Developments of multi-Extreme THz ESR and its application to multiferroic substance

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**Study Goal:** Developments of multi-extreme THz ESR in Kobe will be presented. As an application of multi-extreme THz ESR, antiferromagnetic resonance (AFMR) measurement results of the multiferroic substance YCrO\textsubscript{3} at 1.9 K will be presented.

**Abstract:** THz ESR system under multi-extreme conditions, such as the high magnetic field up to 55 T, the high pressure up to 1.5 GPa and the low temperature down to 1.9 K, has been developed in Kobe. It can cover the THz region between 0.03 and 7 THz using various light sources. By the use of hybrid-type pressure cell, the pressure is extended up to 2.7 GPa recently. Moreover, ESR measurements of micrometer size single crystals became possible up to 370 GHz with our micro-cantilever ESR, and the development on the magnetization detected ESR using SQUID magnetometer (SQUID ESR) has been also achieved.

As an application of multi-extreme THz ESR, AFMR results of multiferroic substance YCrO\textsubscript{3} at 1.9 K in the frequency region from 40 to 722 GHz using the pulsed magnetic field up to 35 T will be presented. YCrO\textsubscript{3} has attracted much interest recently because it shows a biferroicity, where a ferroelectric transition occurs below $T_C = 470$ K with the electric polarization hysteresis and an antiferromagnetic transition with a weak ferromagnetism due to Dzyaloshinskii–Moriya (DM) interaction occurs below $T_N = 140$ K. Not only two AFMR modes with the AFMR gap of $D_1 = 6.5$ T, which corresponds to 181 GHz, and the spin-flop field $H_c = 3.5$ T, which are consistent with the previous AFMR result at 77 K, but also we have succeeded in observing a new AFMR mode with the gap of $D_2 = 12.1$ T, which corresponds to 338 GHz, for the first time.

Moreover, as we extended the AFMR measurement to the high field and high frequency, it turned out that all three AFMR modes converge but not to the paramagnetic $g=1.983$ line. This is rather unusual. Another unconventional part of observed AFMR modes is that $D_1 = 6.5$ T and $H_c = 3.5$ T are very different in spite of very isotropic g-value of $g=1.983$. Although we have calculated AFMR modes by the conventional two sublattice molecular field AFMR theory with various parameters, it turned out to be very difficult to interpret all three AFMR modes.

**Conclusion:** Developments of multi-extreme THz ESR are shown. As an application to multiferroic substance YCrO\textsubscript{3}, two possible interpretations, multi-sublattice AFMR with the higher magnetic phase transition beyond 35 T and the exotic AFMR modes in multiferroic system, are suggested by our AFMR results.