Evidence for a Strong Impurity-Nuclei Nuclear-Magnon Interaction of ^{89m}Y in hcp-Cobalt ◇

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It is well known that a magnetic hyperfine field $B_{\rm HF}$ exists at the nuclear site of atoms dissolved as dilute impurities in a ferromagnetic host lattice such as Fe, Co, Ni, Gd. This hyperfine field is proportional to the electronic magnetization $\vec{M}$, $\vec{B}_{\rm HF} \propto \vec{M}$. M is temperature-dependent, $M(T) = M(T{=}0)(1 - AT^{3/2})$, where A is a constant which is of the order of 10^{-6} K$^{-3/2}$ for Fe, Co, and Ni. For $T < 100$ mK the hyperfine fields differ from the saturation values by $\lesssim 10^{-6}$. It is thus evident that no temperature dependence of the magnetic hyperfine splitting in the milli-Kelvin region has been observed until now.

The question, whether *nuclear-magnetization* effects yield a contribution to the magnetic hyperfine interaction of dilute impurities in ferromagnets had not been addressed until now. It could be speculated that such an effect, if existent, should be large if the hyperfine interaction of the impurity nuclei is within the energy band given by the nuclear-magnon dispersion relation of the host. Therefore we studied the system ^{89m}Y$\underline{\rm Co}^{\rm (hcp)}$ which meets this criterion.

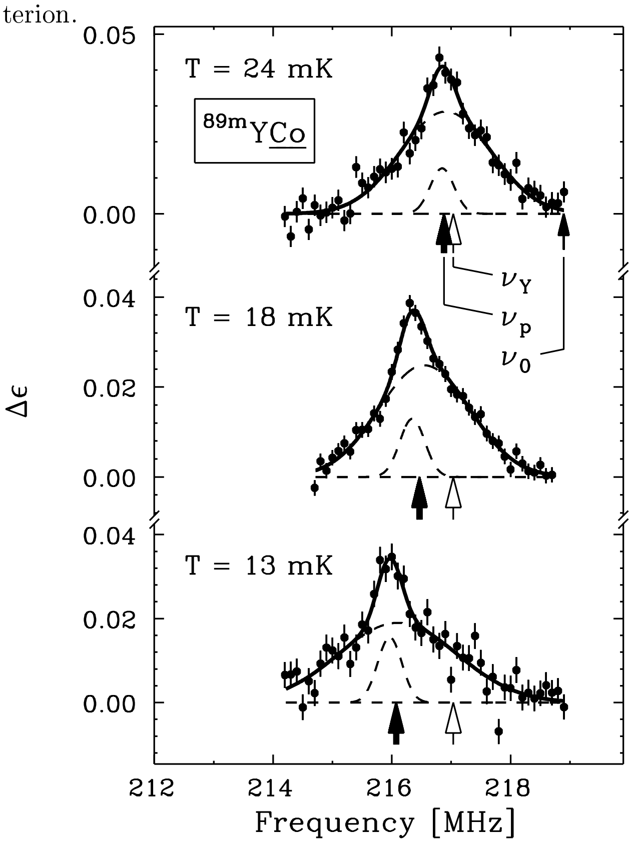

Fig. 1: "FM-off" spectra of ^{89m}Y$\underline{\rm Co}^{\rm (hcp)}$ measured for different temperatures. The intrinsic resonance frequency of ^{89m}Y ($\nu_{\rm Y}$) and the unpulled ($\nu_{\rm o}$) and pulled ($\nu_{\rm p}$) frequencies of ^{59}Co are marked with arrows.

Samples of ^{89m}Y$\underline{\rm Co}^{\rm (hcp)}$ were prepared with recoil-implantation after the nuclear reaction ^{90}Zr(α,5n)^{89}Mo $\to$ ^{89}Nb $\to$ ^{89}Zr $\to$ ^{89m}Y. With a ^{3}He-^{4}He-dilution refrigerator the samples were cooled to temperatures of $\sim$ 10 ... 30 mK, and the hyperfine interaction was measured with nuclear magnetic resonance on oriented nuclei (NMR-ON). NMR-ON spectra are shown in Fig. 1. The resonance could be excited by unmodulated ("FM-off") radio frequency. This indicates that the width of the resonance is partly due to homogenous broadening. The ^{89m}Y resonance structure can be well described by a narrow ($\Gamma \sim 0.5$ MHz) and a broad ($\Gamma \sim 2$ MHz) resonance. The resonance centers are nearly coinciding, the resonance maximum is given by the narrow resonance.

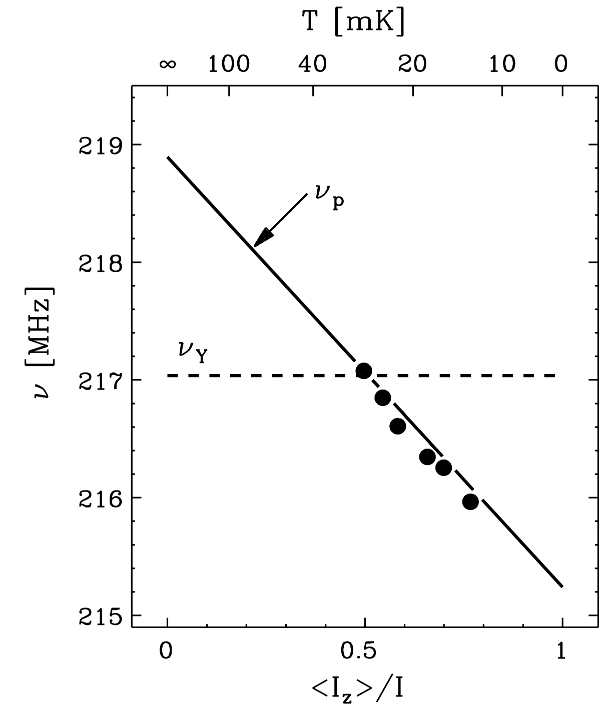

Fig. 2: Dependence of the "FM-off"-resonance maximum of ^{89m}Y ($\overline{\nu}$) on the fractional orientation of the ^{59}Co nuclear spin system (bottom scale) and the respective temperature (top scale). It follows well the frequency of the pulled ^{59}Co resonance (full curve).

In Fig. 2 the frequency of the resonance maximum $\overline{\nu}$ is shown vs. T (upper scale) and vs. the corresponding fractional orientation $<I_z>/I$ of ^{59}Co (lower scale). The solid and broken lines represent the pulled frequency $\nu_{\rm p}$ of ^{59}Co and the intrinsic hyperfine interaction frequency $\nu_{\rm Y}$ of ^{89m}Y, respectively. It is obvious that the magnetic hyperfine interaction frequency of ^{89m}Y is close to the ^{59}Co $k = 0$ nuclear-magnon frequency. This can be interpreted in a way that the precession of ^{89m}Y is "synchronized" by the transverse magnetic field of the collective ^{59}Co mode.

A full description of this work is given in [1].

References

[1] G. Seewald, E. Hagn, E. Zech, Phys.Rev.Lett. **79** (1997) 2550

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