| ESRF | **Experiment title: Testing the Clock Hypothesis and Time Dilation using a Synchrotron Mössbauer Source** | **Experiment number**: HC-1898 |
|---|---|---|
| **Beamline**: ID18 | **Date of experiment**: from: 11/07/2015 to: 22/07/2015 | **Date of report**: 07/09/2016 |
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**Names and affiliations of applicants** (* indicates experimentalists):

Y. Friedman[1]*, R. Roehlsberger[2], H.-C. Wille[2]*, G. Wortmann[3]*

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

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

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


## Report:

The aim of proposal HC-1898 was to test Einstein's Clock Hypothesis, which represents a cornerstone in Relativity Theory [1]. A violation of the clock hypothesis is the influence of acceleration on time dilation. This can be detected by the detection of a significant non-zero relative spectral shift of a Mössbauer absorber in two identical states differing only in their respective accelerations.

This experiment was a follow-up of experiment HC-1361 at ESRF with its findings published in [2]. We used the rotating system with a disk of radius 5cm as in HC-1361, but in order to increase significantly the count rate, the stainless-steel Mössbauer absorber used previously was replaced by a potassium ferrocyanide (with 95% enriched $^{57}Fe$ ) single line absorber. Before the beamtime, we incorporated and tested our rotating system in Beamline ID18 of ESRF.

In order to narrow the rotational broadening of the resonant lines by blocking the peripheral rays of the beam and thus obtain spectra at higher rotation frequencies, the non-adjustable Re metal slit used previously was replaced by a gold plated adjustable (4 degrees of freedom) slit placed above the axis of rotation of the disk outside the vacuum chamber. Finally, in order to provide on-line information on the vibrations of the disk, we implemented an electronic computerized control system comprising of two proximity sensors and an optical sensor.

While performing the experiment with these improvements, we acquired important additional know-how, such as:

how to align initially the beam to the centre of the disk using a horizontal scan of the rotating disk,
how to narrow the broadening of the resonant lines caused by the rotation,
how to monitor vibrations using the control system, and
how to quantify the effects of the non-random vibrations on the spectral shift.

All experiments testing time dilation by measuring the spectral shift of a rotating Mössbauer absorber assume that vibrations do not affect the spectral shift because of their purely random nature and claim that the observed shift is due to time dilation only. Our experiment revealed, however, a shift due to the non-random periodic vibration patterns caused by the rotor/bearing system. These patterns fit the predictions of the Jeffcott model for such a system with non-zero eccentricity. We have calculated this shift due to the non-random vibrations and the resulting relative shift between two states (a) and (b) when the acceleration of the absorber is anti-parallel and parallel to the source, respectively. This relative shift exhibits the same behaviour as the observed relative shift. Hence, the effect of the spectral shift due to vibrations cannot be ignored in any Mössbauer rotor experiments for testing time dilation. The technique we used to monitor the vibrations and the method we devised to quantify the effect of the non-random vibrations on the observed relative shift, are presented in detail in [3].

Using the specially modified Synchrotron Mösssbauer Source (SMS) and KB-optics at the Nuclear Resonance Beamline ID18, we measured the relative spectral shift between the spectra of two identical states when the acceleration of the absorber is anti-parallel and parallel to the source, see Figure 1.

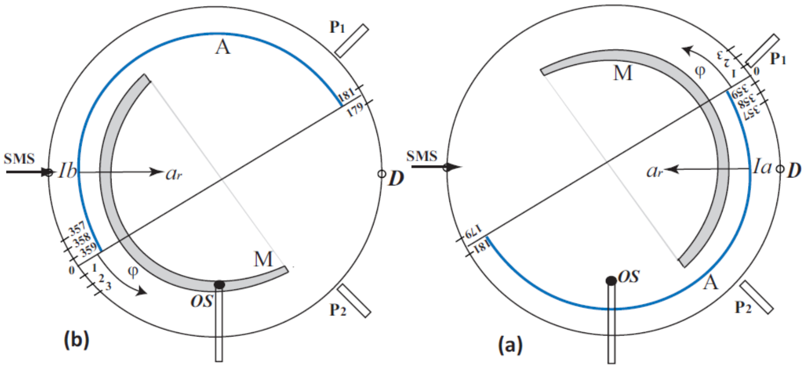
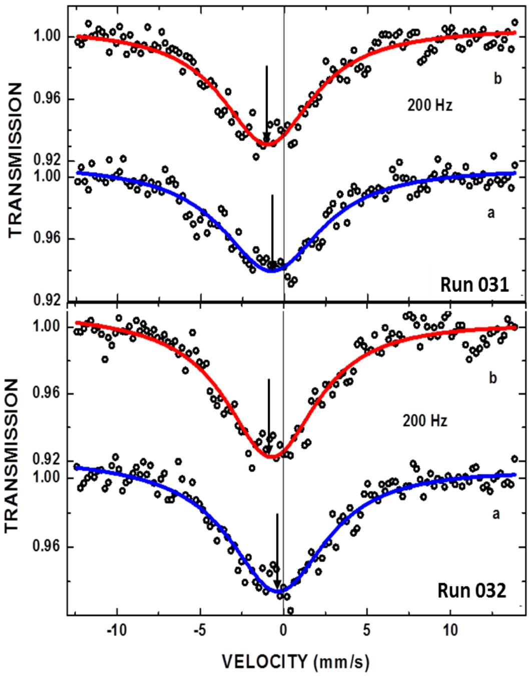



**Figure 1**. The setup and two states (a) and (b), SMS source, semicircular absorber A, optical sensor OS, proximity sensors $\boldsymbol{P_1}, \boldsymbol{P_2}$ and detector D. The black strip M marks the absorber position .

For several runs where the effect of the non-random vibrations was negligible we observed a stable statistically significant non-zero relative shift we were looking for. Figure 2 exhibits the relative shift of 0.41(14)mm/s of 2 runs at 200Hz. This suggests the influence of acceleration on time dilation (for more information, see [4]).




| Run | Effect % | $\gamma$ [mm/s] | Shift $x_0$ [mm/s] | Vibr.sh.[mm/s] |
|---|---|---|---|---|
| 31a | 6.68(18) | 3.29(24) | -0.58(11) | -0.007 |
| 31b | 8.01(27) | 3.14(22) | -1.01 (09) | 0.007 |
| 32a | 7.29(20) | 3.25(20) | -0.22(12) | -0.01 |
| 32b | 8.31(29) | 3.13(21) | -0.61(09) | 0.01 |

Figure 2. The absorption spectra of two runs for states (a) and (b) at 200Hz rotation (left) and corresponding Table of parameters (Effect %, HWHM $\gamma$ and Shift $x_0$ ) and the calculated vibration shift for these spectra

Data analysis is still ongoing to further confirm this. Furthermore, in order to be more conclusive and get a better understanding of the relative spectral shift due to rotation, we plan to repeat the experiment with two disks of different radii rotating in both directions at several rotation frequencies and an improved setup to minimize and control the effect of vibrations.

## References


[1] A. Einstein, Ann. Phys. 35, 898 (1911)
[2] Y. Friedman et al., J. Synch. Rad., 22, 723 (2015)
[3] Y. Friedman et al., Eur. Phys. Lett. (EPL) 114 50010 (2016)
[4] Y. Friedman et al., to be published