only around the zero magnetic field is to use modulation techniques. Two arrangements have been proposed using either frequency (FM NMOR [17]) or amplitude (AMOR [18]) modulation of light. In both arrangements strobed pumping creates the modulated Zeeman coherence and phase sensitive detection is used to extract the magneto-optical rotation amplitude. In addition to the zero-field resonance, two other resonances appear in the demodulated rotation signal when the modulation frequency Ω_m meets $\pm$ twice Larmor precession frequency in a given magnetic field. These high-field resonances result from the optical pumping synchronous with the Larmor precession. The factor of 2 appears because the two-fold symmetry of the optical anisotropy associated with $|\Delta m| = 2$ coherences yields modulation at precisely twice the Larmor precession. The width of these resonances is determined by the coherence lifetime and, in case of long-lived ground states, can be as narrow as the zero field resonance.

In our experiment the AMOR technique was applied: the probe beam was periodically chopped using the acousto-optical modulators. Use of modulation frequencies up to ∼10 MHz allowed detection of resonances in magnetic fields as large as 9 G. This is an order of magnitude higher field compared to previous FM NMOR and AMOR work and demonstrates the method's potential for precision magnetometry in a wide range of fields. This range can be further extended by using electro-optical modulators up to the fields where the nonlinear Zeeman effect starts to affect the signals. Figure 6 shows NFR signal with two AMOR resonances at ± 3 G that are the evidence of driving $|\Delta m| = 2$ coherences at non-zero magnetic fields.

In conclusion, we have demonstrated the nonlinear Faraday rotation for a sample of cold atoms both with cw and modulated laser beams. The use of retroreflected beam alleviated the problem of mechanical perturbation of the cold atoms by the probe beam. In contrast to previous experiments with pure quantum states of oriented spins, the NFR measurements allow control and convenient studies of long-lived superposition states of aligned spins, i.e. quantum superpositions of Zeeman sublevels belonging to a given F. In particular, we are able to vary the degree of Zeeman coherence and monitor its build-up and decay, both in the stationary regime ($B \simeq 0$), and for the Larmor frequencies up to 10 MHz. In addition to its potential for QSE, the NFR effect can be used for measuring a wide range of transient and static magnetic fields with 10 μs time resolution, sub-mG sensitivity, and mm spatial resolution given by the size of the cold atom cloud or the beam waist size. The current results are limited mostly by finite lifetime of trapped atoms and power broadening by the probe beam. Transfer of atoms into an optical dipole trap would make probing time much longer (∼1 s) and the light-atom coupling more effective whereas the use of separate pump and probe beams as opposed to a single pump-probe beam would alleviate power broadening limitations.

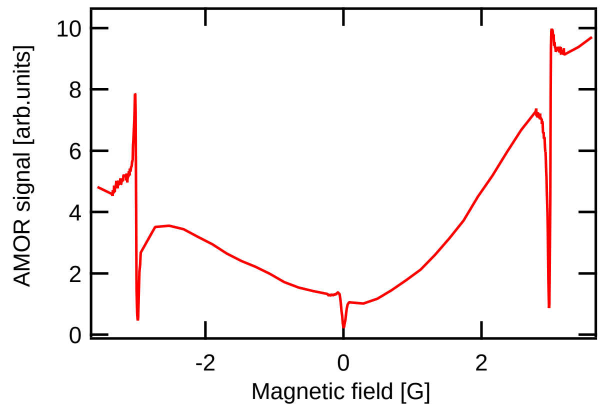

FIG. 6: NFR with amplitude modulated light (AMOR). The narrow central resonance is a typical NFR zero-field resonance and the two high field resonances at ± 3 G result from amplitude modulation of the light with $\Omega_m = 2.8$ MHz. Presence of such high-field resonances allows for precision magnetometry of non-zero magnetic fields. The broad background is the LFR. The slight asymmetry of resonance shapes can be attributed to experimental setup imperfection.

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