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Locking Local Oscillator Phase to the Atomic Phase via Weak Measurement

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We propose a new method to reduce the frequency noise of a Local Oscillator (LO) to the level of white phase noise by maintaining (not destroying by projective measurement) the coherence of the ensemble pseudo-spin of atoms over many measurement cycles. This scheme uses weak measurement to monitor the phase in Ramsey method and repeat the cycle without initialization of phase and we call, "atomic phase lock (APL)" in this paper. APL will achieve white phase noise as long as the noise accumulated during dead time and the decoherence are smaller than the measurement noise. A numerical simulation confirms that with APL, Allan deviation is averaged down at a maximum rate that is proportional to the inverse of total measurement time, tau^-1. In contrast, the current atomic clocks that use projection measurement suppress the noise only down to the level of white frequency, in which case Allan deviation scales as tau^-1/2. Faraday rotation is one of the possible ways to realize weak measurement for APL. We evaluate the strength of Faraday rotation with 171Yb+ ions trapped in a linear rf-trap and discuss the performance of APL. The main source of the decoherence is a spontaneous emission induced by the probe beam for Faraday rotation measurement. One can repeat the Faraday rotation measurement until the decoherence become comparable to the SNR of measurement. We estimate this number of cycles to be ~100 cycles for a realistic experimental parameter.

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