Development of High-Precision Coherent Control and Its Applications

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Coherent control is based on manipulation of quantum phases of wave functions. It is a basic scheme of controlling a variety of quantum systems from simple atoms to nanostructures with possible applications to novel quantum technologies such as bond-selective chemistry and quantum computation. Coherent control is thus currently one of the principal subjects of various fields of science and technology such as atomic and molecular physics, solid-state physics, quantum electronics, and information science and technology. One promising strategy to carry out coherent control is to use coherent light to modulate a matter wave with its optical phase. We have so far developed a high-precision wave-packet interferometry by stabilizing the relative quantum phase of the two molecular wave packets generated by a pair of femtosecond laser pulses on the attosecond time scale. We will apply our high-precision quantum interferometry to gas, liquid, solid, and surface systems to explore and control various quantum phenomena.

1. Ultrafast Fourier Transform with a Femtosecond Laser Driven Molecule[1)]

Wave functions of electrically neutral systems can be used as information carriers to replace real charges in the present Si-based circuit, whose further integration will result in a possible disaster where current-leakage is unavoidable with insulators thinned to atomic levels. We have experimentally demonstrated a new logic gate based on the temporal evolution of a wave function. An optically tailored vibrational wave-packet in the iodine molecule implements 4- and 8-element discrete Fourier-transform with arbitrary real and imaginary inputs. The evolution time is 145 fs, which is shorter than the typical clock period of the current fastest Si-based computers by three orders of magnitudes.

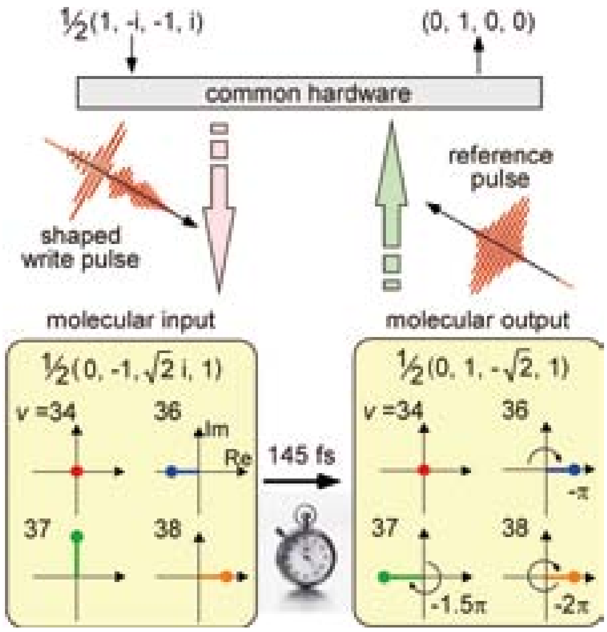

Figure 1. Schematic of the present discrete Fourier transform with an example: 1/2 $(1, -i, -1, i) \rightarrow (0, 1, 0, 0)$. The common transform matrices $\mathbf{w}_4$ and $\mathbf{w}_4^{-1}$ are operated for any arbitrary inputs and outputs, respectively, by the indicated hardware.

2. Optical Modification of the Vibrational Distribution of the Iodine Molecule[2)]

We have demonstrated previously that one can read and write information in a diatomic molecule as the population distribution which referred to as a "population code" [*Phys. Rev. Lett.* **104** (2010) 180501; *Phys. Rev. Lett.* **96** (2006) 093002; *Phys. Rev. A* **76** (2007) 013403]. As a next step to this read and write process, modification of the population code is necessary to develop logic gates. Here we demonstrate that the population code in the iodine molecule can be modified by near-infrared femtosecond laser pulses.

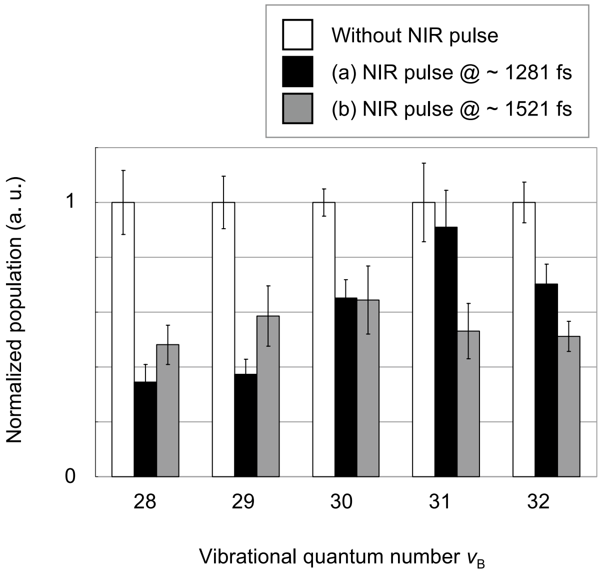

Figure 2. The vibrational distribution of the iodine molecule has been modified with a near-infrared femtosecond laser pulse.

References

1) K. Hosaka, H. Shimada, H. Chiba, H. Katsuki, Y. Teranishi and K. Ohmori, *Phys. Rev. Lett.* **104**, 180501 (2010).
Selected for "Editors' Suggestions" in PRL.
Covered by Physics **3**, 38 (2010).
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2) H. Goto, H. Katsuki and K. Ohmori, *Chem. Phys. Lett.* **493**, 170–172 (2010).

Award

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