# Response to "Comment on 'Observation of nuclear gamma resonance with superconducting tunnel junction detectors'" [AIP Advances 9, 059101 (2019)]

Cite as: AIP Advances 9, 059102 (2019); doi: 10.1063/1.5090973
Submitted: 31 January 2019 • Accepted: 16 May 2019 •
Published Online: 23 May 2019



M. G. Kozin,[1,a)] I. L. Romashkina,[1] L. V. Filippenko,[2] and V. P. Koshelets[2]

## AFFILIATIONS

[1]Skobeltsyn Institute of Nuclear Physics (MSU SINP), Lomonosov Moscow State University, 1(2), Leninskie Gory, GSP-1, Moscow 119991, Russian Federation
[2]Kotel'nikov Institute of Radio Engineering and Electronics of Russian Academy of Sciences, Mokhovaya 11-7, Moscow 125009, Russian Federation

[a)]**Author to whom correspondence should be addressed. E-mail:** kozin@srd.sinp.msu.ru

https://doi.org/10.1063/1.5090973

The Comment contains two main claims, which we consider in detail below.

The first claim is that our results are erroneous because in order to observe the Mössbauer effect at zero relative velocity of the source and the absorber V = 0, it is necessary that they have single emission-absorption lines, whereas in our work the scatterer with a splitted Mössbauer spectrum was used. We cannot agree with this point of view. Recall that Mössbauer effect or nuclear gamma resonance (NGR) is the resonant and recoil-free emission and absorption of gamma radiation by atomic nuclei bound in a solid. Deexcitation of excited Mössbauer nucleus is accompanied not only by emission of gamma radiation but also by emission of X-rays and resonant (conversion and Auger) electrons. It is evident that to observe the Mössbauer effect at V = 0 using the source with a single line and the scatterer with a splitted Mössbauer spectrum it is sufficient to have a nonzero value of the resonant absorption in the scatterer. This effect can be seen clearly in the absorption spectrum given in Figure 3c of the Comment for the alloy $Rh_{0.8}Fe_{0.2}$ used in our work. Due to the overlap of inner neighboring lines, the value of the effect at V = 0 exceeds 20% of the maximum value for the outermost lines of the spectrum. Thus, the effect is noticeable at V = 0 but is absent at high velocities (larger than ± 4.5 mm/s). Since the conversion coefficient of the Mössbauer transition in $^{57}$Fe nucleus is large, the absorption of Mössbauer gamma-quanta in the scatterer results in a large number of conversion electrons (approximately nine electrons for each emitted gamma-quantum) and corresponding number of Auger electrons which are registered by the superconducting tunnel junction (STJ) detector in addition to X-rays. Therefore, the assumption made in the Comment that there must be single peaks both in the source and the scatterer and all subsequent statements based on it are incorrect.

All our experiments have been performed very carefully with great attention to their reproducibility and repeatability, and we are confident in the results published in our paper. Notice that in our study we have presented spectra with ($Rh_{0.8}Fe_{0.2}$) and without (Rh) the Mössbauer effect. Direct comparison of these spectra clearly demonstrates that peaks 2 and 4 in Figure 2(a) and analogous peaks in Figure 4(a) of our article can be ascribed only to resonance electrons appearing as a result of the Mössbauer effect in the scatterer and we cannot suggest alternative explanation for these signals. The absence of pronounced peaks in the remote detector number 2 is accounted for by the attenuation of the electron flow and the change of the regime of electron proliferation from directional to diffusion at distances of the order of 1 mm. This is explained in more detail in paragraph 3 of our article where we give estimations for electron ranges.

The second claim in the Comment is that the STJ detectors have no application prospects in Mössbauer spectroscopy and more specifically for spectroscopy on $^{57}$Fe and $^{119}$Sn isotopes. In fact that is the main issue discussed in the Comment and the arguments are as follows: small thickness of the absorbers, low absorption probability, low area of detectors, absence of total absorption peak etc.

These problems, discussed in detail in the past in the literature on STJ detectors, are well known.

The efficiency of STJ detectors known to be poor for photons with energies exceeding 6 keV, can be increased in a number of ways. For example the material of the absorber can be changed from Nb to Ta. To increase the detector area, one can use the STJ arrays. Another solution is to use intensive beams of synchrotron radiation giving good statistics even for a small single detector.

Notice that although the registration of the total absorption in the detector is desirable, it is not necessary in a working device. Incomplete absorption peaks in STJ detectors in a wide range of thicknesses can be first calibrated, and then used for practical applications.

Principal possibility to use the STJ detectors for registering the NGR for all kinds of radiation: resonant electrons, γ-rays, X-rays and escape peaks with high energy resolution has been experimentally demonstrated in our works. Our position is that only studies can show whether the drawbacks and limitations of STJ detectors can be compensated by their advantages to be used in certain scientific and technological niches including Mössbauer spectroscopy.

A recent paper[1] describes the current state of low-temperature setups for conversion electron Mössbauer spectroscopy (CEMS). It analyzes the advantages and disadvantages of gas detectors, channel electron multipliers and other detectors used for this purpose. The main advantage of STJs detectors is their high energy resolution, which far exceeds the resolving power of proportional counters. So we hope that using new specialized experimental setup for a full-fledged Mössbauer experiment with velocity sweep and optimized detectors will be possible to provide depth selective low-temperature CEMS.

A new application of STJ detectors is mentioned in Ref. 13 of the Comment. These detectors have been used to register the low lying energy level of metastable recoil nuclei embedded directly into the detector.

We also have to mention inaccurate citing in the Comment. In the introduction it is noted that a so-called detector with killed-electrode was proposed in Ref. 3, whereas for the first time it was described much earlier by O. J. Luiten et al. (see quotation below Ref. 2 and references therein). In Ref. 3 of the Comment a new design of STJ detector with Titanium trap in the killed electrode was presented. Also, in the Comment the spectrum of Fig. 3c is ascribed to Ref. 11 while, in fact, in this work it is absent. To the best of our knowledge, the absorption Mössbauer spectrum of $Rh_{0.8}Fe_{0.2}$ has not been published by these authors.[3,4]

## REFERENCES

[1] V. Augustyns, M. Trekels, H. P. Gunnlaugsson, H. Masenda, K. Temst, A. Vantomme, and L. M. C. Pereira, "Multipurpose setup for low-temperature conversion electron Mössbauer spectroscopy," Rev. Sci. Instrum. **88**, 053901 (2017).

[2] O. J. Luiten, M. L. van den Berg, G. Rivas, M. P. Bruijn, I. B. Kiewiet, and P. A. de Korte, "Quasiparticle diffusion and edge losses in Nb/AlOx and Ta/AlOx superconducting tunnel junction photon detectors," in *Low Temp. Detectors*, edited by S. Cooper, Proc. 7th Int. Workshop (LTD-7), Munich, 1997, p. 25–27.

[3] M. G. Kozin, I. L. Romashkina, L. V. Filippenko, and V. P. Koshelets, "Observation of nuclear gamma resonance with superconducting tunnel junction detectors," AIP Advances **6**, 025315 (2016).

[4] V. A. Andrianov, "Comment on 'Observation of nuclear gamma resonance with superconducting tunnel junction detectors' [AIP Advances 6, 025315 (2016)]," AIP Advances **9**, 059101 (2019).