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Quantum phase control using pulsed Stark electric field

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Introduction

Interest for quantum computing and quantum information has been growing, owing quantum superposition and entanglement since D. Deutsch has proposed quantum computing [1]. For the aim of quantum computation realization, some physical systems for quantum computation such as NMR, quantum dots and photons have been proposed and studied[2]. However, there are many problems such as limitation of coherence time, the qubits extensibility and so on. In order to overcome these problems, techniques of controlling and detecting quantum state become increasingly important. Quantum interference control using Stark effect of atom has been performed by Ryabtsev et al [3]. In their study, probability of mixing between the Rydberg states depends on not only initial probability distribution but also phase difference between degenerate states.

We investigate the quantum state control possibilities using Rydberg atom detecting Stark quantum beat (SQB) from excited Rydberg state.

Experiment

The SQB measurement was performed by using PF ring single bunch operation. We used Stark plates applied an electric field to the interaction region. The direction of linearly polarized light was set to +45° with respect to the external electric field direction. This setting makes it possible to excite the superposition state of M=0 and $|M|$ =1 magnetic sublevels. The phase differences between two energy levels could be measured and controlled by applying a pulsed electric field.

Results and Discussion

Fig.1 shows an fluorescence excitation spectrum of Ar below the first ionization theshold. The 18d[3/2] state, which strongly appears in Fig.1, has been investigated well about field dependence of the beats[4]. The SQB of this state can be observed with less than 1V/cm. Flourescence intensity from superposition state caused by Stark effect is expressed as follows.

$$I(\theta, t) \propto \{A + B\cos\theta\sin\theta\cos(\frac{E_1 - E_2}{\hbar}t)\}e^{-t/\tau\hbar}$$

Where θ is angle between plane of polarization and electric feild direction. If we cease impressing external field, time dependent wave function of the Rydberg state get a phase change. Consequently the effect of phase difference appear in flourescence intensity after the pulsed electric field(Fig. 2). Therefore, we can control quantum state by duration time t_p, angle θ and energy splitting width E_1-E_2(which is proportional to field strength in this state) and detect it.

$$\Delta = \int_0^{t_p} \frac{E_1 - E_2}{\hbar} dt$$

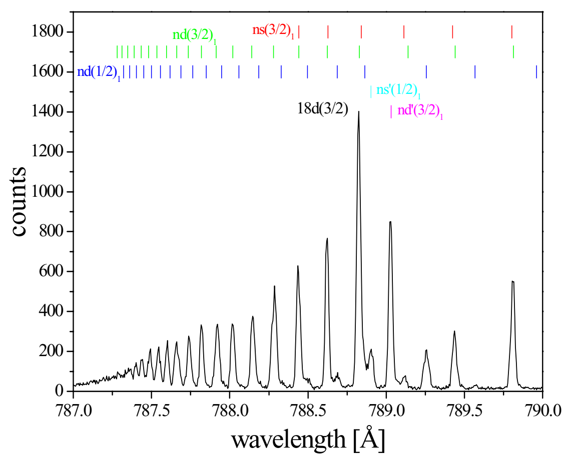

Fig1 Ar fluorescence spectrum

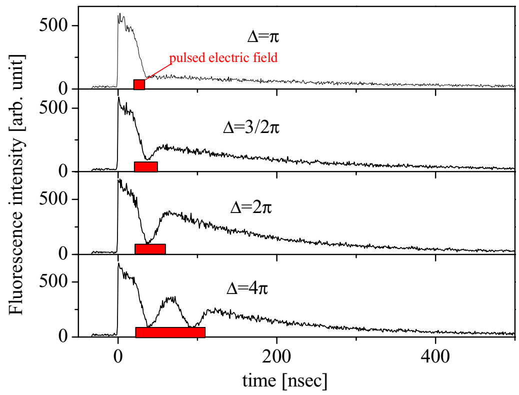

Fig.2 Time dependence of fluorescence intensity

[1] D. Deutsch, Proc. R. Soc. London A **400**, 97 (1985).
[2] I. L. Chuang et al, Phys. Rev. Lett, **85**, 005452 (2000)
[3] I. I. Ryabtsev et al. Phys. Rev. A **61**, 063414 (2000).
[4] T. Aoto et al, J. Ele. Spectros. **144**, 47-50 (2005)

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