6.5 Experimental Observation of the Rotation Properties of Atomic Multipoles

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The nonlinear interaction of optical radiation with resonant media can excite long lived anisotropic states in atomic vapours. The conventional description of these states uses an expansion in a basis of multipole moments, which are represented by irreducible tensor operators. Up to now, most investigations of these multipole moments were concerned with their excitation and observation, not with more specific information about the multipoles, like their orientation in space. In contrast to earlier work, we have developed methods that allow the excitation of multipole moments in specific, experimentally controllable spatial orientations. Complementary optical methods allow the observation of the individual multipole moments of arbitrary order and a direct measurement of their spatial orientation.

We excite the multipole moments by optical pumping in a transverse magnetic field. Using two-dimensional spectroscopy, we can observe multipole moments of arbitrary order. With an optical modulation technique, we can change the spatial orientation of the multipoles. By definition, rotation of a multipole of order q by an angle ϕ changes the phase of any signal component due to this multipole by a phase factor $e^{iq\phi}$. This phase factor is therefore a direct measure of the orientation of the corresponding multipole moment. We have measured this phase-dependence for optically excited multipoles in atomic Na.