Opto-electronic oscillator stabilized by hyperfine atomic transition.

Dmitry Strekalov, David Aveline, Andrey Matsko, Robert Thompson, Nan Yu, and Lute Maleki.

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Abstract

We have built an opto-electronic oscillator (OEO) with a frequency filter implemented by electromagnetically induced transparency (EIT). This internal fundamental frequency reference corresponding to the hyperfine splitting in ^{87}Rb (6.8GHz) allows for efficient stabilization of the oscillator.

Summary

An opto-electronic oscillator (OEO) consists of a laser, optical modulator, optical delay line and filter, photo detector, and amplifier [1]. RF modulated light propagates through the optical system, and then is detected by an optical detector. The electrical signal from the detector is amplified and fed back into the light modulator. This closes the gain loop and provides for self-sustaining RF oscillations. The spectrum, and the spectral purity of such oscillations is determined by the filter and the delay line in the loop. Both the delay line and the filter determine the stability of the signal [1].

In our experiment we use a Rb vapor cell as the OEO filter to achieve stable oscillation at the clock transition frequency of Rb atoms. The schematic drawing of our experiment is presented in Fig. 1. Light modulated at 6.8 GHz by an electro optical modulator (EOM) is sent into an atomic vapor cell. The carrier frequency of the light is resonant with $5S_{1/2}$, F=2 -> $5P_{1/2}$, F=1 transition, while the higher frequency sideband is nearly resonant with $5S_{1/2}$, F=1 -> $5P_{1/2}$, F=1 transition. Due to the effect of electromagnetically induced transparency, the resonant absorption of both waves is reduced if their frequency difference exactly coincides with the frequency of the hyperfine splitting of the rubidium ground state, which allows stabilizing our system with a configuration similar to atomic clocks [2]. Closing the OEO loop, as shown in the picture, we obtain stable RF oscillations.

We observed two distinct types of RF oscillation in the expected range. When the electromagnetically induced transparency (EIT, [3]) conditions are not fulfilled, the system can oscillate at any frequency within approximately 100 MHz range as determined by the bandwidth of the resonant electro optical modulator (EOM) and of the RF amplifiers. Due to RF dispersion of the system, this frequency can be widely tuned by the phase shifter. In addition to this type of oscillation, when the EIT condition is achieved, we observe a regime where the oscillation frequency is "locked" at the atomic hyperfine transition frequency. By a suitable choice of experimental parameters, this desired oscillation can completely suppress the other, broadly tunable type. For a very narrow parameter range both types of oscillation can be simultaneously achieved. We report the results of the experimental investigation of our stabilized OEO performance, and discuss the prospects of its application as high-performance OEO as well as atomic reference clock.

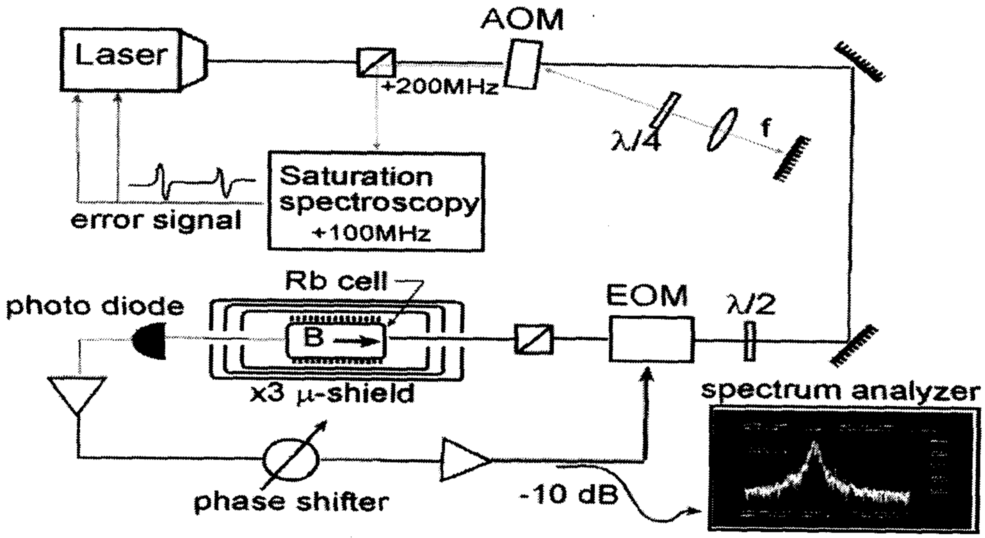

Figure 1. Diagram of the EIT-based OEO experiment.

References:

[1] X. S. Yao and L. Maleki, "Optoelectronic microwave oscillator", J. Opt. Soc. Am. B **13**, 1725-1735 (1996).
[2] J. Kitching, S. Knappe, and L. Hollberg, "Miniature vapor-cell atomic-frequency references", Appl. Phys. Lett. **81**, 553-555 (2002).
[3] E.g.: S.E. Harris, "Electromagnetically induced transparency", Physics Today, 36-42, July (1997); J.P. Marangos, "Topical review Electromagnetically induced transparency", J. Mod. Opt. **45**, 471-503 (1998).

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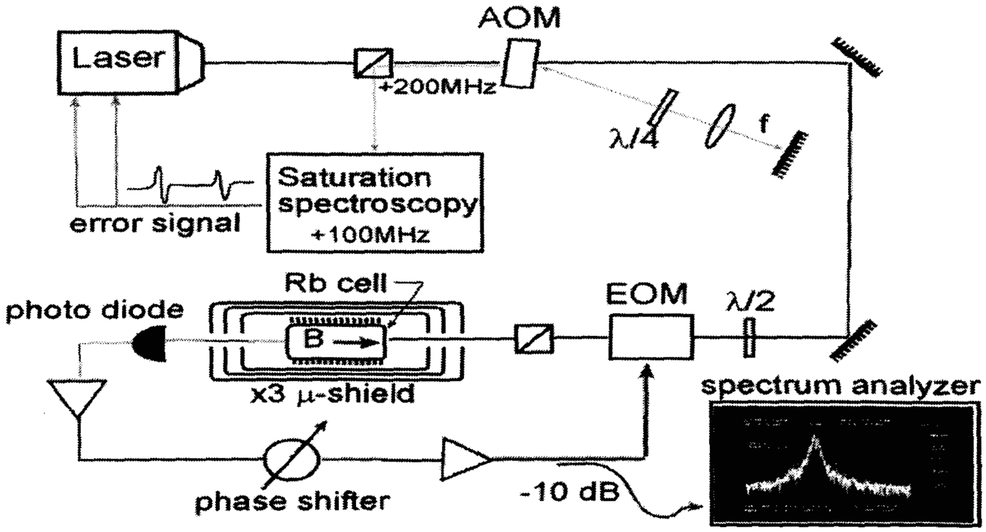

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