Quasi-one-dimensional Bose-Einstein Condensation in Spin-1/2 Ferromagnetic-leg Ladder Organic Magnets

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Recently, several verdazyl radical crystals have been synthesized and found to form ferromagnetic-leg (FM-leg) ladder lattices [1], i.e., leg and rung interactions are ferromagnetic and antiferromagnetic, respectively. They are molecule-based crystals, and each of molecules possesses an S = 1/2 quantum spin. Substitution of halogen atoms to various functional groups allows tuning of the intermolecular interactions, and brings about unique magnetic phase diagrams with quantum phase transitions [2-4].

In this presentation, we provide an overview of quantum critical phenomena in the verdazyl-radical-based spin-1/2 FM-leg ladders 3-Br-4-F-V [2], 3-I-V [3], and 3-Cl-4-F-V [4]; the quantum criticality of the three-dimensional (3D) ordering phase boundaries $T_c(H)$ near the quantum critical points (QCPs) is discussed with respect to the universality of Bose-Einstein condensation (BEC) of lattice-gas bosons. 3-Br-4-F-V is strong-rung type ($\gamma = |J_{rung}/J_{leg}| > 1$) and has two QCPs, the lower critical field H_{c1}, at which the spin gap is closed, and the saturation field H_{c2}. We applied the temperature-window fitting technique [5] to extract the critical exponents of $T_c(H)$ near the QCPs in the limit of zero temperature. It yields the universal power-law of 3D BEC, $T_c(H) \sim |H - H_{c1,2}|^{2/3}$ [6]. This is the first observation of the 3D BEC exponent on FM-leg ladder systems. On the other hand, 3-I-V and 3-Cl-4-F-V are strong-leg type ($\gamma < 1$) and have no spin-gapped state due to frustrated interladder interactions. Therefore, they have only one QCP, the saturation field H_c. The phase boundary of 3-I-V shows the linear power law $T_c(H) \sim (H_c - H)$ in the wide temperature range below 1 K [7]. 3-Cl-4-F-V shows successive phase transitions [4], and we have also found the linear phase boundary of lower temperature phase near H_c. These characteristic power laws would be caused by quasi-one-dimensional BEC with the predominant ferromagnetic interactions, which has been predicted theoretically [8]. Thus, the spin-1/2 FM-leg ladders provide unique opportunity for investigating the relationship between one dimensionality and BEC physics in quantum magnets.

References

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