Motion of the Magnetic Moments Detected by Means of Mössbauer Spectroscopy in Magnetic Systems.

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The motion of magnetic moments in magnetic films subjected to radio-frequency radiation (R.F.R.) has been recently investigated by several authors ([1-3]). In the range of R.F. that they used ($(1\div 6)$ MHz), these authors were able to detect, by means of pick-up coils, the motion of the magnetic moments and to distinguish their full rotation from the partial rotation and from the oscillatory motion. SALANSKII and POLSKII, in particular, detected subarmonic oscillations that could not be explained in the frame of their experiment.

In this letter we show, at our present knowledge for the first time, that the effect of R.F. fields on magnetic systems can be conveniently studied by means of Mössbauer spectroscopy and some preliminary results are reported.

It is known that there exists a coupling between the individual atomic magnetic moments and the lattice vibrations caused by exchange, ordinary dipole-dipole and spin-orbit interactions. These interactions depend on the interatomic spacing and the exchange of energy is thus possible between the magnetic and the vibrational states.

If we measure the Mössbauer spectrum of an iron sample in a R.F. field of frequency ω_{RF}, we expect to find, in addition to the usual six-line Zeeman-pattern, a set of sidebands at energies $\hbar\omega_\gamma \pm n\hbar\omega_{RF}$, where $\hbar\omega_\gamma$ is the energy of the resonant gamma-rays. Such sidebands are caused by the large population of the vibrational modes at $\omega = \omega_{RF}$, excited through the interaction with the magnetic moments. Sidebands in Mossbauer spectra have been produced ([4]) by means of ultracustic modulation of the absorber.

The R.F. used in this experiment ranges from 54 MHz to 63 MHz and the intensity of the associated magnetic fields, H_{RF}, could be as large as ~ 5 G. The samples were thick iron films ($(2\div 20)$ μm thickness) and were placed parallel to the R.F. field. The

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([1]) J. M. KELLY: *Phys. Rev.*, **130**, 499 (1956).
([2]) J. R. MAYFIELD: *Journ. Appl. Phys.*, **30**, 256 (1959).
([3]) N. M. SALANSKII and A. I. POLSKII: *Journ. Appl. Phys.*, **39**, 2 (1968).
([4]) S. L. RUDY and D. I. BOLEF: *Phys. Rev. Lett.*, **5**, 5 (1960).

γ-rays, emitted by a ^{57}Co in Cu source, propagate perpendicular to the absorbing film. The source, properly shielded from the R.F. radiation, was mounted on an electromagnetic transducer associated to a multichannel analiser working in multiscaler mode.

a) Iron film, 90% *enriched in* ^{57}Fe (2 μm *thickness*). In this sample the penetration of the R. F. used in this experiment was approximately 1.5 μm. In Fig. 1*a*) the Mössbauer spectrum in the absence of R.F. field is shown, while 1*b*) and 1*c*) are the spectra obtained in the presence of 54 MHz and 63 MHz R.F. fields respectively.

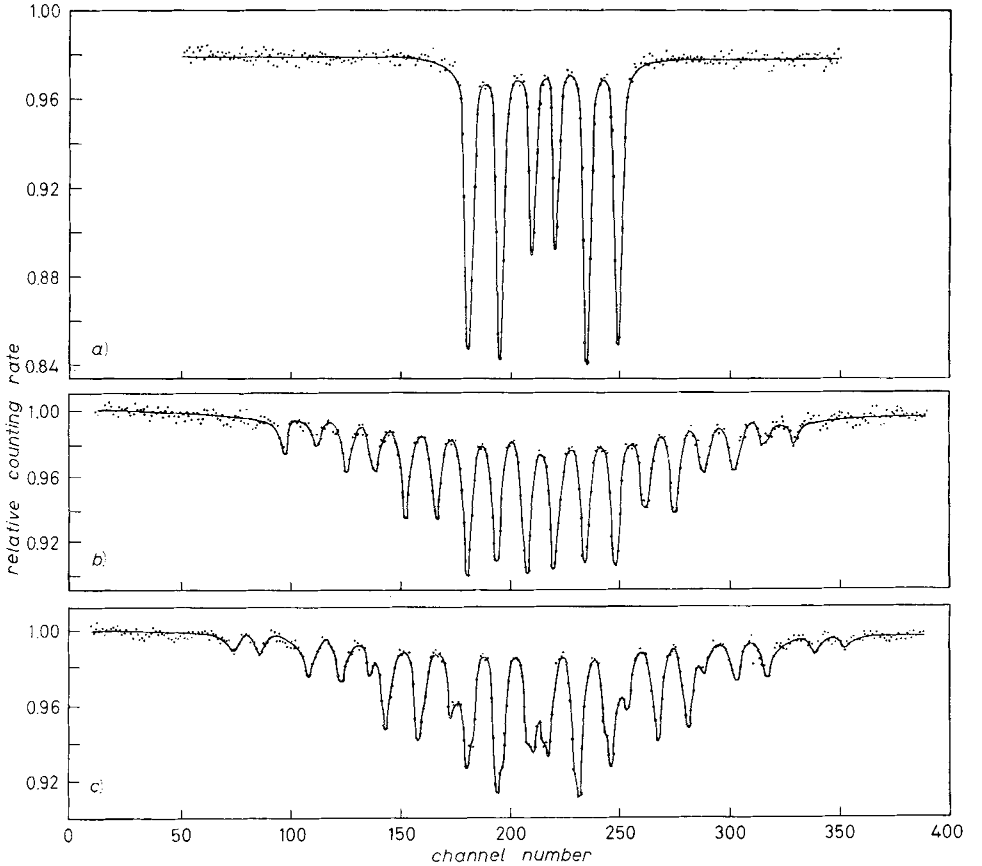

Fig. 1. – Mössbauer spectra for 2 μm iron film (90 % enriched in ^{57}Fe): *a*) in the absence of the R.F. field; *b*) in the presence of a 54 MHz R.F. field; *c*) in the presence of a 63 MHz R.F. field.

The sidebands occurring with the R.F. on are clearly detected up to the third harmonic. The spacing between the sidebands of the same Zeeman line is exactly given by $\hbar\omega_{RF}$. In addition, the intensity of the sidebands was found proportional to the value of H_{RF}.

The relative intensity of the Zeeman lines in Fig. 1*a*) indicates that the total magnetization M_s has a large component in the plane of the film.

([5]) S. CHIKAZUMI: *Physics of Magnetism* (New York, 1964).

b) *Natural-iron film* (10 μm *and* 20 μm *thickness*). – The Mössbauer spectra of these samples are not affected by the presence of a R.F. field. The relative intensity of the Zeeman lines indicates that the total magnetization has a smaller component in the plane of the film than for the 2 μm film.

c) *Stainless-steel film* (5 μm *thickness*). No sidebands were observed with these nonmagnetic samples, showing thereby that their presence is connected to the magnetic order.

As far as the results *a*) are concerned, we can reasonably suppose that the magnetic structure of the sample is a multidomain structure with domains in the plane of the film considerably larger than the domains with the magnetization normal to the surface. This rules out the possibility that the magnetostrictive effects giving rise to the sidebands are caused by the full rotation of the magnetization. The responsible processes can be, therefore, either the oscillation of the magnetic moments within the domains or the motion of the domain walls. The last interpretation (domain wall motion) seems to be supported by the result *b*). If the response to the R.F. field, in the experiment *b*), were the oscillations of the magnetic moments within the domains, we would have detected the presence of sidebands, whose intensity is expected to be small because of the reduced penetration of the R.F. On the other hand, if the response to the R.F. field were the motions of the walls, we would not expect such a motion unless the R.F. penetrates completely the sample. The failure in detecting any sideband in our experiments agrees therefore with the last interpretation. Further experiments are being carried on for thin ferromagnetic films with single-domain structure, in order to focus the effect of the full rotation of the magnetization. In addition the influence of constant magnetic fields superposed to the R.F. field will be studied in detail (*).

(*) *Note added in proofs*. - During the process of publication of these results, the work of N. D. HEIMAN *et al.* (*Phys. Rev. Lett.*, **21**, 93 (1968)) concerning sidebands in Mössbauer spectra was brought to our attention. The results of their experiments are in substantial agreement with the results presented here.