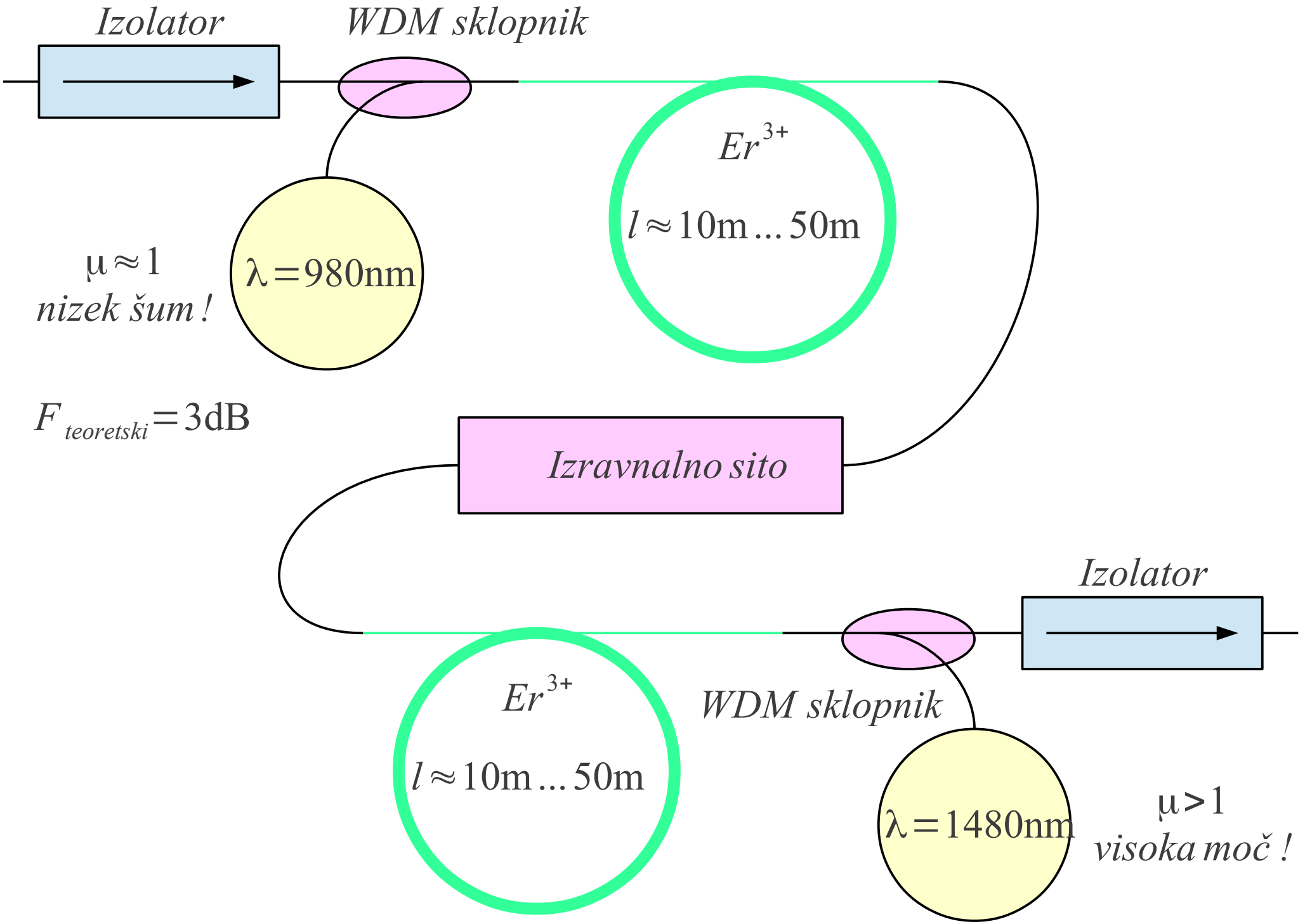
$WDM\,(FDM)\,ima\,N\,kanalov\,(huda\,težava\,OFDM\,v\,radiu)$

$\langle P \rangle = N \cdot P_{kanala}$

$Erbij\,\langle P \rangle\,se\,povpreči\,na\,\tau = 10\text{ms}$

$P_{MAX} = N^2 \cdot P_{kanala}$

$Erbij\,P_{MAX}\,nima\,omejitev\,!$


Izolator
WDM sklopnik
Er^{3+}
$l \approx 10\text{m} \ldots 50\text{m}$
$\mu \approx 1$
nizek šum !
$\lambda = 980\text{nm}$
$F_{teoretski} = 3\text{dB}$
Izravnalno sito
Izolator
Er^{3+}
$l \approx 10\text{m} \ldots 50\text{m}$
WDM sklopnik
$\lambda = 1480\text{nm}$
$\mu > 1$
visoka moč !