21 世紀 COE & 極限量子科学研究センター ジョイントセミナー

Solitary excitations in quantum sine-Gordon spin chains

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概要： The sine-Gordon equation is one of the most famous “soliton” equations, relevant to an extremely broad class of physical phenomena. On the quantum level the sine-Gordon model is one of the paradigms of the quantum field theory. One of the most prominent examples of the sine-Gordon quantum systems is a S=1/2 antiferromagnetic chain perturbated by an alternating *g*-tensor and/or the Dzyaloshinskii-Moriya interaction. Interestingly, in the presence of such interactions, application of a uniform external field *H*, in addition to incommensurate soft modes, induces opening of an energy gap, $\Delta \sim H^{2/3}$. Most importantly, the sine-Gordon equation is exactly solvable. The spectrum of the quantum sine-Gordon spin chain has been predicted to consist of a soliton, antisoliton and their bound states, called “breathers”.

Here, we report a detailed study of the magnetic excitation spectrum in copper pyrimidine dinitrate (Cu-PM), which has been recently identified as an S=1/2 antiferromagnetic chain with a field-induced spin gap, and is probably the best realization of the quantum sine-Gordon spin chain model known to date. By employing high-field high-resolution tunable-frequency submillimeter wave electron spin resonance (ESR) spectroscopy, the field-induced gap has been observed *directly*; *ten* excitation modes were resolved in the low-temperature spectrum, and their frequency-field diagram was systematically studied in magnetic fields up to 25 T. Signatures of *three breather* branches and a *soliton*, as well as those of several multi-particle excitation modes were identified. In addition, we report temperature and field measurements of the ESR spectrum, allowing us to test a new theoretical concept proposed recently by Oshikawa and Affleck [Phys. Rev. Lett. **82**, 5136 (1999)]. Their theory, based on bosonization and the self-energy formalism, can be applied for precise calculation of ESR parameters of spin-1/2 antiferromagnetic chains in the perturbative spinon regime. Excellent quantitative agreement between the theoretical predictions and experiment in both cases is obtained.

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