OBSERVATION OF NUCLEAR EXCITATION BY ELECTRON TRANSITION IN ^{197}Au WITH A SILICON APD ELECTRON DETECTOR

We have succeeded in observing nuclear excitation by electron transition (NEET) in ^{197}Au using a silicon avalanche photodiode (APD) detector [1]. NEET is a rare phenomenon that occurs only when nuclear excitation and electronic transition have nearly the same energy and a common multipolarity during atomic inner-shell ionization. For ^{197}Au, the NEET condition is satisfied in the $K^{-1}(1s_{1/2}) \rightarrow M_1^{-1}(3s_{1/2})$ electronic transition and the $3/2^+ \rightarrow 1/2^+$ nuclear transition (Fig. 1). The common multipolarity is $M1$.

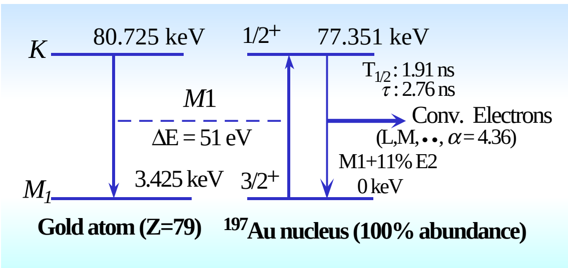

Fig. 1. NEET diagram for ^{197}Au.

The experiment was carried out at the undulator beamline **BL09XU**. A 116-bunch mode was used to detect the delayed radiation emitted from excited nuclei by the time-gate method. Third order X-rays from a Si(111) monochromator were used to obtain high incident energies which cover the nuclear resonance energy (E_R: 77.351 keV) and are higher than the K-shell ionization energy (E_K: 80.725 keV). A 3 µm thick gold foil set at the center of a vacuum chamber was irradiated by the X-ray beam. A silicon APD detector (ϕ3 mm, 30 µm thick) located 2.5 mm above the center of the foil was used to distinguish weak L internal-conversion electrons from the intense radiation promptly emitted by atomic processes. The number of incident photons was estimated from the current through a PIN photodiode detector located on the back side of the gold foil.

By using monochromatic X-rays, the nuclear resonance and the NEET were independently observed using the same experimental setup. The solid circles in Fig. 2(a) show the time spectrum of internal-conversion electrons observed for the nuclear resonance at E_R. Figure 2(b) is the corresponding background measured at 77.455 keV. The tail caused by the prompt radiation, and the peaks at 2 ns intervals caused by the sub-bunches between the main bunches in the storage ring, are seen. In Fig. 3(a), the solid circles show the time spectrum observed at 80.989 keV, which is higher than E_K, and a corresponding spectrum obtained at 80.415 keV which is lower than E_K (Fig. 3(b)). In both Fig. 2 and Fig. 3, the open circles in (a) are background-subtracted intensities, which are fitted by experimental curves. A lifetime of 2.80±0.29 ns, was observed, which is in good agreement with the expected lifetime of 2.76 ns from the resonance level. The decay curve caused by the NEET is clearly distinguished from the background.

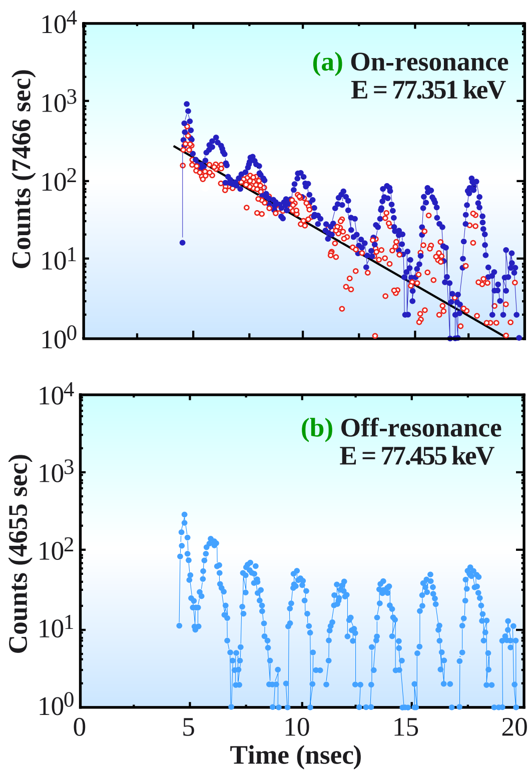

*Fig. 2. Time spectra of the internal-conversion electrons observed: (**a**) the nuclear resonance at 77.351 keV during 7466 s; (**b**) the background at 77.455 keV during 4655 s.*

The NEET probability, P_{NEET} could be precisely determined by comparing the two observed event numbers per photon since the cross section and the level width of the resonance were well known in Mössbauer experiments. The cross section of the NEET, σ_{NEET} is defined as $\sigma_{NEET} = P_{NEET}\,\sigma_K$, where σ_K is the photoelectric cross section of the K shell. Using the measured X-ray width (W); the Mössbauer cross section (σ_0), the level width at E_R (Γ) and a factor depending on the spectral function of X-rays (f_p), the effective cross section of the nuclear resonance is given by $\sigma_R = (\Gamma/W) f_p\, \sigma_0$. The ratio of σ_{NEET} and σ_R is expressed by $\sigma_{NEET} / \sigma_R = R_{NEET} / R_R$, where R_{NEET} and R_R are the numbers per photon events for the NEET and the nuclear resonance, respectively. From the observed event numbers between 5 and 15 ns after the prompt peak, $P_{NEET} = (\sigma_0/\sigma_K)(\Gamma/W) f_p (R_{NEET}/R_R) = (5.0\pm0.6)\times10^{-8}$.

This value is smaller by three orders of magnitude than the previous experimental value of $(5.1\pm3.6)\times10^{-5}$ [2], but is much closer to the calculated value of 1.3×10^{-7} by Tkalya [3]. Due to the simplicity of our experiment, our present value for P_{NEET} is more reliable than the previous experimental value.

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References

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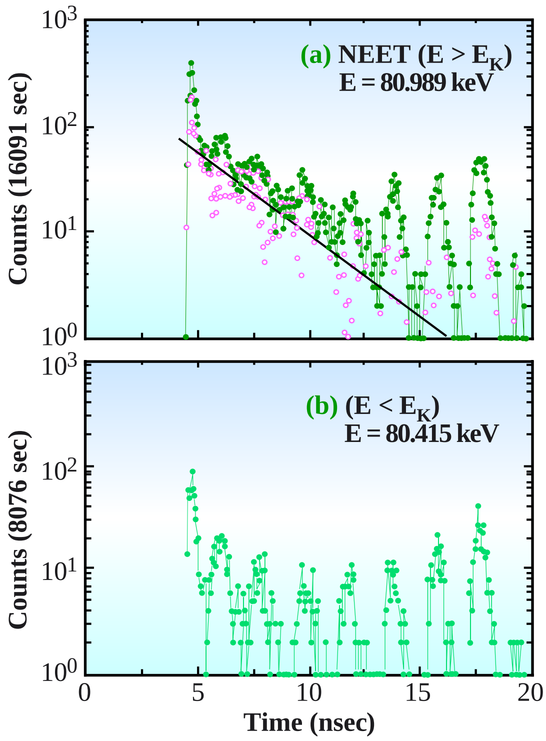

*Fig. 3. Time spectra of the internal-conversion electrons observed for: **(a)** NEET at 80.989 keV (>E_K, E_K: the Au K-shell ionization energy (= 80.725 keV)) during 16091 s; **(b)** background at 80.415 keV (<E_K) during 8076 s.*