자기 광학적 포획에서 맷음변수 구동으로 형성된 두 끌개 사이에 요동에 의해 발생한 전이 현상

Fluctuation-induced Transitions between Attractors in the Parametrically-driven Magneto-optical Trap

Kihwan Kim, Hyoun-Jee Ha, Kiyoub Jang, Ki-Hwan Lee, Heung-Ryoul Noh*, Wonho Jhe
School of Physics and Center for Near-field Atom-photon Technology, Seoul National University, Seoul 151-742, Korea
*Department of Physics, Chonnam National University, Gwangju, 500-757, Korea
e-mail:whjhe@snu.ac.kr

The investigation of fluctuation-induced transitions between the two states has fundamental importance in various fields of science, such as diffusion in solids, nucleation in phase transitions, chemical reactions, and protein folding. The quantitative understandings about the bistable systems was Kramers' equation[1] on the thermally activated escape rate from a potential well. The theory developed by Karmers was carefully tested and proved experimentally with optically trapped brownian particle[2]. Theoretical studies have been extended to comprehend escape rates and paths for driven bistable systems which are not in equilibrium but in periodic states[3]. The experimental studies of such systems have been just analog computations with circuits constructed to mimic the desired equation of motions[4], and parametrically driven Penning trap[5].

Our systems have some strong points to study the fluctuation-induced transitions between the bistable states produced by parametric resonances comparing to Penning trap and analog circuits. As reported in previous paper[6], the limit cycle motions from parametric resonances and nonlinearity were visualized clearly with the CCD camera and photodiodes [Fig. 1]. We also can monitor the noise-induced transitions between two states which differ in their oscillations phase by 180° with visual images. Contrary to the Penning trap, since there are many oscillators in our system, the transitions come out as exponential decays of number difference between two states after removing atoms in one of them [Fig. 2]. The decay rate could be exact transition rates. Moreover, in our system the transitions among the three fixed points where sub-critical bifurcation happens could be investigated and compared to the theory[3], which could not be studied in any other system. The transition rate depends on the fluctuation intensity, that is, the amounts of spontaneous emissions for our setup, on the amplitude of modulation and the frequency of parametric derive. We note that in our system the noise is from spontaneous emissions, which is differ from thermal noise, and characterized very well. We compare the theoretical model to describe Penning trap[3] and the Monte-Calro simulation results. We had to study removing the populations in one of two states on the duration time, phase and intensity of kicking lasers, which push out the atoms in the limit cycle motion.

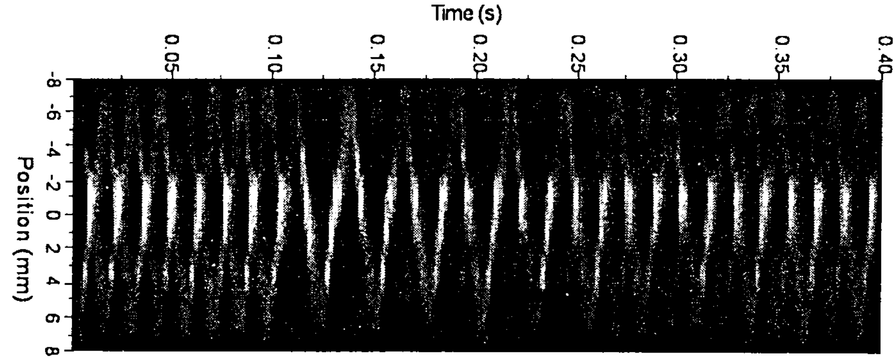

Fig. 1 The contour plot of absorption signal before and after removing one attractor population. This figure is obtained at f=75 Hz modulation frequency and ε=0.9 modulation amplitude.

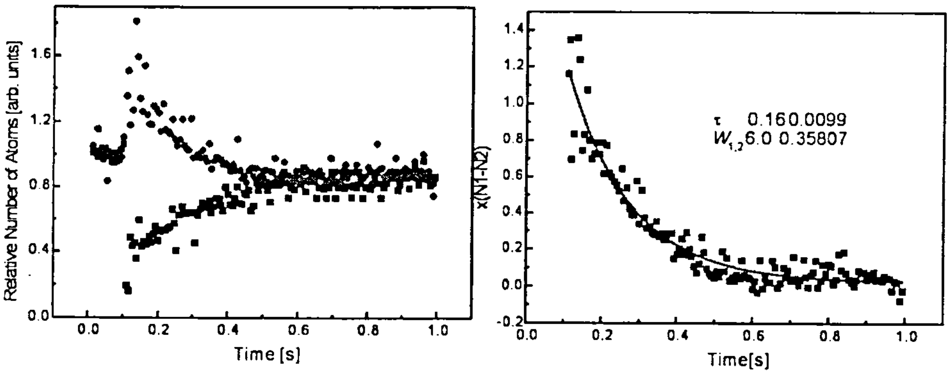

Fig. 2 (Left) The decay and growth of number of atoms in each attractor deduced from Fig. 1. (Right) The difference between large population group and smaller population one. From the data we can obtain the transition rate directly.

1. H. A. Kramers, Physica (Utrecht) 7, 284 (1940).

2. A. Simon and A. Libchaber, Phys. Rev. Lett. **68**, 3375 (1992); L. I. McCann, M. I. Dykman, and B. Golding, Nature (London) **402**, 785 (1999).

3. M. I. Dykman, C. M. Maloney, V. N. Smelyanskiy, and M. Silverstein, Phys. Rev. E **57**, 5202 (1997).

4. D. B. Luchinsky, and P. V. E. McClintock, Nature (London) **389**, 463 (1997); D. B. Luchinsky, P. V. E. McClintock, and M. I. Dykman, Rep. Prg. Phys. **51**, 889 (1998).

5. L. J. Lapidus, D. Enzer, and G. Gabrielse, Phys. Rev. Lett. **83**, 899 (1999).

6. K. Kim, H. -R. Noh, Y. -H. Yeon, and W. Jhe, Phys. Rev. A **68**, 031403(R) (2003); K. Kim, H. -R. Noh, H. J. Ha, and W. Jhe, submitted to Phys. Rev. A.