Detection of Circular Rydberg states in lifetime measurements

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Synopsis The possible reason for the non detection of the circular Rydberg state during the earlier life time measurements is discussed. It is concluded that for populating and detecting a CRS the energy of the ion, Plasmon frequency of the target, position of measurement and step size between two consecutive steps near the last cascade position plays an important role.

Circular Rydberg states (CRS) have much longer radiative lifetimes than low orbital angular momentum states and are therefore candidates for high-fidelity gate operations [1] and determining the relativistic and the quantum electrodynamic effects, the fundamental constants such as the nuclear mass. The electron in CRS decays through the yrast chain following the electric dipole selection rules. The 2p state, the last candidate of the cascade that leads to emission of Ly-α emission takes place in the H-like heavy ions, is populated very late. Each delayed Ly-α transition originating from certain CRS appears as a hump at a particular delay time. Recently these states has been observed in lifetime measurement [2] in a beam-foil experiment which are supported theoretically [3].

For the formation of particular Rydberg state with principal quantum number *n* of an ion with core charge Z; it is possible to predict the ionic velocity v>vc [4] such that vc=wp*(1.43*n*+ 0.64k)^2/Z where wp is the Plasmon frequency of the solid and n and k are the principal and angular quantum numbers. This estimation of the velocity is plotted in fig.1 suggesting that a much higher energy is required to populate low *l* states compared to CRS. We have examined some earlier lifetime measurement [2,5–8] to understand the non detection of CRS. Table 1 represents some experimental data with the possible CRS populated and the measurements taken during the experiments. It is clear from the table that in most of the experiments the data point was not taken up to the desired cascade position or the step size of the measurements was too large to observe the delayed decay. The crude extract of the analysis realizes that the combination of three parameters play a key role for the detection of CRS through lifetime measurement. First is the velocity of the incident particle and Plasmon frequency for populating a particular (*n,l*); second is the measurement position should be around the delay interval of last cascade. Another is the precise measurement with small intervals near the last cascade delay interval with step size of the measurement less than or equal to the lifetime of the last candidate of the chain i.e. 2p or 3p, for the detection of CRS.

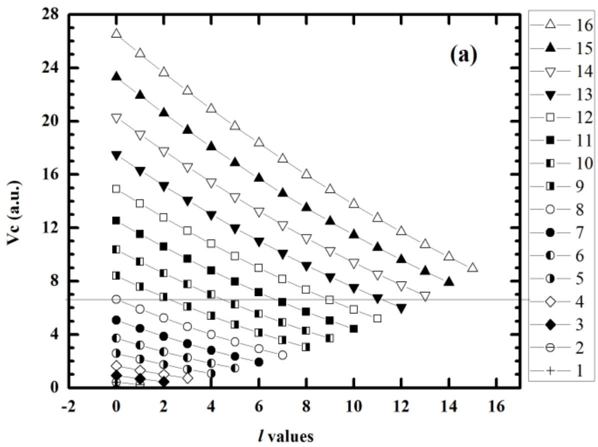

Figure 1. Graphical representation of velocity required to populate a (*n,l*) level for 125MeV S ions. Horizontal line represents velocity corresponding to 125MeV and the states crossing the line are the possible excitations.

Energy,Species	Nc	d (mm)	M(mm)	Comment
125MeV S [5]	14	3.45	2,20	Δd large
2530 MeV Kr, H-like Kr [6]	35	17 ns	0.2ns	Delay not sufficient
700 MeV Kr He-like Kr [7]	25	108.78	10	
163 MeV Ni He-like Ni [8]	17	18.17	10.5	
164 MeV Fe H-like Fe [2]	17	21.56	36	Observed

Table1. Experimental lifetime data with the measured and possible CRS positions. (Nc is the possible principle quantum number of CRS populated d is corresponding delay, Δd is the step size between two consecutive measurements, and M is experimental measured points)

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