III. LASER STABILIZATION

The laser is frequency stabilized on the cavity resonance for the clockwise laser beam, following the well-known Pound-Drever-Hall scheme [26, 27].

The laser beam is frequency-shifted with an AOM mounted in a cat's eye retroreflector to circumvent the angular dependence of the diffracted beam on the RF frequency. Then it is injected clockwise (cw) into the square cavity. The reflected beam provides the measurement of the beam detuning with respect to the cavity, thanks to the rEOM phase modulation at frequency $\Omega = 10$ MHz (see Fig. 1). The modulation depth is set to $\beta \simeq 1$, so that the optical power P_0 is essentially concentrated in the carrier of power $P_c = J_0^2(\beta)P_0$ and in the two first order sidebands $P_s = J_1^2(\beta)P_0$. The reflected power is monitored with the $\mathrm{PR}_{\mathrm{cw}}$ photodetector and its spectrum is shifted towards null frequency with a RF-phase sensitive demodulator which phase φ_{cw} is adjusted so as to maximize the signal amplitude accross a resonance.

This demodulated signal is null at resonance and linear for laser-cavity detunings smaller than the cavity linewidth, with a slope $D = 4\sqrt{P_c P_s}/\Delta\nu_c$. It constitutes the frequency error signal which is fed to the frequency actuators through the servo-loop filters: a fast and fine feedback is provided by the AOM, while the laser piezo-transducer (PZT) and thermo-electric cooler (TEC) actuators account for slower and coarser corrections. The fast controller consists of 3 Proportional Integral (PI) stages with respective corner frequencies 30 kHz, 5 kHz and 3 kHz. The loop gain is adjusted to have a resonance of about 10 dB at the loop resonance frequency $f_r \simeq 180$ kHz. Since the unity gain frequency is 2 to 3 times smaller for a gain margin between 6 and 10 dB, we can estimate the servo-loop bandwidth to 60-90 kHz. The fast controller output is sent on the one hand to the AOM driver, and on the other hand to the medium speed PZT-controller, which consists of a Proportional Integral Differential (PID) stage with an integrator (resp. differentiator) corner frequency 100 Hz (resp. 1 kHz). The proportional gain is set to damp smoothly the AOM command signal towards zero. A similar approach is adopted for the slow TEC-controller, with an integrator (resp. differentiator) corner frequency 15 mHz (resp. 150 mHz) nulling the mean value of the PZT command signal.

To characterize the performance of the frequency stabilization, we intercept the signal immediately before demodulation via a 20 dB coupler. We present on Fig. 3 the power