Abstract

Giant Resonances (GRs) are considered to be high frequency shape vibrations of the nucleus. This nuclear excitation mode exists in different forms, which can be classified according to the numerous modes that the protons and neutrons can oscillate, with or without specific orientation selections of their spin. The characteristic energies, strengths and widths of Giant Resonances are well known, with some GRs such as the Isovector Giant Dipole Resonance (IVGDR) first discovered as far back as before the World War II.

Since the new millennium it became apparent that the Isoscalar Giant Quadrupole Resonance (ISGQR) peak exhibits a fine structure that is independent of probe. Further it has since been established that the IVGDR also exhibits such fine structure. This fine structure as an additional GRs observable has been shown to be a useful tool to determine the damping mechanism of different shape vibration.

Until recently, there has not been experimental data available to comment on the possibility of the existence of fine structure in the Giant Monopole Resonance (GMR). This thesis is dedicated to the investigation of the Isoscalar Giant Monopole Resonance (ISGMR). The ISGMR was excited in nuclei across the periodic table by using inelastic α-particle scattering measurements acquired with a $E_\alpha = 200$ MeV beam at $\theta_{\text{Lab}} = 0^\circ$ and 4°. The high energy-resolution K600 magnetic spectrometer at iThemba LABS was used to detect the scattered alpha particles and an experimental energy-resolution of ~ 70 keV (FWHM) was achieved. This enabled the fine structure in the excitation energy region of the ISGMR to be investigated.

Alpha-particle has been proven to be the best probe to investigate the ISGMR and as such, it has been widely used for nuclei across the periodic table to access the properties of the ISGMR as well as its strength distribution. For that, experiments are conducted at extreme forward angles including 0° and this is since the $L = 0$ Multipole peaks at that angle while all other have much lower yields. The multipole Decomposition Analysis (MDA) technique was employed in numerous studies to extract the $E0$ strength distribution in nuclei. However, due to the limitations in angular acceptance and resolution, the $E0$ strength distributions in the present project was determined via the Difference-of-Spectrum (DoS) method.

$E0$ strength distributions in ^{208}Pb, ^{120}Sn, ^{90}Zr, ^{58}Ni, ^{28}Si and ^{24}Mg were determined and compared to previously published results from (low energy resolution) experiments at the Research Center for Nuclear Physics (RCNP) and Texas A&M University (TAMU). Overall, reasonable agreement was obtained. In order to gain insight into the ISGMR damping mechanism, the extraction of characteristic energy scales from the fine structure observed in the $E0$ strength distributions was performed using the technique of Continuous Wavelet Transform (CWT). The results were compared with theoretical predictions from the Phonon-Phonon Coupling (PPC) and Quasi-particle Random Phase Approximation (QRPA) models. In general, most of the extracted experimental scales were reproduced by the models. Hence, the present analysis suggests that the fine structure of ISGMR in medium to heavy mass nuclei across the periodic table arises from coupling to collective phonons and the non-harmonicity owing to interactions among phonons while it is explained by three factors in the studied light nuclei: deformation splitting of the levels, $E0/E2$ coupling, and Landau fragmentation.

Furthermore, the Fluctuation Analysis technique was employed to extract spin- and parity-dependent level densities of $J^{\pi} = 0^{+}$ in the ISGMR region. The extracted experimental level densities were compared with the phenomenological Back-Shifted Fermi Gas (BSFG) and the microscopic Hartree-Fock-Bogoliubov (HFB) and Hartree-Fock-BCS (HF-BCS) model predictions. This will be important for further studies combining level density data for $J^{\pi} = 0^{+}, 1^{-}, 1^{+}, 2^{-}$ and 2^{+} states obtained from high resolution studies of other giant resonances, in order to test the spin and parity dependence of level densities.