Reduction of residual amplitude modulation to 1×10^{-6} for frequency-modulation and laser stabilization

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Active control and cancellation of residual amplitude modulation (RAM) in phase modulation of an optical carrier is one of the key technologies for achieving the ultimate stability of a laser locked to an ultrastable optical cavity[1]. Furthermore such techniques are versatile tools in various frequency-modulation-based spectroscopy applications[2]. We report a simple and robust approach to actively stabilize RAM in an optical phase modulation process. We employ a waveguide-based electro-optic modulator (EOM) to provide phase modulation and implement an active servo with both DC electric field and temperature feedback onto the EOM to cancel both the in-phase and quadrature components of the RAM to a level of 1×10^{-6}. The remaining RAM allows for Pound-Drever-Hall (PDH) frequency stabilization at the 10^{-17} level which is comparable to the expected thermal noise limit of optical cavities made from single-crystal silicon[3] and employing low thermal noise crystalline mirror coatings[4].

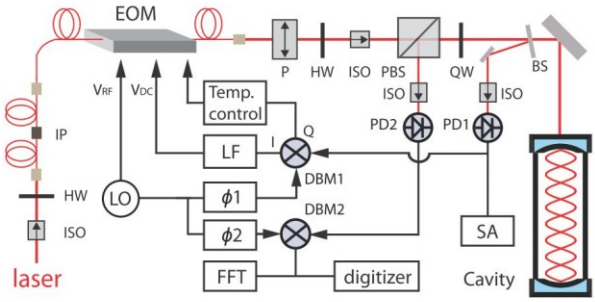

Fig. 1: Experimental setup for PDH laser stabilization combined with active RAM control. The beam splitter (BS) close to the cavity reflects part of the light onto photodiode PD1 to detect RAM. Mixing with the local oscillator (LO) signal used for phase modulation generates the in phase (I) and quadrature components (Q) of the RAM error signal. Photodiode PD2 used for the PDH stabilization detects the out-of-loop RAM signal when the laser is detuned from cavity resonance. Further components: optical isolators (ISO), inline polarizer (IP), free space polarizer (P), half-wave plates (HW), polarizing beam splitter (PBS), quarter-wave plate (QW), double balanced mixers (DBM), loop filter (LF) and phase shifters (ϕ).

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