AIP | Proceedings

Novel Mössbauer experiment in a rotating system: Extra energy shift confirmed

A. L. Kholmetskii, T. Yarman, M. Arik, and O.V. Missevitch

Citation: AIP Conference Proceedings **1648**, 510011 (2015); doi: 10.1063/1.4912716
View online: http://dx.doi.org/10.1063/1.4912716
View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/1648?ver=pdfcov
Published by the AIP Publishing

Articles you may be interested in

Mössbauer experiments in rotating systems and iso red/blue shift
AIP Conf. Proc. **1479**, 1016 (2012); 10.1063/1.4756317

Mössbauer acquisition system for Rayleigh scattering experiments
Rev. Sci. Instrum. **74**, 3035 (2003); 10.1063/1.1575921

Confirmation of magnetic rotation in the A~110 region
AIP Conf. Proc. **495**, 221 (1999); 10.1063/1.1301778

The role of extra-atomic relaxation in determining Si 2p binding energy shifts at silicon/silicon oxide interfaces
J. Appl. Phys. **82**, 2298 (1997); 10.1063/1.366037

The origin of the extra energy in Doppler-shifted photons
Phys. Teach. **15**, 542 (1977); 10.1119/1.2339764

This article is copyrighted as indicated in the article. Reuse of AIP content is subject to the terms at: http://scitation.aip.org/termsconditions. Downloaded to IP: 217.21.43.85 On: Tue, 17 Mar 2015 06:08:34

Novel Mössbauer Experiment in a Rotating System: Extra Energy Shift Confirmed

A. L. Kholmetskii[a], T. Yarman[b], M. Arik[c] and O.V. Missevitch[d]

[a]*Department of Physics, Belarus State University, 4, Nezavisimosti Av., 220030 Minsk, Belarus*
[b]*Okan University, Akfirat, Istanbul, Turkey*
[c]*Bogazici University, Istanbul, Turkey*
[d]*Institute for Nuclear Problems, Belarusian State University, Minsk, Belarus*

Abstract. We report the result of a novel Mössbauer experiment in a rotating system, implemented in Istanbul University, which yields the coefficient k=0.69±0.02 in the expression for the relative energy shift between emission and absorption lines $\Delta E/E=ku^2/c^2$. This result is in a quantitative agreement with a recent experiment on the same subject (A.L. Kholmetskii, et al., Phys. Scr. **79**, 065007 (2009)) and strongly supports the inequality k>0.5, revealed at the first time in (A.L. Kholmetskii, et al., Phys. Scr. **77**, 035302 (2008)) via the re-analysis of Kündig experiment (W. Kündig, Phys. Rev. **129**, 2371 (1963). Possible explanation of the deviation of the coefficient k from the relativistic prediction k=0.5 is discussed.

Keywords: Mössbauer effect, rotating systems, second order energy shift
PACS: 04.20.-q

INTRODUCTION

The majority of Mössbauer experiments in rotating systems had been carried out at the early 60th of the past century (e.g. [1-6]) soon after the discovery of the Mössbauer effect. The goal of these experiments was to verify the relativistic time dilation effect, which induces the relative energy shift

$$\Delta E/E=-ku^2/c^2 \qquad (1)$$

(where k=0.5 according to relativity theory) between a resonant radiation of a source, located on the rotational axis, and a resonant absorber, located on the rotor rim and orbiting with the tangential velocity u (see Fig. 1). For sub-sound $u\approx$300 m/s, the ratio $u/c\approx10^{-12}$, and the energy shift (1) can be reliably measured with iron-57 Mössbauer spectroscopy, allowing us to reach the relative energy resolution 10^{-14} and higher.

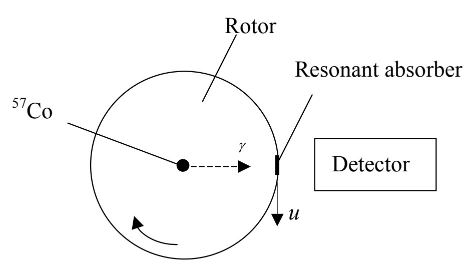

FIGURE 1. General scheme of Mössbauer experiments in rotating systems. A source of resonant radiation is located on the rotational axis; an absorber is located on the rotor rim, while a detector of gamma-quanta is placed outside the rotor system, and it counts gamma-quanta at the time moments, when source, absorber and detector are aligned in a straight line.

All of the authors of the mentioned papers [1-6] reported the value of k=0.5 with the accuracy about 1 %, confirming thus the relativistic prediction. Later the relativistic dilation of time had been confirmed with much better precision ($10^{-8}\ldots10^{-9}$) in experiments on ion beams [7, 8], which somewhat blocked physicists of further interest in the repetition of Mössbauer experiments in rotating systems.

New wave of interest to the Mössbauer experiments in a rotating system emerged after publication of the paper [9], where serious methodological errors in the available experiments of 60th were revealed, which definitely

Proceedings of the International Conference on Numerical Analysis and Applied Mathematics 2014 (ICNAAM-2014)
AIP Conf. Proc. 1648, 510011-1–510011-4; doi: 10.1063/1.4912716
© 2015 AIP Publishing LLC 978-0-7354-1287-3/$30.00

This article is copyrighted as indicated in the article. Reuse of AIP content is subject to the terms at: http://scitation.aip.org/termsconditions. Downloaded to IP: 217.21.43.85 On: Tue, 17 Mar 2015 06:08:34

indicated that the coefficient k in eq. (1) is essentially larger than the relativistic prediction k =0.5, and the deviation many times exceeds the measurement uncertainty.

Based on this result we conjectured that in rotating systems, the energy shift between emission and absorption lines is induced not only via the standard time dilation (which is measured alone in the experiments with ion beams [7, 8] dealing with an inertial motion), but also via some additional effect, which induces an excess of $\Delta E/E$ in comparison with the standard relativistic prediction. This finding stimulated the performance of experiment on this subject [10], where a novel methodological approach was applied, which, like in the Kündig experiment, allowed eliminating the influence of mechanical vibrations of a rotor on the measured value of coefficient k in eq. (1). As a result, the authors obtained [10]

$$k=0.68\pm0.03, \qquad (2)$$

which is even larger than the re-estimated value of k in the Kündig experiment.

Due to the high fundamental importance of this result, its further experimental verification was strongly required.

Here we report the result of measurement of coefficient k in a recent experiment implemented in Istanbul University (IU), which is similar in its methodology to the previous experiment [10], but uses an enhanced rotor system. In this experiment we obtained

$$k_{IU}=0.69\pm0.02, \qquad (3)$$

which well agrees with the previous result (2).

EXPERIMENT AND DATA PROCESSING

In comparison with the experiment [10], where the rotor with the diameter 30.1 cm was used, now we applied a rotor with a diameter about twice smaller (16.11 cm), which allowed increasing the detector's countrate and providing a better statistic quality of the data obtained during the same measurement time. In addition, we expanded the range of variation of tangential velocities of absorber (10-260 m/s), which at the smaller rotor radius implies the essential increase of the range of rotational frequencies and the maximal centrifugal acceleration.

In order to detach the contributions of the time dilation effect and mechanical vibrations in the rotor system to the measured countrate of detector at different ν, we applied the method, which had been approved in the experiment [10].

This method is based on the collection of experimental data for two different resonant absorbers, whose resonant lines are shifted on the energy scale with respect to each other approximately by their line width. As known, chaotic vibrations do not affect the position of resonant lines, and cause only their broadening. Hence an equal broadening of shifted lines of these absorbers, caused by vibration, should induce quite different variation of the detector's countrate with the change of rotational frequency.

Therefore, implementing the joint processing of data obtained with both resonant absorbers, we can separate the variation of detector's countrate, caused by the energy shift (1) from the distortions of countrate, caused by the broadening of lines due to vibrations.

The scheme of our experiment follows to Fig. 1, where the detector is an Ar-Xe proportional counter. It has 90 % detection efficiency and ≤15 % relative energy resolution for 14.4 keV resonant gamma-quanta. The source of resonant radiation is $^{57}Co(Cr)$ with the activity 10 mCi.

We carried out measurements with two resonant absorbers $K_4Fe(CN)_6\times3H_2O$ (absorber 1), and $Li_3Fe_2(PO_4)_3$ (absorber 2), both enriched by ^{57}Fe to 90 %. Each absorber represents a thin film packaged between two berillium layers of the diameter 19 mm and width 0.5 mm; the surface density of both absorbers is 135 mg/cm^2.

The Mössbauer spectra of these absorbers are presented in ref. [10]. The resonant line of absorber 2 is shifted with respect to the resonant line of absorber 1 at (0.295±0.001) mm/s. The value of resonant effect for absorber 1 is 29.0 %, for absorber 2 - 22.1 % at a room temperature.

We used the rotor system developed by the company "Praks-M" (Minsk), which allows a semi-automatic operation with the accuracy of setting the rotational frequency less than 0.1 rps. We applied the rotational frequencies 10, 160, 185, 200, 220, 240 and 257 rps, which correspond to the limited tangential velocity 260 m/s. At the lowest rotational frequency 10 rps, the vibrations in the rotor system are still absent, so that it was taken as the reference point, and the numbers of counts of detectors $N(\nu)$ measured at the larger rotational frequencies were normalized below to the number of counts $N(\nu=10)$.

The measurements were carried out in a cycle mode for both resonant absorbers; each cycle consisted of the measurements of a number of counts of detector of resonant gamma-quanta during 200 s at the rotational frequencies indicated above. We applied 30 such cycles for each resonant absorber, and the mean value of measured counts for both absorbers was $N\approx3\times10^4$ pulses. The relative statistic error is $1/\sqrt{N}\approx0.6\ \%$.

This article is copyrighted as indicated in the article. Reuse of AIP content is subject to the terms at: http://scitation.aip.org/termsconditions. Downloaded to IP: 217.21.43.85 On: Tue, 17 Mar 2015 06:08:34

In the data processing procedure, we considered the coefficient k in eq. (1) as the unknown parameter, and at the first stage we plotted the expected absorption curves for these absorbers at different rotational frequencies ν in the idealized case of the absence of any vibrations in the rotor system. Such idealized curves are shown in Fig. 2a-b at different hypotheses about the value of $0.5<k<1.0$. In Fig. 2b we also present the measurement data for absorber 2 (black points), normalized to the number of counts at ν=10 rps, and their deviation from the corresponding idealized curve at the given k allows us to estimate the broadening of resonant line in comparison with its proper width at different rotational frequencies ν. Implementing such calculations at each chosen value of k, we obtained a set of linewidths $\Gamma_k(\nu)$ at different ν and k, which characterize the influence of vibrations in the rotor system on the shape of resonant lines.

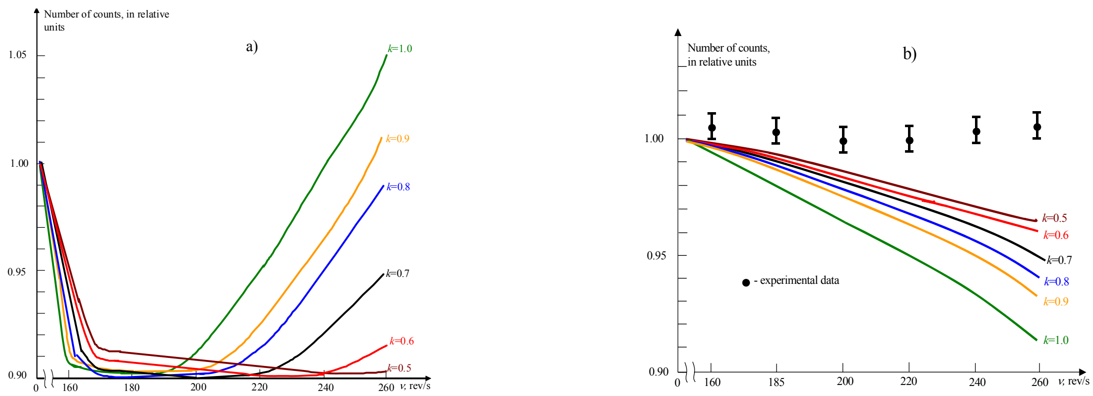

FIGURE 2. Idealized curves for absorber 1 (a) and absorber 2 (b). Black points show the experimental data obtained with absorber 2, plotted in the relative units.

Using the two-dimensional function $\Gamma_k(\nu)$ obtained with the absorber 2, at the next stage we determined the corresponding distortions of the idealized curves for absorber 1 due to vibrations at different ν and k. These real curves are shown in Fig. 3, where the measurements data, normalized to the number of counts at ν=10 rps, are also presented.

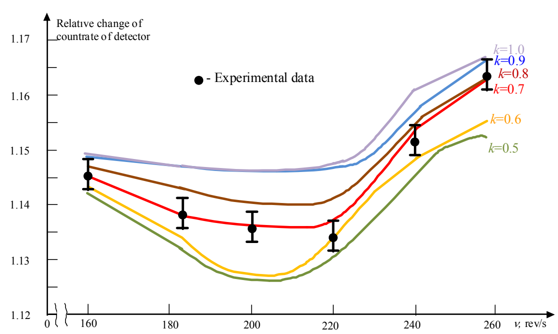

FIGURE 3. Real curves for absorber 1 at different k in comparison with the experimental data, plotted in the relative units (black points, where the error bar has a purely statistical origin).

Then we calculated the standard deviation

$$D(k) = \left[\sum_{\nu} \left(N(\nu) - N_{rk}(\nu) \right)^2 \right]^{1/2} \quad (4)$$

at different k, where the summation is carried out over the values of ν=160, 185, 200, 220, 240, 257 rps; $N(\nu)$ denotes the experimental point (i.e. number of counts at the given ν), and $N_{rk}(\nu)$ stands for the corresponding point of real curve for absorber 1.

Finally we plotted the values of D as the function of k, Fig. 4. We see that this function has the sharp minimum at k=0.69.

This article is copyrighted as indicated in the article. Reuse of AIP content is subject to the terms at: http://scitation.aip.org/termsconditions. Downloaded to IP: 217.21.43.85 On: Tue, 17 Mar 2015 06:08:34

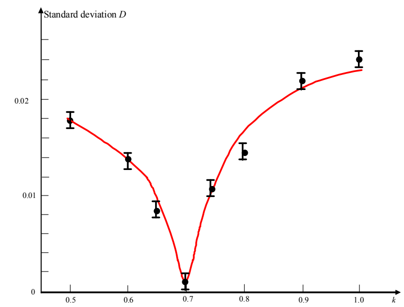

FIGURE 4. Standard deviation between measured and calculated data for absorber 1 versus *k*.

The measurement uncertainty of this coefficient has been determined in suitable computer simulations, and it is equal to ± 0.02.

Therefore, the final result of our measurement is expressed by eq. (3).

Thus, like in the experiment [10], we have confirmed that $k>0.5$, and the deviation between the measured result and relativistic prediction $k=0.5$ many times exceeds the measurement uncertainty. Hence, a plausible physical explanation of this result becomes topical.

CONCLUSION

The presence of an extra energy shift between emitted and absorbed radiation in rotating systems, giving the inequality $k>0.5$ in eq. (1), in fact, had been discovered at 60^{th} of the past century in the Kündig experiment. However, for the unknown reasons this discovery was masked by rough computational errors in the data processing, disclosed in [9].

In our own experiments on this subject, conducted earlier [10], and in the present upgraded experiment, we obtained $k=0.68\pm 0.03$ and $k=0.69\pm 0.02$.

Both special relativity and general relativity are obviously failed to explain this experimental finding, and thus it should be classified as a novel phenomenon lying beound these theories. It seems at the moment that there is the single possible way to explain the Mössbauer rotor experiments via the Santilli isoredshift in rotating systems [11].

ACKNOWLEDGMENTS

The work was done in the framework of the Research Project BAP 5623 of Istanbul University.

REFERENCES

1. W. Kündig, *Phys. Rev.* **129**, 2371-2375 (1963).
2. H.J. Hay, et al., *Phys. Rev. Lett.* **4**, 165-166 (1960).
3. H.J. Hay, In: *Proceedings of the Second Conference on the Mössbauer effect* edited by A. Schoen and D.M.T. Compton, New York: Wiley, 1962, pp. 225-226.
4. T.E. Granshaw and H.J. Hay, In: P*roceedings Int. School of Physics, "Enrico Fermi"*, New York: Academic Press, 1963, pp. 220-222.
5. D.C. Champeney and P.B. Moon, *Proc. Phys. Soc.* **77**, 350-352 (1961).
6. D.C. Champeney, Isaak G.R. and A.M. Khan, *Proc. Phys. Soc.* **85**, 583-593 (1965).
7. R.W. McGowan, et al., *Phys. Rev. Lett.* **70**, 251-254 (1993).
8. I. Bailey, K. Borer, F. Combley, et al., *Nature* **268**, 301-305 (1977).
9. A.L. Kholmetskii, T. Yarman and O.V. Missevitch, *Phys. Scr.* **77**, 035302-035306 (2008).
10. A.L. Kholmetskii, T. Yarman, O.V. Missevitch and B.I. Rogozev, *Phys. Scr.* **79**, 065007-0650012 (2009).
11. R. M. Santilli, *Nuovo Cimento* **51**, 570-578 (1967).

This article is copyrighted as indicated in the article. Reuse of AIP content is subject to the terms at: http://scitation.aip.org/termsconditions. Downloaded to IP: 217.21.43.85 On: Tue, 17 Mar 2015 06:08:34