EUV BEAM-FOIL OBSERVATIONS OF CU- THROUGH GE-LIKE IONS OF IODINE

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The spectra and structure of multiply charged ions with an open n=4 shell have been studied for many years. For Cu-like and Zn-like ions, the data on the fundamental transitions - obtained with laser-produced plasmas or an electron beam ion trap [1] - cover quite a number of elements and reach up to uranium (*Z*=92). For ions with additional electrons in the valence shell, the data and corresponding calculations are much sparser. Also, the calculations tend to be the poorer the more electrons are added [2]. In the middle of the sequence of natural elements, classical light sources have reached their limit, and relativity and QED effects are not yet so large that they would arouse theoretical interest on their own. In short, the reasonably good coverage of the atomic spectra of multiply charged ions reaches only up to about *Z*=28 (Ni). The resonance and intercombination transitions in Cu- and Zn-like ions are known or their trend established for the whole isoelectronic sequence. The lowest-energy ground state transitions in Ga-like ions are reasonably well known only up to about Mo (Z=42) and have been seen, for example, in beam-foil spectra up to Ag (*Z*=47) [3] (notwithstanding some observations at much higher *Z* in an EBIT).

For the lowest-energy (intercombination) transition in Ge-like ions, firm ground ends at even lower values of *Z*. Some beam-foil spectra recorded at Bochum have been interpreted (but not all beyond doubt) as showing those lines. However, cross-references from other light sources are missing, as are accurate calculations. The Bochum beam-foil observations have been extended up to iodine (Z=53). Although the available beam energy was only half of what had been used in a Brookhaven experiment on Cu-like ions [4], the ion beam current was so much higher that nevertheless lines from Cu- and Zn-like ions of iodine could be detected which then served to calibrate the spectra. Nearby lines have the signature pattern of the intercombination line multiplet in Ga-like ions, and candidates for the two intercombination lines in the Ge-like ion are proposed. Prompt and delayed spectra as well as decay curves support the proposed identifications.

Extensive calculations are underway at Lanzhou (J. G. Li, C. Z. Dong). With their help it may become possible to corroborate the tentative identifications so that the isoelectronic trends can be reliably interpolated and somewhat extended.

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Radiative Electron Capture in 200 MeV/u Xe^{54+}-N_2 Collisions at HIRFL-CSRe Internal Target

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Radiative electron capture (REC), as a basic atomic physics process, has been the subject of very intense research over the past several decades[1-5]. The experimental observation of K and L-REC was carried out at HIRFL-CSRe[6] with 200 MeV/u Xe^{54+} bombarding with internal N_2 target. The Xe^{27+} ion beam produced by a superconductor ECR ion source was firstly accelerated to 2.9 MeV/u by the SFC cyclotron, and was finally accelerated up to 200 MeV/u at CSRm. Before ejecting into CSRe, the Xe^{27+} ions was stripped to bare by a 0.2mm-thickness carbon foil located at RIBLL-II. After electron cooling in CSRe, the beam momentum spread was as small as $\Delta P/P \approx 2.2\times10^{-5}$. The N_2 cluster target was produced by the cluster source of internal target system. While N_2 gas was jetted from a 90K nozzle and then passed through a set of skimmers, the intense cluster beam with a well bounded intensity profile was formed at the interaction position[7]. The target thickness was about 10^{13} atom/cm^2. The X-rays were detected by three HPGe detectors which were located at 90°, 120° and 145°, respectively. The detectors were shield by lead sleeves. Comparing to the solid target[1], the spectrum background is strongly restrained. The K- and L-REC photons and the Ly-α and Ly-β transition in Xe^{53+} ions, as well as the Pb $K\alpha_1$, $K\alpha_2$ and $K\beta_1$ were observed. The Pb characteristic X-ray possibly produced by the bombardment of fast neuron on the lead sleeves. For the first time the Xe^{54+} beam was stored and electron-cooled at CSRe, and overlapped the internal target jet. The experimental layout and feasibility, as well as the long-term stability of the CSRe internal target have been verified.

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Absolute determination of X-ray transition energies in H-like and He-like ions

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We present high-precision wavelength measurements for H- and He-like ions performed with the FLASH-EBIT using a flat crystal x-ray spectrometer applying a collimation-free technique [Rev. Sci. Instrum. 76 (2005), S. 073105] which allows to determine absolute Bragg angles without the need of reference lines. We have reduced further the already small leading experimental uncertainty by installing the spectrometer coaxially to the electron beam, thus viewing the ion cloud as a point source. This setup reveals a minute curvature of the x-ray lines on the detector plane which hitherto had to be estimated. Results for the Lyman-α_1 and "w" ($1s2p\,^1P_1 \rightarrow 1s^2\,^1S_0$) transition wavelengths in H-like and He-like argon, sulfur and iron ions with experimental uncertainties of esimated $\Delta E < 5$ meV are sensitive to the far larger QED contributions of 1 eV.

PRODUCTION AND DECAY OF CHLORINE ION EXCITED SPECIES IN AN ELECTRON-CYCLOTRON-RESONANCE ION-SOURCE PLASMA

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Electron-cyclotron-resonance ion sources (ECRIS) are characterized by their capacity to produce large populations of highly charged ions and by high electron temperatures. X-ray emission, including bremsstrahlung and characteristic lines caused by these high-energy electrons due to electron-ion collisions, has been used for plasma diagnostics.

Recently, we published [1] an analysis of K x-ray spectra emitted by sulphur ions in an ECRIS plasma, showing that a complete analysis of these spectra calls for a careful examination of all excitation and ionization processes that lead to the excited states of the different ionic species whose decay will yield the detected lines.

In this communication we present the most important processes for the creation of Cl^{13+} to Cl^{15+} ions excited states from the ground configurations of Cl^{10+} to Cl^{15+} ions in an electron cyclotron resonance ion source, leading to the emission of K x-ray lines. Theoretical values for inner-shell excitation and ionization cross sections, including double-KL and triple-KLL ionizations, transition probabilities and energies for the de-excitation processes, are calculated in the framework of the multiconfiguration Dirac-Fock method. With reasonable assumptions about the electron energy distribution, a theoretical K x-ray spectrum is obtained, which is compared to recent experimental data.

We thank the Pionic Hydrogen collaboration for providing us with the experimental spectra. This research was supported in part by FCT project POCTI/0303/2003 (Portugal), by the French-Portuguese collaboration (PESSOA Program, Contract n° 10721 NF), and by the Acções Integradas Luso-Francesas (Contract n° F-11/09). Laboratoire Kastler Brossel (LKB) is "Unité Mixte de Recherche du CNRS, de l'ENS et de l'UPMC n° 8552". The LKB group acknowledges the support of the Allianz Program of the Helmholtz Association, contract EMMI HA-216 "Extremes of Density and Temperature: Cosmic Matter in the Laboratory".

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Transition properties of the highly-charged Titanium ions

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In present plasma modeling, data such as oscillator strengths, line strengths and wavelengths are needed. While data for all 1s-2p transitions in titanium ions have not been reported, and x-ray emission from titanium is extensively used, such as in fusion experiments and ICF. The Kα 1s-2p transitions are limited to from helium-like to fluorine-like ions as the 2p subshell is filled beyond fluorine. While there are two 1s-2p transitions $1s^2\ S_{1/2}$-1s2p $^2P_{1/2}$ and $1s^2\ S_{1/2}$-1s2p $^2P_{3/2}$ for helium-like titanium, Ti^{20+}, the number varies depending on the number of electrons in the 2p subshell before and after the transition. For example, there are 35 1s-2p transitions giving the same number of Kα lines for carbon--like Titanium, Ti^{16+}. The present results(oscillator strengths, line strengths and wavelengths) are obtained from configuration interaction atomic structure calculations using the code GRASPVU, which includes relativistic effects in Dirac-Fock approximation. The results have been benchmarked for a few ionic states with others. Comparisons with the very few transitions in the

literature as well as those from other codes indicate reasonable accuracy for the present results. These data can be used for Titanium plasma modeling.

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EUV SPECTRA OF TUNGSTEN FROM THE LHD AND LASER PRODUCED PLASMAS

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Because tungsten will be will be used in the next generation fusion device ITER, studies of the behaviour of tungsten in a fusion reactor are already underway at a number of major locations worldwide [1]. Spectra are generally dominated by an intense emission feature due to δn = 0, n =4 – n =4 transitions overlaid by some strong lines from Ag- and Pd- like W XXIX and WXXX in the 4.5- 6.5 nm region [2, 3]. Spectra from highly charged tungsten ions in low density and high temperature plasmas produced in the Large Helical Device (LHD) at the National Institute for Fusion Science emitted after injection of a tungsten pellet into a hydrogen plasma were recorded at plasma temperatures of 1.5 and 3 keV. The profile and extent of the transition array was different in both spectra. Atomic structure calculations [3] showed that the dominant emission in both spectra arose from δn = 0, n =4 – n =4 transitions and the differences could be attributed to the appearance of 4p- 4d transitions from W XXXIX – W XLV in the higher temperature spectrum. Wavelengths and gA values for resonance transitions for W ions with open 4f, 4d and 4p subshells were obtained. We also investigated if low density favours transitions from states accessible primarily from the lowest level in line with recently reported results [3] and found some evidence to support this.

Spectra from ASDEX-U contain structure in the 12 - 40 nm region that essentially is concentrated into two unresolved transition arrays [4]. The first gives rise to relatively intense structure lying between 12 and 25 nm whose profile changes dramatically with temperature while the second consists of a weaker feature in the 27 – 32 nm region that vanishes at higher temperature. We have observed similar features in spectra from both the LHD and laser produced plasmas. Atomic structure calculations show that the 12-25 nm emission largely arises from $\delta n = 0$, n =5 – n =5 transitions in stages lower than W^{28+}. Wavelengths and gA values for these transitions for W ions with open 5p, 5s and 4f subshells were obtained and the results will be presented and compared with observation.

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LINEAR POLARIZATION OF X-RAY PHOTONS IN HFQ TRANSITIONS OF POLARIZED HE-LIKE IONS WITH APPLICATION TO THE SEARCH FOR PARITY NONCONSERVATION EFFECTS

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Theoretical concepts for the production, preservation and controlling of polarized highly charged ion beams in storage rings are investigated. For a control of the degree of ion beam polarization two different methods can be considered: by observing the change of transition rates in an additional magnetic field or by measuring the Stokes parameters for the emitted photons. Here we presented the scheme, based on the observation of the linear polarization of emitted X-ray photons in hyperfine quenched transition. The X-ray polarization appears to be connected to the ion beam polarization. This idea has been suggested earlier and partly exploited experimentally in [1]-[4] for the process of the electron radiative recombination with HCI. In [5] the theoretical polarization studies on the two-step radiative recombination of HCI were reported. In this work we employed a similar idea to control the ion beam polarization via observing the linear polarization of X-ray photons emitted in the process of the HFQ decay of excited levels of polarized He-like ions.

The most important motivation for the production of polarized ion beams is the possibility to observe the parity nonconservation effects in the hyperfine-quenched transitions in He-like highly charged ions, where these effects can reach an unprecedented high value for atomic physics. The measurement of these effects require online-diagnostics of the degree of the ion beam polarization. The possible schemes for such experiments as well as the estimates of the magnitude of the observable parity non- conservation effects are also presented.

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DIELECTRONIC RECOMBINATION WITH ONE-ELECTRON HIGHLY CHARGED IONS

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The line-profile approach (LPA) [1] is applied to evaluation of the electron recombination with highly charged ions within the framework of QED. Both dielectronic recombination and radiative recombination processes are considered. The interelectron interaction is taken into account partly to all orders of the QED perturbation theory. The radiative corrections to the lowest order (electron self-energy and the vacuum polarization) are also included. With this approach the most accurate contemporary results for the electron recombination cross section on the one- electron uranium and gadolinium ions are obtained.

We performed QED calculation of the total cross section of the electronic recombination of H-like ions of uranium [2] and gadolinium. The cross section is presented as a function of the energy of incident electron. Due to the dielectronic recombination process the cross section shows resonances corresponding to the doubly excited (2s, 2s), (2s, 2p), (2p, 2p) two-electron configurations. These resonances are investigated in details. The interelectron interaction for the *ns, np,* nd-electrons (the principal quantum number *n 3)* is taken in all orders of QED perturbation theory. The interelectron interaction for the other electrons (including the negative part of the Dirac spectrum) is considered in the first order of perturbation theory. The dominant part of the radiative corrections (self-energy and vacuum polarization) is also taken into account; the self-energy vertex corrections which are not resonant are missing.

Results of the present calculation for uranium are compared with previous calculations [3, 4]. The interelectron interaction is taken into account in the present work more precisely compared to the previous works. Since the LPA is *ab initio* QED approach, the QED effects are considered systematically. The major discrepancy between the calculations reveals itself in the line shapes of the resonances.

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Laser spectroscopy of evaporatively cooled Ar^{13+} ions at the Heidelberg Electron Beam Ion Trap

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We report on a laser fluorescence measurement of the forbidden visible transition in boron-like Ar^{13+} at the Heidelberg Electron Beam Ion Trap. The M1 $1s^2 2s^2 2p\ ^3P_{3/2} - {}^3P_{1/2}$ transition was resonantly excited using a tunable pulsed dye laser while simultaneously monitoring the fluorescence photons, yielding a wavelength of 441.2558(3) nm. Furthermore, by applying forced evaporative cooling on the trapped ions we were able to resolve the Zeeman splitting of the transition due to the magnetic field used for trapping the ions with a resolving power of $\lambda/\delta\lambda$=15000. It has to be noted that still the present limitation is mainly due to the Doppler width of the trapped ions. Better cooling together with two-photon excitation should allow for further accuracy improvements.

FORMATION OF MULTIPLY CHARGED IONS TROUGH SINGLE PHOTON ABSORPTION

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Atomic and molecular multiple photoionization following absorption of a single energetic photon (provided by synchrotron radiation) is highly dependent of electron correlations (in initial, final and intermediate states) and allows direct spectroscopy of X^{n+} multiply charged ions (up to n=5). Many different processes, direct or sequential -as for instance single or cascade Auger decays following inner-shell ionization- can lead to the production of multiply charged ions in different final states. The detection in coincidence of all the emitted electrons *(from 2 to 5 in multiple ionization processes)* analyzed at high resolution ($\Delta E/E=1.5\%$) with a magnetic bottle time-of-flight electron spectrometer [1] installed on a synchrotron beamline (at BESSY-II, Photon Factory or SOLEIL) during single bunch operation (necessary for electron time-of-flight measurements) allows precise and straightforward spectroscopy of multiply charged ions with the identification of all decay paths and branching ratio.

This experimental technique makes possible the study of complex processes unobserved until now. We have observed, for instance, core-valence double photoionization in $Ne(1s^{-1}v^{-1})$ [2] and double inner-shell photoionization in Xe ($4d^{-2}$) [3] (with a very high cross section) followed by stepwise double Auger decay to Xe^{4+} and also triple Auger decay leading to Xe^{5+}.

Mercury vapour multiple photoionization involving 5p, 5s and 4f inner-shell has been studied at BESSY-II synchrotron on U125/2 beamline and leads to the formation of triply and quadruply charged mercury ions. MCDF calculations have been performed and reveal a very good agreement with the observed Hg^{3+} and Hg^{4+} states [4].

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SPECTRUM SIMULATION OF LI-LIKE COPPER PLASMA

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Lithium-like Cu is one of the most important atomic species in X-ray lasers plasma and target materials [1,2]. Based on the collisional radiative model from the FAC, X-ray emission spectra for L-shell of Li-like Cu plasma consisting of three kinds of Cu ions (Li-like Cu ion and another two neighboring ions) are simulated. Atomic processes in the model include dielectronic recombination (DR), radiative recombination (RR), collisional ionization (CI) and resonance excitation (RE) from the neighbouring ion charge states of the target ion(Li-like Cu ion). It is found that DR, RR, CI and RE , other than direct collisional excitation, are very important processes by analyzing the contribution of different atomic processes to the X-ray spectum. In addition, the relationship between X-ray wavelengths, relatively radiative intensity and the electronic temperature can be seen from the spectra , which could be qualitatively used to plasmas diagnostics.

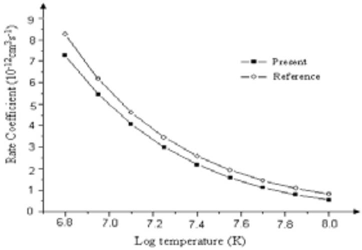

Fig. 1. The total RR rate coefficients of Cu^{26+}

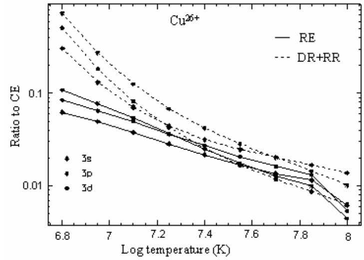

Fig. 2. Rate coefficients of indirect processes relative to direct CE for 3s, 3p, and 3d

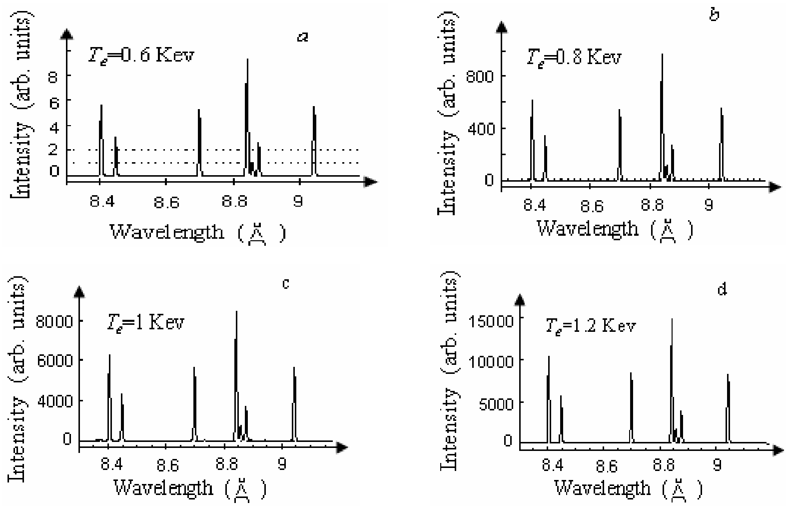

Fig. 3. Simulated spectra of Cu ions

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THE SHIFT OF THE 2p-3d ABSORPTION ARRAY IN IRON PLASMA OPACITY EXPERIMENT

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In the past decades, many experimental measurements and theoretical simulations of the x-ray opacity have been carried out in the fields of inertial confinement fusion, x-ray laser, and astrophysics [1-4]. Among these works, few experiment has referred to the spectra of n=2-3 transitions from partially L-shell-ionized medium-Z plasma such as iron.

In this paper, the transmission spectra of radiatively heated iron plasma were measured on Shenguang II laser facility [5]. In the experiment eight frequency-tripled beams (λ=0.35μm, 2 kJ in 1 ns) were injected into the hohlraum to create a near-Planckian X-ray source. The radiation could volumetrically heat the CH tamped Fe sample to achieve uniformity both in temperature and density. After being smoothed with a lens array, the ninth frequency-tripled laser beam (1200J, 2ns) was focused onto a gold disk to form a uniform surface x-ray backlighting source.

The 2400line/mm flat field grating spectrometer was used to measure the spectrum. The temporal resolution of the measurement was determined by the 100ps gating time of the micro channel plate. By variation of the delay time of the gating start time relative to the main heating pulses, the spectra could be recorded at different times with different iron plasma state.

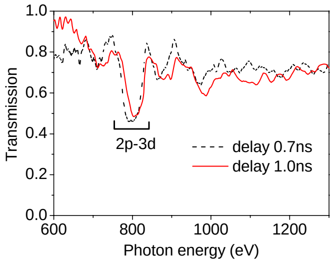

Fig. 1 The transmission spectra measured at 0.7ns and 1.0ns delay

The obvious shift of the 2p-3d transmission array, as shown in Fig.1, was about 8 eV. The experimental results were compared with the results of an UTA code in which the different level-to-level transitions are not treated individually [6]. The ionic balance is very sensitive to the temperature while the excitation balance and the transmissions calculated for each ion do not vary rapidly with the electron temperature. Hence the shape of the spectra was mainly determined by the ion distribution at different temperature and the red shift of the 2p-3d absorption array was attributed to the decrease of the ionization state of the plasma.

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RELATIVISTIC ATOMIC STRUCTURE CALCULATIONS USING GRASP2K

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GRASP2K is a package for large scale relativistic atomic structure calculations based on the multiconfiguration Dirac-Hartree-Fock theory [1]. By an extensive use of default options, together with a naming convention for the files, the package is user friendly with a minimum of input data. However, a large number of non-default options can still be invoked when the need arises. The package implements a biorthogonal transformation method that permits initial and final states in a transition array to be optimized separately, which, in many cases, leads to more accurate values of the resulting rates [2]. In addition to energy structures and transition rates a number of other properties such as hyperfine structure, isotope shift, and splittings in external magnetic fields can be computed.

We present results for a number of systems and properties to illustrate the capabilities and restrictions of the package. Among the properties are energies and transition rates in Carbon and Boron-like ions [3,4,5,6], the electric dipole moment of Radium induced by the Schiff moment [7], and Zeeman splittings in ^{3}He[8].

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Line Profile Calculation

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Spectral line broadening calculation is presented based on a relaxation theory developed by Smith [1]. The primary broadening mechanism considered in this work is the interaction between a radiating atom and the electric field produced by surrounding ions and electrons. Since the perturbing ions can be regarded as stationary during the emission process, the effects of perturbing ions on the radiating atom can be approximated by ion microfield which is calculated by Hooper's [2][3] method. This approximation is valid in the portions of line wing when $|\Delta\omega|$ is larger than V_{av} / λ_{Debye}. The center of line profile is dominated by electron collisional broadening which is treated without impact approximation [4], and can be regarded as a result of the quadratic Stark interaction between the electron microfield and the radiating atom. Electron correlations [5] and distortions of plane wavefunctions of free electrons [6] by charged radiating ions is also considered.

Atomic parameters needed in this work, like transition energy, spontaneous emission rate and radial wavefunctions, are calculated by Flexible Atom Code [7] in which atomic structure is calculated by Dirac-Fork-Slater methods with configuration mixing. The transition matrix elements of one electron and multi electrons ion are calculated via the Wigner-Eckart theorem [8] using wavefunctions produced by FAC.

Finally, profiles of Ly α line of Ar ions has been calculated. A comparison (Figure 1) with other works [9] is made, and fairly good

agreement is achieved. We also calculated line profiles of two electrons ion (Figure 2) which is potentially useful in electron density diagnostics.

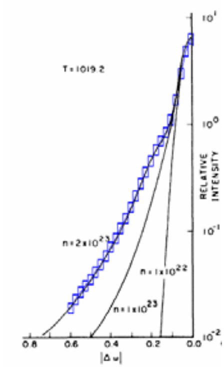

Figure 1 Calculated Ar Ly α line profile at the conditions of Te=1019.2eV, Ne=2×10^{23}cm^{-3} (square). A comparison is made with [8] (solid line)

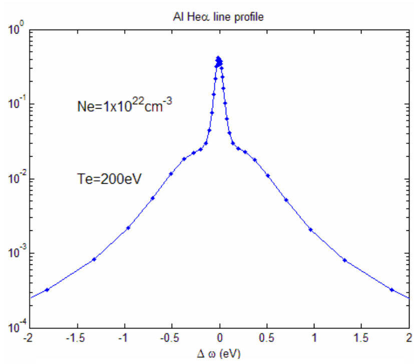

Figure 2 Calculated Al He α line profile at the conditions of Te=200eV, Ne=1×10^{22}cm^{-3}

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Spectra from highly ionized Al plasmas produced by fs-laser pulses

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Short-time x-ray emission from femto-second laser-produced plasmas, which allows the generation of plasmas with high density and high temperature up to a few 100 eV, has been extensively studied in recent years [1-6]. Many efforts have been made to improve electron density with the electron temperature of several hundred eV.

An experiment was carried out on SILEX-I Ti:Sapphire laser facility which delivers 800 nm, 30 fs laser pulse with laser contrast of 10^6 at 1ns before the main pulse. The 30 nm CH-tamped and untamped aluminium targets was selected to study the effect of tamper layer on plasma density. The time-integrated aluminium K-shell emission spectra were measured by a crystal spectrometer. The electron densities and temperatures are determined from the spectra.

The spectra display the He-β, Ly-α, He-α lines together with their adjacent satellites, as shown in Fig 1. The intensity of the X-ray emission from the tamped target is weaker and the Ly-α lines decreased much more, which indicates lower temperature.

The electron densities are calculated from the measured ratio I_{IC} / $I_{He\text{-}\alpha}$. The electron densities (Fig 2) obtained from 30 nm CH-tamped Al targets are higher than that of the untamped Al target at the similar laser intensity about 10^{18} Wcm^{-2}. The result indicates that the tamper can effectively restrain the plasma expansion and improve the electron density. However, the electron density is much lower than the solid density, which can be attributed to the low laser contrast.

The electron temperatures of the plasmas are inferred from the measured x-ray intensity ratios of the Ly-α line to the He-α line. The derived electron temperature shown in Fig 3 shows that the electron temperatures of 30 nm CH-tamped Al targets are lower than that of the untamped Al target.

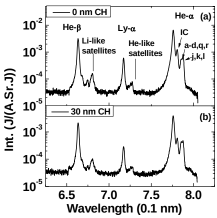

Fig. 1

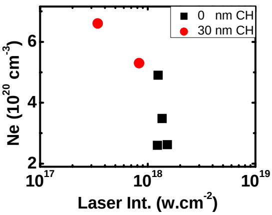

Fig. 2

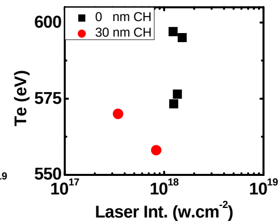

Fig. 3

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RADIATIVE TRANSITION PROBABILITIES FOR NEON-LIKE ARGON IX

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Atomic data for rare gas ions are necessary for diagnostics and modeling of plasmas in various applications. Transition probabilities (A_{ij}) of the successive ions of the Ar homonuclear sequence have been extensively studied in the past because of their frequent presence in industrial and laboratory plasmas but also for their intrinsic interest. In fact, in the Ar ions case there is no d^1 to d^{10} sequence between the *p* and higher shell *s* electrons, thus the Ar IX has the same electron composition with Ne I.

Recent results of our systematic study of rare gas ions [1], concerning A_{ij} evaluation for the main Ar IX multiplets are illustrated. This case is simplier than the Xe IX one [2], because of the aforementioned absence of the *d* electron sequence. The Coulomb approximation (CbA) in *LS* and *jK* coupling was extensively used throughout, with existing experimental energy levels, as shown in the Table 1 example for the two cores of the 3*s* – 3*p* multiplet. Our CbA values of A_{ij} are given in bold in the table, together with available theoretical results, [3] to [5]. A_{ij} obtained with a set of 15 configurations from the CATS code available from the Los Alamos web site [6] are also presented under C15. In general, the spread of the A_{ij} values in Table 1 is rather small.

Core $^2P_{3/2}$

Experimental values			Terms		A_{ij} in 10^7 s^{-1}				
Ei(cm^{-1})	**Ej(cm^{-1})**	**λ(Å)**	**i**	**j**	**CbA**	**C15**	**Ref[3]**	**Ref[4]**	**Ref[5]**
2026545.	2149303.	814.611	3.P2	3.S1	**98.23**	138.54	160.	125.	100.
2026545.	2169931.	697.418	3.P2	3.D3	**229.80**	241.33	218.	235.	180.
2026545.	2170884.	692.813	3.P2	3.D2	**58.66**	106.96		103.	95.
2026545.	2176696.	665.996	3.P2	3.D1	**33.53**	33.29		31.	33.
2026545.	2182177.	642.541	3.P2	3.P2	**136.00**	162.18	114.	152.	158.
2026545.	2192010.	604.357	3.P2	3.P0					
2033118.	2149303.	860.696	3.P1	3.S1	**27.00**	26.36		26.	21.
2033118.	2169931.	730.925	3.P1	3.D3					
2033118.	2170884.	725.869	3.P1	3.D2	**138.25**	122.65		118.	121.
2033118.	2176696.	696.486	3.P1	3.D1	**194.40**	196.31		180.	180.
2033118.	2182177.	670.875	3.P1	3.P2	**65.57**	103.20		97.	89.
2033118.	2192010.	629.358	3.P1	3.P0	**227.00**	255.33	46.	246.	252.

Core $^2P_{1/2}$

Experimental values			Terms		A_{ij} in 10^7 s^{-1}				
Ei(cm^{-1})	**Ej(cm^{-1})**	**λ(Å)**	**i**	**j**	**CbA**	**C15**	**Ref[3]**	**Ref[4]**	**Ref[5]**
2044488.	2189139.	691.319	3.P0	1.P1	**112.80**	123.33	100.	116.	109.
2044488.	2195028.	664.275	3.P0	1.D2					
2044488.	2195887.	660.506	3.P0	3.P1	**90.80**	110.46		102.	108.
2044488.	2265320.	*452.833*	3.P0	1.S0					
2051728.	2189139.	727.744	1.P1	1.P1	**78.00**	102.24	100.	94.	102.
2051728.	2195028.	697.837	1.P1	1.D2	**232.10**	222.01	192.	207.	202.
2051728.	2195887.	693.679	1.P1	3.P1	**105.80**	121.15	104.	112.	104.
2051728.	2265320.	468.182	1.P1	1.S0	**806.20**	707.52	167.	952.	678.

Table 1. Transition Probabilities for Ar IX, 3*s*-3*p* multiplet

More results will be presented and discussed in the Meeting.

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Experiments at NIST towards Hydrogen-like Ions in Circular Rydberg States

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An effort is underway to produce one-electron (H-like) ions in circular Rydberg states, starting from bare nuclei extracted from the NIST electron beam ion trap (EBIT) and cooled in an experimental ion trap designed to facilitate laser spectroscopy. The main goal is to enable tests of quantum electrodynamics (QED) in systems that are potentially useful in improving the determination of fundamental constants that will play an important role in future redefinitions of the International System of Units (SI). Recent works[1,2] showed that, in some cases, the accuracy of predicted energy levels in Rydberg states of hydrogen-like ions is comparable to the high precision of mode-locked-laser frequency combs; the reason is that nuclear complexities and associated vacuum-polarization corrections are completely negligible for high angular momentum states. We report on the initial progress in developing an experimental apparatus, and discuss the possibility of using this experiment for various applications.

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THE BREIT INTERACTION IN DIELECTRONIC RECOMBINATION OF HELIUM-LIKE AND LITHIUM-LIKE HIGHLY CHARGED IONS

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Using the MCDF method and our newly developed codes, we study the affect of Generalized Breit Interactions (GBI) in dielectronic recombination (DR) process of Helium-, Lithium- and Beryllium-like ions of C(Z=6), Ne(Z=10), Ar(Z=18), Ni(Z=28), I(Z=53), Ho(Z=67), Au(Z=79) and Bi(Z=83) atoms. Among these, our calculated DR cross sections of I agree well with the recent experimental results[1]. This manifests the accuracy of the codes. In this work the dependence of the contributions of the GBI to the DR cross sections of different resonance states on the effect Z is studied and concluded, which will be useful for further experimental and theoretical investigations.

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The study of the energy of the $(2s_{1/2}2p_{1/2}^{2}2p_{3/2}^{2})_{5/2}$-$(2s^{2}2p_{1/2}^{2}2p_{3/2})_{3/2}$ x-ray transition in the N-like $^{208}Pb^{75+}$

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The $(2s_{1/2}2p_{1/2}^{2}2p_{3/2}^{2})_{5/2}$-$(2s^{2}2p_{1/2}^{2}2p_{3/2})_{3/2}$ x-ray transition in the N-like $^{208}Pb^{75+}$ was also observed [1] using the Tokyo electron beam ion trap at the University of Electro-Communications, while we measured the Li-like $^{208}Pb^{79+}$[2]. The Pb spectral line energies were measured relative to the Lyman-α lines of the H-like *S* and the 1s4p $^{1}P_{1}$-$1s^{2}\ ^{1}S_{0}$ transition in the He-like *P*. In present work, the line from the N-like lead ions is analyzed and the transition energy is determined to be 2662.98±0.12 eV. We also calculate the transition energies of the $(2s_{1/2}2p_{1/2}^{2}2p_{3/2}^{2})_{5/2}$-$(2s^{2}2p_{1/2}^{2}2p_{3/2})_{3/2}$ lines in N-like ions from Sn (Z=50) through U (Z=92) with the General relativistic atomic structure package Vanderbilt University (GRASPVU) package which based on the multiconfiguration Dirac-Fock (MCDF) method [3]. And the calculations (also other calculations) are compared with the available experimental results.

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High-resolution X-ray spectra of charge exchange measured with the LLNL EBIT Calorimeter Spectrometer

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We review recent measurements of X-ray spectra from charge exchange using a calorimeter spectrometer at the LLNL Electron Beam Ion Trap. The high resolution of this spectrometer allows us to use previously inaccessible spectral diagnostics. Hardness ratios measured in some K-shell CX spectra show unexpected deviations from previously observed trends. We measured triplet-to-singlet ratios in He-like species and find deviations from the statistical capture ratio in some cases. We measured L-shell CX spectra of Li-like to Ne-like S, and show that they are diagnostic of the neutral species in the reaction.