Measurement of the Electric Quadrupole Moment of Nb and Zr Isotopes with MAPON after Recoil-Implantation into hcp-Co ◇

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The standard method for the measurement of electric quadrupole moments of radioactive nuclei has been Laser spectroscopy (LS). However, until now LS is applicable only to nonrefractory elements, for which beams with sufficient intensity are available at on-line mass separators. Therefore another method would be desirable, with which quadrupole moments of radioactive nuclei can be measured, independently on the fact whether these are refractory or not. We introduce such a method, which is applicable to all elements throughout the nuclear chart: Modulated adiabatic fast passage (MAPON) after nuclear-reaction recoil-implantation into hcp-Co single crystals. The first experiments were performed with (α,xnyp) compound reactions and quadrupole moments of Zr and Nb isotopes were determined which are interesting in the context of the proton and neutron effective charge at A ~ 90.

In hcp-Co an electric quadrupole interaction (EQI) exists in addition to the magnetic hyperfine interaction. It causes that the magnetic resonance is split into a set of $2I$ subresonances — I is the nuclear spin — which are separated by $\Delta\nu_{\mathrm{Q}}$,

$$\Delta\nu_{\mathrm{Q}} = 3\nu_{\mathrm{Q}}/[2I(2I-1)], \quad (1)$$

$$\nu_{\mathrm{Q}} = eQV_{zz}/h, \quad (2)$$

where eQ is the spectroscopic quadrupole moment and V_{zz} is the principal component of the EFG tensor. Even if the quadrupole splitting is entirely hidden by the magnetic inhomogeneous broadening it can be measured with MAPON. In this technique the low-temperature (T ~ 10 mK) anisotropy ϵ of the γ radiation is measured as function of the amplitude-modulation-frequency $\Delta\nu$ of an adiabatic-fast-passage radio-frequency pulse. Spectra are shown in Fig. 1.

Isotope	I^π	ν_{Q} [MHz]	Q_{exp} [b]	Q_{the} [b]
^{90}Nb	8^+	−0.512(24)	+0.046(7)	+0.04
^{93}Nb	$9/2^+$		−0.32(2)	−0.38
^{95}Nb	$9/2^+$	+4.637(12)		−0.40
^{96}Nb	6^+	+2.20(9)		−0.23
$^{90\mathrm{m}}$Zr	5^-	+3.78(6)		−0.35
^{91}Zr	$5/2^+$		−0.206(10)	−0.20
^{95}Zr	$5/2^+$	−2.353(7)	+0.22(2)	+0.23

Table 1: Quadrupole interaction frequencies and quadrupole moments of Nb and Zr isotopes. The sign of the quadrupole interaction was determined experimentally in all cases.

The solid lines are the results of *least-squares* fits, taking into account a Gaussian distribution for the quadrupole subresonance separation with center at $\Delta\nu_{\mathrm{Q}}$ and width $\Gamma_{\Delta\nu_{\mathrm{Q}}}$. The MAPON signal is given by the integral of this distribution, i.e. an error function with the half value at $\Delta\nu_{\mathrm{Q}}$ and width $\Gamma_{\Delta\nu_{\mathrm{Q}}}$. The different sign of the MAPON signals of ^{95,96}Nb and ^{95}Zr in comparison to ^{90}Nb and $^{90\mathrm{m}}$Zr is due the fact that the γ anisotropy of ^{95,96}Nb and ^{95}Zr is positive, whereas it is negative for ^{90}Nb and $^{90\mathrm{m}}$Zr. The results for the quadrupole splitting frequencies and spectroscopic quadrupole moments are compiled in Table 1. A full description of this work is given in Ref. [1].

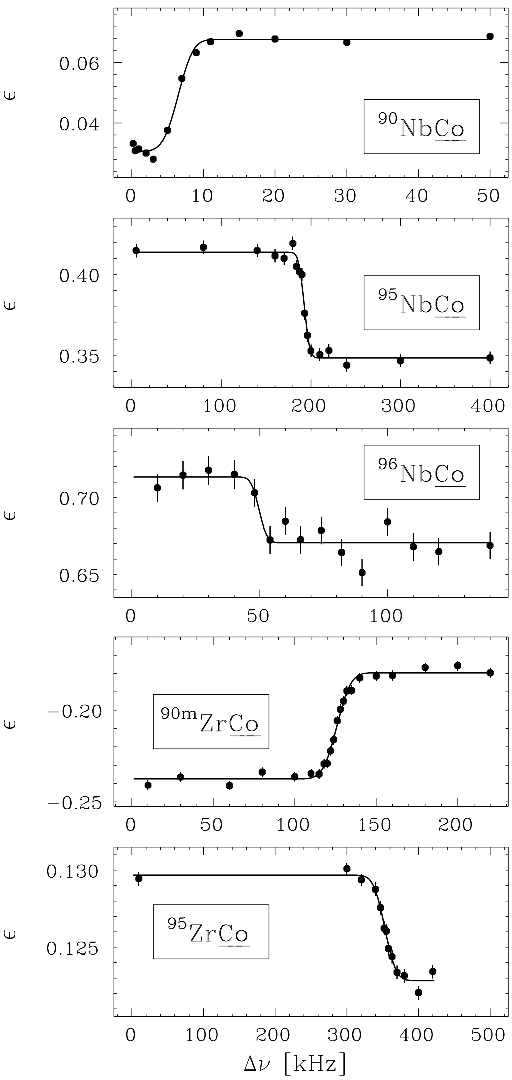

Fig. 1: MAPON spectra of ^{90,95,96}Nb and $^{90\mathrm{m},95}$Zr in hcp-Co.

References

[1] G. Seewald *et al.*, Phys.Rev.Lett **80** (1998) 924

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