EBIT Group

Group Leader

Professor Josh Silver

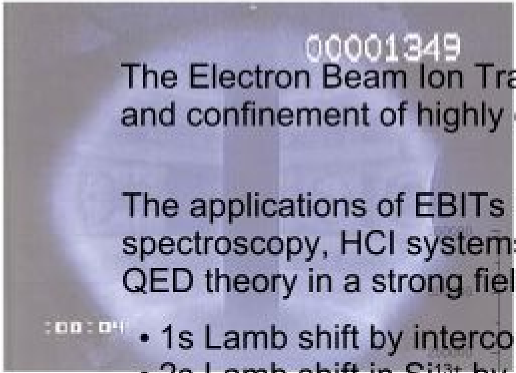
Collaborators

National Physical Laboratory, Teddington
Japan Science & Technology Corporation, Tokyo
Florida State University, Tallahassee
UK Atomic Energy Authority, Culham

Graduate Students

Mike Tarbutt
Dave Crosby
Kristina Gaarde-Widdowson

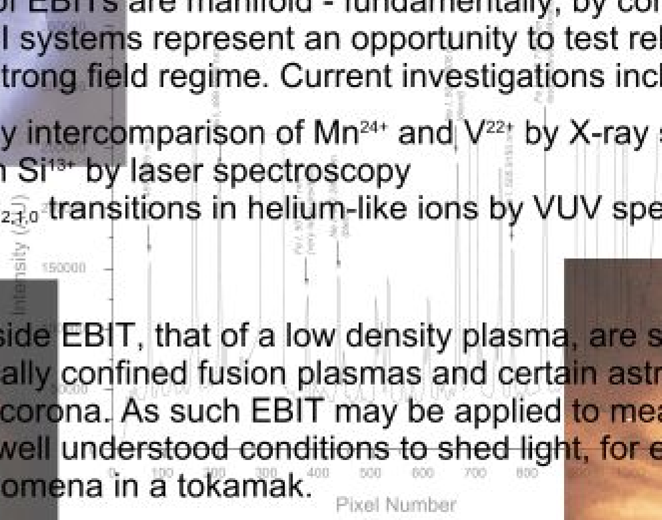
Electron Beam Ion Trap - EBIT

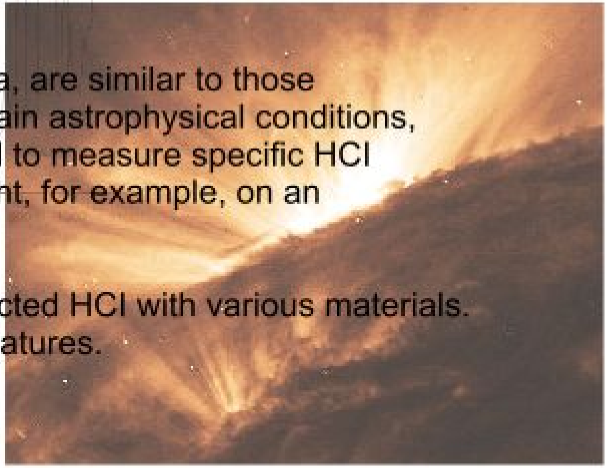


The Electron Beam Ion Trap represents a compact laboratory source for the production and confinement of highly charged ions (HCI) under highly controlled conditions.

The applications of EBITs are manifold - fundamentally, by conducting precision spectroscopy, HCI systems represent an opportunity to test relativistic and QED theory in a strong field regime. Current investigations include:

- 1s Lamb shift by intercomparison of Mn^{24+} and V^{22+} by X-ray spectroscopy
- 2s Lamb shift in Si^{13+} by laser spectroscopy
- $1s2s\,^3S_1$-$1s2p\,^3P_{2,1,0}$ transitions in helium-like ions by VUV spectroscopy





The conditions inside EBIT, that of a low density plasma, are similar to those found in magnetically confined fusion plasmas and certain astrophysical conditions, such as the solar corona. As such EBIT may be applied to measure specific HCI processes within well understood conditions to shed light, for example, on an unexplained phenomena in a tokamak.

A relatively new application of EBITs is to interact extracted HCI with various materials. Such interactions lead to the formation of nano-scale features.

Lamb shift measurements

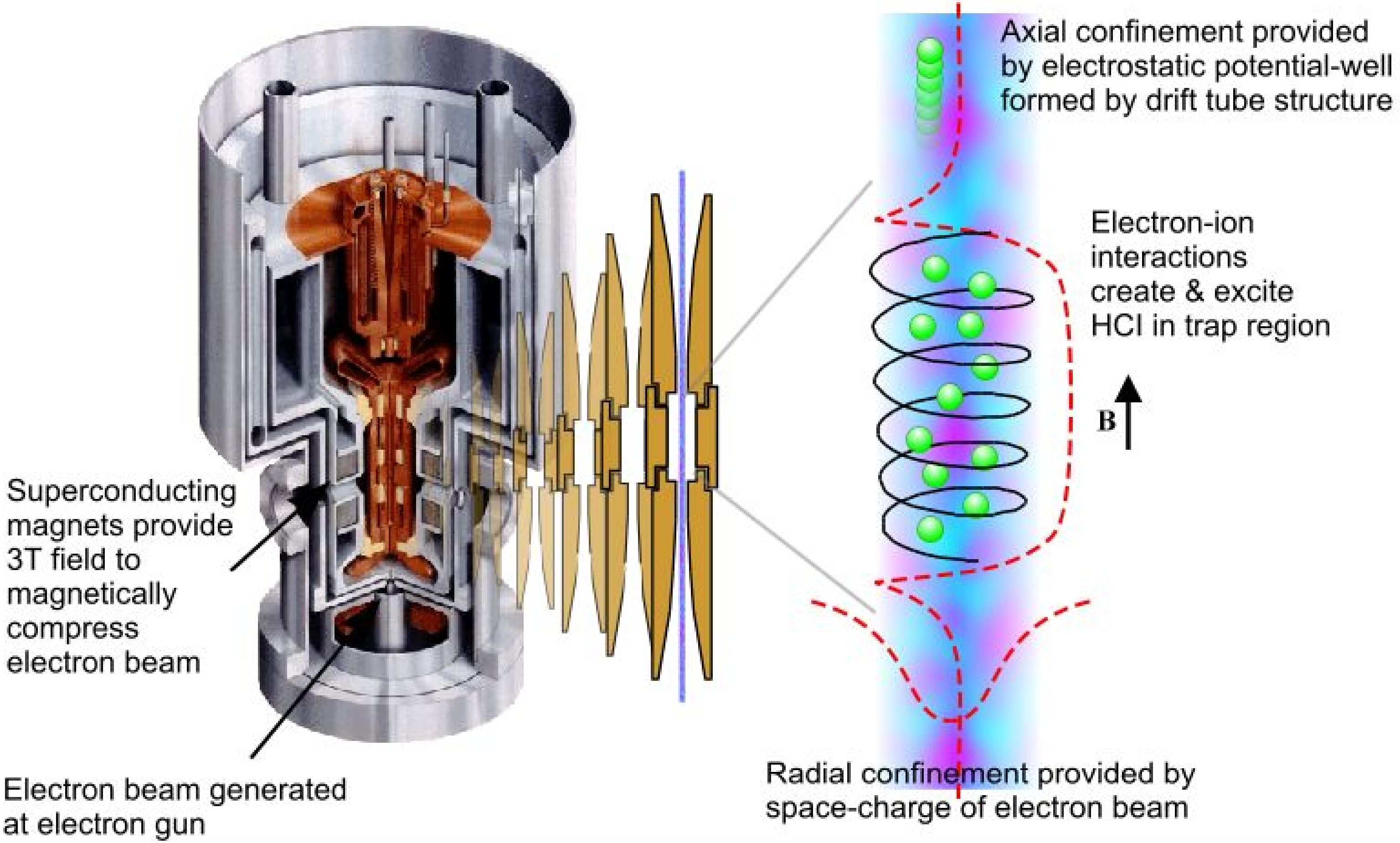
Our starting point is the Dirac equation, leading to the energy eigenvalues for the hydrogenic system (k=j+1/2):

$$E(n,k,Z)=\left(1+\left[\frac{Z\alpha}{n-k+\left(k^2-Z^2\alpha^2\right)^{1/2}}\right]^2\right)^{-1/2} m_e c^2$$

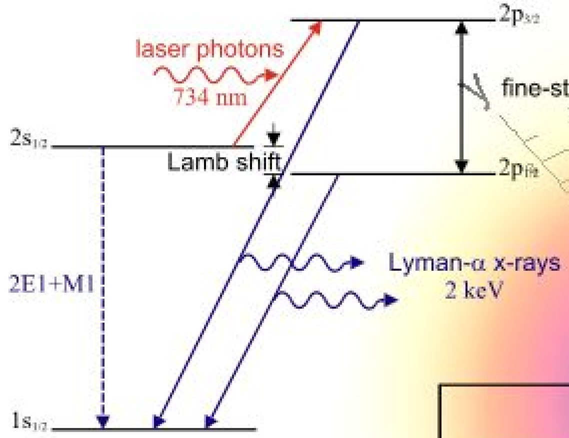
The gross energy structure therefore varies as Z^2.
QED effects result in small shifts from these energy levels which scale principally as Z^4. Thus, one may construct a more precise test of QED from a less accurate measurement by moving to higher-Z hydrogenic systems.

Element	1s Lamb shift (eV)	Theoretical uncertainty (eV)	Experimental Uncertainty (eV)
Ar	0.9383	7.4×10^{-4}	0.016
Ni	5.096	3.7×10^{-3}	0.10
Au	205.3	0.37	7.9
U	458.5	2.7	15

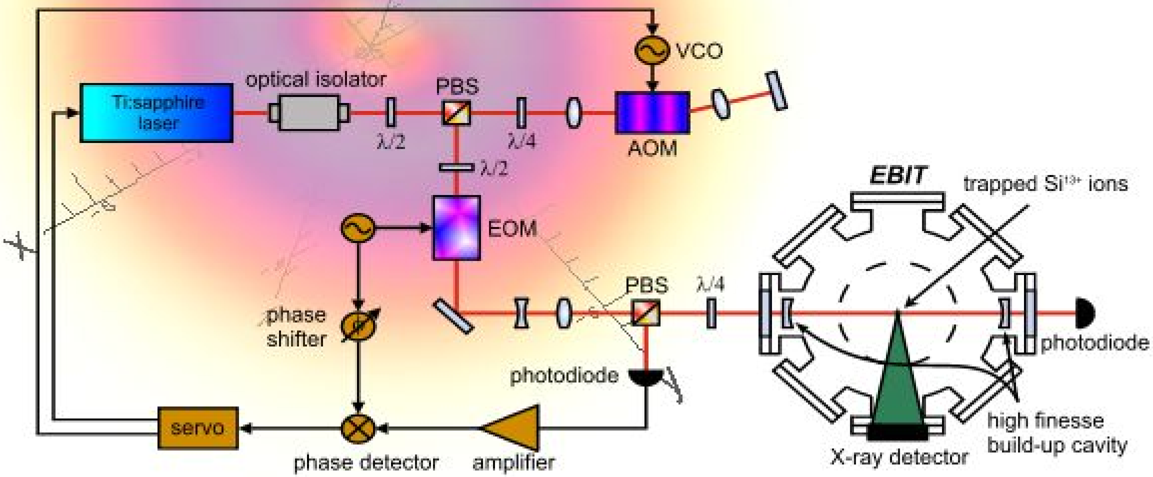
Production of Highly Charged Ions



Laser Spectroscopy of Hydrogenic Silicon

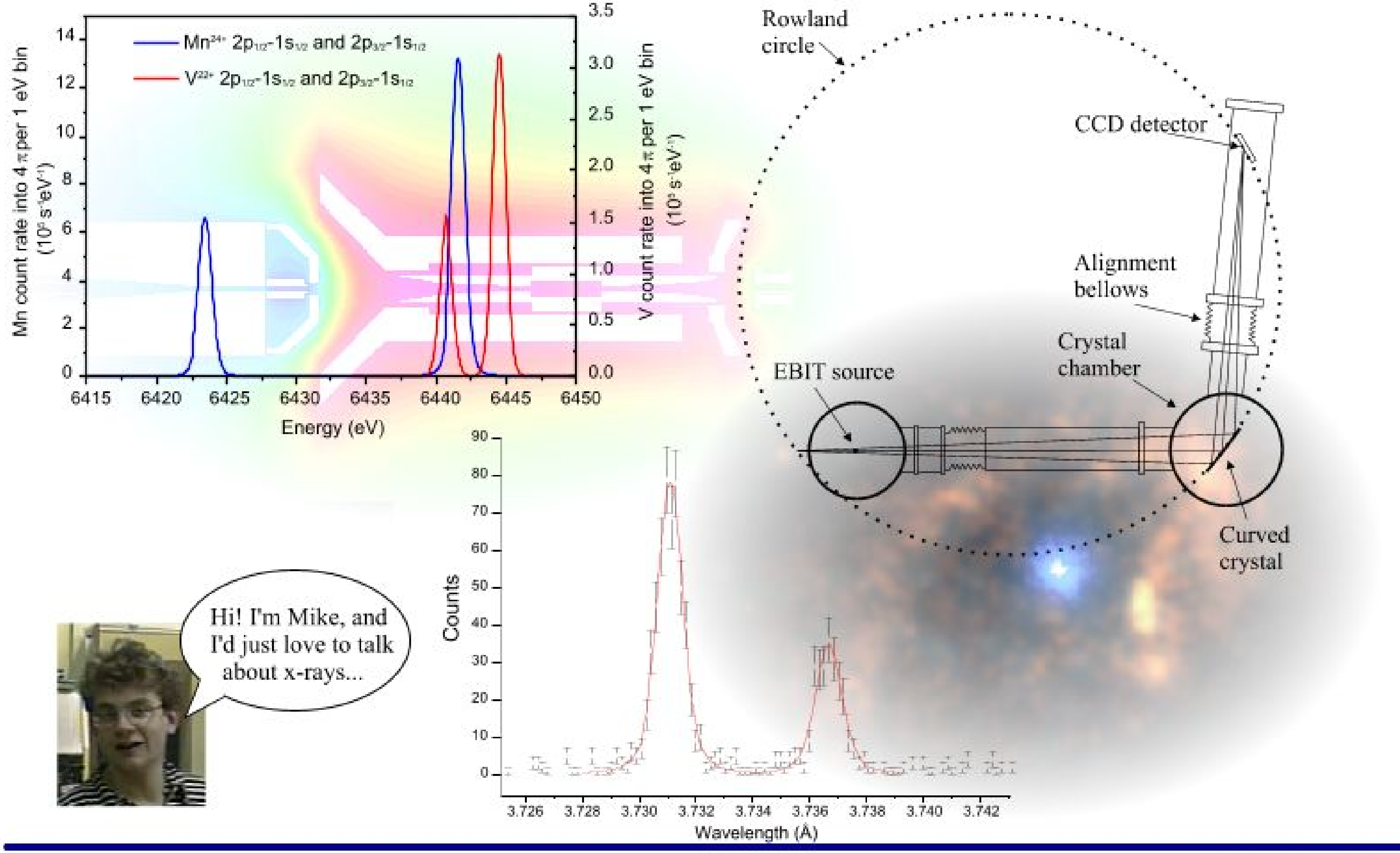


Partial term diagram of the Si^{13+} ion, showing the transition which would be induced in an n=2 laser resonance experiment.

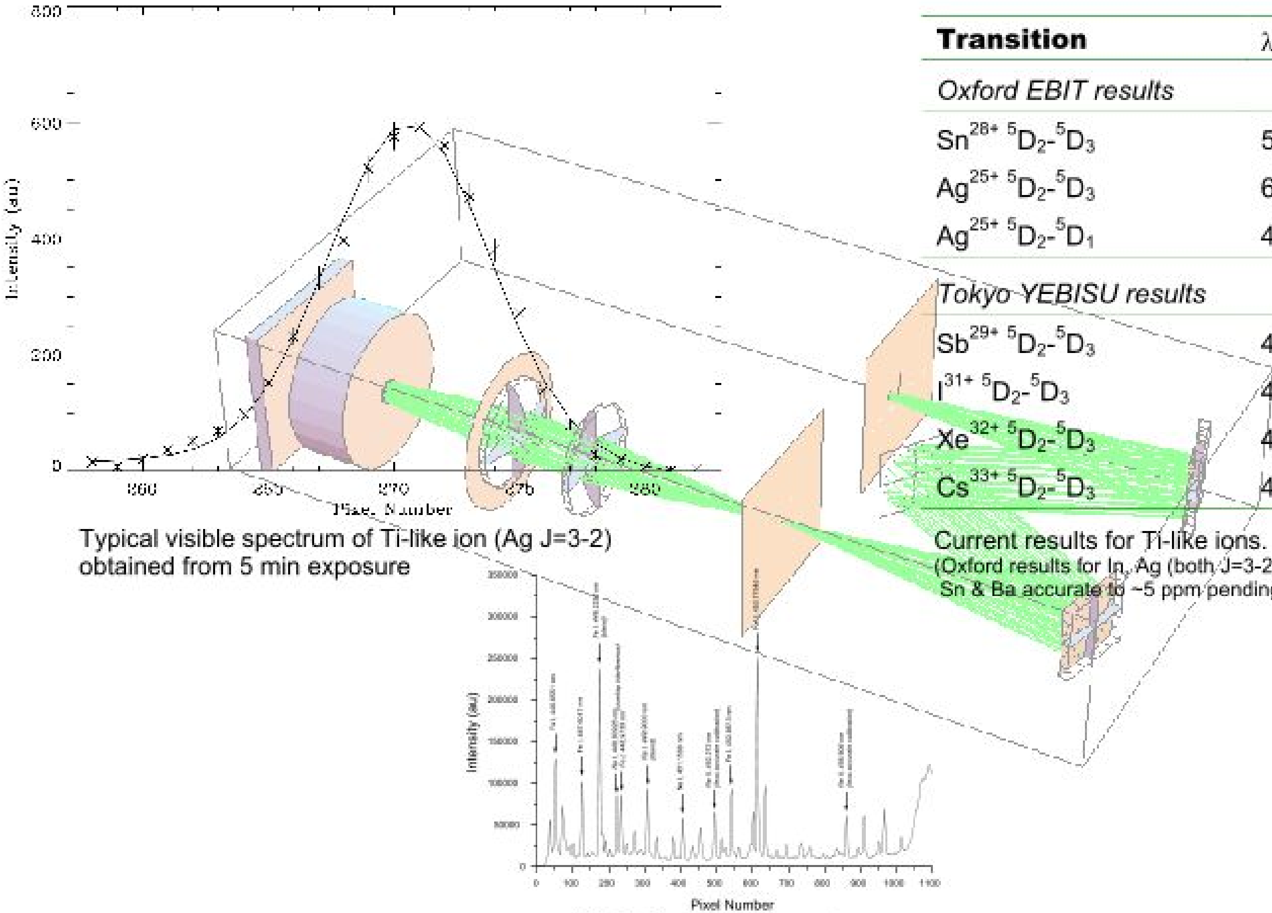


Schematic diagram for the laser system for an n=2 resonance experiment on Si.

X-ray Spectroscopy on EBIT



Visible Spectroscopy of Ti-like Ions



Typical visible spectrum of Ti-like ion (Ag J=3-2) obtained from 5 min exposure

Transition	λ (nm) in air
Oxford EBIT results	
$Sn^{28+}\ ^5D_2$-$^5D_3$	503 (provisional)
$Ag^{25+}\ ^5D_2$-$^5D_3$	631.481(5)
$Ag^{25+}\ ^5D_2$-$^5D_1$	449.435(5)
Tokyo YEBISU results	
$Sb^{29+}\ ^5D_2$-$^5D_3$	470.24(3)
$I^{31+}\ ^5D_2$-$^5D_3$	430.33(8)
$Xe^{32+}\ ^5D_2$-$^5D_3$	413.88(7)
$Cs^{33+}\ ^5D_2$-$^5D_3$	402.14(11)

Current results for Ti-like ions.
(Oxford results for In, Ag (both J=3-2 & J=2-1), Sn & Ba accurate to ~5 ppm pending)

Typical calibration spectrum