# "Testing the Clock Hypothesis of Relativity Theory via Nuclear Resonant Scattering"

## *Experimental report HC-1361*

*Y. Friedman[1], H.-C. Wille[2], J. Haber[2], R. Röhlsberger[2], I. Nowik[3] ,I. Felner[3], G. Wortmann[4] , and E. Yudkin[1]*

[1]*Jerusalem College of Technology, Havaad Haleumi 21, 91190 Jerusalem, Israel*

[2]*Deutsches Elektronen-Synchrotron, Notkestr. 85, D-22607 Hamburg, Germany*

[3]*Racah Institute of Physics, The Hebrew University, 91904 Jerusalem, Israel*

[4]*Department Physik, Universität Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany*

The aim of proposal HC-1361 was to test the so-called Clock Hypothesis, which represents a cornerstone in Relativity Theory [1]. A violation of the clock hypothesis is equivalent to the existence of a universal maximal acceleration [2] and leads to the prediction of a relative Doppler shift between two absorbers that are subject to different accelerations.

As explained in [3], we expected the Mossbauer absorption line to be broadened due to the linear Doppler effect distribution resulting from the finite extend of the beam that hits the rotor. In order to obtain a sufficiently good energy resolution, this type of broadening has to be reduced as much as possible Before the experiment, we obtained explicit formulas for this broadening using the following assumptions. We assume that the beam front is approximately Lorentzian around $b_0$ (with respect to the center of rotation) with width $d$. The rotating absorber has a single absorption line of width $\gamma_0$ and effect size $A_0$. Under these assumptions, the absorption spectra at rotation with frequency $\omega$ will be approximately Lorentzian with isomer shift $\omega b_0$, width $\gamma_r = \gamma_0 + \omega d$ and the effect size is $A_r = A_0/(1 + \omega d/\gamma_0)$. Thus, in order to reduce broadening we have to focus the $\gamma$ ray to the center of the disk. For high $\omega$ values the absorption line is unobserved. This limits the rotational frequency in the experiment. In order to be able to get a measurable Doppler shift we used a disk of larger radius than we planned in our proposal.

A rotating system with a disk of radius $5cm$ was designed and manufactured in Israel. During our beamtime, the search for this Doppler shift was performed using the beam from SMS (ID18), KB optics and the rotating sample. The sample was a semi-circular shape stainless steel foil, which shows a single line Mossbauer spectrum. This creates accelerations opposite in sign, at different times of rotation. The rotor system was specially designed to control the rotation frequencies and to provide information on the absorber's orientation.

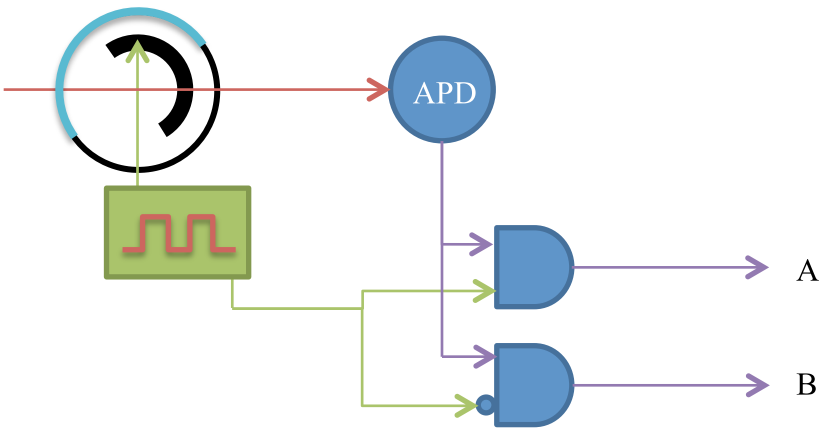


Figure 1. The separation of the signal from the two sides of the disk. A semi-circular absorber is positioned on the rim of the rotating disk. The black strip marks the absorber position . This position with respect to the $\gamma$ ray is defined by a photodiode producing a square wave, which is used to direct the data from the APD to two different channels A and B

Before the beamtime, we incorporated and tested our rotating system in the Beamline ID18 of ESRF. First, we tested the widening formulas using the beam of the SMS after passing the KB optics. We found that the widening fits the predicted formulas, with $d = 14\mu m$. The focusing on the center of rotation was accomplished using the predicted isomer shift, which was working well. In order to be able to measure a statistically meaningful absorption spectrum, our rotation frequency was effective up to 100 Hz. To get information at higher rotational rates, a slit was constructed and mounted at the center of the disk. The use of this slit did, in fact, decrease the widening and fits our predictions, with a slit of $4\mu m$ . This allowed us to obtain statistically significant spectra for rotation frequencies up to 300Hz. The results of the broadening of the absorption line are presented in Figure 2.

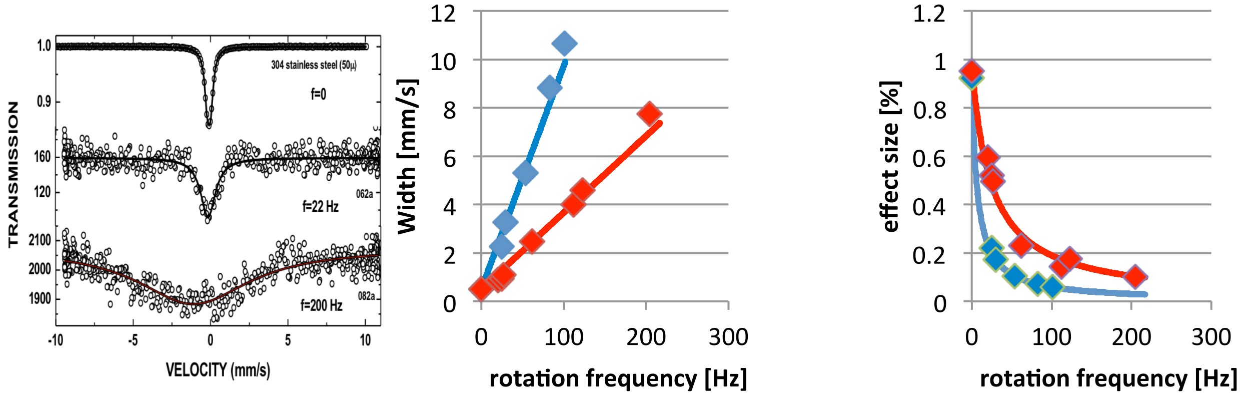


Figure 2 The transmission lines with slit of 4 μm, width and the effect size under rotation. Blue using KB optics. Red using KB optics and a slit of 4 μm.

In order to be able to separate the signals coming from different sides of the disk, we applied the scheme shown in Fig. 1 The rotating system produced a square wave, depending on the position of the absorber at the time it hit the beam. Based on this signal, the SMS system produces two absorption spectra, one for each side. If our prediction of the maximal acceleration is correct, we should be able to see a statistically significant shift between the two sides at rotations above 600Hz. During the beamtime, we measured such separated spectra for rotation frequencies of 100Hz. No significant separation was observed, as expected. We also obtained separated spectra for a rotation frequency of 200Hz where differences of 0.1 mm/s between spectra at the two ends of the rotating disk were easily observable.

To be able to complete the experiment we need to:

- Get additional beam-time at ID18 ESRF, where there are SMS and KB-Optics that are essential to this experiment.
- Replace the SS absorber with an enriched single line powder absorber (such as $K_4Fe(CN)_6$) in order to increase the counting rate.
- Produce a high-quality slit (with d ~ 7μm), mount it in the center of the disk with the possibility to control its position horizontally, vertically and rotationally.

**References**


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[2] Y. Friedman, Yu. Gofman, Phys. Scr. **82**, 015004 (2010).
[3] Y. Friedman, I. Nowik, Phys. Scr. **85**, 065702 (2012)