Spin gap excitations in α-NaV_2O_5 studied by far-infrared spectroscopy

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Sodium vanadate, α-NaV_2O_5, is a quarter-filled spin-ladder compound which undergoes a phase transition at $T_c = 34\,K$. Below T_c a new phase with a different lattice, charge and magnetic order emerges. New lattice order appears as a doubling of the unit cell along ladder legs (b-axis) and rungs (a-axis) and quadrupling in the c-direction. Rung-centered $V^{+4.5}$ charge order changes to zig-zag order of V^{+4} and V^{+5} charges. In the magnetic excitation spectrum spin gap opens and two branches are observed by inelastic neutron scattering. The lower branch has been identified as a singlet to triplet excitation by high field electron spin resonance. We study lattice, charge and magnetic excitations by far-infrared spectroscopy between 3 and $200\,cm^{-1}$ and in magnetic fields up to 12T. In zero magnetic field the triplet resonance appears at $65.4\,cm^{-1}$. By applying magnetic field we observe all three transitions from the singlet ground state to the triplet sublevels $S_z = -1, 0, +1$ and study their selection rules in Faraday and Voigt configurations. The zero-field splitting between the triplet state sublevels is less than $0.2\,cm^{-1}$. It appears that the dominant interaction responsible for the oscillator strength of otherwise forbidden singlet to triplet transition is the coupling of the triplet state to other excitations.