Digital System for Keeping Optical Frequency Comb in Long-Term Stable Operation

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A passive optical resonator is a special sensor used for measurement of lengths on the nanometer and sub-nanometer scale. A stabilized optical frequency comb can provide an ultimate reference for measuring the wavelength of a tunable laser locked to the optical resonator. If we lock the repetition and offset frequencies of the comb to a high-grade radiofrequency (RF) oscillator its relative frequency stability is transferred from the RF to the optical frequency domain. Experiments in the field of precise length metrology of low-expansion materials are usually of long-term nature so it is required that the optical frequency comb stays in operation for an extended period of time. The optoelectronic closed-loop systems used for stabilization of combs are usually based on conventional analog electronic circuits processing signals from photodetectors. From an experimental point of view, these setups are very complicated and sensitive to ambient conditions and disturbances, especially in the optical part, therefore maintaining long-time operation is not easy. The presented work deals with a novel approach based on digital signal processing and software-defined radio algorithms. We are using a two-stage stabilization scheme. A frequency-locked loop (FLL) pre-stabilizes the offset frequency and steers it into the capture range of a phase-locked loop (PLL) that consequently takes control. Such combination of FLL and PLL together with additional control logics is also able to handle situations when the PLL unexpectedly goes out of lock and so it is capable of keeping the optical frequency comb in a long-time stable operation. The stability of the resulting system was investigated. Allan deviations from data measured during 8 days of operation were computed. The resulting long-term stability of the setup is better than 1.6×10^{-11}.

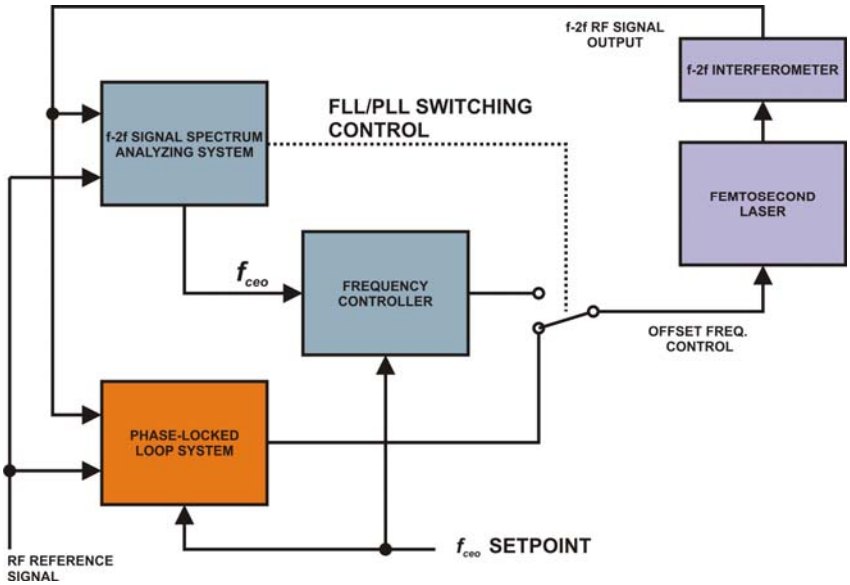

Fig. 1: The block schematics of the two-stage system for long-term stabilizing of the offset frequency of the optical frequency comb.