Photon-trap spectroscopy of size-selected cluster ions: "Direct" measurement of optical absorption

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A novel experimental technique is presented for optical absorption spectroscopy of size-selected free cluster ions. The technique employs an ion trap and an optical cavity; cluster ions stored in an ion trap interact with photons trapped in a cavity. The storage lifetime of photons in the cavity provides "direct" probe of extinction of light with an extremely high sensitivity (photon-trap spectroscopy [1,2]: an extended scheme of cavity ring-down spectroscopy). The "direct" measurement of photoabsorption is unique to this technique, which is contrasted with conventional action-spectrum measurements relying on "indirect" information from photodissociation or laser-induced fluorescence [3]. In addition, the use of an ion trap instead of ordinary ion-beam experiments allows measurements under controlled experimental conditions such as a temperature and a magnetic field.

We have developed an experimental setup illustrated in Fig. 1(a). The first experiment was performed on the atomic ion of manganese, Mn^+, which shows ultraviolet absorption due to $^7P_J \leftarrow {}^7S_3$ (J = 2,3, and 4) transitions. Spectra of hyperfine structures, Zeeman splitting, and Faraday rotation were measured under a magnetic field up to 3 T [2]. The stored Mn^+ ions were even spin-polarized by a circularly polarized light [4]. Very recently, we succeeded in the experiment of silver cluster ions, Ag_N^+. Preliminary results of absorption measurement of Ag_9^+ are shown in Fig. 1(b), presenting temperature dependence down to 10 K. These spectra are to be contrasted with those assigned to surface-plasmon resonance by photodepletion spectroscopy of hot silver clusters.

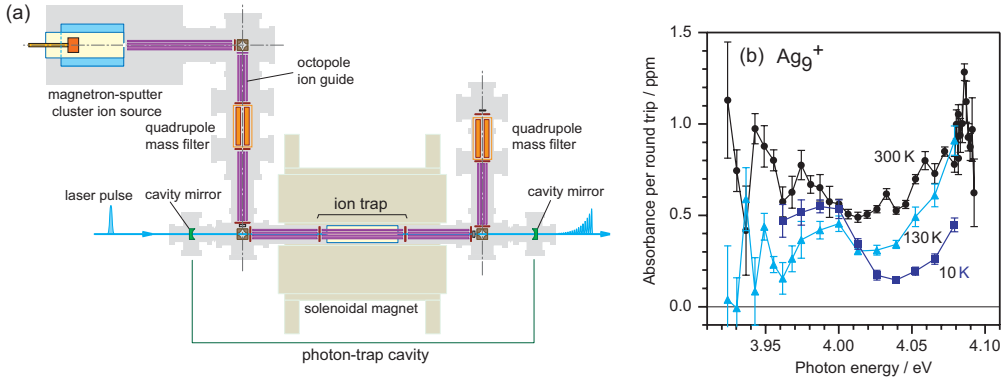

Figure 1: (a) Experimental setup. (b) Temperature dependence of absorption spectra of Ag_9^+.

[1] A. Terasaki *et al.*, J. Opt. Soc. Am. B **22**, 675 (2005); K. Egashira *et al.*, J. Chem. Phys. (Communication) **126**, 221102 (2007). [2] A. Terasaki *et al.*, J. Chem. Phys. (Communication) **127**, 231101 (2007). [3] A. Terasaki: J. Phys. Chem. A (Feature article) **111**, 7671 (2007). [4] T. Majima *et al.*, Phys. Rev. A **77**, 033417 (2008).

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