Many-body interaction between nuclear spins and electron spins with Nambu-Goldstone mode
核スピン系と南部・ゴールドストーンモードを有する電子スピン系の多体相関

We have uncovered an unusual nuclear spin relaxation process due to interaction with the canted-antiferromagnetic (CAF) state in bilayer system with the total filling factor 2 by measuring the full profile of the ν =2/3 spin phase transition (SPT). The CAF state has a linear dispersion arising from Nambu-Goldstone mode. Our measurements indicated that the downward nuclear spin polarization completely relaxed after one second interaction with the CAF state differently from the conventional nuclear relaxation observed in other (spin singlet and ferromagnetic) states existing in the bilayer system with the total filling factor 2. Such very rapid and unexpected redistribution of nuclear polarization occur only when the current pumping time was greater than the 200 seconds, which means a large nuclear polarization. The threshold-like behavior could indicate the possibility of a collective relaxation from a large ensemble of polarized nuclear spins. Our nuclear magnetometry scheme and analysis of the ν =2/3 SPT peak can be used to identify the CAF state from different phases.

We theoretically investigate the nuclear spins / electron spins interaction in the QH systems as hybrid quantum systems driven by the hyperfine interaction. In particular, we concentrate the interaction between the nuclear spins and the Nambu-Goldstone (NG) mode with the linear dispersion relation associated with the U(1) spin rotational symmetry breaking. Such an interaction is described as nuclear spins collectively coupled to the NG mode, and can be effectively described by the Dicke model. Based on the model, we suggest that various collective spin phenomena realized in quantum optical systems also emerge in the QH systems and these features probably relate with the above mentioned novel experimental results.

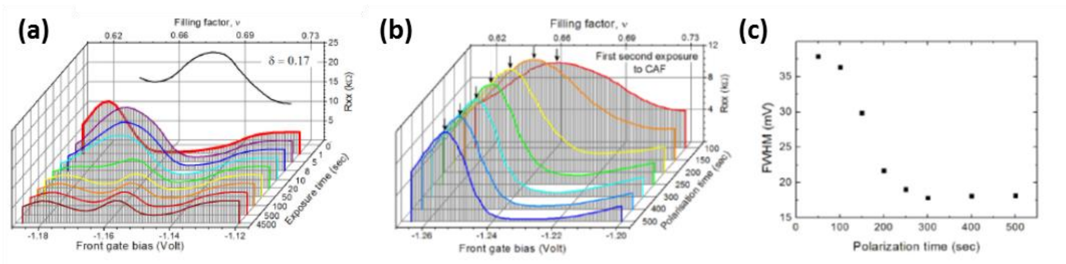

Fig. 1 (a) The evolution of the SPT peak as a function of an exposure time to the CAF phase δ =0.17 (δ is a parameter representing imbalance between two layers and δ =0.17 corresponds to the center of the CAF phase). The sudden change in nuclear polarization distribution occurs within one second. The solid black line in (a) is the initial SPT peak profile taken prior to interactions with electrons of the bilayer. (b) The SPT peaks after one second of exposure to the CAF phase δ =0.17 as a function of polarization time *P* ranging from 100 to 500 seconds. The black arrow indicates the spin transition positions which depend on the hyperfine field B_N. (c) The full width at half maximum (FWHM) as a function of polarization time extracted (a). All measurements were carried out at *B* = 5.75 T and 50 mK.

Representative publication:
1. M. H. Fauzi, S. Watanabe, and Y. Hirayama, "Nuclear magnetometry studies of spin dynamics in quantum Hall systems", Phys. Rev. B 90, 235308 (2014).
2. Y. Hama, M. H. Fauzi, K. Nemoto, Y. Hirayama, and Z. F. Ezawa, "Dicke model for quantum Hall systems", New Journal of Physics, 18, 023027 (2016).