A SYSTEMATIC STUDY OF THE 4d-GIANT RESONANCE IN Xe^{n+} (n = 0, 1~7)

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The 4d giant resonance structure that apperas in the photoabsorption spectra of process in heavy atoms and ions has been a subject of interest in atomic physics for a long time. [1, 2]. The broad resonance appeared is understood to be an effect of the double minimun final Hartree-Fock potenital for *f*-partial state and the electron-electron dynamic correlation. Generally speaking, the variation in shape and location of the 4d resonance structure for different heavy atoms and ions is due to differences in their respective final states. The initial states of these atoms or ions have relatively little effect on the the 4d resonance structures because the 4d levels are hardly affected by the outer shell electrons. Morever, it should be noted that a bound-free transition becomes possible due to the formation a short-range type efective potential for the *f*-partial wave resulting from electron-electron correlation [2].

Using the density function theory[3] we calculated the photo-absorption cross section of the 4d-giant resonance of Xe and Xe^{n+}, where n = 1, 2,~ 7. For each species, the total spectrum, including discrete and continuum states[4]. The photo-absorption (ionization and excitation) cross section, $\sigma(\omega)$, as a function of energy ω (in atomic units) is given by the imaginary part of the dynamic polarizability $\alpha(\omega)$:

$$\sigma(\omega) = \frac{4\pi\omega}{c}\Im[\alpha(\omega)]. \qquad (1)$$

The dynamic polarizability in the presence of an external field $V^{ext}(\mathbf{r},\omega)$ is given in terms of $\chi^{IPA}(\mathbf{r}, \mathbf{r}', \omega)$ and a self-consistent field $V^{SCF}(\mathbf{r}',\omega)$. To obtain $V^{SCF}(\mathbf{r}',\omega)$, a set of integral equations which includes the exchange-corrected, self-energy-free potential is approximated by the local density approximation. Using this method we calculated 4d photoabsorption spectra for Xe^{n+} where n=0,1-7.

The upper figure on the right shows the calculated spectra of Xe^{3+} (resolution 500meV). The lower figure on the right shows the corresponding data [5]. Detailed discussion particularly on the global shapes of the absolute cross sections will be given in the symposium.

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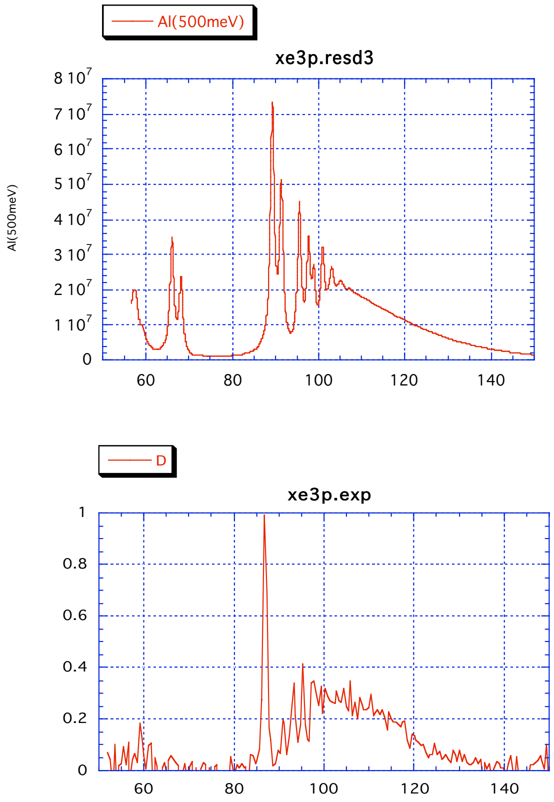

The upper fig. is calculated photoabsorption spectra for Xe^{3+} as a function of the photon energy in eV. The lower fig. shows the corresponding experimental one by Koizumi *et. al* [5]

PHOTOIONIZATION OF HIGHLY CHARGED IONS IN AN ELECTRON BEAM ION TRAP BY SYNCHROTRON RADIATION

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Recent results achieved at the Free Electron Laser (FEL) at Hamburg, FLASH on the resonant excitation of Fe^{23+} ions by 49 eV photons [1] have shown that the combination of an electron beam ion traps (EBIT) with an FEL is a powerful method for investigating the interaction of VUV to x-ray radiation with highly charged ions (HCI). Photoionized ions generated within the trap volume by the photon beam are extracted after a suitable interaction time and guided behind the collector by an electrostatic 90° deflector towards a Wien-type velocity filter. A position sensitive microchannel plate detector is used to count the extracted ions in the different charge states with high efficiency. The preparation of the HCI target and the overlapping of the photon beam with it, as well as the diagnostics of the photoionized ions generated are sketched in Figure 1. Current experiments at the synchrotron facility BESSY are exploring now Fe an Ar ions in the photon energy range from 50 to 180 eV.

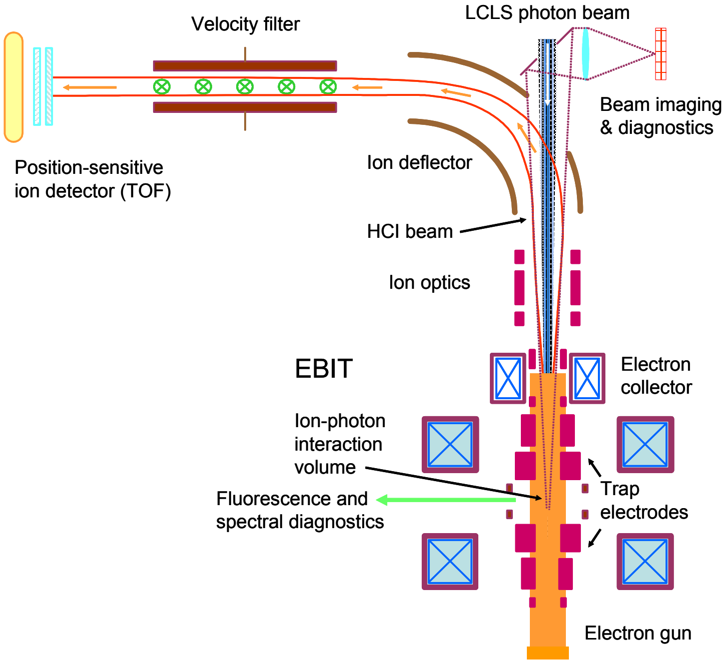

Fig. 1. Experimental setup for photoionization studies in an EBIT.

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LOWLY IONIZED Ar AND Xe PLASMA DIAGNOSTICS AND MODELING

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Collisional-Radiative (C-R) models are needed both for non-equilibrium plasma diagnostics and for modeling. For diagnostics, non-intrusive emission spectroscopy allows for evaluation of the local electronic temperature and density; it also provides information on the constituents and the most important processes encountered in the plasma. For plasma modeling, a substantial amelioration of the codes is obtained by coupling the C-R statistical equations with the basic model equations [1].

We have developed and used various C-R models for diagnosing and modeling of Ar and Xe plasmas in existing propulsion [2] and fusion [3] devices. Moreover, the optical emission of Ar and Xe plasmas in dielectric barrier discharges was registered and compared with the theoretical spectra coming from our models [4]. C-R models containing the ground state and a number of excited levels of the ionized states were used previously for studying the I, II and III spectra of Ar and Xe. Multiplets of the IV and V spectra have also been included in our C-R models. Although these models were able to reproduce the more intense lines of the plasma, lesser lines were sometimes absent, because the corresponding configuration levels were not included in the model.

To improve the theoretical spectra, additional transition probabilities $A_{i,j}$ have been calculated and introduced in the models, as they play an essential role in emission spectroscopy, together with the excitation-desexcitation cross sections. Our calculations use a Coulomb Approximation (CbA) code [5] and the *ab initio* code contained within the SUPERSTRUCTURE package developed at University College [6]; the obtained data are compared with evaluated sets from NIST [7]. Special attention was given to transitions involving the lower metastable levels $1s^3/1s^5$ of the Ar and Xe (4*s* and 6*s* configurations). Transitions involving the 4*s* – 4*p* and 4*s* – 5*p* multiplets of the Ar I and the 6*s* – 6*p* and 6*s* – 7*p* multiplets of the Xe I spectra are very important for various low temperature applications, as they often lead to the most intense Ar/Xe I visible lines.

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EFFECTS OF DEBYE PLASMAS ON THE RESONANCE STATES OF HIGHLY STRIPPED TWO-ELECTRON IONS USING THE STABILIZATION METHOD[*]

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The effects of screened Coulomb potentials in atomic or molecular processes have become an active and relevant search topic in the recent years ([1-4], references therein). Recently, we have initiated resonance state calculations ([3-4], references therein) on different atomic and molecular systems under the influence of screened Coulomb potentials. In the present work, we investigate the resonance states of two-electron atoms, Mg^{10+} and Si^{12+} interacting with screened Coulomb potentials of the form : $\exp(-\mu r)/r$, where μ is called the Debye screening parameter ($\mu=1/\lambda_d$, λ_d the Debye length). We employ highly correlated exponential basis functions, supported by a widely used quasirandom process [1,3] of the form $\varphi_i = r_1^L P_L(\cos\vartheta)\exp[-(\alpha_i r_1 + \beta_i r_2 + \gamma_i r_{12})] \pm$ exchange, for S-, P- states calculations, whereas for D-wave resonance calculations, we employ CI-type basis functions with certain approximations [4]. The stabilization method [5], a simple and powerful technique that needs only L^2 type basis functions, is used to extract resonance energies (E_r) and widths (Γ). We have obtained several doubly-excited *S*-, *P*- and *D*- waves resonance states of the proposed systems for each μ, below the n=2 thresholds of the respective two-body subsystems. In Fig.1, we present lowest S- and D-wave resonance widths of Mg^{10+} and Si^{12+} as functions of μ.

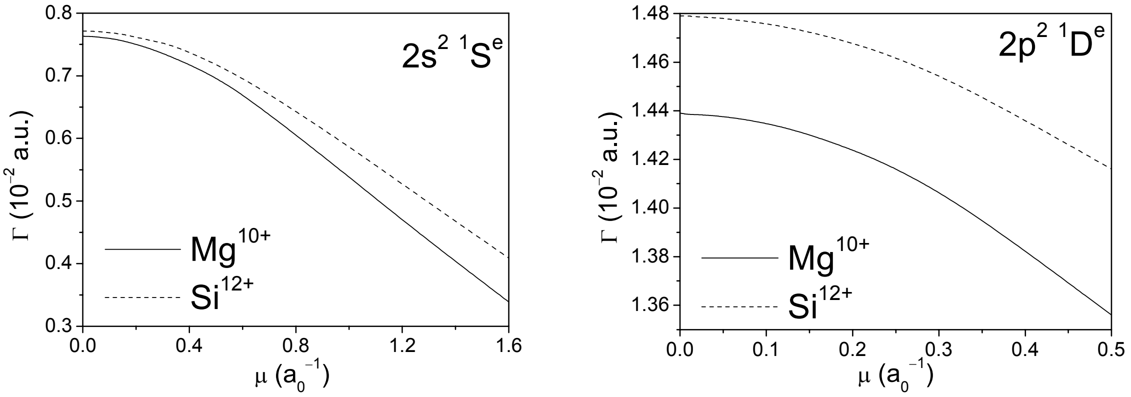

Fig. 1. Lowest S- and D- waves resonance widths of Mg^{10+} and Si^{12+} in terms of μ.

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PROBING ELECTRONS AND IONS IN STAGNATION LAYERS AT THE COLLISION FRONT BETWEEN COLLIDING LASER PRODUCED PLASMAS

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The domain of laser produced plasmas has been an active area of research since first studies in the 1960's and has spawned a wide range of applications such as Pulsed Laser Deposition [1], Inertial Confinement Fusion [2], Particle Accelerators [3], X-Ray lasers [4] and other light sources such as tin plasmas for EUV Lithography [5]. We have used an optical Nomarski laser interferometer to determine the evolution of the electron density profile for laterally colliding laser produced plasmas at early times in the plume life cycle (<100ns). We have also employed a framing camera and optical spectrometer coupled with a gated CCD (ICCD) to track ions with different charge states at the collision front between the two colliding laser produced plasmas in synchronisation with the electron density distributions. High time resolution has permitted us to observe the earliest phases of the plasma – plasma interaction. In particular we observe the formation of tightly confined structures in the electron density maps close in time to the optical emission from the optical emission from ion stagnation. We take this as the first signature of stagnation at the midplane.

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TWO-PHOTON TRANSITIONS IN THE HE$^+$ ION EMBEDDED IN STRONGLY COUPLED PLASMAS[*]

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There has been considerable interests in the investigations of atomic processes for atoms/ions embedded in weakly coupled plasmas (Ref. [1] and references therein). In this work, we extend our investigations to study ions immersed in strongly coupled plasmas. Here, we report an investigation of two-photon transitions in the He$^+$ ions embedded in strongly coupled plasmas. We employ the Ion-Sphere (IS) Model [2] to simulate the plasmas effect on the embedded ions. The Hamiltonian of the system, with energy expressed in Rydberg units and Z=2, is

$$\left[-\nabla^2 + V(r)\right] \Psi(r) = E_0 \Psi(r) \tag{1}$$

with

$$V(r) = -\frac{2Z}{r} + \frac{(Z-1)}{R}\left[3 - \left(\frac{r}{R}\right)^2\right] \quad \text{and} \quad R = \left[\frac{(Z-1)}{4\pi n_e/3}\right]^{1/3} . \tag{2}$$

Here, R is the radius of the IS sphere, and n_e is the number density of the electrons in the IS sphere. We use B-spline to represent the wave functions. The dimensionless transition amplitude, calculated using the pseudo state method and following the diplole selection rule, is given by

$$D_l = \frac{1}{2}\sum_{np} \left[\frac{1}{E_{np} - E_i - \omega} + \frac{1}{E_{np} - E_f + \omega}\right] R_{1s}^{np} R_{2s}^{np} , \quad \text{with} \quad R_{ks}^{np} = \int_0^R dr r^3 \chi_{np} \chi_{ks} , \tag{3}$$

where χ_{ks} are the bound S-states and χ_{np} are the intermediate *P*-wave states; ω is the energy in Rydbergs for one of the two photons. E_i, E_f, and E_{np} are the energies for the initial *S*-state, final *S*-states, and the intermediate *P*-states respectively. In Figure 1, we present absorption coefficients $|D_l|^2$ for the 1*s*-2*s* and 1*s*-3*s* transitions for R=2.0 and 6.0 a.u., respectively. It is seen that resonant enhancement occurs in both cases, and a transparency frequency appears in the 1*s*-3*s* transition.

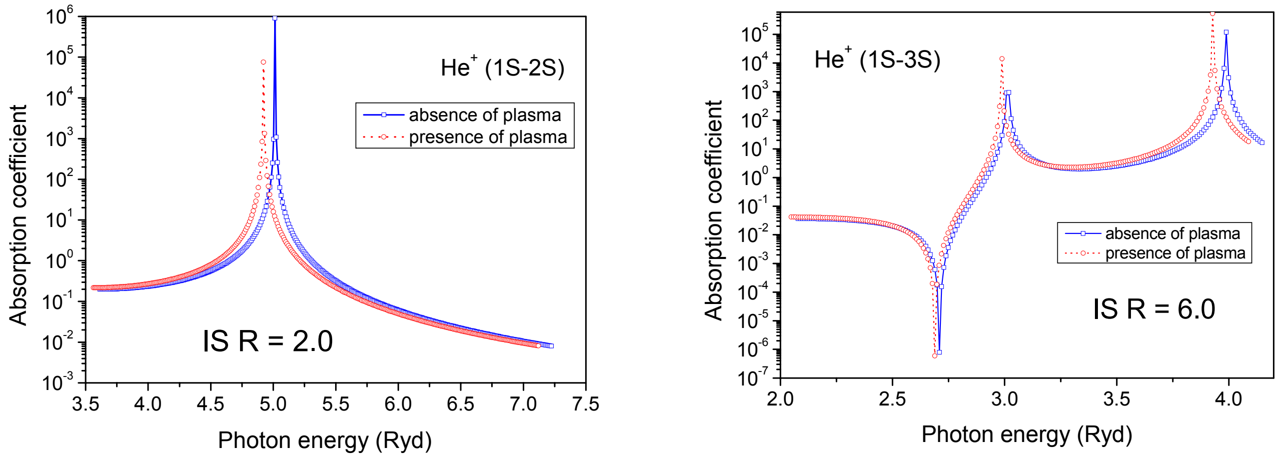

Fig. 1. Two-photon 1*s*-2*s* and 1*s*-3*s* transitions in the He$^+$ ion embedded in strongly coupled plasmas simulated by the Ion-Sphere model.

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ATOMIC PROCESSES OF DAMDE ON BIO-MOLECULES IRRADIATED BY XFEL

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The analysis of three-dimensional structure of single bio-molecules has lately attracted considerable attention for the application of x-ray free electron lasers (XFEL) [1, 2]. This analysis comes from diffraction patterns, which are produced from the irradiation of XFEL onto the bio-molecules. However, the x-ray flux required for this analysis is so large that the bio-molecules are damaged, that is, the atoms in the bio-molecules are more often ionized. This damage appears as noise for the analysis of the three dimensional structure. Therefore, it is indispensable to estimate the damage.

We treat C, N, O atoms which are the main elements of bio-molecules and some atomic processes such as photo-ionization, Compton scattering, Auger, electron impact ionization, and radiative transitions. The atomic data of Auger and radiarive transitions are shown in Ref. [3]. By the application of the atomic data of these processes to rate equations, we have calculated the change of electronic states or charge numbers as a function of times for various parameters such as x-ray flux, x-ray pulses, and wavelength of XFEL the size of bio-molecules .

Figures 1 (a) and (b) show the change of charge number of C as a function of time for the wavelength of 0.1 nm and 0.1 nm of XFEL, respectively. The x-ray flux, pulse of XFEL and the size of bio-molecules are 10^{22}/pulse/mm^2, 10 fs, and 20 nm, respectively. We have found that shorter wavelength produce smaller damage. In our presentation, we will show the results for various parameters and suitable parameters for the experiment of diffraction pattern of bio-molecules.

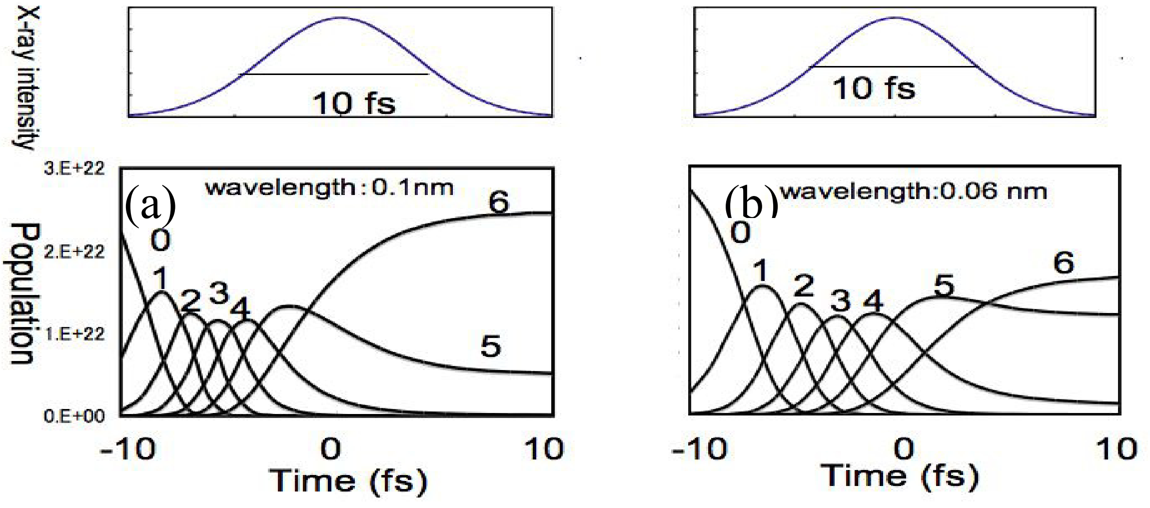

Figure 1 Population of charge number of C vs. time for the wavelengths of (a) 0.1 nm and (b) 0.06 nm, respectively.Upper figure shows the x-ray intensity. The pulse, flux of x-rays, and the size of bio-molecules are 10 fs, 10^{22} /pulse/mm^2, and 20 nm, respectively. The figures shown here are charge numbers.

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Progress of Opacity Experiment on “Shengguang II” Laser Facility

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Abstract

The x-ray opacities of hot, dense plasmas have long been of interest due to their important and urgent need in studies of inertial confinement fusion (ICF), x-ray lasers and astrophysics. Theoretical calculations of opacities are quite complex and usually include numerous approximations. Therefore, experimental measurement of opacity is very important to verify the theoretical models. Many measurements of opacity with sample temperature of lower than 60eV had been done in laboratories during the past decades with the advent of high power laser. In recent years, a serials of opacity diagnostics have been developed at Research Center of Laser Fusion in China. The ninth laser beam has also been established on the “Shengguang II” eight-beam high power ns laser facility, which has duration of about 100ps and can be used as a short pulse backlighting beam in the opacity experiment. Two types of cavity(connical cavity called as type I target, and cylindrical cavity with foam baffle called as type II target) were designed to convert the eight-beam laser into x-ray radiation to efficiently heat the sample and to prevent the sample from irradiation of the reflected laser. The typical opacity experiments have been carried out on “Shengguang II” laser facility. It was shown that the sample temperature of about 95 eV has been reached using the type II target which is much higher than that using the type I target. The type II target can be further used in the opacity experiment for high temperature plasmas in future.