Controlling pendular qubit states with nonresonant two-color laser pulses

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There are various physical systems serving as platforms to realize quantum computing or quantum simulation. The molecular rotational state of polar molecules is one of the quantum platforms that attract many researchers' attention [1]. Nowadays, the molecular qubit states are coherently controlled by well-established methods utilizing a resonant microwave electric field [2-4].

In this presentation, we propose a nonresonant-laser-based method to coherently control the molecular qubit states. We exploit quasi-adiabatic molecular orientation dynamics created by nonresonant nanosecond two-color laser pulses, which have been studied by our group for the last few years [5,6]. Figure 1(a) shows the adiabatic interaction between a nonresonant one-color laser pulse and a polar molecule (an OCS molecule is used in the present study). In the presence of the laser field, the two lowest-lying rotational quantum states designated by |0,0> and |1,0> experience the energy shifts and the two states are degenerate in the presence of the one-color laser pulse. The entire laser-molecule interaction process over the time is purely adiabatic, because there is no transition matrix elements between the two states.

When a two-color laser pulse is used, however, the adiabaticity is not ensured. In general, the 2ω laser pulse has a shorter duration than the ω laser pulse. As shown in Fig. 1(b), in the leading edge of the two-color laser pulse, the molecule is exposed only to the ω laser pulse. At this moment, the adiabaticity is ensured as in the case shown in Fig. 1(a). However, as the intensity of the 2ω laser pulse starts to increase, the transition between the two states are allowed abruptly, which makes the two states be completely mixed. As shown in Fig. 1(b), we consider this abrupt transition point as t_1. Assuming the temporally symmetric laser pulses, there is another abrupt transition point at t_2 near the trailing edge of the 2ω laser pulse. In the time between the two transition points of t_1 and t_2, the laser-molecule interaction can be considered as transiently adiabatic.

After the entire laser-molecule interaction is finished, the final state is determined as a result of quantum interference between the four possible quantum paths. Therefore, the final state amplitudes can be controlled by the peak intensity of the ω laser pulse. In the presentation, we will show and discuss our numerical and experimental results. The nonresonant laser method can be applied to any molecules regardless of energy structures of the molecules.

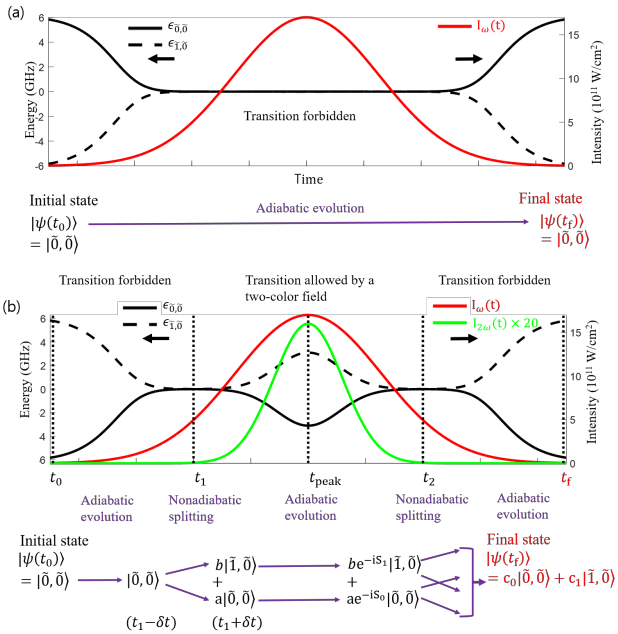

Figure 1. (a) Adiabatic laser-molecule interaction dynamics by a nonresonant nanosecond one-color laser pulse. (b) Quasi-adiabatic laser-molecule interaction dynamics by nonresonant nanosecond two-color laser pulses.

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