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SUB-SHOT-NOISE FM SPECTROSCOPY OF COLD RUBIDIUM ATOMS

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Frequency-modulation(FM) spectroscopy is a sensitive technique for measuring weak absorptions. Two key advantages of FM spectroscopy are measurement on a null signal and at high(RF) frequencies where both the laser noise and the electronic system noise are small. Conventionally, the laser frequency is directly modulated. Alternatively, in FM noise spectroscopy, frequency noise in a laser plays the role of coherent frequency modulation when filtered in a narrow band-width.

The shot noise, which is the inherent noise of standard lasers, was considered a fundamental limit to the sensitivity of FM spectroscopy. The goal of our experiments was to demonstrate sub-shot-noise FM noise spectroscopy using amplitude squeezed light. The amplitude squeezing enhances the signal-to-noise ratio by reducing the amplitude noise to below shot noise. The amplitude squeezed light can be generated by a semiconductor laser which is driven far above the lasing threshold by a constant current source.

We used laser cooled rubidium atoms as our sample because it is a simple system with very narrow linewidth(10 MHz). Rubidium atoms were cooled to about 200μK in a magneto-optical-trap(MOT). At such low temperature the Doppler broadening is negligible.

A constant-current-driven solitary semiconductor laser showed very small or no squeezing. In order to enhance the amplitude-squeezing the probe laser was injection-locked with the light from another semiconductor laser(master) which was stabilized by feedback from an external grating. The injection-locking also provided precise frequency control and tunability. The amplitude noise was squeezed by 0.7 dB below the shot-noise level. The frequency noise of the probe laser was used as the frequency modulation.

The FM-to-AM conversion noise signal was obtained as the laser frequency was swept towards one of the rubidium transition. A RF spectrum analyzer measured RF power in a narrow bandwidth at a fixed frequency(75 MHz) which can be chosen anywhere within the detection bandwidth. A direct transition with natural-linewidth and a Raman transition between the probe and the trap laser with sub-natural-linewidth were observed on the sub-shot-noise background. This scheme can be used as a simple and inexpensive technique for doing precision spectroscopy.