Nuclear Science Research Facility
- Beams and Fundamental Reaction -

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Scope of Research

Atoms, nuclei, and dark matter particles in the Universe are studied with quantum electronic methods: Current research subjects are 1) search for a cosmological dark-matter candidate particle, axion, in the Universe with the Rydberg-atom cavity detector, 2) highly excited Rydberg atoms in an electric field and their applications to fundamental physics research, and 3) nuclear magnetism in 3-5 semiconductors with laser-assisted Overhauser process and optical pumping.

Research Activities (Year 2002)

Presentations

Selective pulsed-field ionization in highly excited Rydberg atoms (Experiment), Shibata M, Tada M, Kishimoto Y, Kominato K, Ooishi C, Yamada S, Saida T, Haseyama T, Funahashi H, Yamamoto K, and Matsuki S, Spring Meeting, Phys. Soc. Jpn., Kusatsu Shiga, 26 March.

Selective pulsed-field ionization in highly excited Rydberg atoms (Theory), Kishimoto Y, Tada M, Shibata M, Kominato K, Ooishi C, Yamada S, Saida T, Haseyama T, Funahashi H, Yamamoto K, and Matsuki S, Spring Meeting, Phys. Soc. Jpn., Kusatsu Shiga, 26 March.

Fourth-order dependence of the Stark shift on the electric field in highly excited Rydberg atoms, Haseyama T, Tada M, Kishimoto Y, Kominato K, Shibata M, Ooishi C, Yamada S, Saida T, Funahashi H, Yamamoto K, and Matsuki S, Spring Meeting, Phys. Soc. Jpn., Kusatsu Shiga, 26 March.

Review of axion searches, Matsuki S, First Sendai International Conference on Neutrino Science, Sendai, Japan, Sendai, 16 March.

Grants

Matsuki S, Search for Dark Matter Axions, Grant-in-Aid for Specially Promoted Research(2), 1 April 1997 - 31 March 2003.

Manipulating ionization path in a Stark map: stringent schemes to selectively field-ionize highly-excited Rydberg atoms

Rydberg atoms have been widely utilized for fundamental physics research [1,2]. Highly excited Rydberg states with the principal quantum number n larger than 80, however, have not yet been utilized in detail, partly because it is more difficult to detect selectively a particular state. It is important to develop a sensitive, selective ionization method for such highly-excited Rydberg atoms for further applications such as to long wavelength microwave detections. We investigated systematically the characteristics of the pulsed field ionization in the highly excited Rydberg states[3]. It was found that in these highly excited Rydberg states, the field ionization proceeds in two ways, that is, via 1) tunneling, and 2) autoionization-like processes. Indeed field ionization spectrum shows, in general, two peaks which are due to the two processes mentioned above. Lower peak is due to the process (2), while the higher peak corresponds to the process (1).

Along with these investigations, we have developed new stringent schemes to selectively ionize highly excited Rydberg atoms by manipulating the ionization path in a Stark map[4]: Low angular momentum states such as s and p states in Rb which are situated below and above the adjacent manifold, respectively, for example, are firstly chosen as initial states of interests. The s (p) state is then moved adiabatically to the lowermost (uppermost) state in the adjacent manifold by applying the slowly rising (low slew-rate) pulsed electric field, thereby transferring adiabatically the first avoided-crossing. Then the lowermost state is driven to higher electric field, thus causing ionization with a pulsed electric field in high slew-rate regime.

Manipulating schemes and resulting ionization spectra are shown in Fig. 1 together with the relevant Stark map and ionization paths. Related pulse profile is also shown in the figure. In order to make the selectivity more stringent further, applied pulsed field is modified as to have a three-step profile[4]. The spectrum observed with such a scheme clearly shows that the selection between the s and p states ionization-signals is quite stringent and much more improved than the previous one-step method[4].

These schemes can be applied to the quite sensitive microwave detection at the wavelength region of longer than 10 cm. One of such applications is to the detection of dark matter axions in microwave cavities[2,5]. Also the method may be applied to the detection of fundamental forces such as Casimir force.

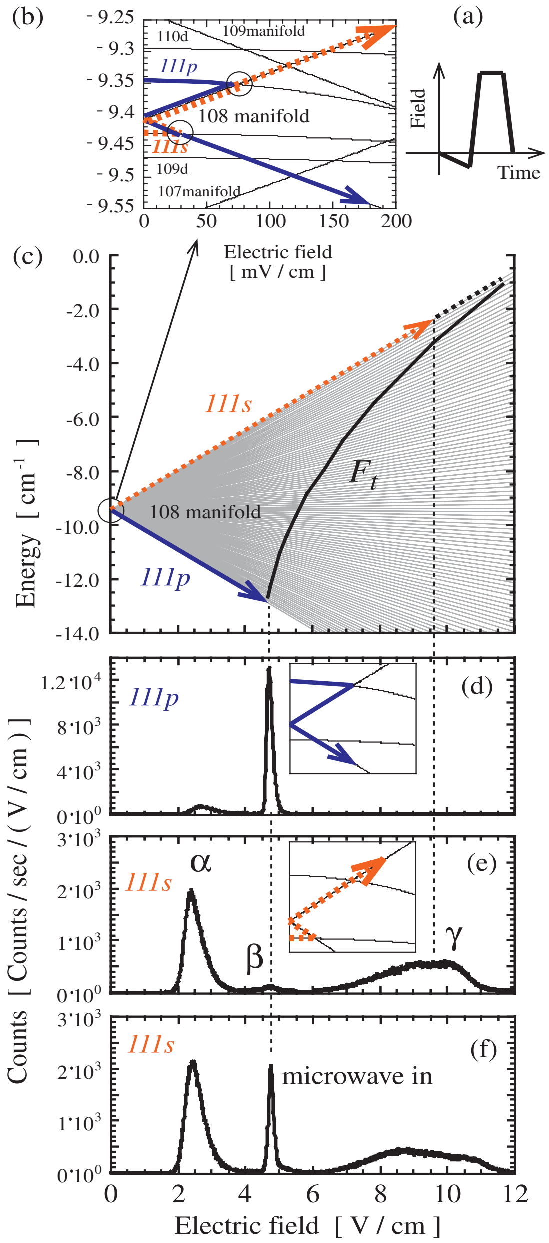

Fig.1 Stark energy diagram near the n=108 manifold and field ionization spectra of the 111p and 111s states with a pulsed field ionization scheme. a) pulse profile used, b) enlarged Stark map at low electric field region, c) Stark map near the 108 manifold, and ionization paths manipulated with the present schemes, d) ionization spectrum of 111p state, e) the same of 111s state, f) ionization spectrum of 111s state with microwave in , frequency of which corresponds to the transition frequency between the 111s and 111p states.

1. T. M. Gallagher, *Rydberg atoms* (Cambridge University Press, Cambridge, 1994).
2. I. Ogawa, S. Matsuki and K. Yamamoto, Phys. Rev. **D53** (1996) R1740, and references cited therein.
3. Y. Kishimoto et al., Phys. Lett. A**303** (2002) 279.
4. M. Tada, et al., Phys. Lett. A**303** (2002) 285.
5. K. Yamamoto et al., Proc. Int. Conf. on Dark Matter in Astro- and Particle Physics, Heidelberg, 2000 (Springer-Verlag, Heidelberg, 2001) p638.