Parametric four-wave mixing in atomic vapor induced by a frequency-comb and a cw laser

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In recent years, atomic coherence effects have been explored in four-wave mixing to produce frequency up-conversion using either low power continuous wave (cw) lasers or pulsed lasers. In this work, we report the observation of a collimated blue light generated in rubidium vapor due to the combined action of a mode-locked (fs) laser and a cw diode laser. In the experiment a diode laser, stabilized in temperature and with a linewidth of about 1 MHz, is used to excite the $5S_{1/2} \rightarrow 5P_{3/2}$ transition. A train of pulses generated by a mode-locked Ti:sapphire laser (MIRA, Coherent) can excite both $5S_{1/2} \rightarrow 5P_{3/2}$ and $5P_{3/2} \rightarrow 5D$ transitions. The two beams, with parallel linear polarizations, are focused in a 5-cm long sealed Rb vapor cell. The vapor cell is heated up to $\approx 100^\circ$C and contains both $^{85}$Rb and $^{87}$Rb isotopes in their natural abundances. The induced coherence among $5S_{1/2} \rightarrow 5P_{3/2} \rightarrow 5D \rightarrow 6P_{3/2}$ transitions produces, by parametric four-wave mixing (PFWM), a coherent beam at 420 nm. Under the coherent accumulation condition, where the atomic relaxation times are greater than the fs laser repetition period, we show that each individual mode of the frequency comb contribute to the nonlinear signal. The signature of this behavior is the observation of the frequency comb structure in the excitation spectrum of the coherent light, indicating that each mode is responsible for the generation of a blue beam with a frequency determined by the parametric process. We measure the dependence on the Rb density of the collimated blue light generated in the forward direction for different diode laser intensities. The measurements were performed as a function of the diode frequency allowing us to realize a velocity-selective spectroscopy. For each mode, the atomic density dependence is characterized by a sharp growth and rapid saturation. An important feature revealed by our setup is that only one scan of the diode laser allows us to generate several blue beams with a frequency separation equal to the repetition rate of the fs laser. Studies of the spectral and temporal characteristics of the blue emission are in development. Another feature to be explored is the fixed phase relation between the modes of the frequency comb and the possibility to transfer this phase relation to the generate beams.