NUCLEAR RESONANT SCATTERING OF SYNCHROTRON RADIATION BY ^{40}K

For the hyperfine-interaction studies of nuclear resonant scattering, synchrotron radiation has a number of distinct advantages when compared with a conventional radioactive source. In addition, the use of synchrotron radiation allows a direct measurement of the spectrum of phonon energy in solids or the diffusive motion of atoms in liquids. Although the energy tunability of synchrotron radiation allows performing nuclear resonance excitation experiments of various nuclides, the resonance excitation with synchrotron radiation has been confined only for a few isotopes. Therefore, the increase of the nuclides that can be excited with synchrotron radiation is extremely important. Among these nuclides, potassium is one of the most important elements in material and biological sciences, and a Mössbauer resonance has been observed for the potassium isotope ^{40}K [1,2]. Due to the lack of any radioactive parent nuclide populated for the 29.83 keV first excited state of ^{40}K, it was impossible to observe the Mössbauer effect by implementing ordinary radioactive sources. For this reason, inbeam methods for nuclear reactions {(*d, p*) and (*n, γ*) reactions} on the predominant potassium isotope ^{39}K were adopted to observe the Mössbauer effect, however, resulting in serious damage of the sample, which is frequently used as a source. This brought the ^{40}K nuclide to be one of the most important nuclides for nuclear resonance excitation experiments with synchrotron radiation. We have now measured the nuclear resonant scattering of synchrotron radiation using ^{40}K for the first time [3].

The experiments were performed at the JAERI beamline **BL11XU** . The storage ring was operated in a 116-bunch mode, giving a bunch distance of 41.3 ns. The measured sample was KCl powder, whose isotope ratio of ^{40}K was 4.03%. A double crystal Si(3 3 3) monochromator produced incident X-ray radiation with a bandwidth of ~ 2 eV at an energy of ~ 29.83 keV. An Al plate of 2 mm thick was placed in front of the slits to reduce the first harmonic radiation (9.94 keV) passing through the monochromator. A Si-avalanche photodiode detector

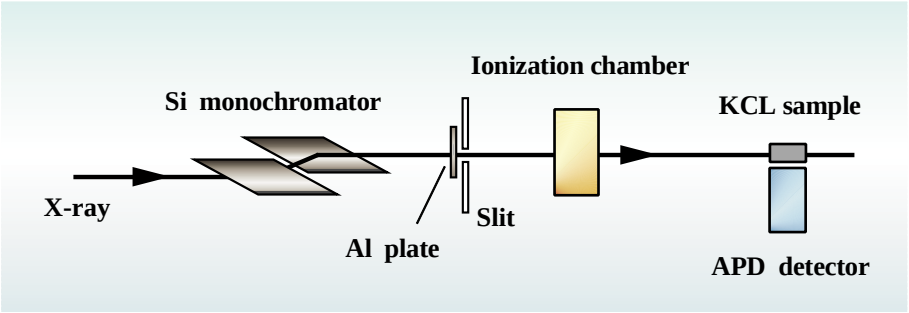

Fig. 1. Experimental setup.

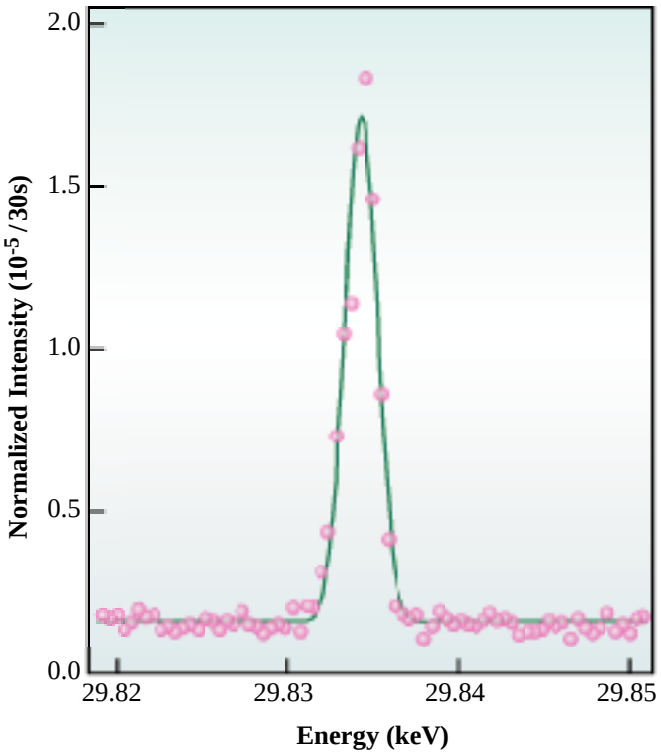

Fig. 2. Energy spectrum of delayed emission from ^{40}K in KCl. Solid circles represent the delayed counts normalized by the counts of the prompt scattering. The solid line is a Gaussian fit to the normalized delayed counts.

with a diameter of 3 mm was used to detect the scattering from the KCl sample [4]. Figure 1 shows the experimental setup. To search the nuclear resonance excitation of ^{40}K, we performed an energy scan of the incident X-ray radiation by changing the Bragg angle of the Si(3 3 3) monochromator. The measured energy spectrum is shown in Fig. 2. The nuclear resonance scattering by ^{40}K is clearly observed. In this measurement, the absolute energy of the first excited state of ^{40}K was obtained as 29.834 ± 0.011 keV, which was in good agreement with the previous reported value of 29.8299 ± 0.0006 keV [5]. The measured time spectrum of nuclear resonant scattering from ^{40}K in the KCl sample is shown in Fig. 3. In the time spectrum, no quantum beat was observed, which coincided with the cubic-symmetrical electronic states of K^+ ions in KCl crystal. Therefore, the observed spectrum can be fitted with a simple exponential time distribution. From this spectrum, the half-life of the first excited state was found as 4.13 ± 0.12 ns, being consistent with the value of 4.24 ± 0.09 ns previously reported [5].

In conclusion, we were capable of observing the nuclear resonant excitation of the first excited state of ^{40}K and have measured the time evolution of the decay. Our observation of the nuclear resonance excitation of ^{40}K indicates the possibilities in electronic and vibrational studies on potassium. This promises a bright future in the study of potassium in both material and life sciences.

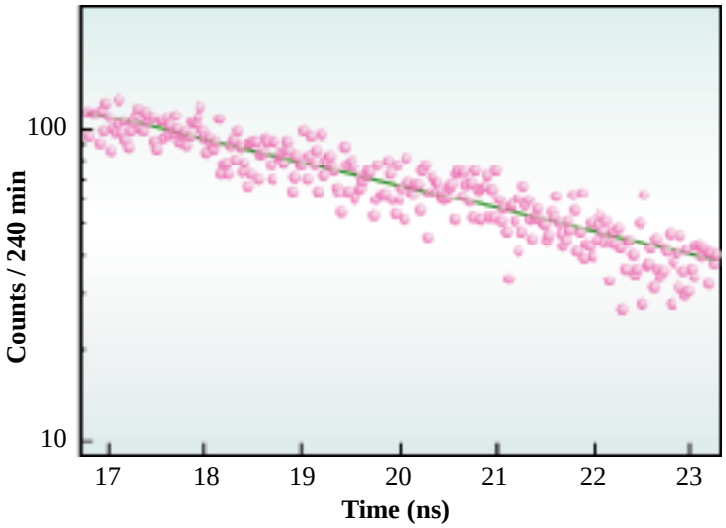

Fig. 3. Time distribution of the nuclear resonant scattering of synchrotron radiation by ^{40}K in KCl. The measured spectrum (solid circles) is fitted by an exponential function, and the half-life of the first excited state of ^{40}K was evaluated to be 4.13 ± 0.12 ns.

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