Singular continuous and nonreciprocal phonons in quasicrystal

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Since quasicrystals lack the translational symmetry of crystals and exhibit quasiperiodic long-range order, they are expected to exhibit exotic physical properties not found in crystals. Although the understanding of the static structure of quasicrystals has been advanced with higher dimensional spaces, the understanding of the dynamic response of quasicrystals is still not satisfactory.

The lattice dynamics of quasicrystals consist of phonons and phasons, which corresponds to excitations in real and complementary space, respectively. The most characteristic feature of the phonons in quasicrystals is a gap feature at the so-called pseudo Brillouin zone boundaries (PBZB), which positions are defined by $q_{PBZB} = Q_{Bragg}/2$. Early studies of i-AlPdMn in 90's did not find a clear gap [1]. Later, a clear pseudogap was observed by using inelastic X-ray scattering in both i-ZnMgSc quasicrystal and ZnSc 1/1 approximant[2]. However, these pseudogaps were observed at q= 0.5~0.7 Å^{-1}, corresponding to the wave length of 10~12 Å. At such short scales, the aperiodic features may not appear clearly.

In order to seek for lattice dynamics related to aperiodicity, we focused on phonons at low-energies because it reflects dynamics at larger scale. By using the state-of-the-art neutron time-of-flight spectrometers DNA and AMATERAS at J-PARC, we studied the acoustic modes in i-AlPdMn with various energy resolution extending from 0.003 to 1.4meV [3]. We found hierarchical dip structures in the acoustic mode, which are scaled by golden mean τ. This τ-scaling in the dip energies strongly indicate the observed dip feature are related to aperiodicity. Furthermore, asymmetric signals were found in both Q and energy, indicating characteristic nonreciprocal phonon propagation in quasicrystals.

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