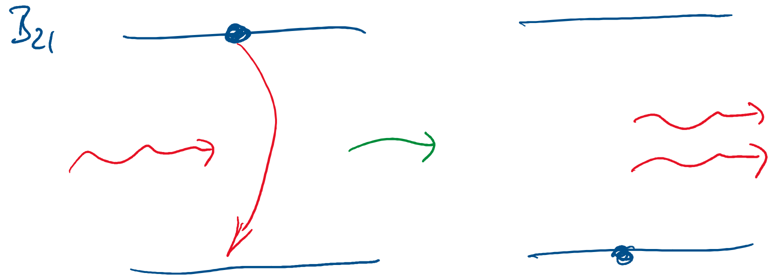
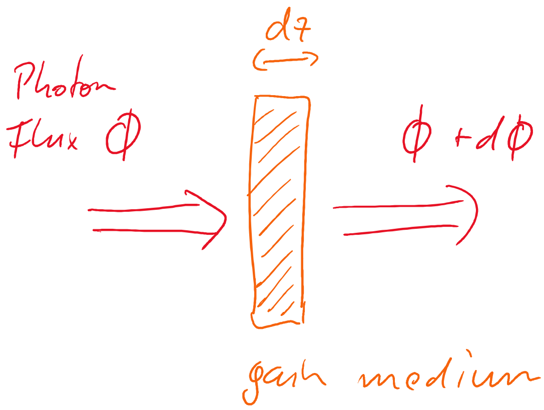
LASER

Light
Amplification by
Stimulated
Emission of
Radiation

Demtröder
Laser spectroscopy Vol 1
Chapter 5





$$d\Phi = \underbrace{\Phi \cdot \sigma_{21} \cdot N_2}_{\text{stim. emission}} - \underbrace{\Phi \sigma_{12} \cdot N_2}_{\text{absorption}}$$

$\sigma_{12} = \sigma_{21}$ cross section

$$d\Phi = \Phi \cdot \sigma_{12} (N_2 - N_1)$$

↳ population imbalance (like w)

amplification $\hat{=}$ $d\Phi > 0$ $\Leftrightarrow$ $N_2 > N_1$

amplification requires inversion

length of medium

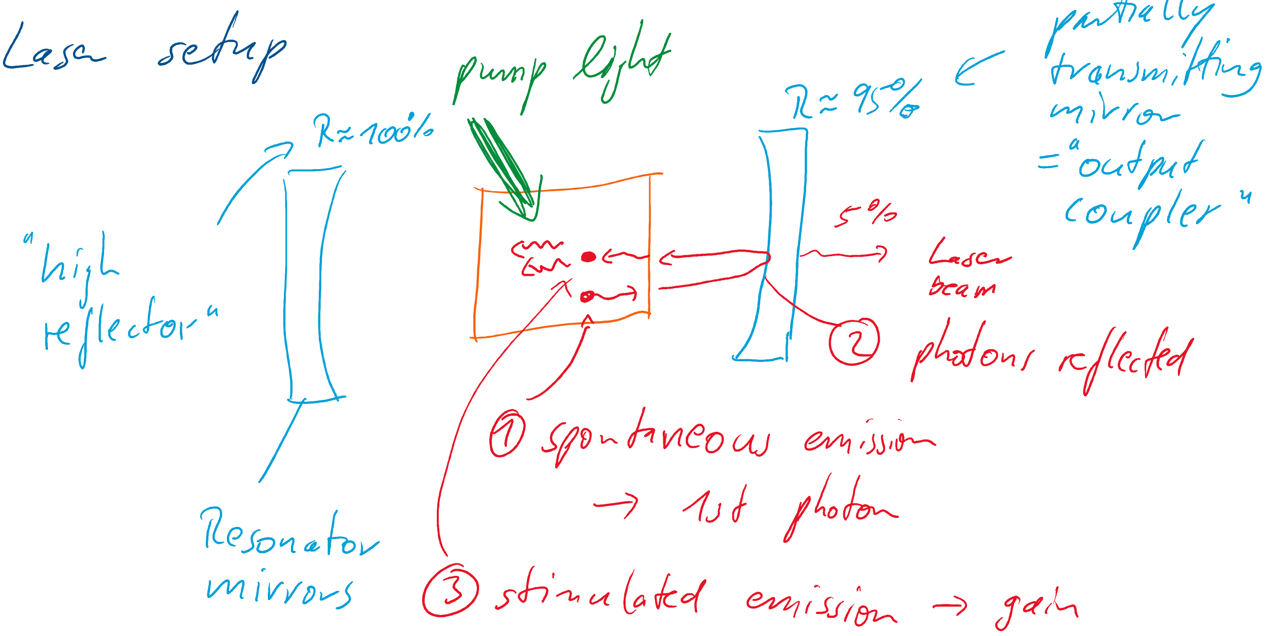
amplification requires inversion

$$\Phi = \Phi_0 \, e^{\sigma_{21}(N_2 - N_1)\cdot \ell}$$

← length of medium

exponential gain

Laser setup



lasing starts when gain ≟ losses

round trip loss is compensated by round trip gain

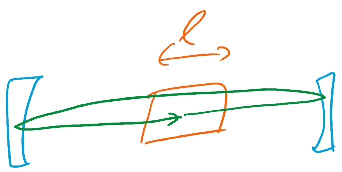
⇒ lasing threshold

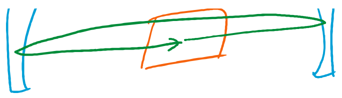
$$R_1 \cdot R_2 \cdot e^{(2\sigma(N_2 - N_1)\ell)} = 1$$

$R_1 \cdot R_2$: mirror reflectivities

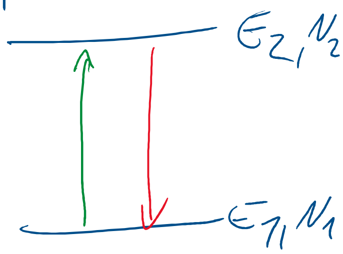
2: 2 passes per round trip

ℓ: length of gain medium



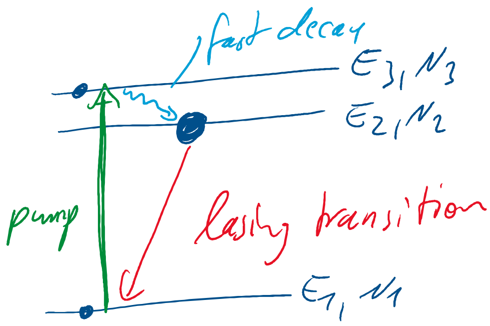


2level system : no good



no lasing possible because $(N_2 - N_1)$ max $= 0$ equal population

3rd level : works



E_2 "long" lived µs....ms

inversion between E_2 and E_1

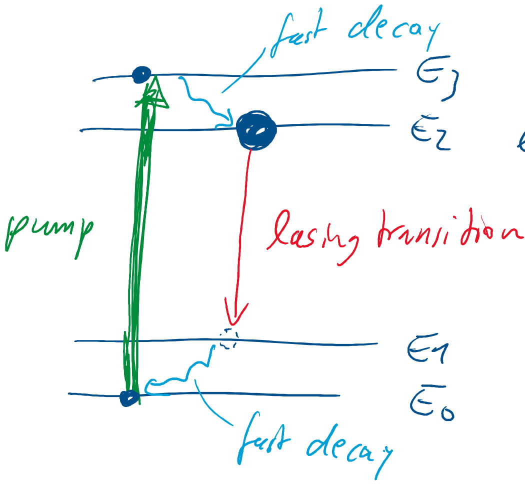
4 levels $\hat{=}$ "ideal"

↓

"no" absorption of laser light

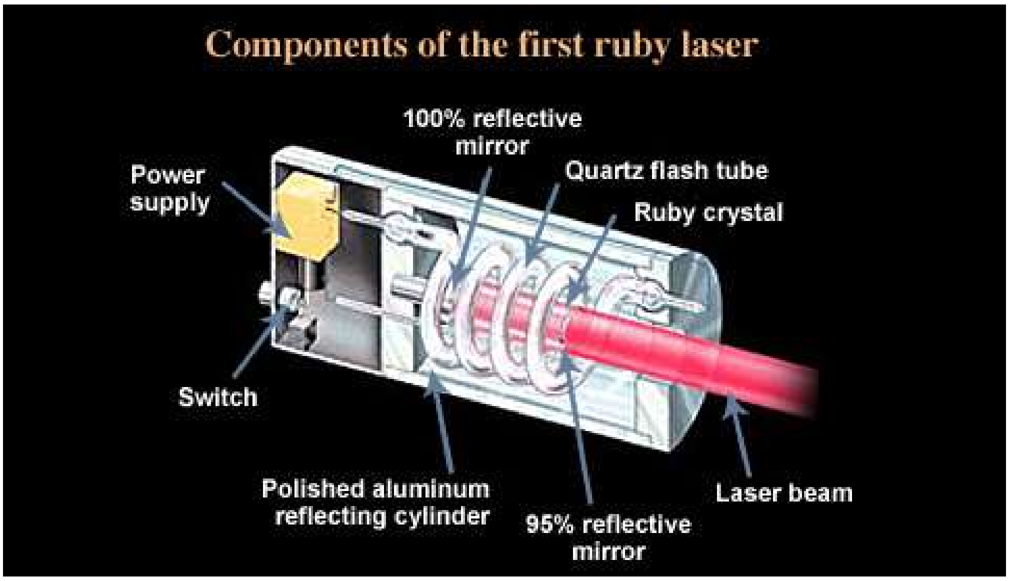
because $N_1 \approx 0$ at all times

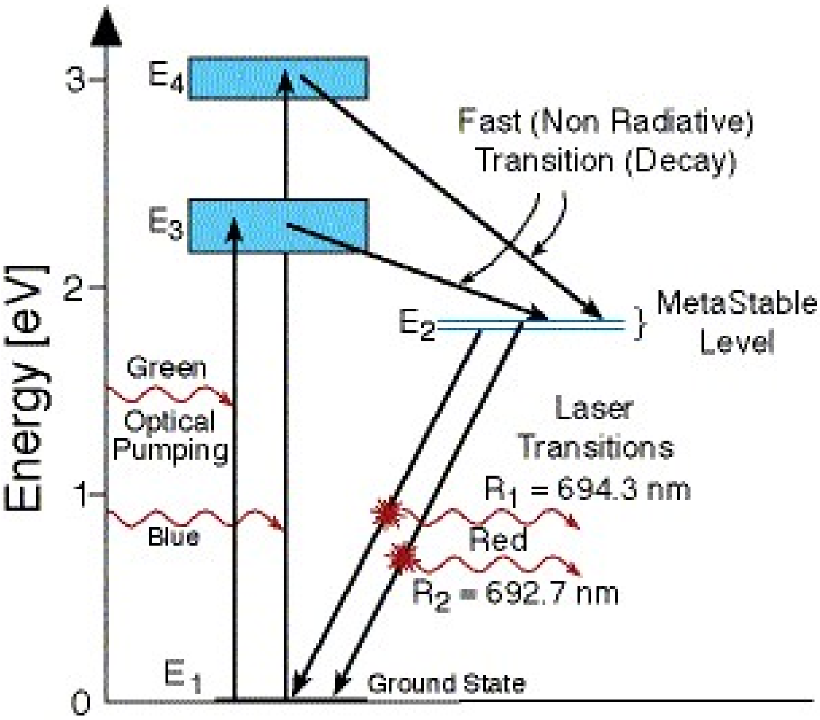
due to fast decay $N_1 \rightarrow N_0$



① The 1st laser: Ruby laser

Theodore Maiman
No Nobel prize!!



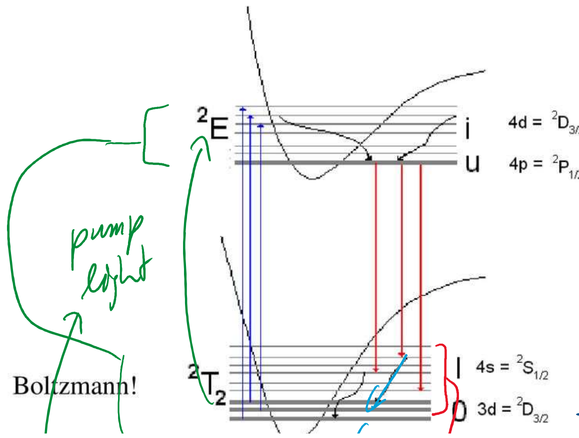


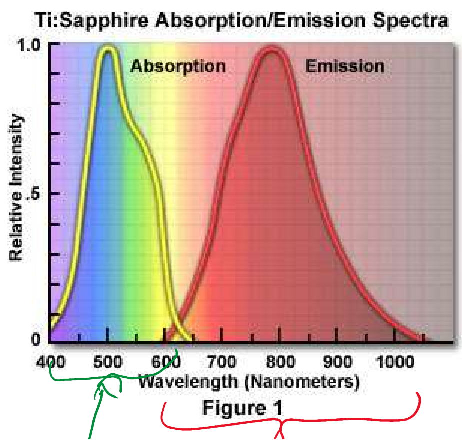
Ruby

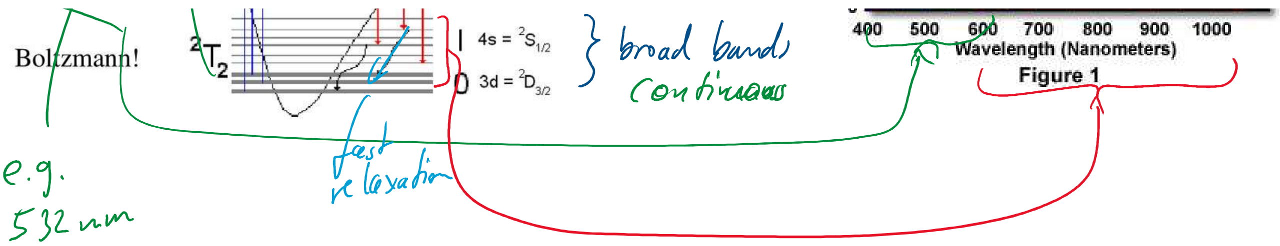
not very tunable

② Ti: sapphire Ti^{3+} ions in Al_2O_3

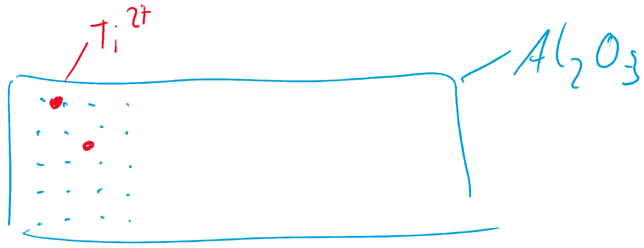
Energy level scheme







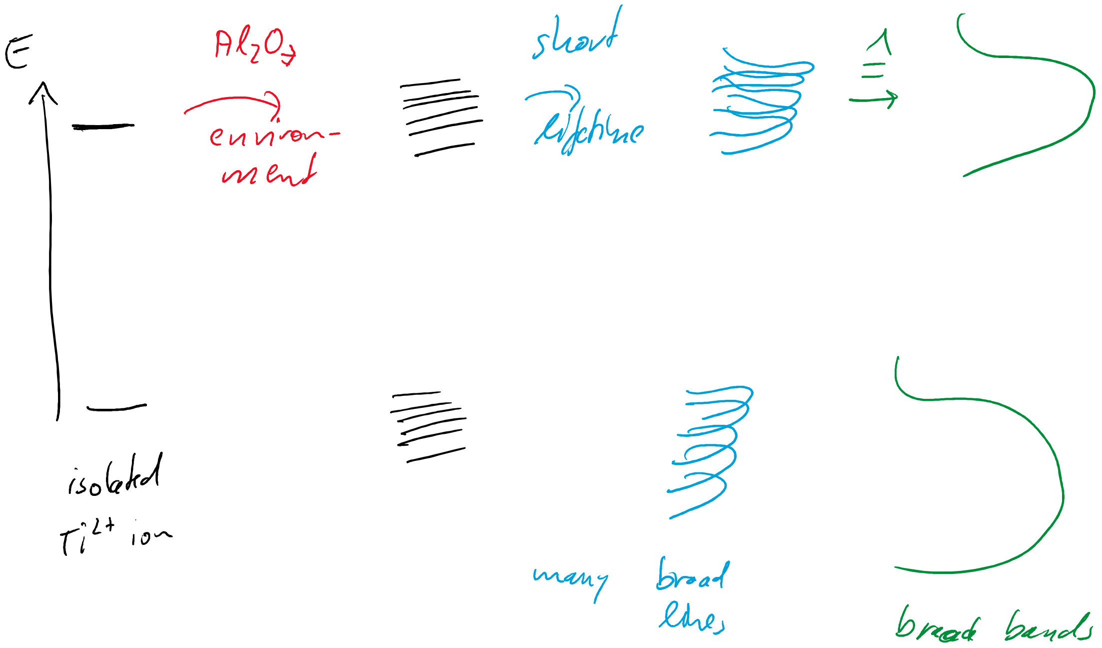
bands: not discrete lines, but broad overlapping ones



ions in lattice see different B, E fields

$\Rightarrow$ Zeeman & Stark shifts

fast relaxation $\rightarrow$ broad levels



very useful laser

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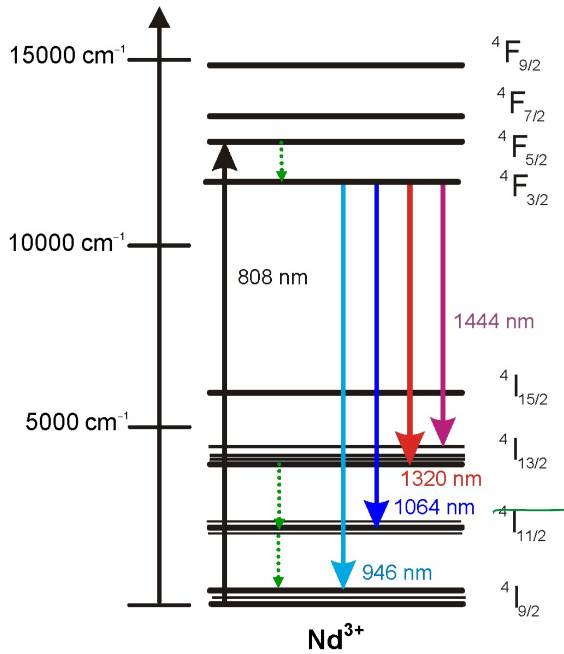
③ Nd:YAG $\quad Nd^{3+} : Y_3 Al_5 O_{12}$



1064 nm useful

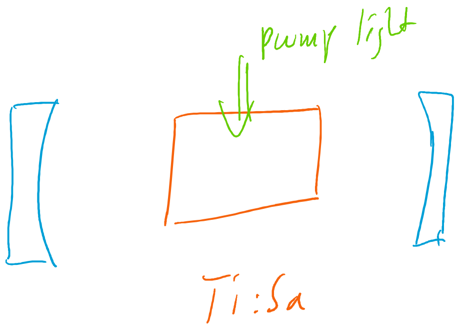
↓

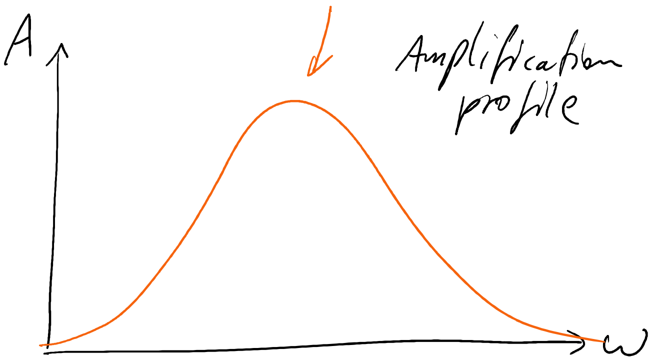
frequency doubling (SHG)

↓

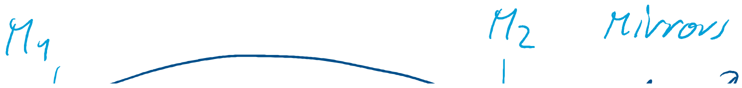
532 nm

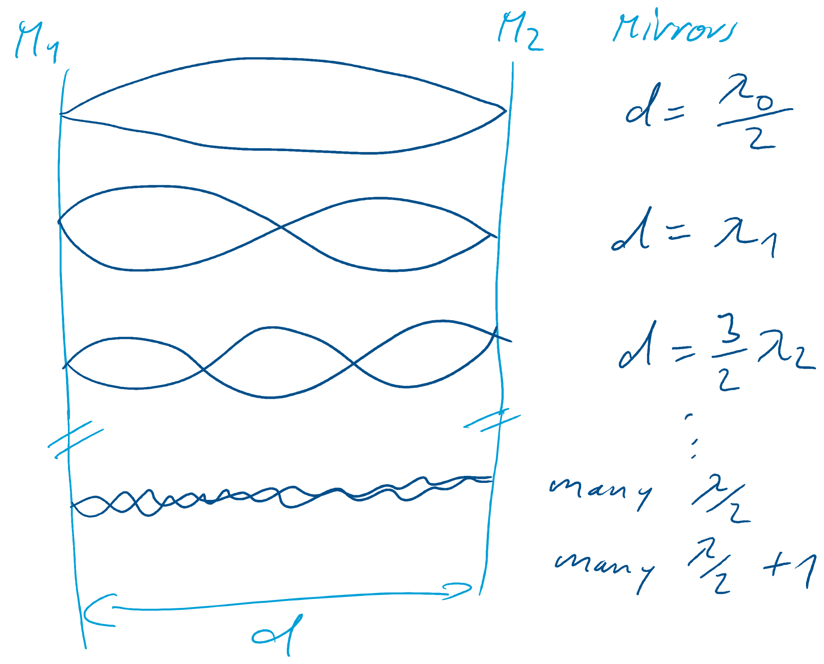
Properties of laser radiation

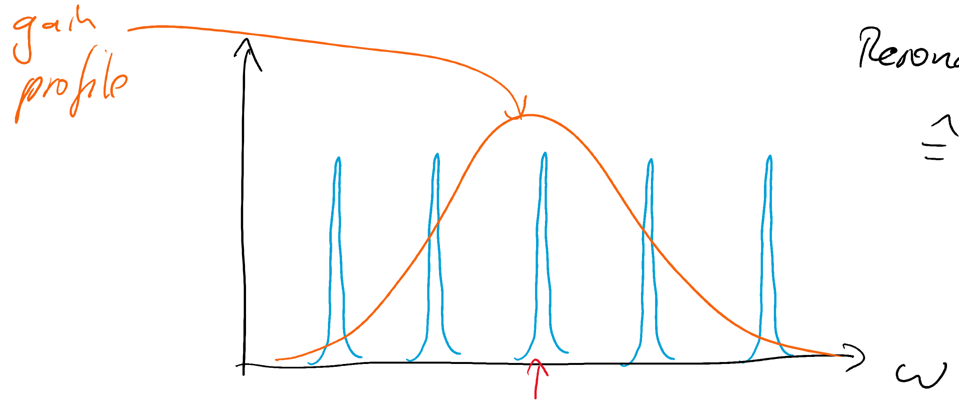




Resonator modes







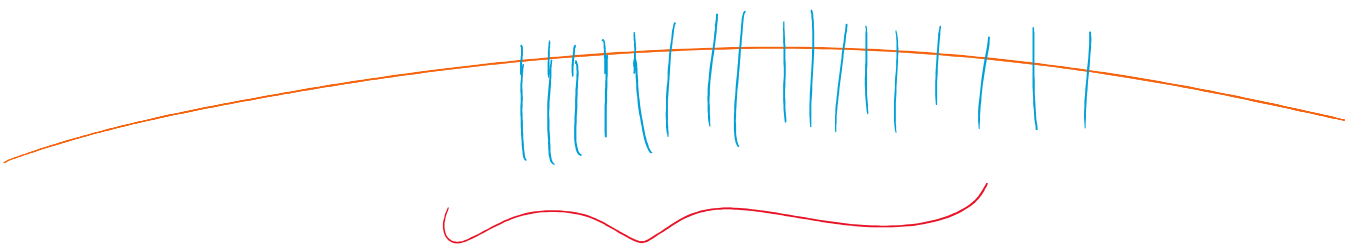
Resonator modes ≙ standing laser fields

this mode will "win" because it has the highest gain

$\Rightarrow$ no more gain for the other modes

You want broad gain profile → widely tunable laser

Resonator modes are usually narrowly spaced



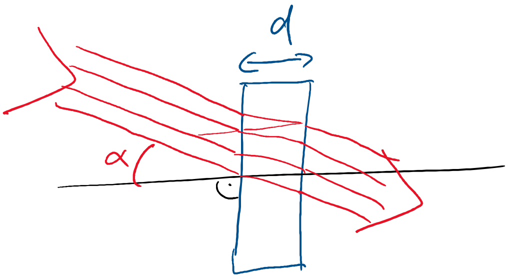
loses lases somewhere here

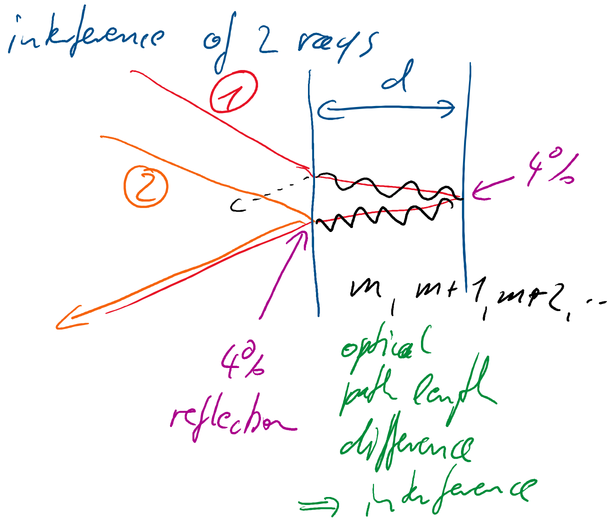
⇒ additional frequency selection devices

Frequency selection:

① resonator length ≙ distance between the HR & OC

② Etalon ≙ glass plate





Transmission of Etalon

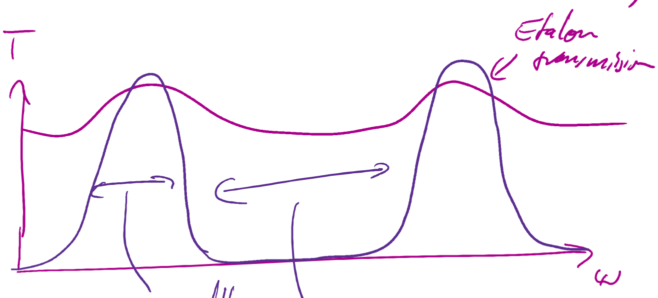
$$\lambda_m = \frac{2d}{m}\sqrt{n^2 - \sin^2\alpha}$$

↑ transmission wavelength of m_{th} maximum

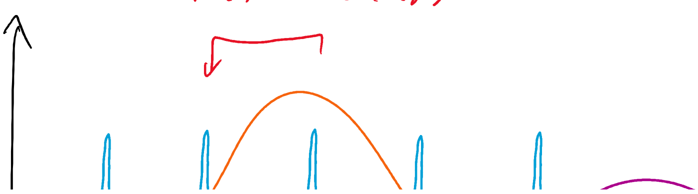
only small reflectivities (4% for $n = 1 \rightarrow 1.5 \rightarrow 1$)

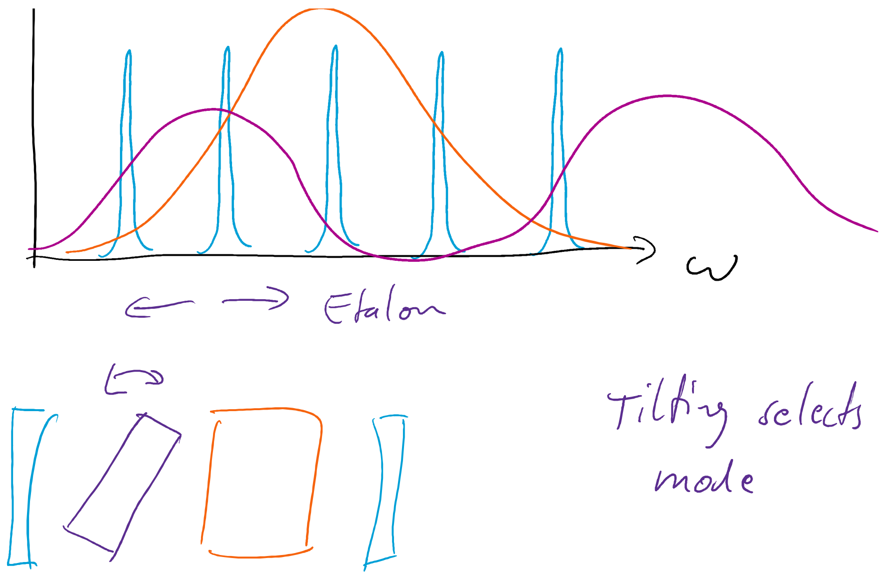
⇒ "bad" resonator

glass plate + "HR" coating 90%



this mode lases better





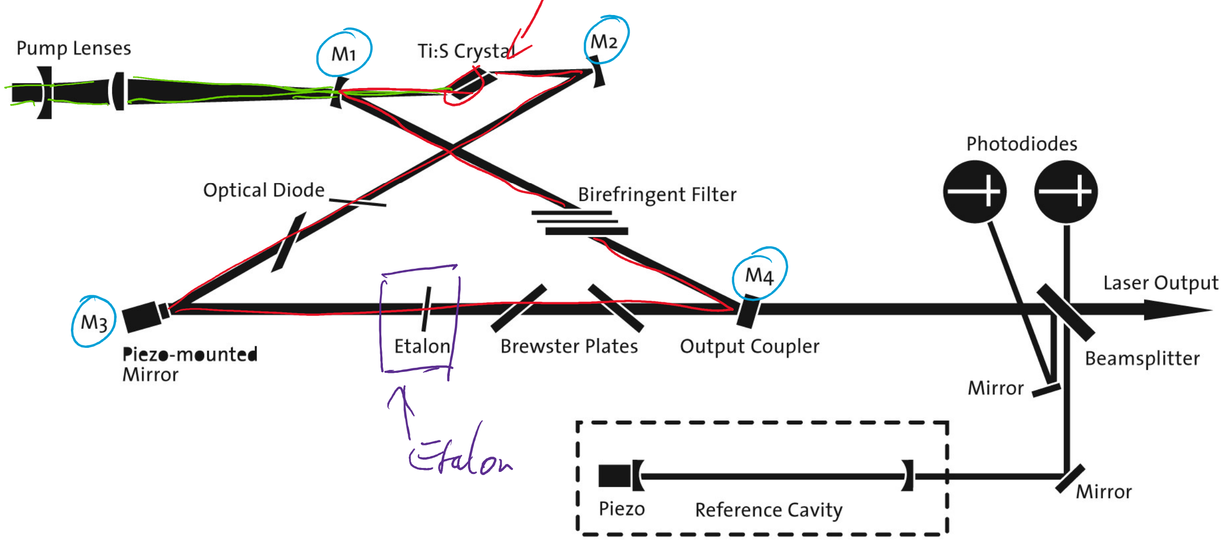
Tilting selects resonator mode

Typical laser

Ti:Sa ring laser ⇒ 4 mirrors
bow-tie geometry

Optical Schematic of the MBR-110 Ti:Sapphire Laser

Verdi 532 nm input



M1 is dichroic

High Transmission for 532 nm pump light
High Reflectivity for 700 ... 900 nm laser light