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**NUCLEAR GAMMA-RESONANCE OBSERVATION IN CONDITIONS  
 OF COMBINED LINEAR AND TRANSVERSE DOPPLER SHIFTS  
 AND FEATURES OF RELATIVISTIC THEORY**  
**V.G. Kirichenko<sup>1</sup>, O.V. Kovalenko<sup>1</sup>, T.A. Kovalenko<sup>1</sup>, Yu.I. Gofman<sup>2</sup>**

<sup>1</sup>*Kharkov National Karazin University, High Technology Institute  
 31 Kurchatov St., Kharkov, 61108, Ukraine*

*E-mail: [val\\_kir48@mail.ru](mailto:val_kir48@mail.ru)*

<sup>2</sup>*Jerusalem College of Technology, Department of Applied Physics  
 P.O. B. 16031, Jerusalem 91160, Israel*

*E-mail: [gofman@jct.ac.il](mailto:gofman@jct.ac.il)*

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We consider the problem of nuclear gamma-resonance observation and the effects of displacement energy gamma rays in conditions of combined linear and quadratic Doppler effect. The main result of this experiment was concluded in the possibility of realization of second order Doppler shift observation in the range of the combined shifts with help of commutation electronic schemes for coherent transverse and linear shifts. This gives simplifications in experimental procedure. We reached the values of minimum measurable linear velocity of about  $10^{-5}$  mm/s· pulse using the isotope Sn<sup>119</sup>. It confirms the real possibilities of measurement method Doppler shift using the Mossbauer effect to determine the maximum acceleration and the prospects for development of such researchers.

**KEY WORDS:** Nuclear gamma resonance, linear and quadratic Doppler effect, the scheme of registration, the shift of the spectrum, extended theory of relativity, maximal acceleration

**ОСОБЛИВОСТІ СПОСТЕРЕЖЕННЯ ЯДЕРНОГО ГАММА-РЕЗОНАНСУ ОБЕРТОВИХ ОБ'ЄКТІВ ТА  
 РОЗШИРЕНА ТЕОРІЯ ВІДНОСНОСТІ**

**В.Г. Кіріченко<sup>1</sup>, О.В. Коваленко<sup>1</sup>, Т.А. Коваленко<sup>1</sup>, Ю.І. Гофман<sup>2</sup>**

*Харківський національний університет імені В.Н. Каразіна, Інститут високих технологій  
 61108, м. Харків, пр. Курчатова, 31*

<sup>2</sup>*Єрусалимський технологічний інститут - Махон Лев, Відділення прикладної фізики  
 п.с. 16031, Єрусалим 91160, Ізраїль*

Розглянуто проблема спостереження ядерного гамма-резонансу і зсув енергії гамма-випромінювання в умовах комбінованого лінійного і квадратичного ефекту Доплера. Основний результат цього експерименту полягає в можливості реалізації спостереження доплерівського зсуву другого порядку за допомогою електронних схем комутації для когерентних поперечних і лінійних зрушень. Це спрощує проведення експерименту. Ми досягли за допомогою ізотопу Sn<sup>119</sup> мінімально вимірного значення лінійної швидкості близько 10<sup>-5</sup> мм/с·імп. Це підтверджує реальні можливості методу вимірювання доплерівського зсуву за допомогою ефекту Мессбауера для визначення максимального прискорення і перспективи для розвитку таких досліджень.

**КЛЮЧОВІ СЛОВА:** ядерний гамма-резонанс, лінійний і квадратичний ефект Доплера, схема реєстрації, зсув спектра, розширена теорія відносності, максимальне прискорення

**НАБЛЮДЕНИЕ ЯДЕРНОГО ГАММА-РЕЗОНАНСА В УСЛОВИЯХ КОМБИНИРОВАННОГО ЛИНЕЙНОГО И  
 ПОПЕРЕЧНОГО ДОПЛЕРОВСКИХ СДВИГОВ И ОСОБЕННОСТИ ТЕОРИИ ОТНОСИТЕЛЬНОСТИ**

**В.Г. Кириченко<sup>1</sup>, О.В. Коваленко<sup>1</sup>, Т.А. Коваленко<sup>1</sup>, Ю.И. Гофман<sup>2</sup>**

<sup>1</sup>*Харьковский национальный университет имени В.Н. Каразина, Институт высоких технологий  
 61108, г. Харьков, пр. Курчатова, 31*

<sup>2</sup>*Иерусалимский технологический институт - Махон Лев, Отделение прикладной физики  
 п.я. 16031, Иерусалим 91160, Израиль*

Рассмотрена проблема наблюдения ядерного гамма-резонанса и смещение энергии гамма-излучения в условиях комбинированного линейного и квадратичного эффекта Доплера. Основной результат этого эксперимента заключается в возможности реализации наблюдения доплеровского сдвига второго порядка с помощью электронных схем коммутации для когерентных поперечных и линейных сдвигов. Это упрощает проведение эксперимента. Мы достигли с помощью изотопа Sn<sup>119</sup> минимально измеримого значения линейной скорости около 10<sup>-5</sup> мм/с·имп. Это подтверждает реальные возможности метода измерения доплеровского сдвига с помощью эффекта Мессбауэра для определения максимального ускорения и перспективы для развития таких исследований.

**КЛЮЧЕВЫЕ СЛОВА:** ядерный гамма-резонанс, линейный и квадратичный эффект Доплера, схема регистрации, смещение спектра, расширенная теория относительности, максимальное ускорение

Some fundamental problems of physics such, as gravitational red shift, Planck mass  $l_m$  and Planck length  $l_p$ , acceleration of particle to ultrahigh energies corresponded to wave length  $\lambda \sim l_p$ , expansion of the universe and many others solved and can be solved by using Doppler effect. As well known, Doppler effect is the dependence of wave frequency from velocity of observer or analyzer relative to its source. Doppler effect is widely used in astronomy to measure radial velocities of stars and galaxies, temperature measurement in plasma physics and astronomy, Doppler

radars, medical imaging, flow measurements and many other applications [1, 2].

In recent years, scientific and technical interest to the problem of monitoring and implementation of the Doppler effect in the Mössbauer spectroscopy was renewed. This is due both to the possible use of the Mossbauer effect in the technique of detection of small shifts, angles, speeds and acceleration for implementation of the Mossbauer effect in solving the fundamental physics problems of space – time: the unit of length, the anisotropy of space, the stability of the temporal and spatial intervals, minimum and maximum velocities and accelerations.

For effective using of the unique resolution of the nuclear gamma-resonance known as Mossbauer effect [3] is necessary to create new methods of observation. Application of the nuclear gamma - resonance for the experimental verification theory of relativity and theory of gravity is based on minimum ratio  $\Delta E/E$  ( $\Delta E = \Gamma$  - line width and  $E$  - the energy of gamma - quanta) which values reaches  $3.1 \cdot 10^{-13}$  and  $5.2 \cdot 10^{-16}$  for the isotopes  $\text{Fe}^{57}$  and  $\text{Zn}^{67}$  respectively, and on the rare possibility of using for it's observation combined linear and quadratic Doppler effect. This made it possible to verify the presence of the gravitational red shift on Earth [3] with accuracy to within 1%, to test the central field of the Schwarzschild equation [4-8]. It is noted that in nuclear gamma - resonance experiments it is necessary to use more accurate measure of linear and quadratic Doppler effect. This method should include the improvement devices of measurement and control the speed and acceleration of moving objects in space, which have previously created gyroscopic device based on the Mossbauer Effect [9-11].

An important application of the Mössbauer effect in modern physics is an experimental verification of the extended theory of relativity (ETR). It obtained from the new approach to the analysis of relativistic effects which is based on the symmetry of space-time, the isotropy of the space and principle of relativity [12,13]. This approach explains existence of the limit speed of light from fundamental properties of space-time, in particular. ETR predicts the existence of a maximal acceleration [14]. This is fundamentally new relativistic phenomenon, which relates the special and general relativity, requires a careful verification. Evaluation of maximum acceleration  $a = (1.006 \pm 0.063) \cdot 10^{19} \text{ m/s}^2$ , was given in [14] from experimental date [7]. But it requires repetition and new types of experiments with the use of modern high-precision experimental techniques, of course. A maximum acceleration effect is more shows at high values of accelerations, thus. It expect or very high force or very small masses or both together. Analysis of the acceleration for different physical phenomena in cosmology, nuclear physics and other areas of modern physics show that the greatest acceleration observed in collisions of nuclear particles [15], in particular.

The aim of this study is to improve the accuracy of nuclear gamma-resonance observation and the effects of displacement energy gamma rays in conditions of combined linear and quadratic Doppler effect in physical systems related with moving and rotating objects.

### EXPERIMENTAL RESEARCH METHOD

For alternative to [16, 17] the source of the Mossbauer isotope  $\text{Sn}^{119}$  gamma - rays was used the nuclei  $\text{Sn}^{119}$  in  $\text{CaSn}^{119\text{m}}\text{O}_3$  matrix. The refined wavelength with energy 23.87 keV is  $\lambda = [18]$ . The scheme of observation of combined linear and transverse Doppler shifts is given on Fig. 1.

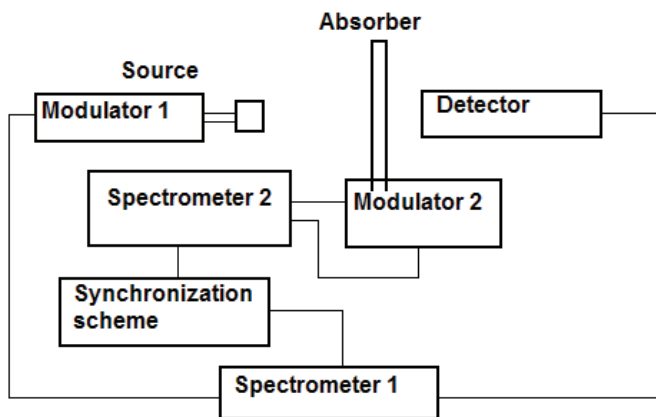


Fig. 1. The scheme of combined linear and transverse Doppler shifts observation

sensitive to vibrations. Previously it was shown that at the measurement of small linear and angular displacements of objects the cross Doppler effect with the Mössbauer technique obstacles arise first of all due to the vibrations, the pulses, disturbance of the strict orientation of objects in space, the inhomogeneous distribution of resonant nuclei on the surface of the object.

### RESULTS AND DISCUSSION

Traditionally, the experimentally measured value of the isomer shift of the absorption line or scattering relative to the standard is the resultant of two shifts: the shift determined by the electron density distribution  $\delta_{\text{chim}}$  and the shift

This scheme was realized the synchronous motion of the source  $\text{Sn}^{119}$  gamma – rays (linear Doppler shift) and absorber  $\text{SnO}_2$  (transverse Doppler shift). It was very simple and gives the time interval of synchronization with accuracy  $10^{-4}$  s.

Operation of the scheme is to the synchronization of the radial and transverse motion of the source and absorber in the same spatial plane. The ability to change the angle between the axes of the source and absorber is provided. This can be used to study the effects of anisotropy. The number of studies to measure the second order Doppler shifts using the Mossbauer isotope  $\text{Sn}^{119}$  is small. This is because the line width is much greater than that of the isotope  $\text{Fe}^{57}$ . On the other hand, the observation of the Mossbauer effect on  $\text{Sn}^{119}$  is less

determined by the rms velocity fluctuations of the nuclei  $\delta_{\text{temp}}$ :

$$\delta_{\text{is}} = \delta_{\text{chim}} + \delta_{\text{temp}}. \quad (1)$$

Determination of second order Doppler shifts was carried out by measuring  $\delta_{\text{temp}}$ . According to the Einstein model of solids for  $\delta_{\text{temp}}$  the following expression can be obtained:

$$\delta_{\text{TEMP}} = \frac{3}{4} \frac{\hbar \omega_E}{M_C} \text{cth} \left( \frac{\hbar \omega_E}{2kT} \right). \quad (2)$$

Values  $\omega_E$ , in turn, can be determined from the temperature dependence of the effect probability

$$\frac{R}{\hbar \omega_E} \left[ \text{cth} \left( \frac{\hbar \omega_E}{2kT_2} \right) - \text{cth} \left( \frac{\hbar \omega_E}{2kT_1} \right) \right] - \ln \frac{f_{T_1}}{f_{T_2}} = 0. \quad (3)$$

The calculation results suggest that the observed increase  $\delta_{\text{iz}}$  with decreasing temperature fully explained by the second order Doppler effect. And besides this shift of the spectra in the direction of positive values of the Doppler radial velocity does not depend on the type of the Mössbauer isotope, because it does not include the nuclear characteristics, unlike to the shift defined by electron density.

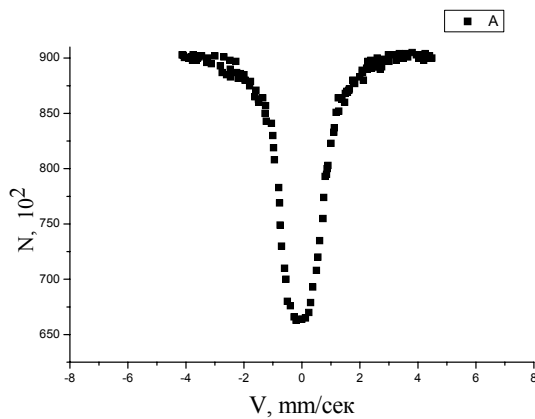


Fig. 2. Mossbauer spectrum of  $\text{SnO}_2$

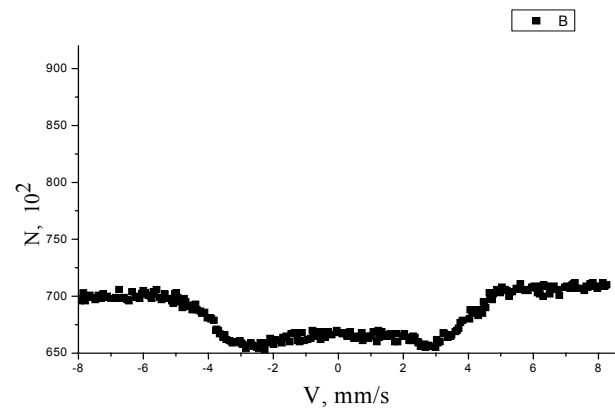


Fig. 3. Mossbauer spectrum of  $\text{SnO}_2$  under influence transverse motion

We try to show that in our case, spectral shift toward positive values Doppler of radial velocity is observed under the transverse motion of the absorber. It is shown the spectrum of the initial absorber  $\text{SnO}_2$  at absence of transverse motion (Fig. 2). The splitting of a single line of  $\text{SnO}_2$  and the formation of an asymmetric doublet spectrum with very weak asymmetry (Fig. 3) is observed at synchronization with an accuracy of up to  $10^{-4}$ s a linear shift required for the registration of the spectrum and the transverse motion.

In our case the source and absorber, characterized by single lines of emission and absorption were used. The dependence of the resonant transmission of gamma rays from linear radial Doppler velocity (spectra on Fig. 2, 3) under the parameter  $X = A\omega$  for the determination of small displacements was obtained, where the  $A$  – amplitude  $\omega$  – frequency of transverse motion.

The Doppler shift energy of gamma - rays for the laboratory coordinate system, i.e. the frequency  $\nu$  of  $\gamma$  – rays, is given by:

$$\nu = \nu_0 \left( 1 + \frac{g}{c} \cos \alpha - \frac{1}{2} \frac{g^2}{c^2} \right). \quad (4)$$

Here  $\nu_0$  - frequency of  $\gamma$  - rays for fixed relative to each other the source and absorber,  $\alpha$  - the angle between the recording  $\gamma$  - rays and the velocity vector of the relative motion of the source or sink,  $\nu$  - the relative velocity of source on to the absorber. Usually in the expression (4) it is necessary to take the instantaneous values  $\vec{V}(t)$ .

It is necessary to search for ways to effectively eliminate its influence on the instrument readings. In addition to measuring the linear velocity and displacement by nuclear gamma - resonance it is possible to carry out measurement and control of transverse velocities and accelerations.

It were built dependences of the velocities of linear displacement of the number recruited in each point of the pulse and had a trend line (Fig. 5,6) for a more complete analysis of the asymmetry of the weak positive (velocity in Fig. 3) and the negative part of the spectrum.

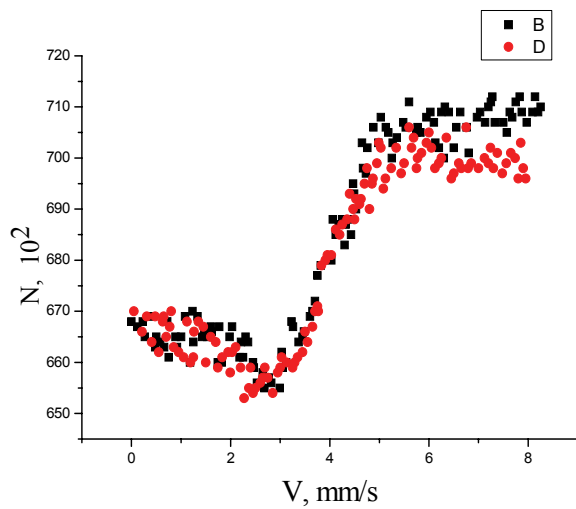


Fig. 4. Slow asymmetry of Mossbauer spectrum of  $\text{SnO}_2$  under influence transverse motion

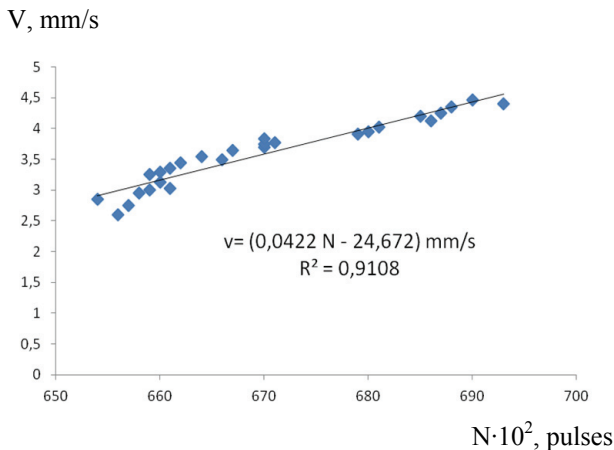


Fig. 5. Dependence of the linear Doppler velocity of the number of pulses on the most steep part of the resonance curve in the negative part of the spectrum (Fig. 3,4)

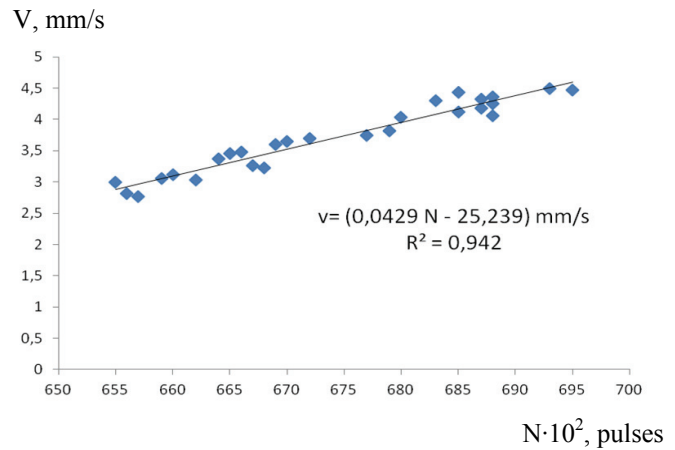


Fig. 6. Dependence of the linear Doppler velocity of the number of pulses on the most steep part of the resonance curve of the positive part of the spectrum (Fig. 3,4)

The maximum high accuracy of electromagnetic irradiation frequency measurement using Mossbauer effect allows to test of one of the consequences of general relativity - "transverse Doppler effect" [16]. As shown [12] in the ERT Doppler shift between inertial system  $K'$  and accelerated system  $\tilde{K}$  moving together is determined by the coefficient  $(1 - a/A)$  due to the acceleration  $\tilde{K}$  relatively  $K'$ . Evaluation of maximum acceleration  $a = (1.006 \pm 0.063) 10^{19} \text{ m/s}^2$ , using experimental data [5] was carried out. Such a significant acceleration it is possible to reach at modern experimental installations, at particular, at CERN's the muon storage ring [17].

## CONCLUSIONS

The main result of this experiment was concluded in the possibility of realization of second order Doppler shift observation in the range of the combined shifts with help of commutation electronic schemes for coherent transverse and linear shifts. This gives simplifications in experimental procedure. We reached the values of minimum measurable linear velocity of about  $10^{-5} \text{ mm/s} \cdot \text{pulse}$  using the isotope  $\text{Sn}^{119}$ . It confirms the real possibilities of measurement method Doppler shift using the Mössbauer effect to determine the maximum acceleration and the prospects for development of such researchers.

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Linear dependences (Fig.3,4) allow us to evaluate the achieved accuracy of spectrum shift in the transverse displacement, which is standard value of  $0.01 \text{ mm/s}$  under normal conditions reached maximal accuracy evaluation is  $10^{-5} \text{ mm/s} \cdot \text{pulse}$  at measurement accuracy of the resonance transmission. Shift of the right side of the spectrum relative to the left side is  $3 \cdot 10^{-5}$ . This is due to the use of an isotope with a broad emission line, which eliminates the advantages of insensitivity to vibrations.

The main result of this experiment was concluded in the possibility of realization of second order Doppler shift observation in the range of the combined shifts with help of commutation electronic schemes for coherent transverse and linear shifts. This gives simplifications in experimental procedure.

As example the values of the contributions from the second order Doppler shift for  $\text{Fe}^{57}$  nuclei are small and approximately equal to  $0.00005 \text{ mm/s}$  [16].

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**Kirichenko Valerij Grigir'evitch** - Associate Professor of Department of Material Reactor Building and Physical Technology

Research interests: Solid State Physics, Hyperfine Interactions, Mössbauer Effect, Phase Transformations, Surface Science, Low Temperature Physics, Nuclear and Nano Materials.

Scientific Publications: Three books, three review papers and about 300 scientific and methodological publications.



**Kovalenko Olga Vladimirovna** - graduate student at Kharkov National University named V.N. Karazin.

Research interests: solid state physics, magneto-optics, hyperfine interactions. She is author of 39 publications.



**Kovalenko Tat'yana Aleksandrovna** - research associate at the Kharkov National University named V.N. Karazin.

Research interests: solid state physics, radiation material science. She is author of more than 20 publications.



**Gofman Yuriy** - Ph.D., lecturer, Department of Applied Physics, Jerusalem College of Technology, Jerusalem, Israel, laureate of honorary award for the development of science and hi-tech in Jerusalem "Jerusalem on Rise" (2009).

Field of interest: radiation damage and radiation technology of materials, modern physics.