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Optical spectroscopy of PrFe3 (BO3) 4: Crystal-field and anisotropic Pr-Fe exchange interactions

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Abstract

High-resolution polarized optical absorption spectra of PrFe3 (BO3) 4 in the paramagnetic and antiferromagnetic phases are reported. The measured energies of the crystal-field (CF) levels within the 4 f2 configuration of Pr3+ in the paramagnetic PrFe3 (BO3) 4 are described by the CF model that involves the 4 f2 /4f5d and 4 f2 /4f6p configuration interactions. Ordering of Fe spins along the crystalline c axis below TN =32K is confirmed by the analysis of the spectra of Er3+ introduced as a probe into PrFe3 (BO3) 4. To account for the observed changes in the optical spectra of Pr3 + at temperatures below TN, in particular, for the shift of the CF levels, splitting of the CF doublets, and the appearance of forbidden lines, the Pr-Fe exchange Hamiltonian defined by seven parameters is considered. The theoretical approach has been tested by calculating the temperature dependence of the magnetic susceptibility. A good agreement between theory and optical and magnetic experimental data is found demonstrating the validity of the model used. The obtained results confirm that the model of the iron dimers inside the spiral chains of Fe3+ (O2-) 6 octahedrons introduced by us earlier for NdFe3 (BO3) 4 and modified in the present work may serve as a basis for analyzing the low-temperature properties of other rare-earth iron borates.

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