R&D Theme

Arranging individual trapped ions with junction traps

Progress until FY2022

1. Outline of the project

We reviewed the research and development status of 2-dimensional and 3-dimensional microfabricated ion traps used for quantum information processing. 2-dimensional ion traps are superior for handling many ions. On the other hand, when photon is used for transmitting quantum states, the number of ions manipulated in each trap can be reduced and extensive transportation of ions is no longer necessary. In addition, in transmitting photons from ions, it is very important to firmly determine the position of the ion traps in order to couple them with the fiber at a high efficiency. For this purpose, a 3-dimensional trap is preferable. In this research, we are developing a trapping device using 3 dimensional microfabricated electrodes that can simultaneously trap and array different elemental ions (Ca and Sr) in a 3-dimensional trap for sympathetic cooling.

2. Outcome so far

In designing the microelectrodes for the ion trap, we examined electric field analysis software capable of performing numerical calculations and selected the software to be used. Using this software, we considered the shape of the junction based on the microelectrode technology that could be fabricated.
We conducted a close examination of software required for numerical analysis of electric fields. Specifically, we created 3-dimensional ion traps in three software packages that can calculate ion trajectories in AC electric fields and confirmed their usability.

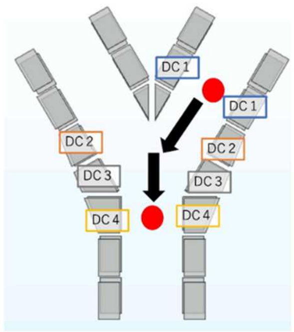

Figure 1: Ion transport model in junction 3-dimensional microfabricated trap

Of these, the software C is a general integrated simulation software based on the finite element method, which is compatible with high-frequency RF and allows different mesh sizes to be set for microfabricated and non-microfabricated areas, so it suitable for the calculation of microfabricated electrodes. We also confirmed that the software has been used in previous studies, which is preferable for constructing our calculation models. Since it is compatible with high-frequency RF and does not require long computation time even for models with microstructures, we decided to use the software C in this research.
Numerical analysis was conducted to quantitatively evaluate the electrode configuration and applied voltage that would allow ions to move through the two-way junction shown in Figure 1. Ions were transported from the red circle of DC1 to the red circle of DC4 in the junction shown in Figure 1 on the various conditions of electrode configurations. Figure 2 shows an example of the ion trajectory results.

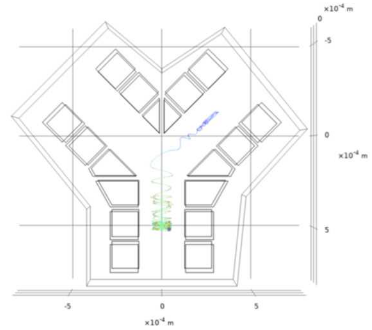

Figure 2: Ion orbitals in the transport of junctions

It is now possible to set the temporal variation of the DC voltage setting to allow transport of ions depending on the angle of the junction.
We prepared the vacuum system, electric field drive system, observation system, optical system, laser source system, etc. to set up the apparatus required for the trap and laser cooling of Ca and Sr ions.

3. Future plans

We will fabricate a prototype of a 3D microfabricated electrode and first aim to observe Ca ions by ion trapping and laser cooling. Once the ions can be observed, we will work on ion transport by changing the DC electrode as calculations. We will trap and observe Sr ions for simultaneous trapping and observation of multiple elements and ion manipulation in an arbitrary order using junctions.