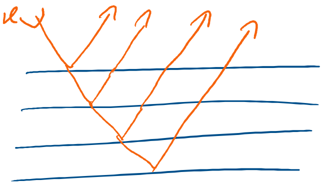
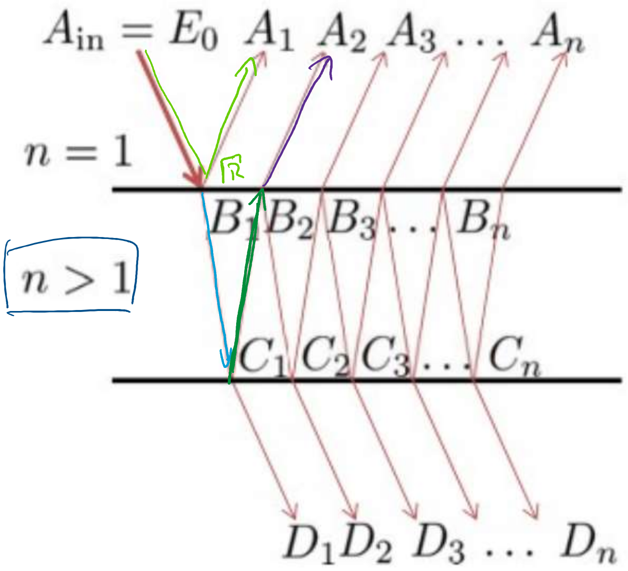
Optical coatings ⇒ laser mirrors
etalons
anti-reflection coatings
dichroic mirrors (reflectivity depends on λ)
⋮

multi-beam interference



e.g. 1 glass plate



amplitudes that interfere

intensity reflection R
amplitude reflection coeff. $\sqrt{R}$

$|A_1| = R^{\frac{1}{2}} \cdot |A_0|$ reflected

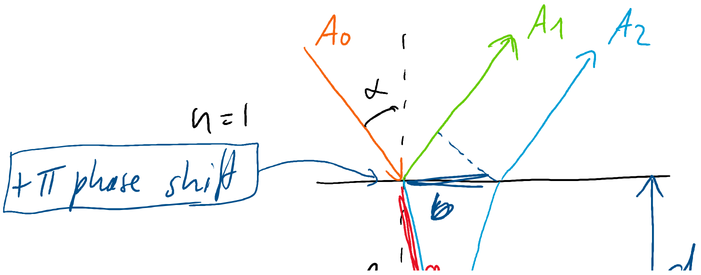
$|B_1| = (1-R)^{\frac{1}{2}} |A_0|$ transmitted

$|C_1| = R^{\frac{1}{2}} \cdot |B_1| =$
$= R^{\frac{1}{2}} (1-R)^{\frac{1}{2}} |A_0|$

$|A_2| = (1-R)^{1/2} |C_1|$

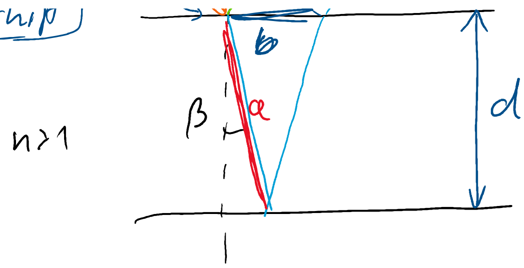
These are the amplitudes of the reflected & transmitted beams

Interference: look @ phase differences, too



optical path length difference
$\Delta s = 2na - b \cdot \sin\alpha$

+π phase shift



$$\Delta s = 2na - b \cdot \sin\alpha$$

$$= \dots\dots$$

$$= 2d\left(n^2 - \sin^2\alpha\right)^{\frac{1}{2}}$$

Snellius: $\frac{\sin\alpha}{\sin\beta} = \frac{n_2}{n_1} = \frac{n}{1}$ here

wave phase difference $\Delta\varphi = 2\pi \frac{\Delta s}{\lambda}$

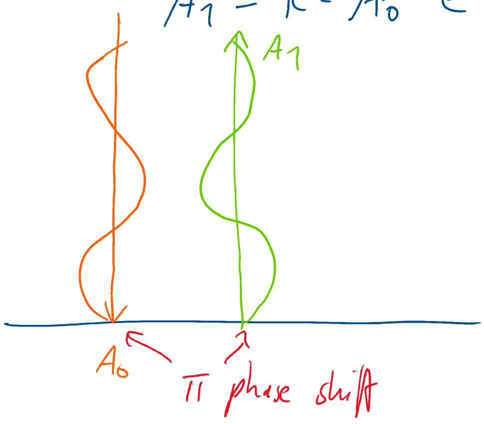
+ possible phase jumps in reflection ✓

↳ π phase shift if $n_{lo} \to n_{hi}$

A_1 gets π phase shift

$$|A_1| = R^{\frac{1}{2}} |A_0|$$

$$A_1 = R^{\frac{1}{2}} A_0 \cdot e^{i\pi} = -R^{\frac{1}{2}} A_0$$



Summing over all partial waves:

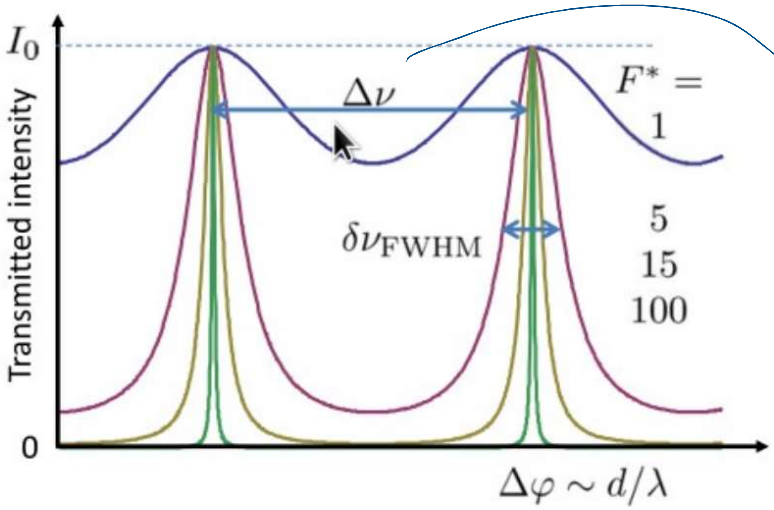
$$A_{reflected} = -A_{in} R^{\frac{1}{2}} \frac{1 - e^{i\Delta\varphi}}{1 - R \cdot e^{i\Delta\varphi}}$$

with $\Delta\varphi = 2\pi \frac{\Delta s}{\lambda}$

intensities:

$$I_R = I_0 \cdot R \frac{4 \sin^2\left(\frac{\Delta\varphi}{2}\right)}{(1-R)^2 + 4R\sin^2\left(\frac{\Delta\varphi}{2}\right)} \quad \text{reflected}$$

$$I_T = I_0 \frac{(1-R)^2}{(1-R)^2 + 4R\sin^2\left(\frac{\Delta\varphi}{2}\right)} \quad \text{transmitted}$$



$\Delta\nu$ = FSR
Free spectral range

100% transmission on resonance!

$$F^* = \text{finesse} = \frac{\pi\sqrt{R}}{1-R}$$

$R = 0 \rightarrow F^* = 0$

$R \rightarrow 1 \rightarrow F^* \rightarrow \infty$

$\Delta\nu$ = FSR = distance between 2 peaks

$$\Delta\nu(\alpha = 0) = \frac{c}{2nd}$$

↑ perpendicular laser incidence

c: speed of light in vacuum

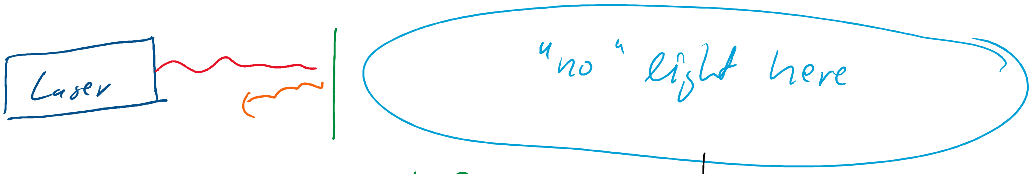
$2nd$: optical path length $2d \cdot n$ (n: ref. index)

$\delta\nu_{FWHM}$ = width of transmission peaks

$$= \frac{\Delta\nu}{F^*} \iff F^* = \frac{\Delta\nu}{\delta\nu_{FWHM}}$$

↑ can be measured by scanning a laser

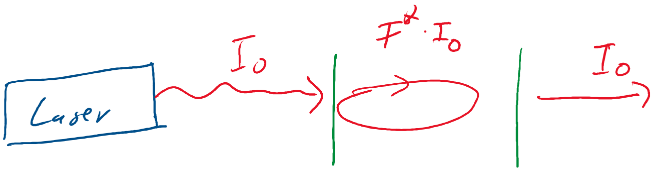
Side note: 100% transmission at central λs!



very high R
mirror

all light is reflected

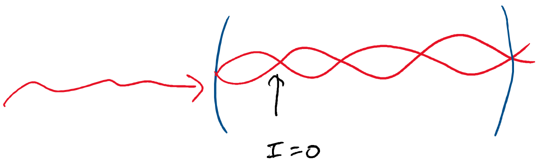
put a 2nd
mirror into
region without light



100% light transmission
↑
for the correct mirror spacing

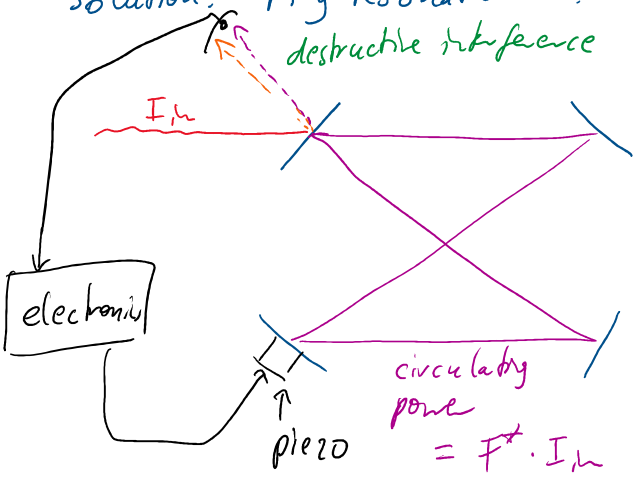
F^* gives the number of interfering beams
≙ intensity enhancement
↙

Power enhancement for weak transitions
↳ "on average"



standing wave

Solution: ring resonator : 4 mirrors



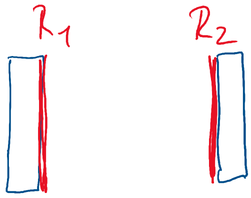
no standing wave
↙
travelling wave
⇒ $I = const$ inside

piezo moves
mirror to maintain opt. path length inside 4 mirror cavity

Example :

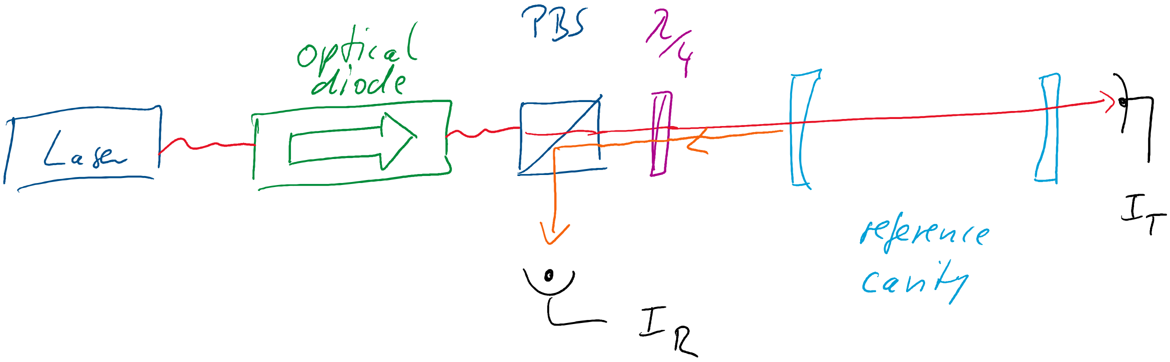
single glass plate $\quad R = 0.04 \Rightarrow F^* = 0.7$

resonator cavity



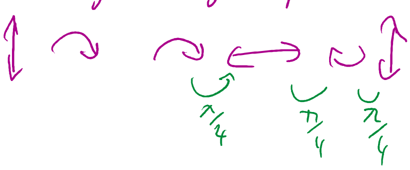
unequal mirrors: $$F^* \approx \frac{\pi\,(R_1 R_2)^{1/4}}{1-(R_1 R_2)^{1/2}}$$

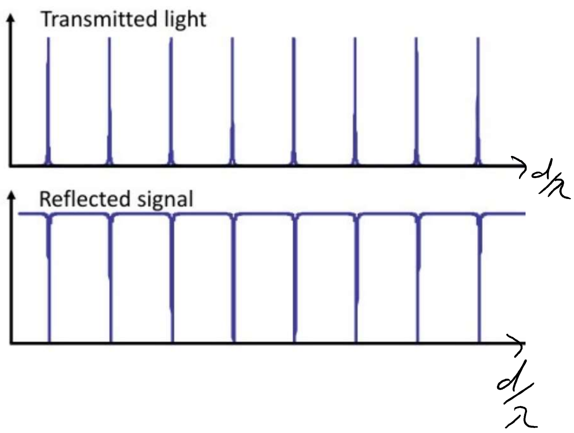
Stabilizing a laser onto another resonator



PBS: splits beam into horizontal & vertical polarization

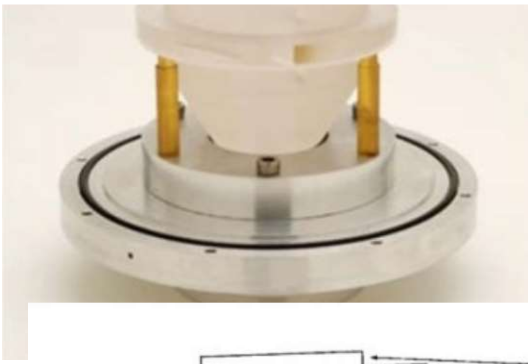
λ/4 : quarter-wave plate
changes light polarization





mirror

ULE spacer
ultra-low expansion
(thermal)



expansion
(thermal)