Towards the spectroscopy of ^{229}Th nuclear isomeric transition using nuclear resonant scattering at SPring-8

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The first excited nuclear state of ^{229}Th is known to be an only laser-accessible nuclear excited state; the excitation energy is around 8 eV [1,2] (wavelength $\lambda \sim 150$ nm; VUV-region). If fact, it is the lowest nuclear excited state found in Nature so far. This level energy is so low that the radiative lifetime of the level is expected to be relatively long, called *isomer state* (estimated $10^3 \sim 10^4$ s.). The quantum state of nucleus is quite insensitive to outer environment compared to electronic states in atomic shell. Therefore, the optically controllable nuclear state of ^{229}Th is not only a valuable exception in nuclear physics, but also expected to be useful for ultra-precise measurement of time and space. Such optical "nuclear clock" is expected to be superior to currently most precise atomic clock where atomic transition is exploited in the isolated atom [3, 4]. More precise determination of its energy and measurement of the radiative lifetime of the state is strongly motivated as an important step to expand the related researches.

We successfully populated into the ^{229}Th isomer state by using nuclear resonant scattering (NRS) through the second-excited state (29.19 keV), performed at SPring-8 [5]. This is the first active excitation into the isomer state, and expected to be an important step to conduct a spectroscopy of the optical transition from the isomer state. Now we are trying to detect the VUV-photon from the NRS-assisted isomer state using the ^{229}Th-doped VUV-transparent crystal; ^{229}Th:CaF_2. We will report the present status of our project in this talk.

[1] B. Seiferle *et al*., *Nature*, **573**, 243 (2019).
[2] T. Sikorsky *et al*., *Phys. Rev. Lett.* 125,142503 (2020).
[3] E. Peik and C. Tamm, *Europhys. Lett.* 61, 360 181 (2003).
[4] L. Wense, B. Seiferle, *Eur. Phys. J.* A 56, 277 (2020).
[5] T. Masuda *et al*., *Nature*, **573**, 238 (2019).