Single-pulse large momentum transfer with double Raman diffraction

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We present a theoretical analysis of Raman beamsplitters in a retroreflective geometry. Our focus lies on large momentum transfer (LMT) with a single light pulse in a double diffraction scheme and on the comparison to already existing configurations with Bragg diffraction .

LMT pulses are a topic of current interest since large interferometric areas lead to an increased sensitivity. LMT is often realized for Bragg and Raman diffraction by a multiple pulse sequence [1,2]. This method is intrinsically limited as each pulse imprints additional imperfections.
The double Raman diffraction scheme allows a momentum-space splitting of $4\hbar k$ between both paths by a single pulse. Sequential pulses then allow LMT [3]. We explore whether higher-order momentum transfer can be realized with only one pulse. Thus, the area is increased by two effects: double diffraction and higher-order diffraction.
We present the results of our numerical study which investigates fidelity, diffraction efficiency and the influence of Stark shifts. Moreover, we compare them to recent results for already existing configurations using Bragg diffraction [4,5]. We show that light shifts in double diffraction are symmetric and the sensitivity with respect to the laser phase is lower in Raman diffraction than in Bragg diffraction.

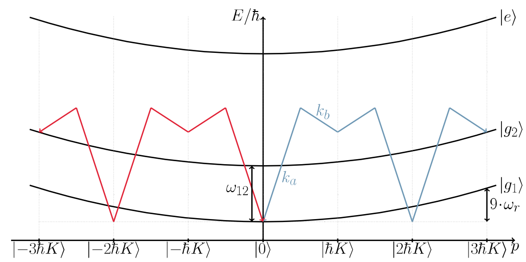

Figure 1: Energy-momentum diagram for a third-order double Raman diffraction process. The total energy $E/\hbar$ is plotted as a function of momentum p. The internal hyperfine ground states of the atom are denoted by $|g_2\rangle$ and $|g_1\rangle$, separated by an energy difference $\hbar\omega_{21}$, whereas $|e\rangle$ corresponds to an excited state. Two laser pairs induce transitions between $|0, g_1\rangle$ and $|\pm 3\hbar K, g_2\rangle$ (red and blue line), with $K=k_a+k_b$, while populating the states $|\pm\hbar K, g_2\rangle$ and $|\pm 2\hbar K, g_1\rangle$ only virtually.

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