Development of High-Precision Coherent Control and Its Applications

Department of Photo-Molecular Science
Division of Photo-Molecular Science II

OHMORI, Kenji	Professor
KATSUKI, Hiroyuki	Assistant Professor
HOSAKA, Kouichi	IMS Fellow
DELAGNES, Jean-Christophe	Post-Doctoral Fellow*
SHIMADA, Hiroyuki	Post-Doctoral Fellow
GOTO, Haruka	Graduate Student
INAGAKI, Itsuko	Secretary

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. READ and WRITE Amplitude and Phase Information by Using High-Precision Molecular Wave-Packet Interferometry[1)]

We demonstrate an experimental approach to read and write populations and relative phases of vibrational eigenstates within a wave packet created in the *B* state of the iodine molecule by using a pair of phase-locked femtosecond laser pulses. Our highly-stabilized optical interferometer keeps attosecond stability and resolution in the interpulse delay. These stability and resolution have realized an exquisite tuning of the interference of two vibrational wave packets to manipulate the relative populations and the relative quantum phases among the relevant vibrational eigenstates. These populations and phases have been retrieved by measuring fluorescence from the upper *E* state induced by another nanosecond (ns) or femtosecond (fs) probe laser pulse. The bandwidth of the ns probe pulse is narrow enough to select only a small portion of the rotational progression of a particular vibrational band of the *E*–*B* transition. By scanning the probe wavelength, we measure the population distribution of the vibrational eigenstates within the wave packet. The fs probe pulse is used to measure quantum beats arising from the temporal evolution of the wave packet. Combining these two complementary measurements, we can read both population and phase information written and stored in the wave packet.

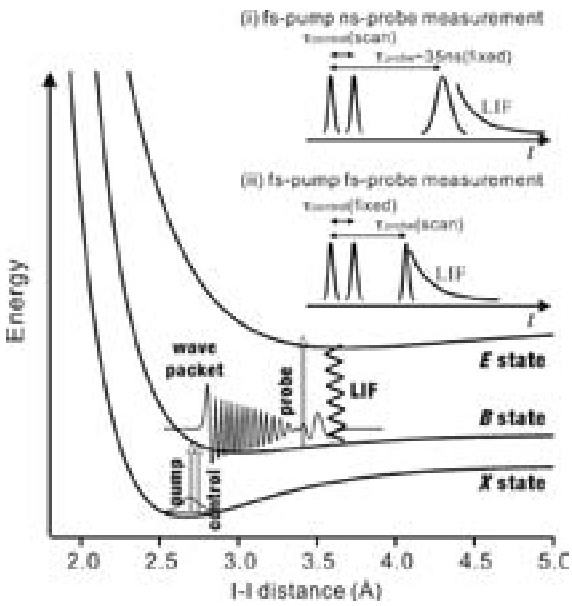

Figure 1. Pump-control-probe scheme for the real-time or state-resolved measurement of wave-packet interference with the femtosecond or nanosecond probe pulse. The potentials are only schematic.

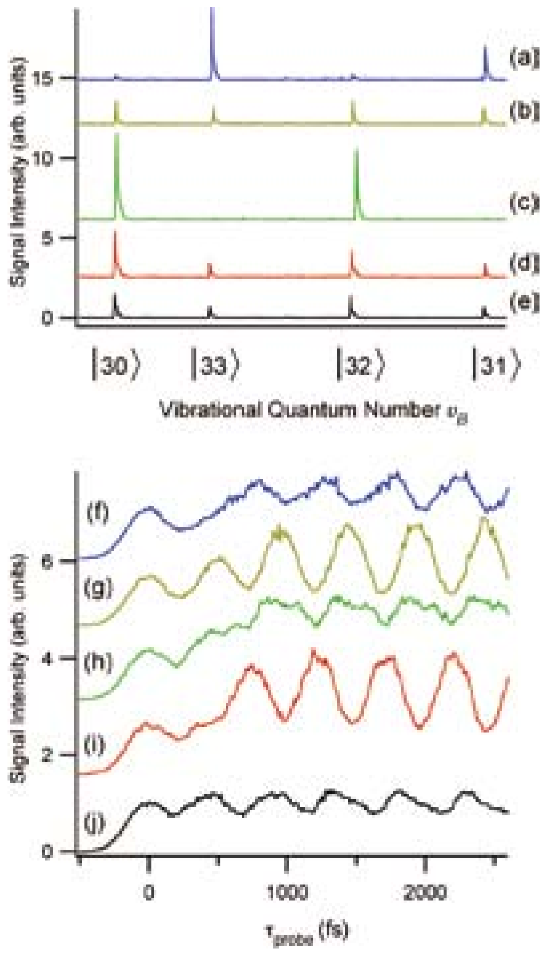

Figure 2. Wave packet interference measured with the pump and control delay $\tau_{control}$ tuned to ~(1+1/2) T_{vib} (~760 fs), where T_{vib} is a classical vibrational period of I_2. (a)–(d) "POPULATION CODES" measured by scanning the wavelength of the ns probe pulse. The relative phase θ_{p-c} of the pump and control pulses is increased in steps of ~π/2 in going from (a) to (d). (e) Population code written without the control pulse and displayed for reference. The five population codes are displaced vertically from one another for clarity. (f)–(i) "PHASE CODES" measured with almost the same θ_{p-c}'s as for (a)–(d), respectively. (j) Phase code written without the control pulse and displayed for reference. The five phase codes are displaced vertically from one another for clarity. A possible deviation of θ_{p-c} within each set of the population and phase codes is estimated to be < 0.2π for the sets (a)–(f) and (c)–(h), and < 0.03π for (b)–(g) and (d)–(i).

Reference

1) H. Katsuki, K. Hosaka, H. Chiba and K. Ohmori, *Phys. Rev. A* **76**, 013403 (13 pages) (2007).

Awards

OHMORI, Kenji; Japan Academy Medal.
OHMORI, Kenji; JSPS Prize.

* Present Affiliation; Senior Lecturer, The University of Bordeaux, France