

Optical measurement of the isotope shifts and hyperfine and superhyperfine interactions of Nd in the solid state

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Abstract

We report the observation of optically resolved isotope, hyperfine, and superhyperfine structure in the spectrum of Nd³⁺ ions in YLiF₄, isotopically pure in ⁷Li. This observation was made on the (4f³-4f³), 4I_{9/2}(1)→4F_{3/2}(1) transition of Nd³⁺ ions present as impurities at ppm levels. The optical linewidths of the transitions of the even mass number isotopes, ¹⁴²Nd, ¹⁴⁴Nd, ¹⁴⁶Nd, ¹⁴⁸Nd, and ¹⁵⁰Nd, are only 45 MHz which makes it very easy to resolve the isotope shift of 115 MHz/unit mass. The hyperfine structure of the two odd mass number isotopes, ¹⁴³Nd and ¹⁴⁵Nd, are resolved and the hyperfine parameters are determined in both the ground and electronically excited states. Some of the transitions have linewidths as narrow as 10 MHz. These are the narrowest optical inhomogeneous linewidths observed in solids. In addition, each even isotope line is split by 30 MHz. The observed splitting is assigned to a superhyperfine coupling between Nd³⁺ and its nearest-neighbor fluorine nuclei. Here, a superhyperfine splitting has been resolved in an optical spectrum. The optical line shapes for the even isotopes are calculated as the sum of all transitions between the superhyperfine components (Nd³⁺ with its eight nearest-neighbor F nuclei) of the ground and excited electronic states, considering both magnetic dipole-dipole (including spin-transfer contributions) and contact interactions. The results are in quantitative agreement with experiment.
