Towards a fast PDH-locking of an optical cavitiy using a Bias-T

Basic idea and theory

The gravimeter experiment wants to measure local gravitational fields using the principles of Bloch-oscillations of cold atoms, probed by a static laser field. For this purpose, a precisely tuned laser beam creates a standing wave in a vertical ring-cavity. Ultra cold strontium atoms are drawn into the periodic potential. Because of the opposite, position-dependent forces of light field and gravitation, the cold atoms will oscillate harmonically. The oscillation frequency can be measured due to an amplitude and a phase shift, the atoms imprint on the standing wave in the cavity.By comparing phase and intensity of the transmitted with the reflected light field, one can measure amplitude and frequency of the Bloch oscillations. With these results, it is possible to obtain the driving gravitational forces of the atoms.

To do so, it is necessary to precisely tune the laser frequencies used in the experiment. For this purpose, we use an ECDL designed by Daniel Steck. The extended cavity length narrows the linewidth of the laser already down to ≈ 10 kHz. The next important step is to lock the laser to various frequencies to create the magneto-optical trap (MOT) or to form the standing wave in the cavitiy, for example.

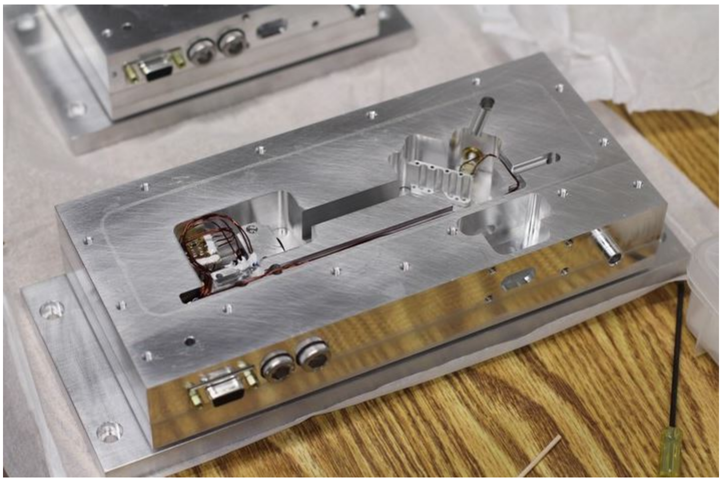

Abbildung 0.1: Picture of an ECDL. The missing grating and biprism pair were added later.

In this experiment, we use Pound-Drever-Hall locking schemes to lock two different ECDL's and the ring cavity to an ultra stable high-finesse cavity.

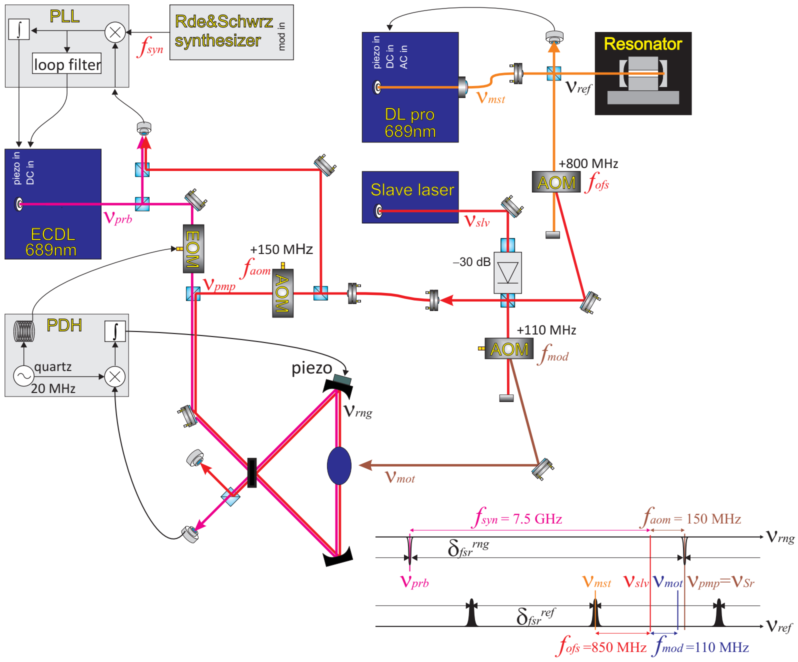

Abbildung 0.2: Picture of the complete locking scheme. The resonator and the DL pro are in the lab next door. In the end, both ECDL's and the cavity will be locked to this resonator.

The purpose of the following work was, to find a way to circumvent some electronical problems with the ECDL and to test a possible locking method, using the Pound-Drever-Hall signal.

Locking and electronical setup of the ECDL

To constantly lock the ECDL laser to a certain frequency, one has to create some sort of clearly visible error signal. Basically, this kind of signal generates a voltage (or current) value, depending proportionally on the frequency misalignment.

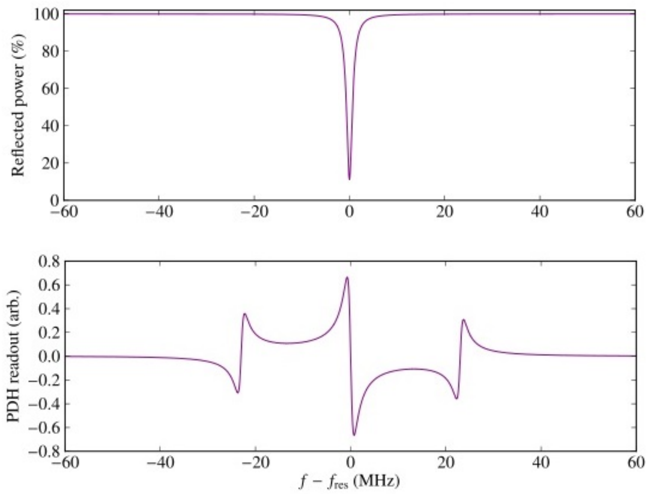

Abbildung 0.3: Simulated picture of a PDH-signal. The upper picture shows the refleced power, the lower picture the PDH-signal.

The PDH-scheme, which generates a signal as shown in figure 0.3, is created by superposition of two beams, coupled to a cavity. First, there have to be side-bands around 20 MHz modulated onto the main laser beam, using, for example, an EOM. This beam is then reflected on the coupling mirror of the cavity, the second one is reflected on the internal mirror and partly exits the cavity again. The obtained signal is mixed with the original modulation and includes some highly fluctuating parts. These can be filtered out, producing the PDH-signal.

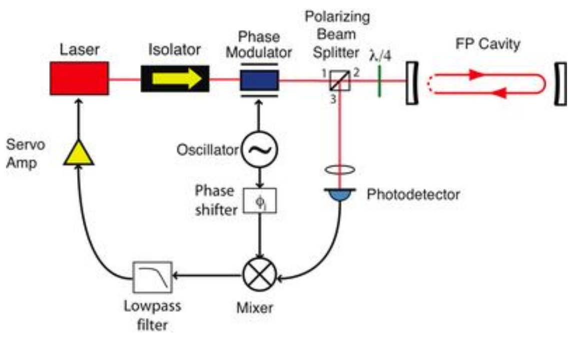

Abbildung 0.4: Scheme, how the PDH-signal is created. The servo amp can be a piezo with an integrator. An other option is to send the signal directly to the laser current.

As shown in figure 0.2, slow changes in the laser frequency will be sent to the piezo attached to one mirror of the cavitiy. An integrator will take care of temperature drifts, by slowly adjusting the cavity lenght. Very fast changes can't be corrected by the slowly reacting piezo. Instead this signals will be sent directly to the laser current, via a loop filter, which will compensate for some possible phase shift. Unfortunately, the ECDL in the design of Daniel Steck is secured against high frequency fluctuations. In order to avoid damage to the diode, a protection circuit is added to the eletronical setup of the ECDL. Figure 0.5 shows the frequency dependence of the signal power.

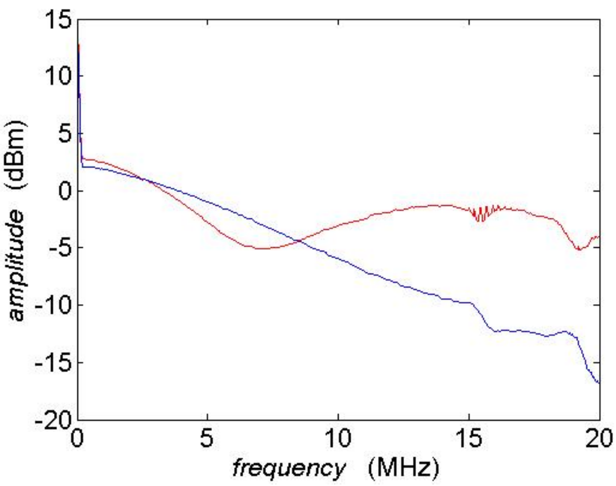

Abbildung 0.5: Frequency dependence of the protection circuit. Red: input power. Blue: Output power.

It is clearly visible, that for higher frequencies, the signal power decreases. To circumvent these dampening effects, the original protection circuit was removed and some alternatives tested.

1. The first idea, was to replace the original circuit with another one from Thor Labs. Before doing so, the TL circuit was tested.

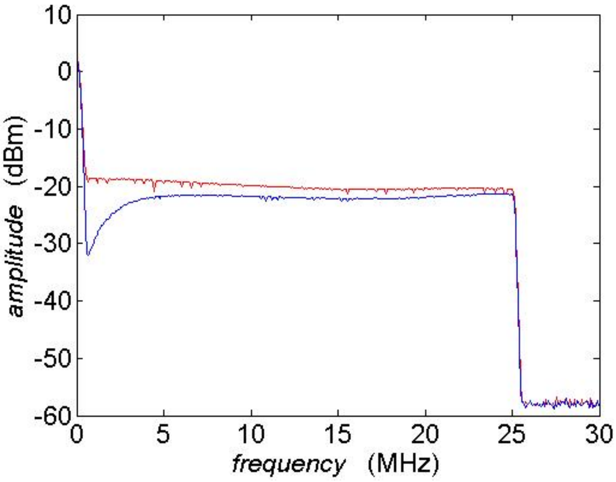

Abbildung 0.6: Frequency dependence of the Thor Labs protection circuit. Red: input power. Blue: Output power. There is no change for higher frequencies, but for lower ones.

Unlike the original circuit, the TL circuit does not show significant decrease at high frequencies. Unfortunately, there are some dampening effects at low frequencies, up to 5 MHz. Clearly, the second protection circuit was also no choice.

2. As it seemed problematic to protect the Laser Diode from high frequency fluctuations and feed in a high frequency correction signal on the current input, the electronic setup of the PDH was slightly altered. If it's feasible to send the PDH-error signal directly to the laser diode, without using the laser driver input, it should be possible to bypass any kind of protection electronics. Therefore, a Thor Labs Bias-T was tested for high frequencies.

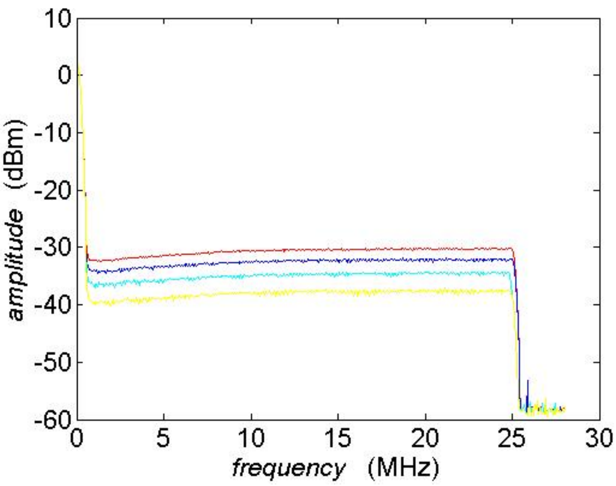

Abbildung 0.7: Frequency dependence of the Thor Labs Bias-T. Red: input power. Yello, cyan, blue: Output power with increasing supply voltage. There is no change in the output power at all.

As shown in picture 0.7 there is no frequency dependance of the Bias-T. Additionally, a schottky-diode mounted on the Bias-T acts as a protection for the laser diode.

PDH-signal

To test the function of the Bias-T - if it's fast enough to imprint high frequency corrections on the laser current - the original PDH-setup was changed. Instead of using an EOM to create side bands, a 25 MHz signal of very low power (about -15 dBm) was sent to the Bias-T to produce side bands. If possible, the Bias-T should generate a nice error signal, with which the laser could easily be locked to a optical cavity. For this test, a linear cavity was used. The result is shown in picture 0.8.

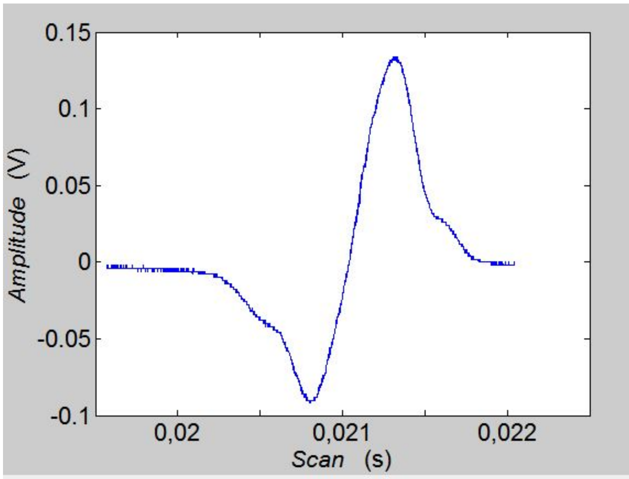

Abbildung 0.8: PDH-signal, using the Bias-T to generate side bands. A linear cavity was used. The slight unsymetrical signal shape is due to some higher modes, which also couple to the cavity.

The form of the signal is not purely a PDH signal, due to some higher modes, which are also coupled to the linear cavity. Nevertheless, the main central part of the error signal is clearly visible and can be used to lock the ring cavity to the laser.

In the experiment itself, the Bias-T is not supposed to generate side bands. It will only have to imprint the correction signal onto the laser current. This setup was chosen to test the Bias-T for this application. As the results point out, the Thor Labs Bias-T is a nice replacement of the of the original protection circuit.