Electro-optic modulator for Advanced LIGO

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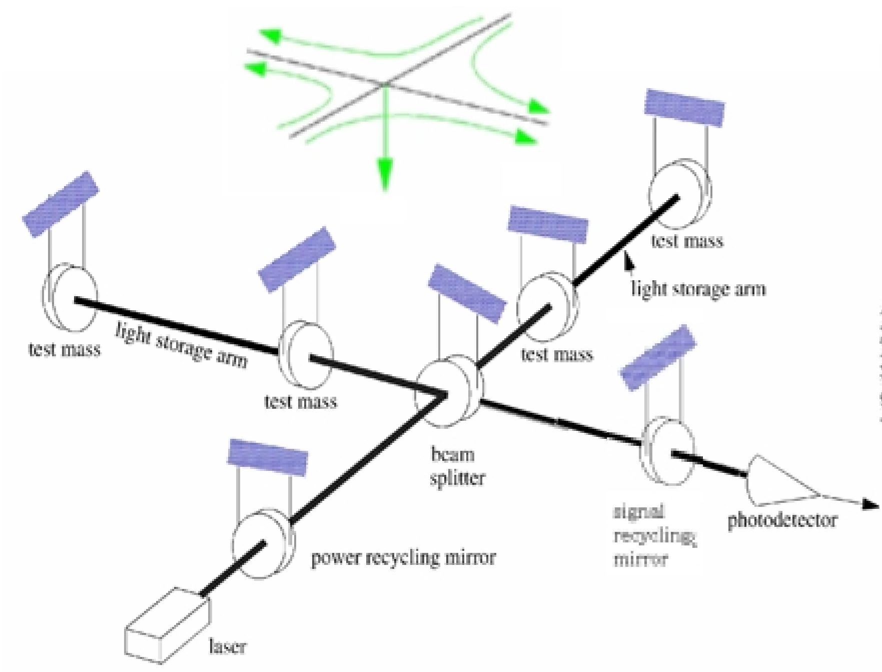
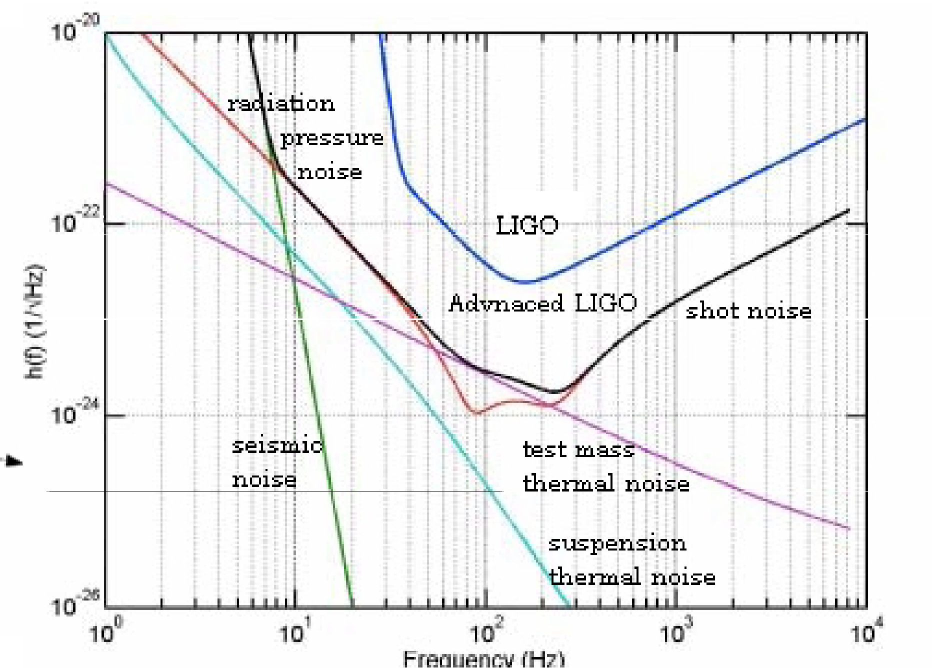
Laser interferometer gravitational wave observatory (LIGO)

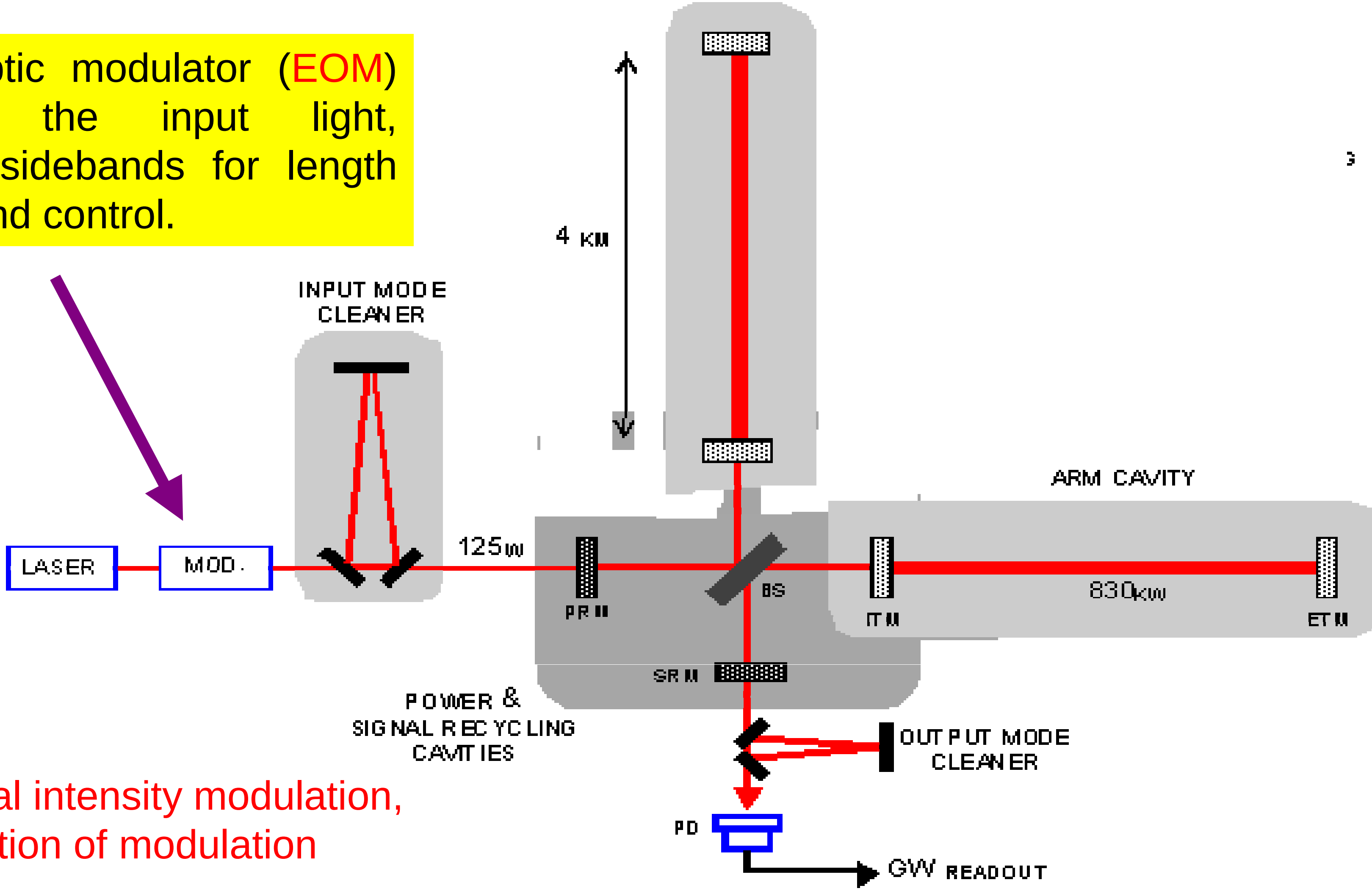
Michelson laser interferometer senses the small perturbation (~$10^{-20} m/\sqrt{Hz}$) in the arms caused by Gravitational Waves (GW).





EOM

Electro-optic modulator (EOM) modulate the input light, generate sidebands for length sensing and control.

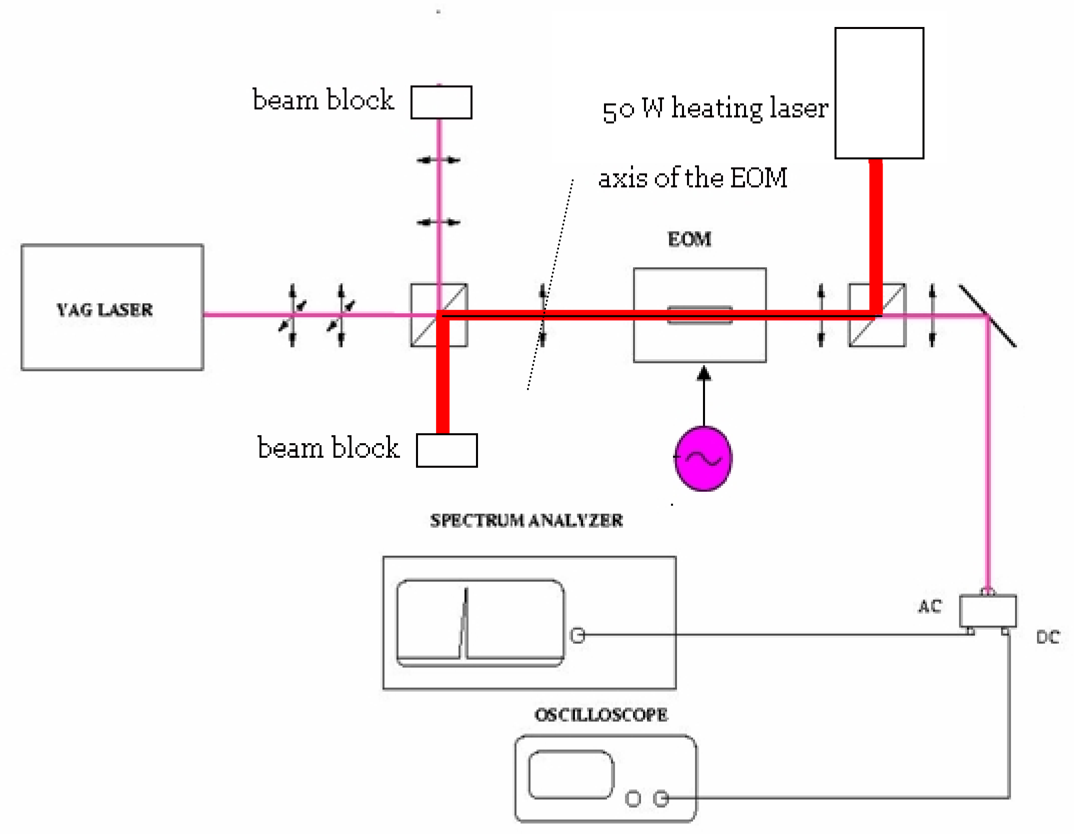


Problems:

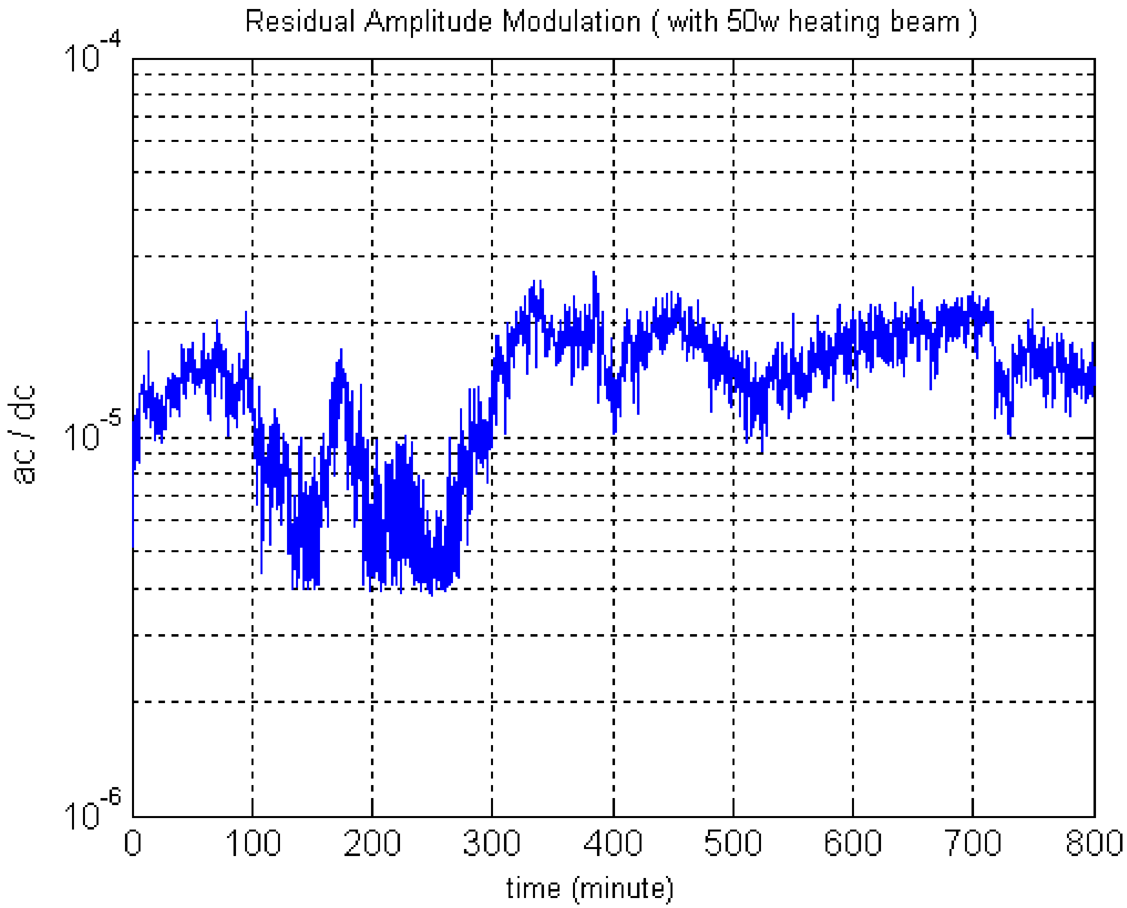
1. Residual intensity modulation,
2. Fluctuation of modulation index,
3. Phase noise of sidebands.

Residual intensity modulation measurement

- Residual intensity modulation noise, which could be coupled into the readout signal of the interferometer, is due to misalignment of the EOM relative to the polarization direction of the incoming light.



Residual intensity modulation



Variation of the modulation index and phase noise of sidebands

$$E = E_0 e^{i[\varpi t + m\sin(\Omega t+\phi)]} \approx J_0(m)E_0 e^{i\varpi t} + J_1(m)E_0 e^{i[(\varpi+\Omega)t+\phi]} - J_1(m)E_0 e^{i[(\varpi-\Omega)t-\phi]}$$

Variation of the modulation index δm

▼

Intensity fluctuation of the carrier light

▼

Radiation pressure noise

For m = 0.1, δm must < $10^{-7} / \sqrt{Hz}$

Phase noise $\delta\phi$ could be coupled into the power fluctuation of the signal in the dark port.

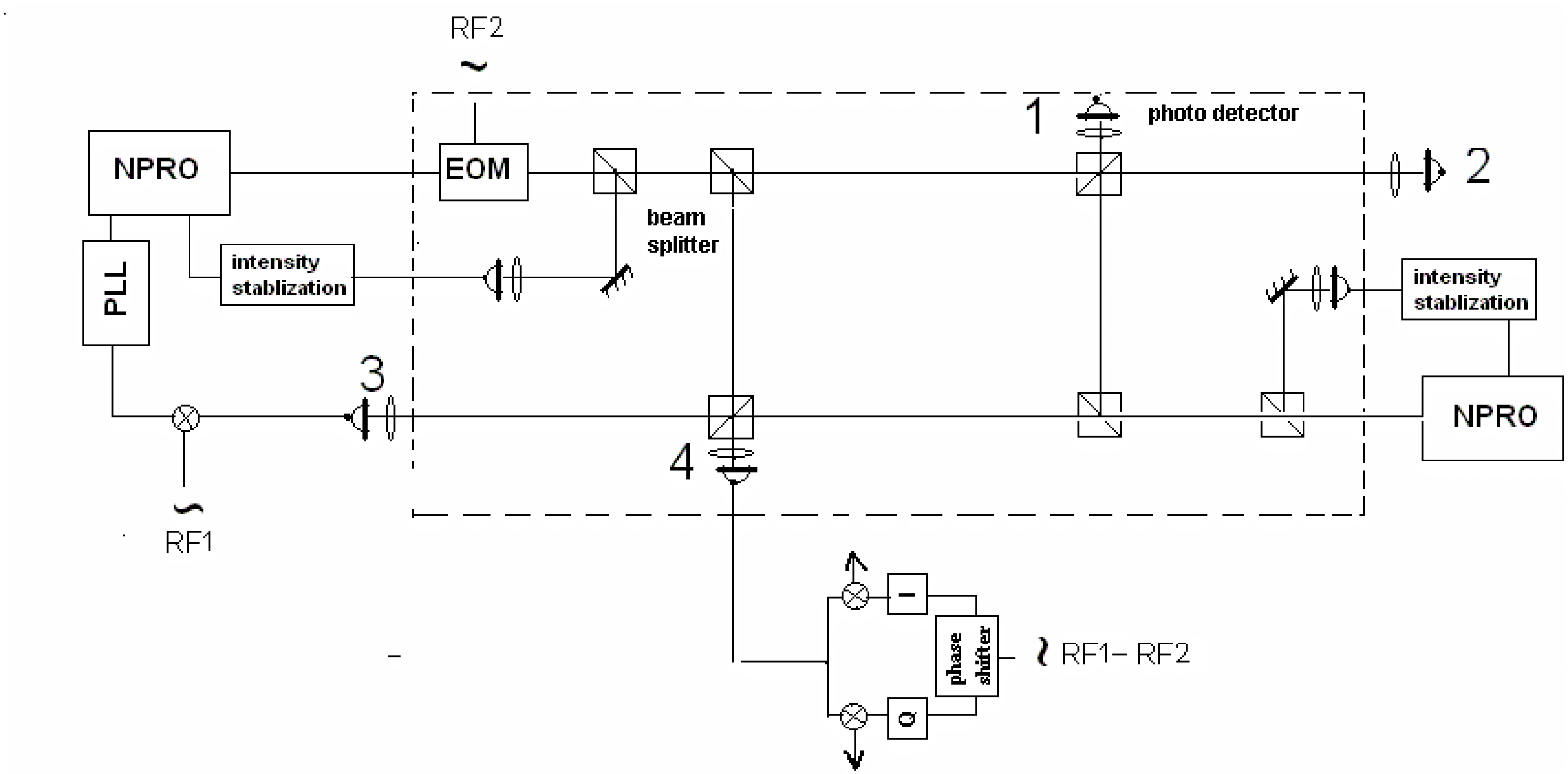
For RF sensing, the requirement on sidebands phase noise depends on the asymmetries of the interferometer caused by the recycling mirrors. For example, at high frequencies, I_{SSB} must < -160 dBc/Hz.

For DC sensing, the coupling effect will be smaller then RF sensing. The requirement is relaxed, but to be determined.

Experiment setup

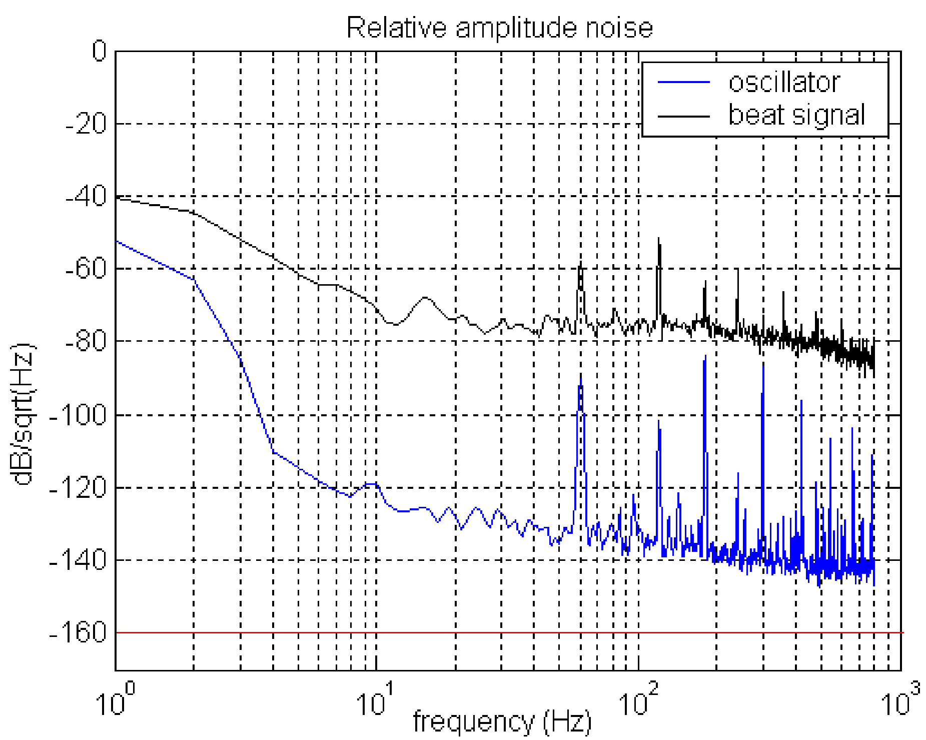
- Phase lock two lasers, beat the sidebands of one laser with the reference laser and track the amplitude and phase information of the beat signal ($\delta m < -\frac{160dB}{\sqrt{Hz}}$).

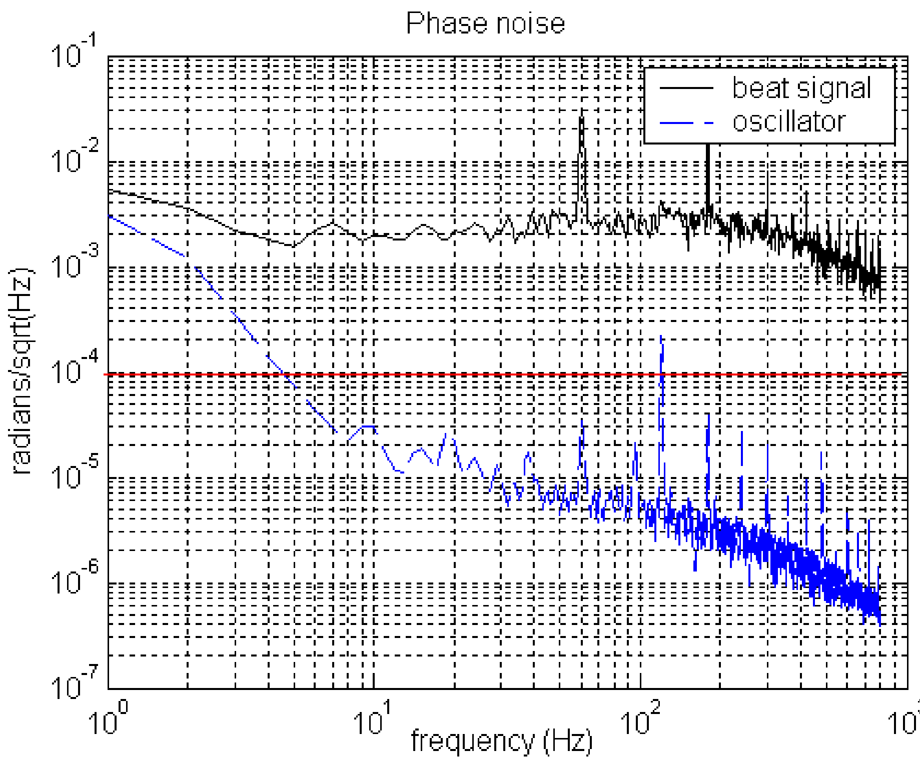
demodulated beat signal ~ $J_1(m) A_\Omega E_1 E_2 \cos(\Delta\phi) \sin(\delta\phi_\Omega)$



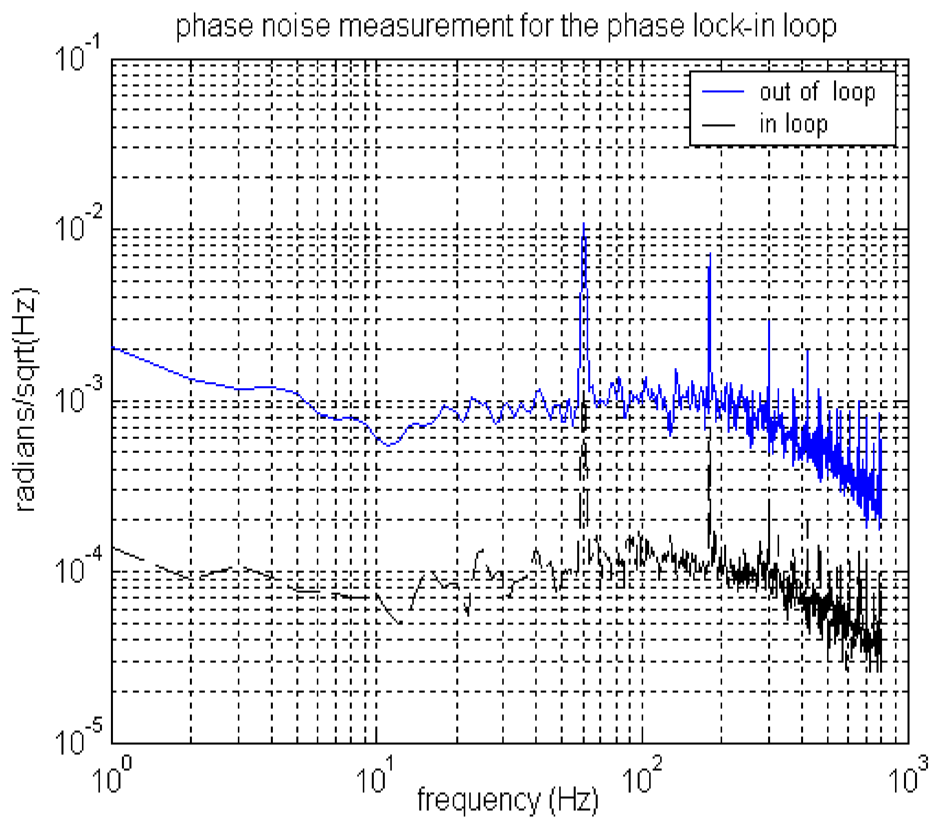
Progress

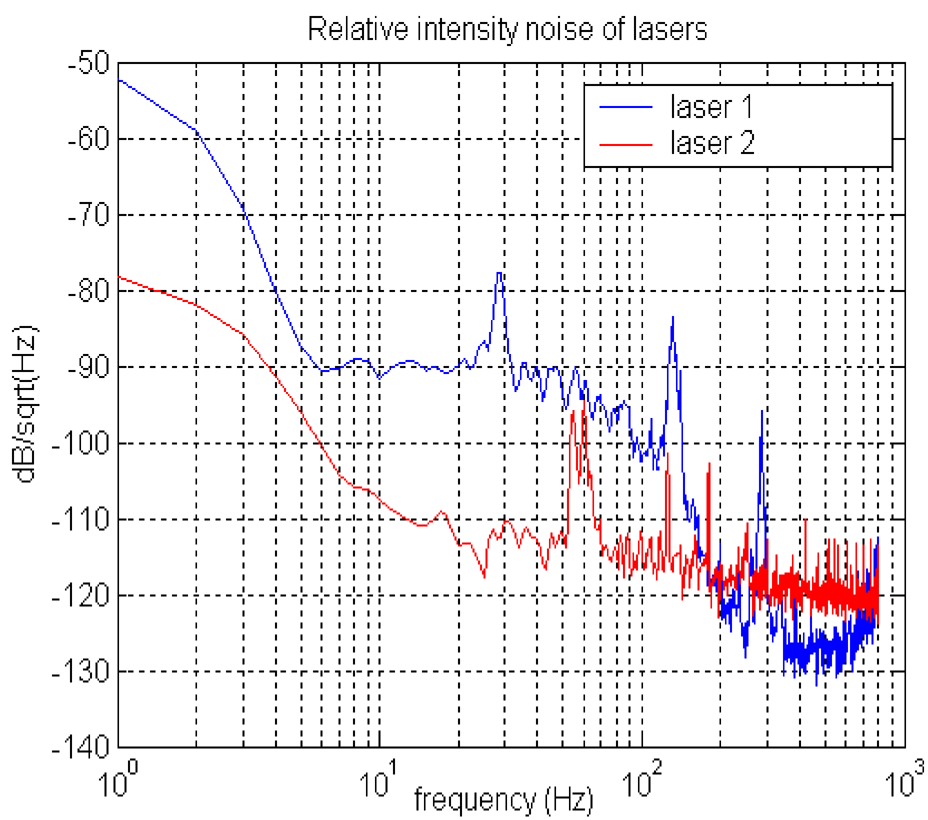
- Local oscillator characterization
- Signal from the photo detector without vacuum and intensity stabilization of the laser source





Phase locking noise and laser intensity noise





Need to be done

- Find or build better oscillators
- Intensity stabilization of laser sources
- Go to vacuum
- …..