Lattice dynamics, crystal-field excitations and quadrupolar fluctuations of YbRu$_2$Ge$_2$

Mai Ye*, E. W. Rosenberg, I. R. Fisher, and Girsh Blumberg

1Department of Physics and Astronomy, Rutgers University, NJ, USA and 2Department of Applied Physics, Stanford University, CA 94305, USA

We report Raman scattering results of YbRu$_2$Ge$_2$ single crystals to explore the phononic and crystal-field (CF) excitations. This heavy-fermion metal enters a $B_{1g}$-symmetry ferroquadrupolar (FQ) phase below $T_Q=10K$. We establish the CF level scheme of the ground multiplet. We demonstrate that the static Raman susceptibilities in both $B_{1g}$ and $B_{2g}$ quadrupole channels exhibit a Curie-Weiss behavior with the Weiss temperature about 10K lower than $T_Q$. Electron-lattice coupling is crucial for the FQ transition to happen. Moreover, temperature-dependent study of four Raman-active phonon modes shows that the intensities of the $A_{1g}$ and one $E_g$ modes increase significantly on cooling, which is explained by a near-resonant coupling between these two phonon modes and CF transitions.