OPTIMIZATION OF THE MINIATURIZED BACKSCATTERING MÖSSBAUER SPECTROMETER *MIMOS* G. Klingelhöfer, P. Held, J. Foh, F. Schlichting, R. Teucher, E. Kankeleit, Inst. f. Kernphysik, TH Darmstadt, Schlossgartenstr. 9, 64289 Darmstadt, Germany; E.N. Evlanov, O.F. Prilutski, G.V. Veselova, E.A. Duzheva, Space Research Institute (IKI), Moscow, Russia.

Introduction. A Mössbauer spectrometer for the mineralogical analysis of the Mars surface is under development [1,2,3]. This instrument will be installed on a Mars-Rover, which is part of the Russian Mars-96 mission [4]. The MB experiment will be positioned by a robotic arm to take spectra from the fine soil on the surface, from rocks and from deeper layers of the soil, which will be accessible by a drilling device. The use of permanent magnets similar to the magnet array which is included in the US MESUR Pathfinder mission [5], in combination with the MB instrument will allow a magnetic separation of the magnetic phase in the Martian dust [6]. The electromechanical drive and the electronic components have been miniaturized. Solid state detectors (PIN-diodes) are used for γ- and x-ray detection in backscattering geometry. In this paper we will discuss especially the detector system, the temperature behaviour and the shielding of the radioactive ^{57}Co Mössbauer source.

Method. The MB backscattering technique, which needs no sample preparation, is highly suitable for a rover mission with the possibility for selecting samples. The main disadvantage of backscattering is the secondary radiation caused by the 122 keV transition. For a reduction of the background at 14.4 keV and the 6.4 keV x-ray line, good energy resolution of the detector system is required but also high count-rate capabilities with the strong sources to be used. For this reason Si-PIN-diodes were chosen as detectors. The general setup of our "**MI**niaturized **MO**essbauer backscattering Spectrometer" (MIMOS) is shown in fig. 1.

Mössbauer Source Shielding. The ^{57}Co source mounted on the small drive is surrounded by a graded shield. Collimated radiation passes through a Be window and the reemitted radiation is detected by a ringlike array of PIN-diodes behind the same Be window. Most important is an effective shielding of the PIN diodes from direct and cascade radiation. The 8 mm inner diameter graded shield consists of concentric tubes of 0.5 mm thick brass, 1 mm U, 1 mm W and another 0.5 mm brass. In fig. 2 the spectrum of the backscattered radiation, measured with one of the PIN diodes of the detector system (see fig. 1) is shown. No direct 122 keV radiation is seen in the detectors, only the 122 keV radiation scattered by the sample is detected. This shielding acts also as collimator, limiting the maximum emission angle to 25° and reducing the cosine smearing to a level that still allows a reasonable separation of the outer lines of γ- and α-Fe_2O_3.

Detector System. For a backscatter geometry a detector system covering a large solid angle is needed to minimize data acquisition time. The detector system consists of Silicon-PIN-diodes with 5 x 5 mm^2 or 10 x 10 mm^2 active area in an array arrangement as indicated in two options in fig.1. A thickness of about 400 µm is a good choice according to our experience.
Spectra of ^{57}Co/Rh radiation backscattered from a Stainless Steel (SS) plate, measured in- and off resonance, which are equal in recording time, are shown in fig. 2. A continuum is seen above 122 keV resulting from the few 692 keV γ quanta which are not completely absorbed in the shielding. No photo peak appears at 122 keV. But this radiation shows up in a broad compton distribution. A second compton distribution originates in the detector itself as seen in the rising slope starting below 40 keV. On top of these we see a peak at 22.1 keV due to the Ag backing of the detector. Below that in SS at zero velocity the 14.4 keV MB resonance line and also the 6.4 keV x-ray line dominate.

The temperature dependence of the parameters of the source similar to the one which will be used for the Mars-96 MB-experiment has been investigated experimentally in order to check its performance. The ^{57}Co source had the following characteristics: rhodium matrix, Ø 4 mm, thickness 6 µm, activity 122 mCi, linewidth 0.172 mm/s. The measurements were made in a temperature interval from 79 K to 295 K in transmission geometry using a liquid nitrogen cryostat. The Mössbauer absorber (SNP) was driven with sinusoidal velocity waveform. No splitting of the source lines in the studied temperature interval was found and the linewidth remains constant. As expected, a change in isomeric shift of 0.015 mm/s due to the relativistic second-order Doppler shift and a variation of the resonance yield according to the temperature dependence of the Debye-Waller factor were found for the temperature interval on the Mars surface. From this results we conclude that this type of sources can be used for our experiment.

Computer simulations. The statistical significance of the measured data will depend strongly on the background radiation seen by the detectors. It depends for instance on the intensity of direct radiation from the ^{57}Co source, the radiation from other nearby devices with radioactive sources (especially the radioisotope thermal electric generator (RTG) with 8.5 W thermal power), the compton backscattering of high-energy radiation of our source by the Martian surface, the electronic noise of the detectors and so on. Of importance is the proper design of the radiation shield. Some of the background characteristics can be measured easily in laboratory experiments (see above) but for other parameters this is difficult. Therefore a Monte Carlo computer program was developed to simulate the radiation background in order to optimize details of the design. It allows the evaluation of the properties of the radiation shield, the estimation of the influence of the high-energy γ-rays from our ^{57}Co source and from the RTG, as well as the calculation of the radiation spectrum produced by photon interaction with the device structure and the Martian soil. The real geometry and elemental composition of the critical experiment parts (especially the shield) are therefore considered in the calculation. Preliminary results of these simulations are: (i) the main source of background radiation will be due to scattering by the Martian surface, (ii) the direct radiation from the source can be decreased below the necessary limits by using a radiation shield having a sufficiently small mass of less than 30 grams, (iii) the background produced by the RTG will be smaller than the background due to scattering. With some additions this program will be used later on for the evaluation of Mössbauer spectra from the Martian surface.

Summary and Outlook. MB spectroscopy is now widely accepted as a new tool for space research. Besides the Russian Mars-96 mission, in the European MARSNET proposal, a network of fixed stations on the surface of Mars, Mössbauer spectroscopy is also included. Recently a proposal for a more powerful European Mars Rover was presented to ESA, also having a MB spectrometer on board. Besides the development of an instrument, which is currently done also by another group [7], a number of laboratories have started programs on so-called Mars Sample Analogs, which are studied not only by MB technique. Correlations of the MB results to magnetic properties, reflectance spectroscopic data etc. are most important.

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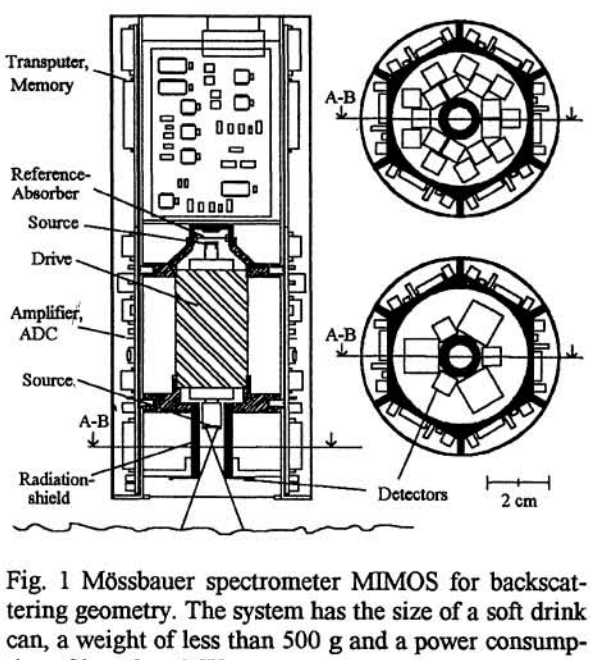

Fig. 1 Mössbauer spectrometer MIMOS for backscattering geometry. The system has the size of a soft drink can, a weight of less than 500 g and a power consumption of less than 3 W.

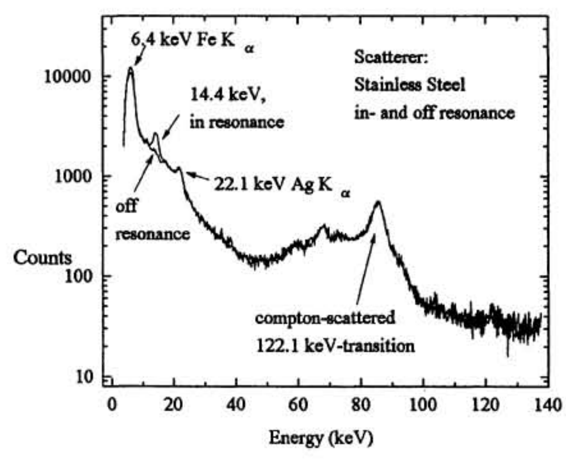

Fig. 2 Energy spectra of backscattered $^{57}Co/Rh$ radiation, using a prototype of the MIMOS spectrometer.