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QED and electron collisions in the super strong fields of K-shell actinide ions

P. Beiersdorfer

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Principle Investigator: ....Peter Beiersdorfer
Division V
Phone...................................3-3985
Email… ....beiersdorfer@llnl.gov
Mail Station L-260

Co-Investigators:................Elmar Träbert (V Division)
....Hui Chen (V Division)
....Daniel Thorn (V Division)
....Mau Chen (V Division)
....Kennedy Reed (V Division)
……………………………...Bret Beck (N Division)
……………………………...John Becker (N Division)
....Stephane Terracol (I Division)
....Kwok-Tsang Cheng (A Division)
....Richard Kelley (Goddard Space Flight Center)
....Caroline Stahle (Goddard Space Flight Center)
....Kevin Boyce (Goddard Space Flight Center)
....Greg Brown (Goddard Space Flight Center)
....Scott Porter (Goddard Space Flight Center)
....Jonathan Sapirstein (Notre Dame University)

Objective: Atomic physics of high-Z, heavy ions is very different from that encountered in low-Z or medium-Z ions. The reason is the ultra strong nuclear field found only in the heaviest ions. The highest-Z atomic systems available to physical investigation, the actinides, therefore, offer rich new physics that cannot be studied any other way. This ranges from new dominating forces in electron-ion collisions to tests of fundamental theories. A measurement of the two-loop Lamb shift in uranium is by many considered to be the 'holy grail' of high-field QED tests of atomic systems. Such measurements have been attempted at heavy-ion accelerator facilities but have yet to succeed because of the difficulty to make measurements with the required accuracy. Also, electron collisions behave very differently in such tightly bound systems. The magnetic interaction between the ion and the incoming free electron (the so-called generalized Breit interaction) is essentially non-existent in collisions involving low and medium-Z ions. This interaction is therefore missing in essentially all electron collision codes. But in heavy, highly charged ions like uranium, the generalized Breit interaction readily is the dominant force, changing electron collision cross sections by a factor of two. This has never been experimentally observed. In fact, no K-shell emission spectrum of any heavy high-Z ion higher than krypton (Z=36) has ever been recorded from a collisional source. By studying the heaviest actinides such fundamental science can be extended to regimes where the highest precision tests can be made.

Accomplishments: We successfully carried out our project. An overview is given below, and details can be found in references cited in the following.

(1) We have resumed operation of the world's only source of stationary highly charged ions SuperEBIT [1]. This source is located at LLNL.

(2) We have developed an injection system for introducing actinides into SuperEBIT. For this we implemented a 2J laser injection system that now routinely operates on SuperEBIT.

(3) We have implemented a new high-energy microcalorimeter on SuperEBIT for x-ray and gamma ray measurements [2]. This calorimeter was built by our collaborators at NASA Goddard Space Flight Center and was delivered to us in October 2003. It has been used to measure the gamma rays produced by U-233 decaying into 229-Th, as well as from highly stripped U ions.

(4) We have studied electron-ion collisions in the fully relativistic regime and tested magnetic sublevel calculations. [3,4]

(5) We have made a series of made measurements that progressively improved the accuracy of our QED measurements [4-9]. This series culminated in the best-ever QED measurement in highly charged uranium ions, which enabled us for the first time to isolate the two-loop QED contributions [10,11].

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