Intermittent photo-association induced by a time-dependent continuous field

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1st Perspectives on Oscillation Control

Introduction

The formation of metastables molecules through photoassociation is the subject of study in several areas of science, such as cellular automata for flow traffic, formation of molecules produced by alkaline atoms, which may lead to the development of clocks atomic and also in the investigation the properties of metastable molecules such as ozone, hydrogen, helium and others. It was also observed that some properties of Bose-Einstein condensates in diluted gases are due to the existence of molecular metastability. The present study shows that it is possible to find specific external fields (in high regime of frequency and amplitude), in which the system trajectories are temporarily trapped in regions of constant negative energy producing metastable molecules, which corresponds to a stable state distinct from the fundamental equilibrium state of the system, in this case, the phase space shows that the trajectory is partially trapped for a period of time in quasi-tori causing the molecule to take longer to escape from the potential well.

Results and Discussions

We consider the dimensionless forced Morse potential like model for describing the relative motion of the nuclei of a diatomic molecule and a time-dependent perturbation, acting on the non-perturbed Hamiltonian, which couples the non-linear electric dipole moment, then the total Hamiltonian is

$$H(x,p,t)=\frac{p^2}{2\mu}+\frac{1}{2}\left(e^{-2x}-2e^{-x}\right)-\varepsilon_0\sin(\omega t)\frac{e^{-\xi(x+x_e)^4}\,sin(\eta(x+x_e))}{\eta}$$

We choose the position $x=7$, the momentum $p=-0.5$ which correspond to the positive energy $E_f=0.120$ and the parameters $\mu=1$, $\eta=1$, $x_e=1$ and $\xi=1$. After several computational simulations we fixed the external frequency $\omega=15$ and two values for the perturbation amplitude $\varepsilon_0=11$. In Figure 1 we present the time-evolution of the particle energy;

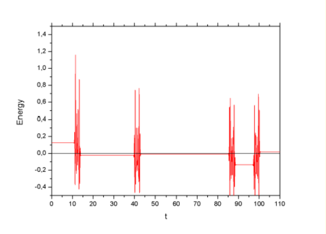

Figure 1 – Total energy (E) of the system as function of time.

The red curve in Figure 1, shows that the particle starts with positive energy and at t ~11 spends a short interval of time with oscillating energy between positive and negative values; around t ~15 up t ~40 it remains trapped in the well, identified by the first plateau; from t ~40 it oscillates again with positive and negative energies until t ~45, thereafter it is trapped in a second large negative energy plateau until t ~85 and experience a third oscillation up t ~88; in the range t: [~88 - ~97] the third negative plateau occurs; next the particle oscillates once again in the interval t: [~97 - ~100] and from there it dissociates.

The visualization of this effect can be seen in the green projection of the energy cube of Figure 2.

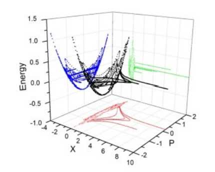

Figure 2 – Energy cube of the system for and the amplitudes.

In Figure 2 we see three quasi-tori which are associated with the three plateaus of the red curve in Figure 1, because when the particle is on a quasi-torus, it has temporarily constant energy and when the particle is in the chaotic sea, its energy varies between negative and positive values

Conclusions/Remarks

We consider the Morse potential to represent the chemical bond of diatomic polar molecules and introduce a perturbation that couples the external and continuous laser electric field with the electrical molecular dipole, which is considered non-linear. For a particular set of parameters, we observe molecular photo-association. However, the photo-association is not the usual, it occurs for some time intervals separated by chaotic bursts. This intermittent photo-association is an effect not yet reported and leads to meta-stable molecules. We point out that if the laser field is turned off while the molecule has negative energy, it becomes a stable and permanent molecule

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