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Photoexcitations of many-electron atoms and ions by twisted light

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Synopsis The photoexcitation of (multi-electron) atoms and ions by twisted light has been explored within the framework of the density matrix theory and Dirac's relativistic equation. It is shown that the population of the excited atoms and, hence, their fluorescence emission are sensitive with regard to the transverse linear momentum and the (projection of the) total angular momentum of the incident light.

Research on optical vortices, popularly known also as *twisted* light, has attracted much interest during the past two decades. These vortex beams, although freely propagating in space, can be understood as beams of photons (and similar for electrons), which individually carry a well defined orbital angular momentum (OAM) along their propagation direction. Indeed, the OAM of light is closely related to the spatial distribution of the electromagnetic field. — Today such optical vortex beams are found in various applications, from the manipulation of microparticles, to imaging and microscopy.

Although the spin and orbital angular momentum of twisted light and its interaction with matter has been explored in some detail, little attention has been paid so far to the atomic excitation and ionization processes in such light fields. A question of particular interest concerns the selection rules and how the bound-bound and bound-free transitions are modified by the OAM of the light. To address these questions, we have investigated the interaction of complex atoms with Bessel beams [1, 2]. Expressions were especially derived for the density matrix of the excited atomic states and the angular distribution as well as the polarization of the subsequent fluorescence radiation [3]. Apart from *head-on* collisions of atoms with twisted photons, we also considered the more realistic scenario in which a photon beam, prepared for instance as a single beam or the coherent superposition of two Bessel states with different projections m_1 and m_2 of the total angular momentum (TAM), collides with a macroscopic atomic target.

In Ref. [3], detailed calculations have been performed for the $3s\ ^2S_{1/2} \to 3p\ ^2P_{3/2}$ excitation of neutral sodium by a coherent superposition of two Bessel beams. For this photoexcitation, Fig. 1 displays the alignment parameters A_{2q}, $q = -2,..2$ of the $^2P_{3/2}$ state, i.e. the relative population of the magnetic substates, as function of the *opening* angle of the beam, $\theta_k = \arctan(\kappa/k_z)$, and which defines the ratio of the transverse κ and longitudinal k_z linear momenta of twisted incident beams. As seen from this figure, the individual population of the substates occurs to be sensitive w.r.t. to both, the TAM of the beam and their opening angle.

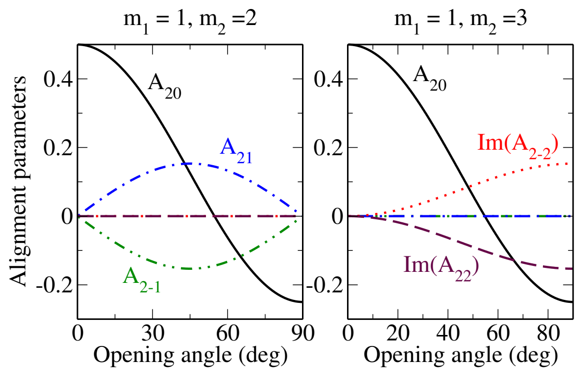

Figure 1. Alignment parameters A_{2q} of the $3p\ ^2P_{3/2}$ level of neutral sodium following the absorption of twisted light. The calculations were performed here for a coherent superposition of two Bessel beams with different projections m_1 and m_2.

We therefore hope that future measurements on the (angular and polarization) properties of the 'yellow' sodium line will provide further information about the interaction of the twisted light with atoms.

References

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