

## Line Profile Property of Autoionizing States

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**Synopsis** This work studied the interference effect between dielectronic recombination and radiative recombination of highly charged tungsten ions. Our result shows a coexistence of Fano and Lorentzian line profile of autoionizing states.

Photon absorption spectroscopy is a powerful tool for uncovering the structure of atoms, molecules and solids. Symmetric Lorentzian and asymmetric Fano line shapes are fundamental spectroscopic signatures related to the structural and dynamical properties. Recently Ott *et al.* published a paper in Science[1], where they introduced a temporal-phase formalism, which enables mapping the Fano asymmetry parameter  $q$  to a phase  $\phi$  of the time-dependent dipole response function, and presented experimental results of laser-transforming Fano profile into Lorentzian line shape after attosecond-pulsed excitation of autoionizing states in helium. This is a very important step forward of quantum phase control and would allow a general interpretation of effects such as electromagnetically induced transparency (EIT), lasing without inversion, and would have further application in amplification of extreme-ultraviolet light, or even x rays that resonantly interacting with atoms.

In this presentation, we show experimentally that an autoionizing state can have both Fano and Lorentzian behavior naturally, depending on the process involved. This study utilized the inverse process of photon absorption ionization, electron ion recombinations, including both resonant and non-resonant process. Dielectronic recombination (DR), as the main process of the resonant recombination, is considered as a two-step or indirect process. Whereas, the non-resonant recombination, also named as radiative recombination (RR), is considered as a direct process. DR and RR will interfere with each other when they have the same initial and final state, and the Fano profile is then expected, especially in highly charged high-Z elements, see work from LLNL[2], Heidelberg EBIT[3] and Tokyo EBIT[4].

In order to study the variation of the Fano profile

(consequently the Fano parameter) of a given autoionizing state, we selected the DR resonances which go through an intermediate state with decay channels to both the final states with no excited electrons and the final states with two excited electrons. In the former case, both dielectronic and radiative recombination will occur, interference and hence the asymmetric line profile should be expected. In the latter case, only dielectronic recombination (so no interference) will take place, because radiative recombination of an electron with an ion in the ground state can not end up in a final state with more than one electron in excited orbit.

The experiment was done at the Shanghai electron beam ion trap (Shanghai EBIT)[5]. During the experiment,  $W(CO)_6$  was continuously injected into the EBIT, and the electron beam energy was scanned through the resonant energies of  $KL_3L_3$  DR of Be-like up to O-like W ions, while the X ray photons from the recombination were detected by a HPGe detector.

Our result shows that an autoionizing state can have dual Fano and Lorentzian line profile properties naturally, depending on the process involved. Our result implies that excitation of the state through different paths, for example one photon versus multi-photon excitation, or even one step versus multi-step excitation, can lead to different Fano profiles for the same resonant state.

## References

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