3 - 12 Progress of Atomic & Molecular Spectroscopy Group in 2016

Yu Deyang and Cai Xiaohong

In 2016, the Atomic & Molecular Spectroscopy Group made progress on spectroscopy study in ion-atom collisions, data analysis of hollow atoms, and preparation of new experiments.

X-ray spectra of K-shell hollow krypton atoms produced in single collisions with 52 – 197 MeV/u Xe^{54+} ions, measured at the CSRe internal, are analyzed. Energy shifts of the $K\alpha^S_{1,2}$, and $K\beta^S_{1,3}$ transitions are obtained. Thus, the average number of the spectator L-vacancies presented during the X-ray emission is deduced. From the relative intensities of the $K\alpha^S_{1,2}$ and transitions, the ratio of K-shell hollow krypton to singly K-shell ionized atoms is determined to be 14%~24%. In the collisions, the K-vacancies are mainly created by the direct ionization which cannot be calculated within the perturbation descriptions. The experimental results are compared with a relativistic coupled channel calculation performed within the independent particle approximation. The target thickness as well as the integrated luminosity for nitrogen are determined from the beam energy loss in the CSRe[1]. The feasibility of the energy-loss method is confirmed, which may have an important impact on future internal target experiments at HIRFL-CSR.

The X-ray emissions are measured by the interaction of 1 500 ~ 500 keV Xe^{q+} (q = 12, 15, 17, 19, 21, 23, 26 and 29) ions with Zn target[2]. When $q < 29$, the L characteristic X-rays from Xe^{q+} ions and a broad M-shell molecular orbital X-ray band from the transient quasi-molecular levels are observed. It is found that their yields quickly increase with different rates as the incident energy increases. Besides, the widths of the broad MO X-ray bands are about 0.9~1.32 keV over the energy range studied and are proportional to $v^{1/2}$ (v is the projectile velocity). Most remarkably, when the projectile charge state is 29, the broad X-ray band separates into several narrow discrete spectra, which was never observed before. The extreme ultraviolet spectra of highly charged copper ions are measured[3]. 82 lines from Cu XV to Cu XXIII in the 160−360 Å wavelength range are identified as the transitions of the $2p^23p$–$2p^23d$, $2p^43s$–$2p^43p$, $2p^43p$–$2p^43d$, $2p^53s$–$2p^53p$, $2p^53s$–$2p^53p$, $3s3p$–$3p^2$, $3s^23p^3$-$3s3p^4$, $3s^23p$–$3s3p^2$, $3s^23p^3$–$3s3p^4$, and $2p^4$ $(^3P)3s$–$2p^4(^3P)3p$, in which 40 spectral lines have been newly and accurately measured.

A Fast Recoil-Ion Momentum Spectroscopy (FRIMS) with a new layout is designed, in order to explore the dynamics of fast recoil ions. The recoiled ions with up to 2 keV energies are expected to be collected. It is expected to be able to eliminate the huge amount of interference events produced in distant collisions, in which the recoiled ions are with low energies.

The positron-electron annihilation study in strong coulomb field of highly charged ions is proposed at the future heavy-ion storage ring, the High Intensity heavy ion Accelerator Facility (HIAF). The single-quanta annihilation (SQA), the elastic scattering and the bremsstrahlung of electrons and positrons, the nuclear excitation by positron-electron annihilation, and the transfer excitation process by positron-electron annihilation are considered. A small positron storage ring (with a circumference of about 10~20 m) is proposed. It will provide a positron beam of about 100 mA at 0.1~3 MeV. Considering the rotation frequency of the positrons is about 10^7 Hz, and the storage lifetime of the positrons is about 10^2 ~10^3 seconds, the supplementary positron beam is about 10~100 pA. The cross-section of SQA in this region is around 0.1~1 barns[4], and the DQA channel is about 10 ~ 100 times stronger. When 10^{11} ions are storied in the HIAF-SRing at 500 MeV/u, the luminosity of the crossed-beam is estimated to be around 3 ~ 5×10^{25} $cm^{-2}s^{-1}$, if the diameter of the both beams are 1 mm. Thus, the event rate of SQA is expected to achieve 3~50 s^{-1} at the proposed conditions.

The partnership of theoretical and experimental atomic physics are continued between our group and the Department of Physics, St. Petersburg State University. Dr. Y.S. Kozhedub worked in our group and contributed on interpretation of our experimental results with the relativistic coupled-channel calculations.

References

[1] C. Shao, D. Yu, R. Lu, et al., Chin. Phys. C, 40(2016)117002.
[2] Y. Guo, Z. Yang, B. Hu, et al., Scientific Reports, 6(2016)30644.
[3] Z. H. Yang, S. B. Du, M. G. Su, et al., Astro. J., 152(2016)135.
[4] J. C. Palathingal, P. Asoka-Kumar, K. G. Lynn, et al., Phys. Rev. Lett., 67(1991)3491.