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A coincidence Mössbauer experiment with $^{119m}$Sn


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Résumé. — La distribution en temps de la radiation Mössbauer filtrée est étudiée expérimentalement. Les résultats obtenus sont en très bon accord quantitatif avec la théorie développée par Lynch, Holland et Hammermesh en 1960. On en déduit que les désaccords observés dans l'expérience de la dépendance en temps de la radiation diffusée sont dus à certaine raison n'étant pas prise en considération et ne sont pas dus à l'approche théorique.

Abstract. — The time distribution of resonantly filtered Mössbauer radiation is investigated experimentally. The results are in very good quantitative agreement with the theory developed by Lynch, Holland and Hammermesh in 1960 [1]. It is concluded that the observed discrepancies in the experiments on time dependence of resonantly scattered radiation [3] are due to some unaccounted reason and not to the theoretical approach.

1. Introduction.

In 1960 Lynch, Holland and Hammermesh [1] published a paper in which they showed that a resonant absorber placed between a Mössbauer source and a detector modifies the decay exponent so that eventually the modified exponent goes over the normal, unmodified one — i.e. in some periods after the formation of the excited state more counts are recorded with an absorber than without it. Our experiment aims to observe and compare with theory the « negative absorption » as Wu et al. [2] called it. The comparison should be accurate since some unexplained deviations still exist in scattering experiments [3]. Those scattering experiments are very precise and the observed discrepancies (at the place of the first minimum, theory and experiment differ 4-10 times) question the applicability of the theoretical approach. Also we shall try to understand better what we observe.

The present work describes an experiment similar to that first one [1] but with another source and better time resolution.

2. Experiment.

The experiment is carried out with a source $^{119m}$Sn. Figure 1 shows the experimental arrangement.

The start signal is given by the 25.3 keV X-ray following the totally converted 65.7 keV transition which feeds the Mössbauer level. The 23.9 keV gamma-ray from the decay of the metastable state serves as a stop signal.
The time resolution of the set up is approximately 2.5 ns. It was measured by Compton scattering of the 60 keV gamma radiation from $^{241}\text{Am}$ source, photomultipliers facing each other. A similar figure was obtained by a computer fit of an unfiltered exponent. This time resolution was achieved with stilbene crystals instead of plastic scintillators. The stilbene crystals provide less dynamic range for the CF discriminator (higher effective atomic number and therefore more photoeffect for low energy photons).

For a typical « run » of 5-15 days two spectra were recorded with periodic commutation — a $I_r$ spectrum (energy shift of several natural linewidths $\Gamma$ between source and absorber) and a $I_0$ spectrum (off-resonance spectrum, Doppler velocity $V = \infty$). After random coincidences and prompt peak subtraction the ratio of the two spectra is calculated, thus normalizing and « rectifying » the exponent — this procedure is equivalent to a multiplication of the time dependent spectrum by a factor $\exp(T/\tau)$, here $\tau$ is the mean lifetime of the resonance level. Also when dividing the two spectra any possible apparatus non-linearities are avoided. The energy shifts between source and absorber and the thickness of the absorber are chosen so as to observe clearly the most interesting case — the excess of counts in certain periods after the formation of the excited state.

3. Discussion.

The experiments definitely confirmed the phenomenon of « negative absorption ». Moreover, the experiment is in very good agreement with the theory — the solid lines on figure 2 are the theoretical calculations using the Hammermesh [1] formula. No numerical integration was done since the resolution time is much less than the mean lifetime. The conclusion is that the reason for the observed deviations in scattering experiments [3] most probably is not in the theory developed by Thieberger et al. [4] which theory follows the same approach as in [1]. The calculations in both papers are based on classical optics — the resonant media is characterized by a complex index of refraction. Of course there is no « negative absorption », the only possible reason for the excess of counts in certain periods is that some photons are delayed in the absorber — this is consistent with the idea for complex index of refraction.

However when using such an approach (later this approach was confirmed quantum mechanically [5]) it should be remembered that there are two important differences in comparison to conventional optics: A) the delay in time is due to resonant centres dispersed randomly in the absorber and it is independent of the average distance between them, and B) the delay is not due to a change of the velocity of propagation of the photon, it is due to a very interesting phenomenon — the photon is delayed by a resonant centre without exciting it — « capturing effect » [6].

A) and B) are not in contradiction with classical optics since the quantity index of refraction has been generalized for randomly dispersed centres at average distance much greater than the wavelength of the incident photon or particle (see e.g. [7]). The index of refraction is expressed by the forward scattering amplitude, the density of the scattering centres and the wavelength of the incident photon or particle. The forward scattering amplitude is a result of the interaction of the incident wave with a single scattering centre.

These arguments may help to understand better why the classical formalism works so well.

The delay phenomenon in forward direction and the radioactive decay are related to some extent — an unstable state exists for a certain time. The delay in forward direction is energy dependent, it depends on the energy difference $E - E_0$. $E$ is the energy of the incident photon, $E_0$ is the resonance energy of the scatterer. This implies the idea that the decay process may also be energy dependent.

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References