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Tunable dual-frequency laser source for coherent population trapping cesium atomic clocks

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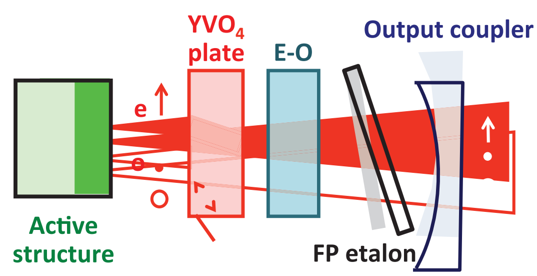
Coherent population trapping (CPT) has been demonstrated as an interesting technique for miniature atomic frequency references [1,2] and quantum information. It is based on the coupling of the two hyperfine ground states of an alkali atom – namely cesium (^{133}Cs) for atomic clocks – through excitation to a common atomic level by two phase-coherent laser fields nearly resonant with the atomic transitions. The frequency difference between the two laser fields is tuned at the atomic frequency splitting in the microwave range, equal to 9.192 GHz for ^{133}Cs atoms. Outputs powers in the mW range and narrow-linewidth emission (<500 kHz) are required for the two laser beams.

We report the design and evaluation of a new laser source dedicated to CPT experiments, based on the simultaneous emission of two cross-polarized longitudinal modes inside the same laser cavity. The laser source is an optically-pumped vertical external-cavity semiconductor laser (VECSEL) emitting at 852 nm. This configuration takes benefit of the intrinsically strong correlation between the two laser lines which share the same cavity; additionally, the frequency difference is tunable by adjusting the cavity anisotropy. Finally, the low relative-intensity-noise (RIN) of VECSELs on a wide spectral range is of particular interest for this application, as it should provide a high-purity RF beat-note phase spectrum [3]. A dual-frequency VECSEL should thus have major potentials for miniature atomic clocks.

The active structure comprises 7 GaAs quantum wells embedded in $Al_{20\%}Ga_{80\%}As$ barriers grown on a high-reflectivity Bragg mirror; it is pumped with a fiber-coupled laser diode emitting up to 1 W at 670 nm. The laser cavity length is 10 mm, corresponding to a free-spectral-range of 12 GHz. A 500 µm-thick birefringent YVO_4 plate induces a lateral separation of the ordinary and extraordinary polarizations of 50 µm on the structure, and a fixed frequency difference $\Delta\nu$ ~5.7 GHz. A 50 µm-thick silica etalon is used to tune the central wavelength over ~10 nm and to force the single-frequency emission at each polarization. Finally, the frequency difference between the two laser lines is tuned by adjusting both the applied voltage and the temperature of a MgO:SLT electro-optic modulator. The overall laser cavity, including the pump optics, are integrated in a temperature-controlled 90 mm × 90 mm × 40 mm casing.



Experimental setup of the dual-frequency VECSEL

In this configuration, the VECSEL source emits a single laser beam with two distinct frequencies, corresponding to cross-polarized adjacent longitudinal modes of the laser cavity. The maximum output power reaches ~5 mW on each polarization. The laser lines are tuned around the D_2 Cs line, at 852.1 nm. Measurements of the frequency difference tunability and detailed analysis of the spectral properties of this new laser source with regard to its application for CPT atomic clocks will be presented at the conference.

References

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