A Frequency-Comb-Stabilized Laser for Cooling Sr^+ Ions

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Lasers for Doppler cooling of trapped ions demand light sources with MHz-level frequency accuracy and long term stability. This is often achieved with external- or extended-cavity semiconductor lasers that are locked to Doppler-free absorption lines. Here, in contrast, the use of a DFB laser stabilized to a frequency comb for cooling Sr^+ ions is explored.

The setup is shown in Fig. 1. A 843-nm DFB laser (Nanoplus) is amplified and doubled to 422 nm using a 20-mm long ppKTP crystal. Frequency stability is achieved by locking the fundamental to a 100 MHz frequency comb (MenloSystems): the beat note (0-50 MHz) is detected, conditioned and sent to a frequency-to-voltage converter. Feedback to the laser is provided via a proportional-integral loop filter, the set point of which is computer controlled. Improvement in the short term stability of the beat note is demonstrated in Fig. 2.

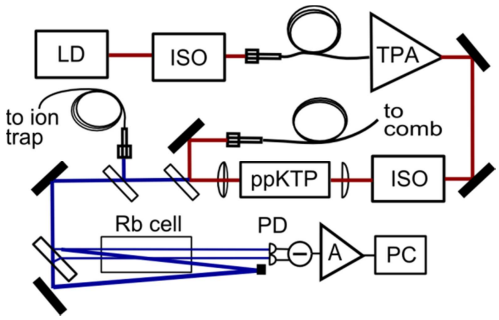

Fig. 1: A 843-nm DFB laser is amplified and doubled to 422 nm using a ppKTP crystal. The fundamental beam is locked to a frequency comb. The Rb cell provides the frequency reference. LD: laser diode; ISO: optical isolator; TPA: tapered amplifier; PD: photodiode; A: electronic amplifier; PC: computer.

The problem, then, is to find the correct comb line. Fortuitously, ^{85}Rb has a hyperfine component only 440 MHz away from the Sr^+ cooling transition[1]. Thus, a small Rb saturation spectrometer was assembled, and the locking electronics was modified so that the cooling laser can be quickly (< 1 ms) 'jumped' from one fringe to the next. This enables one to search for the ^{85}Rb hyperfine transition, and then to controllably move into position for ion cooling with MHz-level accuracy.

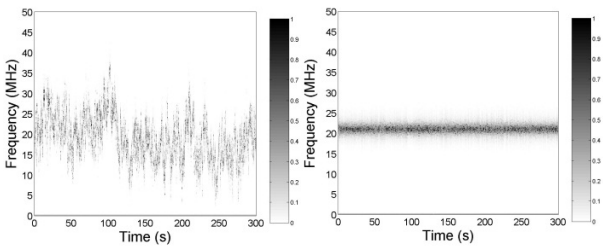

Fig. 2: Normalized power spectral density (linear scale) of the beat note as a function of time for the free running (left) and locked laser (right). The linewidth of the beat note in the locked case is 2 MHz. Spectrum analyzer sweep time was 50 ms.

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[1] A.A. Madej *et al.*, "Rb atomic absorption line reference for single Sr^+ laser cooling systems", Appl. Phys. B, vol. 67, p. 229-234, 1998.