Probing the critical behavior in the evolution of GDR width at very low temperatures in A $\sim$ 100 mass region[†]

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Although a wealth of data exists on the angular momentum dependence of width of giant dipole resonance (GDR) in different mass regions, the measurement of the GDR width at low temperatures ($T < 1$ MeV) is rather scarce due to the experimental difficulties in populating the nuclei at low excitation energies. The present work aims at providing systematic experimental data on the GDR width, specifically, at this very low temperature region. It is also our endeavor to systematically assess the different theoretical models and understand the complete nature of the damping mechanism as a function of T inside the atomic nucleus.

The increase of the GDR width as a function of T is described reasonably well within the Phonon Damping Model (PDM)1). The GDR damping mechanism is caused by coupling of the GDR to noncollective particle-hole (ph) and particle-particle (pp) [hole-hole (hh)] configurations. The coupling to the various ph configurations leads to the quantal width (exists even at $T = 0$), whereas the thermal width arises owing to the coupling to pp and hh configurations which appear at $T > 0$ because of the distortion of the Fermi surface. Thermal pairing since is also included, since in finite systems it does not collapse at the temperature of the superfluid-normal phase transition in infinite systems, but decreases monotonically as T increases. The macroscopic Thermal Shape Fluctuation Model (TSFM)2,3), on the other hand, is based on the fact that large-amplitude thermal fluctuations of the nuclear shape play an important role in describing the increase of the GDR width as a function of T. The TSFM, however, cannot explain the T dependence below 1.5 MeV in different mass regions. Recently, by modifying the phenomenological parameterization (pTSFM)3), a new fitting formula, called the Critical Temperature included Fluctuation Model (CTFM), was proposed4), which gives a good description of the GDR width behavior for both T and J in the entire mass region.

In this work, a systematic measurement of the apparent GDR width has been carried out in the unexplored region ($T = 0.8 - 1.5$ MeV) for ^{97}Tc using alpha induced fusion reactions. This is the first measurement of the GDR width at finite temperature in A $\sim$ 100 mass region both above and below the critical point and can be effectively used to verify the existing theoretical models. The experiments were performed at the Variable Energy Cyclotron Centre (VECC), Kolkata. A self supporting 1 mg/cm^2 thick ^{93}Nb target was bombarded with alpha beams produced by the K-130 cyclotron. Four different beam energies of 28, 35, 42 and 50 MeV were used to form the compound nucleus (CN) ^{97}Tc at the excitation energies of 29.3, 36, 43 and 50.4 MeV, respectively. The high energy γ-rays from the decay of ^{97}Tc were detected using the high energy photon spectrometer LAMBDA.

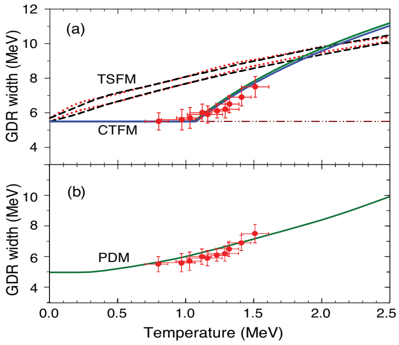

Fig. 1. (a) GDR width as a function of temperature. Symbols are experimental data. The TSFM calculations with shell effect (dotted lines) and without it (dashed lines) are shown for $J = 0\hbar$ (lower) and $J = 30\hbar$ (upper). Continuous lines are the CTFM predictions for $J = 10\hbar$ (lower) and $J = 20\hbar$ (upper). (b) The solid line shows the result of PDM calculations, performed at $J = 0$ by using the single-particle energies obtained within the deformed Woods-Saxon potentials with the deformation parameter $\beta = 0.134$, and including exact canonical-ensemble thermal pairing gaps for neutrons and protons.

The data have been compared with the TSFM, CTFM and PDM. Interestingly, the CTFM and PDM give the similar results and agree with the data, whereas the TSFM differs significantly even after incorporating the shell effects (Fig. 1).

References

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