The Global COE Program

"The Next Generation of Physics, Spun from Universality and Emergence"

Bilateral International Exchange Program (BIEP, invite) report

Send report to: Your responsible Professor in Kyoto University

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(Year/Month/Day)2009/11/09

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Research Project

Title	**Study of optical lattice quantum computing using Yb atoms**
Duration	**2009 6/1-2009 8/31**

Summary:

In order to achieve quantum computation on neutral atoms, for example in an optical lattice, it is necessary to control each atomic q-bit independently, this could never be performed to this day. During this BIEP, we aimed to achieve single-atom addressing of Ytterbium atoms in optical lattice using very strong magnetic field gradients to spatially resolve their levels. To this day, we have shown successful optical tweezer atom moving as well as cooling down to a temperature below 1 micro-K in a crossed dipole trap, and have successfully observed global fluorescence and could even go down to observing only one hundred atoms' fluorescence. Checking our Signal to Noise ratio, we estimated that with a few improvements, we are very close to single-atom detection. Single-atom detection is naturally the first step towards single-atom addressing. For fluorescence observing, we notably invested time building up a new 399 nm frequency locked laser system : some of the light obtained from an External Cavity Laser Diode was locked to the resonance of a high finesse Ultra-Low Expansion cavity after acousto-optic modulation, while another part was amplified and send to the experiment for Magneto-Optical Trapping (MOT) and fluorescence detection. Finally, I would like to highlight the importance I attached, during this internship, in acquiring experimental knowledge of atomic Physics basic technique, which my previous studies couldn't bring me .

Motivations

Since it has been demonstrated that a quantum computer could solve the factorization problem in sub-exponential time (Shor algorithm), quantum computation has become a very intensively investigate field. One possibility of implementing a q-bit is to use a very narrow transition (≪ clock-transition ≫) on a neutral atom. Neutral atoms have the advantage of having a rather long coherence time since they do not feel much influence from environment (unlike ions for example) and of being easily stored in great quantity and limited volume, typically in an optical lattice.

For our experiment, we chose to use Ytterbium atoms for the remarkable properties of their transition, which combines very long lifetime (good for coherence time) and very strong magnetic dipole-dipole interaction (eventually interesting for quantum gates implementation). However, one of the major drawbacks of neutral atoms is the difficulty to selectively address them in an optical lattice, mainly because of light diffraction limit. Our plan to overcome this difficulty is to Zeeman shift the atomic levels, this with a strong spatial dependence, i.e. a very strong magnetic field gradient (several hundreds of Gauss per centimeters). The first step in this direction is to show that we are capable of observing the very weak fluorescence emitted by a single-atom.

Our June-August achievements

Of course, technically we are still very far from performing quantum computation. However, during the three months we achieved successful transfer of our atoms into a glass cell region, which has easy optical access, via an optical tweezing system, as well as the realization of a crossed dipole trap. Finally, we could observe fluorescence from as few as one hundred atoms in the glass cell using a specially constructed frequency locked 399nm laser to create an optical molasses. We also calculated our Signal to Noise ratio, and we believe that we are very close to single-atom detection

Benefits to the graduate students in the host institute

During my stay, I discussed many Japanese students in the Lab in English about physics as well as the study in Paris. I believe that many Japanese students seemed more motivated through these discussions. Their English ability is absolutely improved through the conversation and the presentation in English in weekly seminars in the Lab.

Comments and requests to the GCOE program

Thank you very much for giving me this wonderful opportunity. Much more flexibility in administrative issues is, however, absolutely necessary.

I already sent the complete version of my study in the BHIP program.