Entanglement of Orbital Angular Momentum in Non-Sequential Double Ionization

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Entanglement provides a computational resource, and the possibility of entanglement enhanced imaging processes [1]. Attosecond physics has led to ultrafast imaging procedures on the scale of attoseconds (10^{-18}s). However, the potential for entanglement to optimize or improve attosecond imaging is relatively unexplored. There is growing interest in entanglement in attoscience, with a focus on ion–electron entanglement. These studies often involve the calculation of a continuous variable density matrix and entanglement measures, which are challenging to compute and interpret.

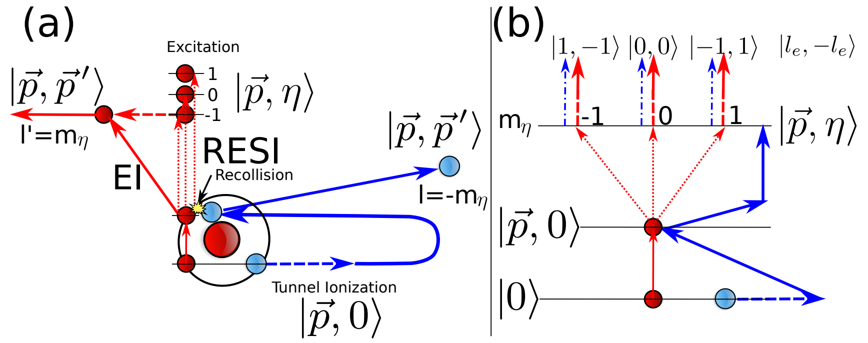

Figure 1: (a) NSDI process. Ionization via laser field is depicted by a dashed line and excitation in the singly charged ion is denoted by dotted lines. (b) The final OAM states ($|l_e,-l_e\rangle$) in an entangled superposition; -1, 0, 1 refer to the values of m_η of the intermediate excited state, $|\mathbf{p},\eta\rangle$. Taken from [2].

Recent progress in the measurement of electron vortex states, carrying orbital angular momentum (OAM) [3], offers a solution to the above problems. We exploit the OAM—inherent to all free particles, to clearly demonstrate the manifestation of entanglement in non-sequential double ionization (NSDI) [2], a highly correlated two-electron ionization process, see Figure 1. Through conservation laws [4] and the superposition of excited states, we demonstrate that the OAM in NSDI is entangled. Using the OAM allows for a simple analysis, that enables identification of targets that maximize the entanglement and a reduction in the number of measurements required to detect the entanglement. Furthermore, the entanglement survives averaging over the focal volume. The use of OAM in attosecond processes provides a new avenue, to further the aim of imaging and controlling matter on ultrafast times scales. Furthermore, photoelectron-OAM entanglement demonstrates the fundamental non-classicality of NSDI.

References

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