Abstract

In chapter 1.1, the basic theory of revival and fractional revival phenomena of a wave packet and the autocorrelation function are described. In 1.2, Rydberg atomic system and the diatomic molecular systems are introduced. Next, we have discussed the coherent state in section 1.3. In chapter 1.4, explanation of phase space Wigner distribution, Schrödinger cat states and the definition of sub-Planck scale structure are given. The basic idea of two time scale revival and fractional revival phenomena are described in section 1.5. We end the chapter with definitions of Fourier transform, short-time Fourier transform and the wavelet transform.

In chapter 2, we demonstrate the possibility of realizing sub-Planck scale structures in the mesoscopic superposition of molecular wave packets involving vibrational levels. The time evolution of the wave packet, taken here as the SU(2) coherent state of the Morse potential describing hydrogen iodide molecule, produces cat-like states. Interference of these cat-like states produces sub-Planck structures in phase space. We investigate the phase space dynamics of the coherent state through the Wigner function approach and identify the interference phenomena behind the sub-Planck scale structures. The optimal parameter ranges are specified for observing these features.

In chapter 3, we study the revival and fractional revivals of a diatomic molecular wave packet of circular states whose weighting coefficients are peaked about a vibrational quantum number $\overline{\nu}$ and a rotational quantum number $\overline{j}$. Furthermore, we show that the interplay between the rotational and vibrational motion is determined by a parameter $\gamma = \sqrt{D/C}$ where D is the dissociation energy and C is inversely proportional to the reduced mass of the two nuclei. Using I_2 and H_2 as examples, we show, both analytically and visually, that for $\gamma \gg \overline{\nu}, \overline{j}$, the rotational and vibrational time scales are so far apart that the ro-vibrational motion gets decoupled and the revival dynamics

depends essentially on one time scale. For $\gamma \sim \overline{\nu}, \overline{j}$, on the other hand, the evolution of the wave packet depends crucially on both the rotational and vibrational time scales of revival. In the latter case, an interesting rotational vibrational fractional revival is predicted and explained.

In chapter 4, we show that the time frequency analysis of the autocorrelation function is, in many ways, a more appropriate tool to resolve fractional revivals of a wave packet than the usual time domain analysis. This advantage is crucial in reconstructing the initial state of the wave packet when its coherent structure is short-lived and decays before it is fully revived. Our calculations are based on the model example of fractional revivals in a Rydberg wave packet of circular states. We end by providing an analytical investigation which fully agrees with our numerical observations on the utility of time-frequency analysis in the study of wave packet fractional revivals.