A high-stability frequency reference based on I_2 at 541.5 nm for precise He spectroscopy

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Atomic He has been the subject of many investigations with the aim to test QED and to measure the fine-structure constant α [1, 2]. At LENS, high precision spectroscopy of $2^3S \rightarrow 2^3P$ helium transitions is done by using a diode laser based spectrometer described in [2, 3]. To improve the accuracy of these frequency measurements on helium, we have built a new laser source, based on fiber-amplified tunable Distributed Bragg Reflector (DBR) diode lasers at 1.083 μm frequency-doubled with a periodically-poled $KTiOPO_4$ (PP-KTP) crystal [4].

With this set-up, we have locked the 1083 nm diode laser onto the saturated absorption of B-X hyperfine transitions of I_2 at 541.5 nm, using Frequency Modulation (FM) spectroscopy[5]. To characterize the stability of the iodine frequency reference, we had to fiber-amplify and to double two identical lasers simultaneously. This twin-lasers set-up was made by using just one fiber-amplifier, a single domain of the PP-KTP crystal and a single Electro-Optic Modulator (EOM) to phase-modulate the green radiation. The Doppler background was eliminated by using two Acousto-Optic Modulators (AOM), to amplitude-modulate, independently, the pump of each laser beam. The two probe beams were detected and demodulated, at the phase-modulation frequency, with two specially designed low-noise electronic devices. After proper electronic conditioning, the feed-back signal is fed to the piezo-electric ceramics controlling the extended-cavity mirrors of the diode lasers. Locking the two lasers onto isolated hyperfine components of the B-X R(34) 27-0 line of I_2, we measured the Allan variance of the beat signal of the infrared radiations and we obtained a relative stability of 1.7 10^{-12} in 1 sec.

With the set-up described in [2] that makes use of a fixed frequency master oscillator and of a phase-locked slave laser that is scanned across the He* resonances, we plan to significantly improve the accuracy of helium frequency measurements by using the I_2 transitions as master oscillator reference. Therefore the frequency stability of the slave laser has been improved by more than one order of magnitude, in 1 sec, with respect to the previous set-up, and even better in long term time scales. In addition, absolute frequency measurements of the He transitions can be performed if the I_2 locked laser is compared to the relatively nearby I_2 locked Nd:Yag standard transition.

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