A. N. Artem'ev, V. A. Kabannik, Yu. N. Kazakov, G. N. Kulipanov, E. A. Meleshko, V. V. Sklyarevskiĭ, A. N. Skrinskiĭ, E. P. Stepanov, V. B. Khlestov, and A. I. Chechin. *An experiment in excitation of a Mössbauer level of ^{57}Fe with synchrotron radiation.* Possibilities for the use of synchrotron radiation (SR) for Mössbauer studies and nuclear spectroscopy have been discussed by several authors.[1,2] Our experiment represents an attempt to use SR to excite a collective nuclear state in a single crystal under the conditions of Bragg diffraction and to study its temporal characteristics. The work is being done by a group drawn from the Institute of Nuclear Physics of the Siberian Division of the Academy of Sciences (IYaF SOAN) and the I. V. Kurchatov Institute of Atomic Energy (IAÉ).

The following basic problems must be solved in the design of the experiment.

1) isolation of a narrow line with the desired energy from the continuous SR spectrum;

2) ensuring long-term stability of the monochromator's passband when an SR beam of high power (up to 2 W/mm²) is incident on its first crystal;

3) suppression of background scattering by electrons in the specimen, which is necessary because the passbands of even the best monochromators are many orders wider than the excited level ($\Delta E/E = 3 \cdot 10^{-13}$).

We used a single crystal of hematite α-Fe_2O_3 enriched with the isotope ^{57}Fe. This choice was dictated by the following circumstances:

—matching of the parameters of the excited level to those of the SR beam (energy, lifetime, SR pulse repetition frequency);

—thorough understanding of the stationary diffraction of γ rays on hematite single crystals[3,4] and the purely nuclear reflections available in hematite;

—the availability of isotope-enriched hematite crystals of sufficiently high quality and the necessary size.[1)]

In the experiment, the SR beam leaving the electron storage ring strikes a two-crystal monochromator, is deflected by it through an angle of ~30° downward from the plane of the accelerator, and is then reflected from the working hematite crystal. The axis of rotation of the hematite lies in the vertical plane and is perpendicular to the SR beam.

The monochromator takes the form of two perfect germanium single crystals which are mounted on a common base in a high-dispersion position. This monochromator has a narrow passband whose energy depends only on the angle between the crystals. It is tuned with the aid of 14.4 keV γ radiation from a ^{57}Co source. Subsequent adjustments to the SR beam are made by rotating it as a whole and finding the position in which the intensity of the transmitted beam is highest.

The hematite crystal is mounted in the position corresponding to the purely nuclear (777) reflection. Previous measurements[4] had shown that in this reflection scattering by electrons is suppressed by a factor of at least 10^5 with respect to allowed reflections. Further suppression of the nonresonant background is obtained through the polarization of the SR beam, the proximity of the scattering angle to 90° ($\theta_B \approx 41°$), and the appropriate orientation of the scattering plane.

The chosen reflections [(111) in the monochromator and (777) on the hematite] also make it possible to quench the harmonics with energies $2E_0$ and $3E_0$. The radiation with energy $4E_0 \approx 57.5$ keV strikes the detector, but its intensity is low and it does not interfere with the measurements. This radiation can also be used to set the hematite to the Bragg-reflection position.

The gamma rays reflected from the hematite are registered by a scintillation detector (an FÉU-85 photomultiplier with an NaI(Tl) crystal 0.1 mm thick). A resonant absorber of enriched polycrystalline hematite coupled with a vibrator is placed in the path of the beam to detect the effect.

According to estimates, the SR beam contains 10^3 photons/mrad·sec (at a current of 100 mA and $E_e = 2.2$ GeV), and an effect of ≈7% can be expected in the proposed scheme at a counting rate of ≈10 cts/sec.

The electronic section of the apparatus permits analysis of the distribution in time of the 14.4 keV radiation. The lifetime of the state with this energy for an isolated ^{57}Fe nucleus is ≈100 nsec, but the collective nuclear excitation in the crystal should be much shorter-lived, and its decay does not follow a simple exponential law.[5] A rough estimate gives 15–20 nsec for the average lifetime, consistent with the observed broadening of the resonance lines in the purely nuclear reflection spectra.[4]

Measurements were made on the SR beam of the IYaF SOAN VÉPP-3 electron-positron storage ring at Novosibirsk during the latter half of 1977. Unfortunately, the storage ring was capable at that time of operating only at reduced levels (energies below 2 GeV, currents below 30 mA). It was impossible to observe

[1)]The enriched hematite crystals were grown by J. Novak at the Physics Institute of the Czechoslovak Academy of Sciences (Prague).

the effect under these conditions, and we were obliged to confine the measurements to the levels of the background and of its distribution in time. The experiment indicated satisfactory agreement between the calculated and measured intensity values. The halfwidth of the instantaneous-coincidence background peak was 9 nsec, and the background level between SR pulses was $\approx 6 \cdot 10^{-4}$ of the height of this peak. The design used to mount the first monochromator crystal (a thin germanium crystal on a thick copper radiator base) ensured satisfactory constancy of monochromator parameters throughout the entire range of SR intensities. The preprint of Ref. 6 gives a more detailed description of the experiment.

We believe that the experimental scheme that we chose has substantial advantages over the proposals of other groups,[7,8] basically because we used a purely nuclear reflection from a single crystal.

The work will be continued at the end of this year or the beginning of next year after reconstruction of the VÉPP-3 storage ring has been completed.

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