Spontaneous coherence of magnons in spin-polarized atomic hydrogen gas

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A macroscopic occupation of the ground state and long-range correlations between particles are the hallmarks of Bose-Einstein condensation in cold atomic gases. Similar phenomena are also observed in systems of wave-like excitations (quasiparticles) such as photons, excitons, and spin waves (magnons). Spin waves in cold gases are propagating perturbations of spins, manifesting as travelling fluctuations of the macroscopic magnetization. The propagation results from the cumulative effect of the identical spin rotation (ISR) effect due to exchange interaction. In spin-polarized atomic hydrogen gas magnons can be trapped and controlled by magnetic forces in a manner similar to ordinary atoms with magnetic moments. We show that at high hydrogen gas densities the magnons accumulate in their ground state and exhibit long-term coherence, profoundly changing the electron spin resonance spectra of the atomic hydrogen gas.

In our experiments the gas of atomic hydrogen is hydraulically compressed to high densities of $5 \cdot 10^{18}$ cm^{-3} at temperatures 0.2 - 0.6 K in a magnetic field of 4.6 T. We observed a variety of spin wave modes caused by the ISR effect with strong dependence on the spatial profile of the polarizing magnetic field. The ISR magnons of atomic hydrogen are high field seeking excitations, and are trapped in regions of strong magnetic field [1]. We demonstrate confinement of magnons in two magnetic traps of distinct geometries, toroidal and spherical, the latter combined with a linear magnetic field gradient. Above a critical value of the hydrogen atom density a sharp and prominent peak emerged in the CW ESR spectrum. We also recorded pulsed ESR spectra where the gas was probed with a small tipping angle resonance excitation. In the resulting free induction decay signals a similar feature was observed: a rapid decay and a subsequent refocusing of the transversal magnetization into a slowly-decaying single-frequency tail. We interpret these effects as signs of spontaneous coherence and argue for an explanation in terms of Bose-Einstein condensation of magnons.

References

[1] O. Vainio *et al.* PRL **108** 185304 (2012)