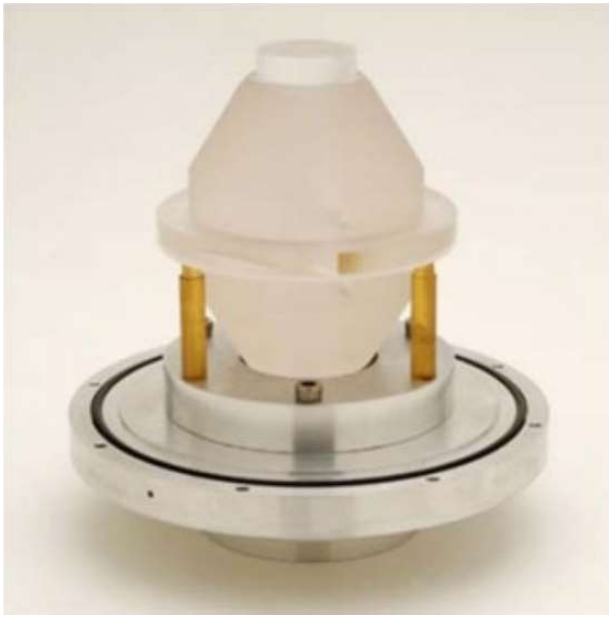
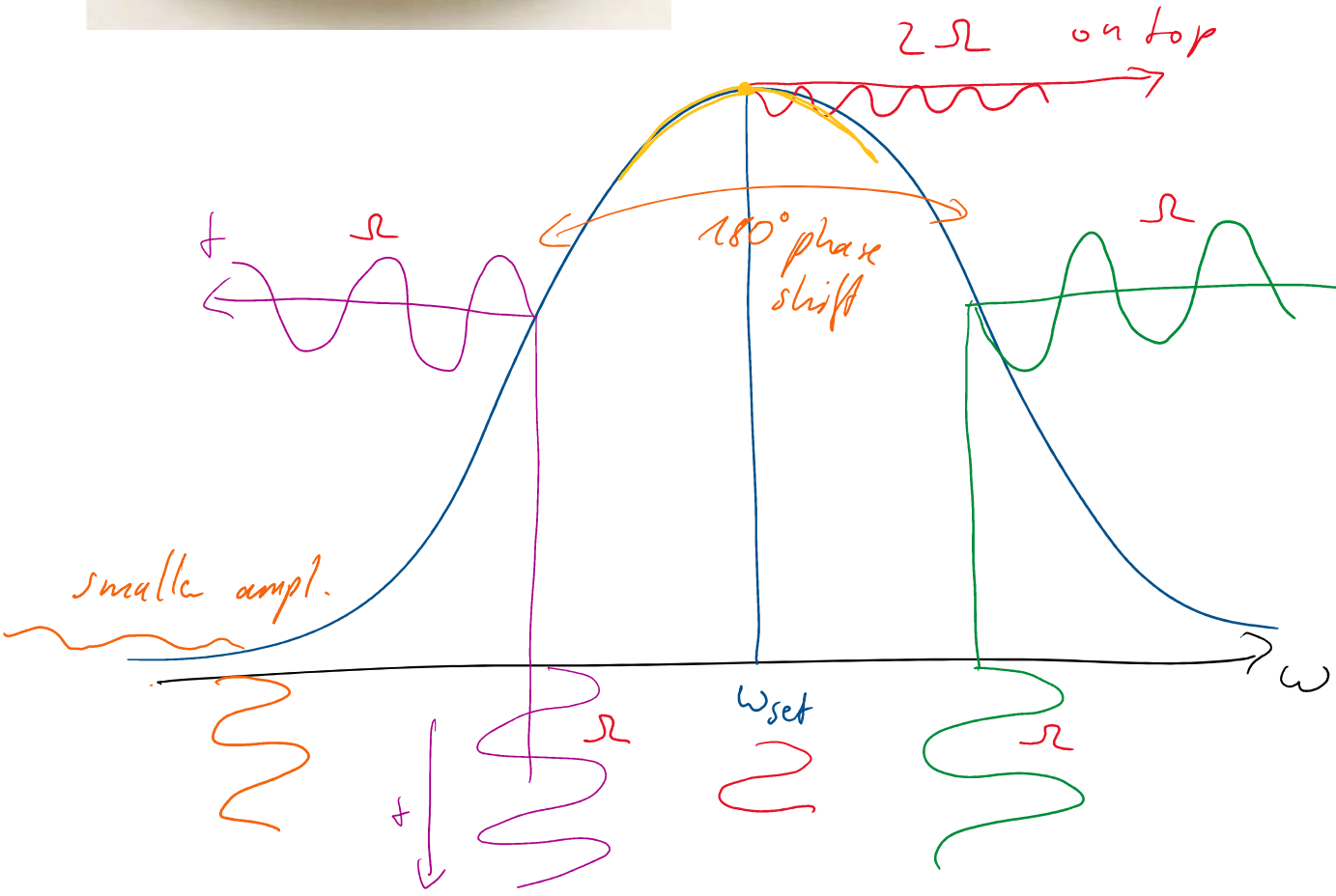
Pound-Drever-Hall (PDH) Lock

Donnerstag, 1. Juni 2023 12:36

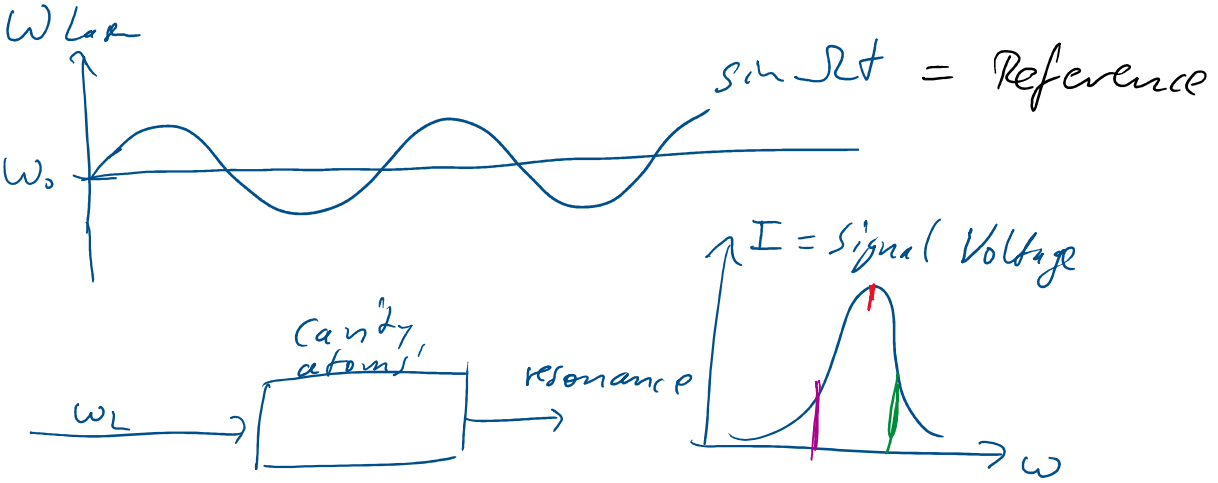


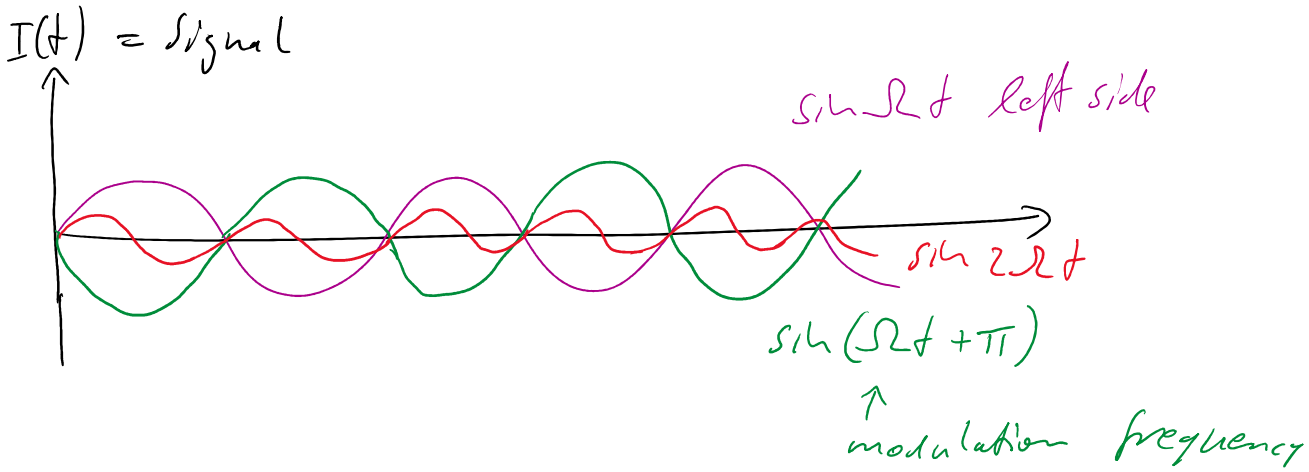


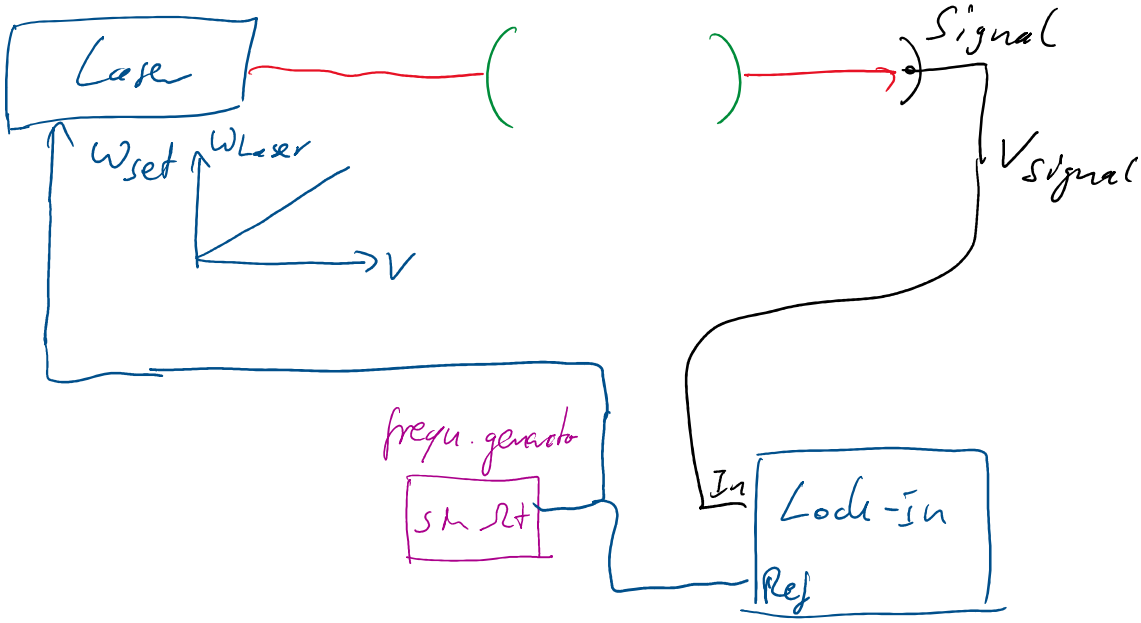
Lock-In Amplifier = phase-sensitive detector

Laser $E(t) = E_0 \sin(\omega_0 t + \sin \Omega t)$

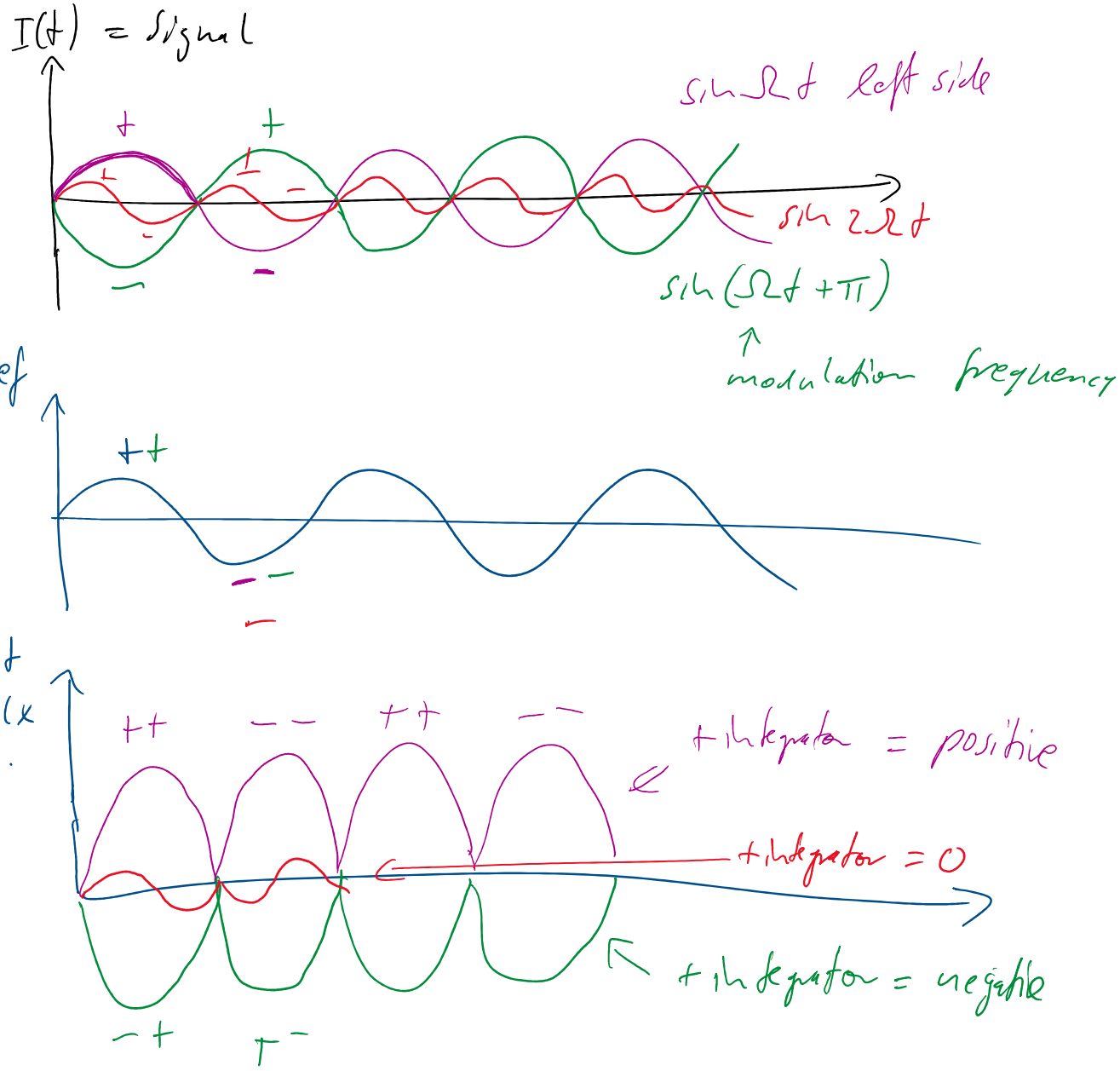
$\omega(t) = \omega_0 + \sin \Omega t$

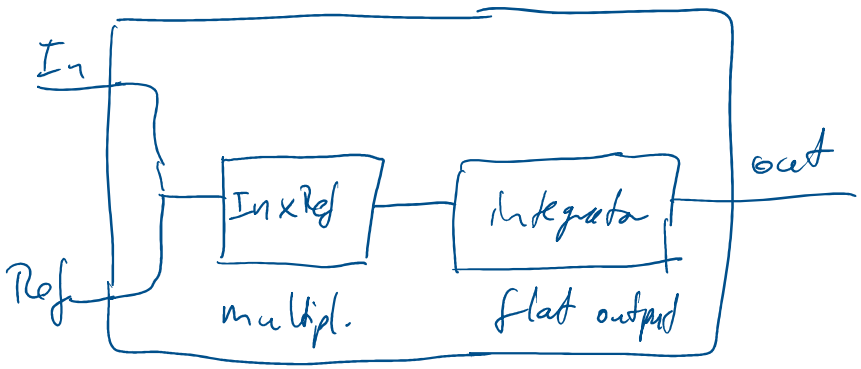




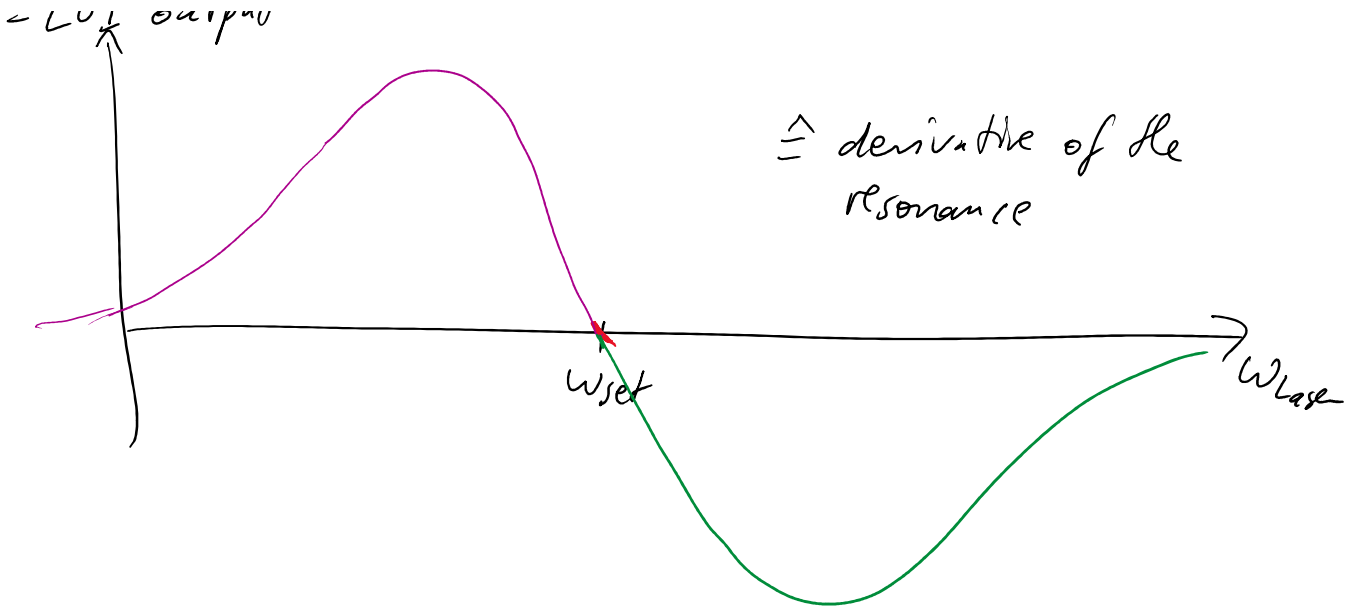


$I(t) = \text{Signal}$



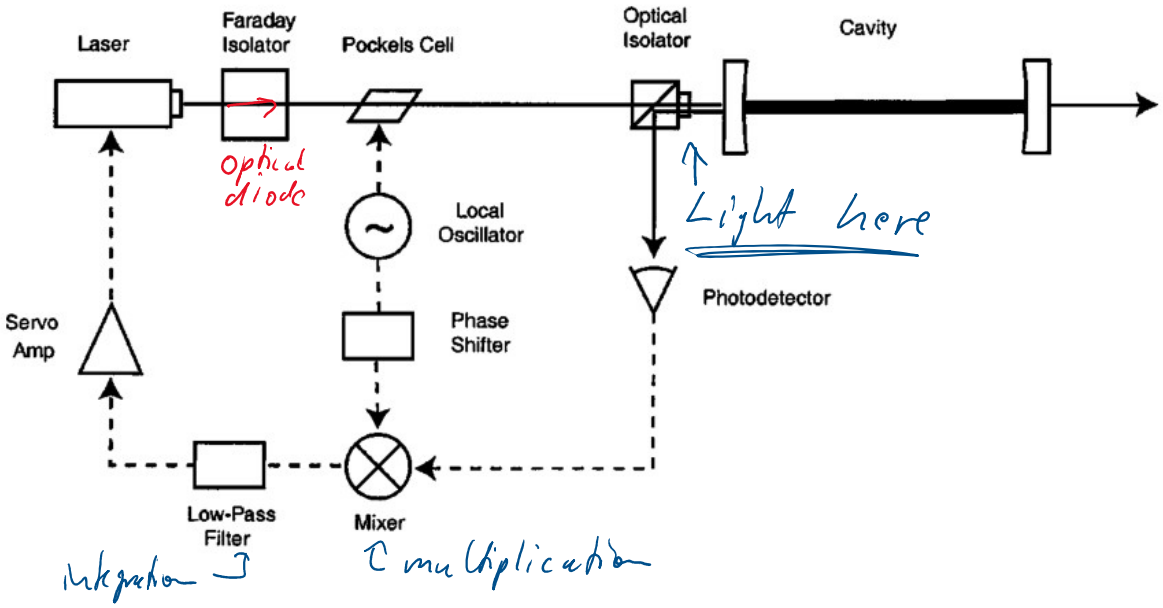


Error signal
= LOI output



Pound-Drever-Hall PDH Lock

Black, Am. J. Phys. (2001)



$E_{inc} = E_0 e^{i\omega t}$

$E_{refl.} = E_1 e^{i\omega t}$

E_0, E_1 = complex

↓

they have a phase

reflection coefficient

$$F(\omega) = \frac{E_{ref}}{E_{inc}} = \frac{r\left(\exp\left(i\frac{\omega}{\Delta\nu_{fsr}}\right)-1\right)}{1 - r^2 \exp\left(i\frac{\omega}{\Delta\nu_{fsr}}\right)}$$

E_{inc}

$$1 - r^2 \exp\left(i \frac{\omega}{\Delta\nu_{fsr}}\right)$$

r = Amplitude reflection of mirror

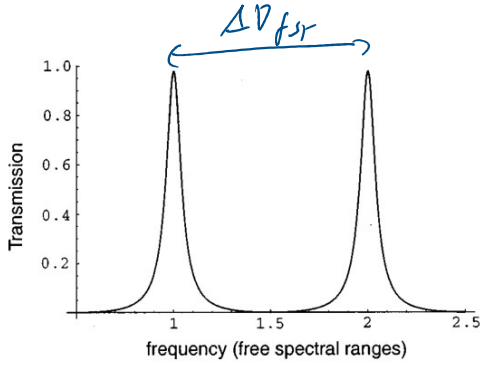
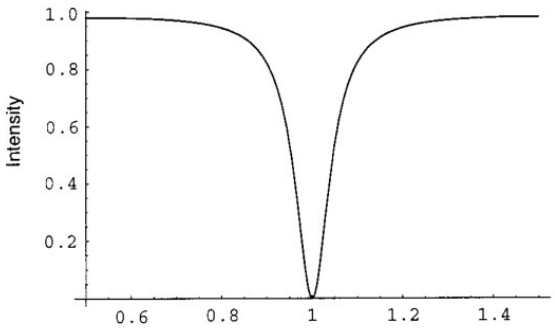


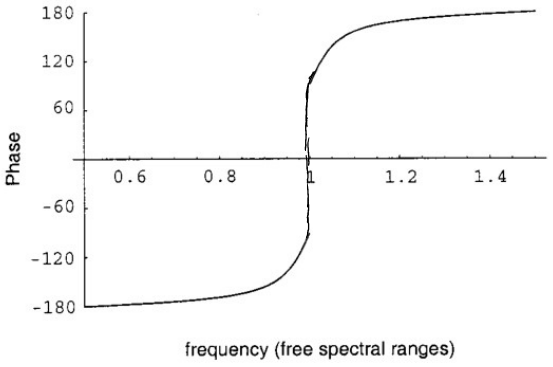
Fig. 1. Transmission of a Fabry–Perot cavity vs frequency of the incident light. This cavity has a fairly low finesse, about 12, to make the structure of the transmission lines easy to see.

$E_{refl.}$ = coherent sum of directly reflected incoming light and light leaking out of the cavity

$F(\omega)$



real part



Im. part

$$E_{inc} = E_0 e^{i(\omega t + \beta \sin \Omega t)}$$

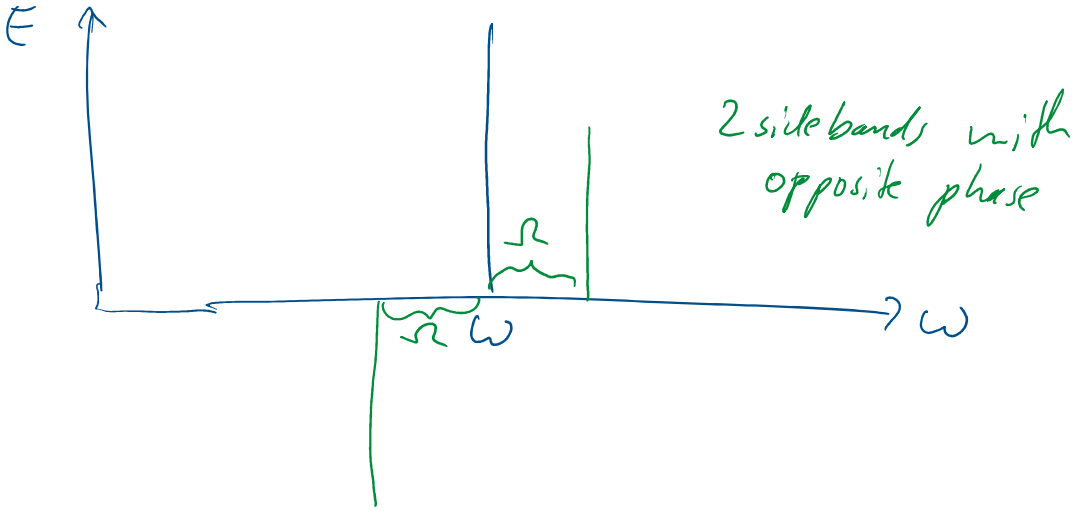
↑ phase change by Pockels cell

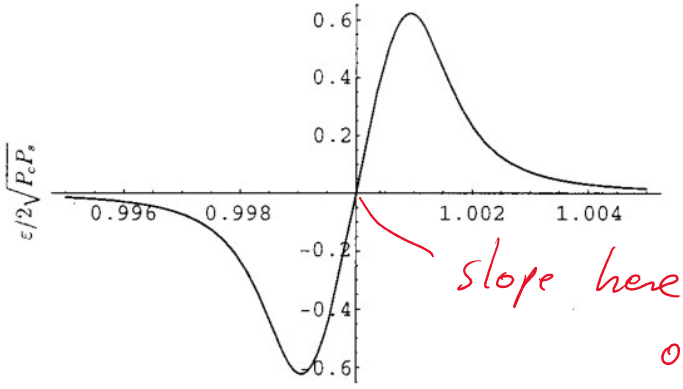
↑ modulation index

$$\approx \left[J_0(\beta) + 2iJ_1(\beta) \sin \Omega t\right] e^{i\omega t}$$

$\approx [J_0(\beta) + 2iJ_1(\beta)\sin\Omega t]\, e$

Bessel





slope here defines the quality of the laser lock

Fig. 6. The Pound–Drever–Hall error signal, $\epsilon/2\sqrt{P_c P_s}$ vs $\omega/\Delta\nu_{\rm fsr}$, when the modulation frequency is low. The modulation frequency is about half a linewidth: about 10^{-3} of a free spectral range, with a cavity finesse of 500.

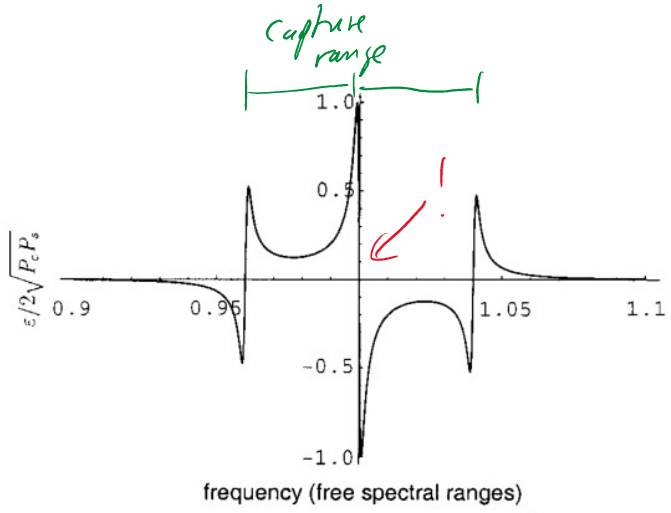


Fig. 7. The Pound–Drever–Hall error signal, $\epsilon/2\sqrt{P_c P_s}$ vs $\omega/\Delta\nu_{\rm fsr}$, when the modulation frequency is high. Here, the modulation frequency is about 20 linewidths: roughly 4% of a free spectral range, with a cavity finesse of 500.