EESTI NSV TEADUSTE AKADEEMIA TOIMETISED. 30. KÖIDE
FÜÜSIKA * MATEMAATIKA. 1981, NR. 2

ИЗВЕСТИЯ АКАДЕМИИ НАУК ЭСТОНСКОЙ ССР. ТОМ 30
ФИЗИКА * МАТЕМАТИКА. 1981, № 2

https://doi.org/10.3176/phys.math.1981.2.12

УДК 539.172.3 : 539.2

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# TIME-DIFFERENTIAL MÖSSBAUER SPECTRA OF $^{119}$Sn

*R. KOCH, E. REALO.* $^{119}$Sn AJALISELT DIFERENTSEERITUD MÖSSBAUERI SPEKTRID

*Р. КОХ, Э. РЕАЛО.* ВРЕМЕННЫЕ ДИФФЕРЕНЦИАЛЬНЫЕ МЕССБАУЭРОВСКИЕ СПЕКТРЫ $^{119}$Sn

*(Presented by K. K. Rebane)*

Recent advances in time-differential Mössbauer spectroscopy have enabled to discover and study a number of relaxation processes in solids with relaxation times of the order of tens and hundreds ns (see, e. g. [1–4]). Detailed measurements have been performed without exception for the 14.4 keV Mössbauer transition of $^{57}$Fe, whose lifetime $\tau = 140$ ns and which has a strong 122—14.4 keV $\gamma - \gamma$-cascade. The application of this technique to other Mössbauer isotopes would allow to investigate different types of relaxation processes and to widen the range of relaxation times.

We present here our measurements of time-differential Mössbauer spectra (TDMS) with an improved time resolution for the 23.9 keV transition of $^{119}$Sn ($\tau = 25.9$ ns) both for the transmission and the scattering geometry.* For this isotope a 26 keV *X*-quantum accompanies the highly converted ($\alpha = 5322$) M4 transition (65.7 keV) and gives a time-reference signal of the formation of the 23.9 keV Mössbauer level. Therefore, the TDMS for $^{119}$Sn are measured by detecting the 26 keV *X*-ray — 23.9 keV $\gamma$-ray delayed coincidence. One transmission experiment of this kind has been reported so far [5], but a relatively low time and energy resolution (or stability) has suppressed the details of the time-dependent phenomena of TDMS. The results of the present study show that well-resolved TDMS for $^{119}$Sn can be obtained and that detailed investigations of the relaxation effects can be extended to $^{119}$Sn-containing materials.

TDMS of $^{119}$Sn were measured by a stabilized Mössbauer spectrometer combined with a delayed coincidence system described in [3]. For $^{119}$Sn experiments $\gamma$-ray detectors were replaced. A $\varnothing$ 50×50 mm plastic scintillator with a side hole for a $\gamma$-source served as a 26 keV *X*-ray detector. For the transmission geometry the 23.9 keV $\gamma$-rays were detected by a $\varnothing$ 30×1.5 mm NaI(Tl) scintillator and for scattering by a plastic resonance scintillation counter. All scintillators were coupled to fast EMI 9813QB photomultipliers. A 60 μm Pd-filter was used to reduce the X-ray background of the $\gamma$-detectors.

* The results were reported at the 5th Bilateral Seminar USSR—FRG on the applications of gamma-resonance spectroscopy and related problems (Dushanbe, Oct. 7—15, 1980).

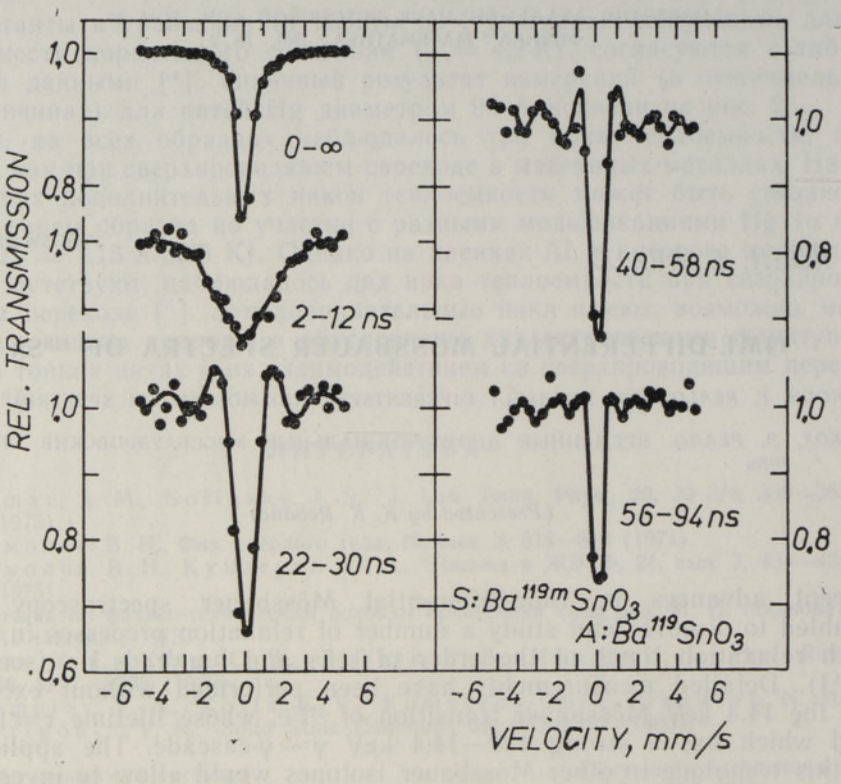


Fig. 1. A TIMS (0—∞) and four TDMS for different delay time intervals, ns.

The resonance scintillation detector consisted of a thin (0.1 mm) plastic scintillator filled with a fine powder of the resonant absorber $Ba^{119}SnO_3$ (enriched up to 90% in $^{119}Sn$). The effective thickness of the resonant material was $\beta=0.5$. This detector detects the conversion electrons emitted after the resonance absorption of the 23.9 keV Mössbauer radiation [6]. The time-resolution of the detector is determined by a fast scintillation decay time (2—3 ns) of the plastic. A comparatively large conversion coefficient $\alpha=5.12$ and a low photoeffect efficiency of the thin plastic scintillator layer ensure high effect-to-background ratios of 3—4 for time-integral Mössbauer spectra (TIMS) and they enable the statistical accuracy of TDMS to be improved.

The calibration of the Doppler velocities was performed by a laser interferometer-calibrator. The time calibration of the system was obtained with a 10 MHz precision quartz generator-divider. The time-resolution of the 26—23.9 keV delayed coincidence system at full width at half maximum was 6 ns. Four TDMS for different 10—20 ns time intervals in the delay time range from 0 to 300 ns were measured simultaneously. The time needed for one experiment was about 50—70 h.

The TDMS for a 10 μCi $Ba^{119m}SnO_3$ γ-source *vs* a single-line $Ba^{119}SnO_3$ absorber with $\beta=2.0$ for four different predetermined delay time intervals and a TIMS (0—∞) measured at 295±2 K are shown in Fig. 1. The width of the central line decreases as the mean delay time increases. At the wings of the central peak, there are clearly seen oscillations for three longer delay time windows. The time-dependence

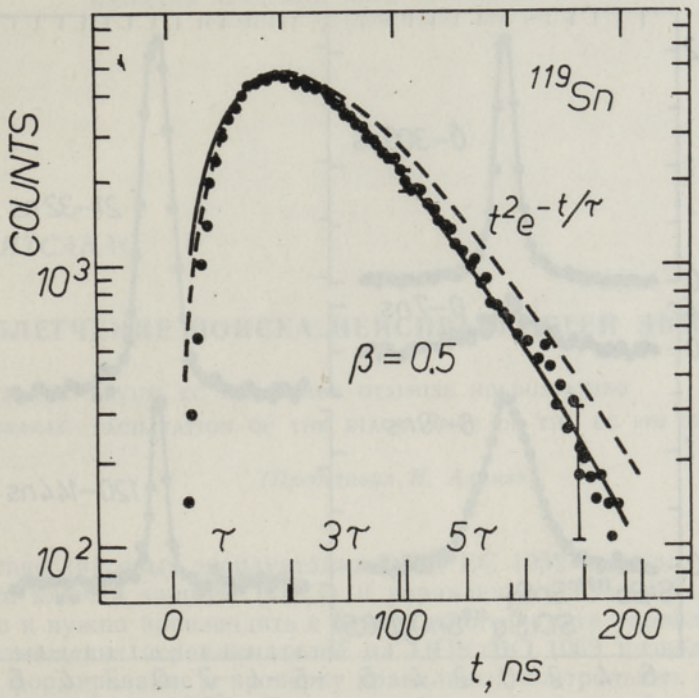


Fig. 2. The time-dependence of resonantly scattered 23.9 keV radiation of $^{119}$Sn. The background contributions have been subtracted. The solid and dashed curves are calculated dependences (see text).

of the parameters of the central line (amplitudes and widths) are in a satisfactory agreement with the corresponding theoretical estimates calculated for the model of time-dependent transmission [7]. An observation of large-amplitude oscillations confirms that a high time resolution and stability have been maintained during the experiment.

Fig. 2 shows the time distribution of resonant scattering, where the conversion electrons emitted after resonance absorption are detected as a function of delay time for a stationary matched Ba $^{119m}SnO_3$ γ-source — Ba $^{119}SnO_3$ resonance detector combination. The background contributions due to random and prompt coincidences as well as photoeffect are subtracted. The largest contribution caused by photoeffect in the detector was determined in a separate experiment with the vibrating γ-source, when the source-detector resonance was completely destroyed.

The solid line in Fig. 2 was calculated using the equation of the time-dependent resonant scattering for a scatterer thickness $\beta=0.5$ and energy shift $\Delta\omega=0$ [8]:

$$I(t) \sim t\, e^{-t/\tau}[1 - J_0^2(\sqrt{2\beta t/\tau}) - J_1^2(\sqrt{2\beta t/\tau})].$$

The dashed line shows the form of this function for a very thin scatterer $\beta \to 0$, then $I(t) \sim t^2 e^{-t/\tau}$. The calculated curves are normalized to the maximum. The agreement between the experimental distribution of resonant scattering at exact resonance ($\Delta\omega=0$) and theory is good. Our preliminary experiments for relative source-detector shifts $\Delta\omega \neq 0$ showed large discrepancies similar to those found in [8].

The TDMS of $^{119}$Sn scattering measured for the delay time intervals

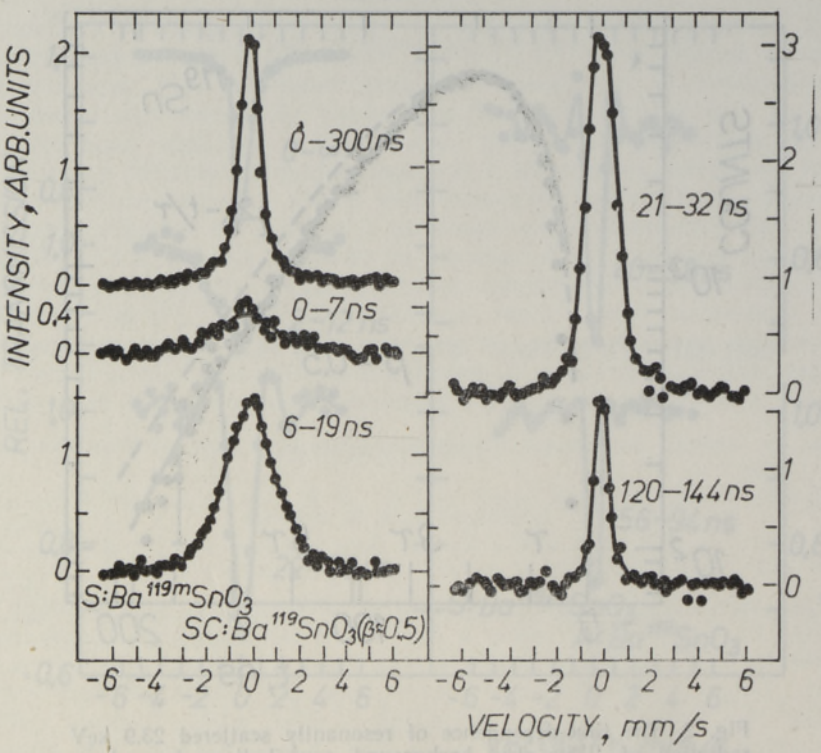


Fig. 3. A TIMS (0—300 ns) and four TDMS for $^{119}$Sn scattering for different delay time intervals, ns.

of 0—7, 6—19, 21—32 and 120—144 ns as well as a TIMS (0—300) for a comparison are shown in Fig. 3. The time-dependence of these spectra is mainly expressed in the changes of the linewidth with the delay time variation. For large delay times $t > 3\tau$ experimental linewidth values lower than that of the TIMS and the double natural width $2\Gamma_0$ were obtained. According to the scattering theory the oscillation-type modifications of the central line are of small intensity (about the order of statistical errors). More detailed comparisons of experimental TDMS and model calculations are in progress.

The authors are grateful to K. K. Rebane for his continuous interest and valuable suggestions.

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Received
Dec. 9, 1980