Quantum Selection Rules for Atomic Transitions with Twisted Light: Theory vs Experiment

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Twisted photons, or photons with additional angular momentum along their propagation direction were predicted to defy conventional quantum selection rules for photo-absorption by atoms [1], with the relative strengths of quantum transitions that are strongly dependent on atom’s position with respect to the optical vortex center.

Recently, in collaboration with QUANTUM center in University of Mainz, we were able to verify these selection rules experimentally [2]. Over 60 transition amplitudes (with two of them shown in Figure 1) were measured for $^{40}$Ca$^+$ ions in Paul trap with sub-wavelength position resolution for different topological charges of incoming light and were found to be in good agreement with theoretical predictions.

This study provides a tool for controlling quantum transitions with twisted photons on the targets with sub-wavelength dimensions, such as atoms, quantum dots, or nanostructures.

Figure 1. Quantum transition amplitudes (in arbitrary units) for 729nm $^4S_{1/2} \rightarrow ^3D_{5/2}$ transitions in $^{40}$Ca$^+$ ions for the right-circularly polarized twisted light with total angular momentum projection=$2\hbar$ as a function of the ion’s distance $b$ to the optical vortex center. Theory calculations are for Bessel mode (blue dashed and green long-dashed) and Bessel-Gauss mode (black solid and black dotted). Shown are transitions with into different Zeeman sublevels: $\Delta m=1$ (plane-wave-allowed) and $\Delta m=2$ (plane-wave-forbidden).

References