III-K Wave Packet Engineering Using a Phase-Programmable Femtosecond Optical Source

We proposed “wave packet engineering” which realizes mutual conversion between phase information of photonic and quantum wave packets by means of light-matter interaction. A phase-programmable femtosecond optical source is indispensable for such interactive control of photonic and quantum wave packets. We demonstrate control of quantum wave packets in organic molecules and semiconductors using phase-programmed pulses.

III-K-1 Molecular Phase-To-Amplitude Converter Using Femtosecond Wave Packet Engineering

MISAWA, Kazuhiko; MATSUDA, Isao[1]; LANG, Roy[1]
([1]Tokyo Univ. Agric. Tech., CREST(JST))

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The intensity of the spontaneous emission from a cyanine dye molecule (IR-140) is measured to evaluate the remaining excited-state population after photoexcitation with femtosecond chirped pulses. The chirped pulses are prepared by using the chirp variable device with a chirped mirror pair. The center wavelength, pulse energy, and duration of the output from the chirp device are 790 nm, 2 mJ, and 40 fs, respectively. The spectral profile does not change irrespective of the chirp condition. The ethanol solution of IR-140 at a concentration of 2×10^{-4} M is circulated in a 0.5-mm thick quartz cell. The fluorescence intensity is increased and decreased in case of positively chirped (PC) and negatively chirped (NC) excitations, respectively, with respect to the Fourier transform limited (TL) excitation. This chirp dependent fluorescence (CDF) results from the coherent interaction between the chirped pulses and the quantum wave packet in the material. The stimulated emission efficiency is different between the NC and PC excitation. At low excitation the stimulated emission is not efficient and CDF is negligible. As excitation is increased,CDF becomes remarkable. The intensity change is up to about 25 percent of the total intensity. To explain the dependence on the excitationintensity, we perform a quantum mechanical calculation based on a three-level model. Theoretically, an oscillatory dependence like Rabi oscillationis expected in case of NC excitation. However, such strong stimulated emission pumping is not experimentally remarkable. This is due to not only low excitation, but also dephasing in dye molecules.

III-K-2 Wave Packet Engineering Using a Phase-Programmable Femtosecond Optical Source

MISAWA, Kazuhiko; MATSUDA, Isao[1]; HASHIMOTO, Naoyuki T.[1]; LANG, Roy[1]
([1]Tokyo Univ. Agric. Tech., CREST(JST))

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A new optical telecommunication method combining time and frequency domain multiplexing is proposed by using phase-controlled femtosecond pulses. Each pulse in a pulse train can be used as data packet with data bits in the frequency domain. We name the new principle as “wave-packet engineering” to adjust amplitude and phase of the wave function in device materials arbitrarily by controlling spectral phase of femtosecond pulses. The optical phase-to-amplitude converter is demonstrated with organic dye molecules, in which the phase information in the phase-modulated pulses can be demodulated into the luminescence intensity. Luminescence intensity from cyanine dye molecules observed to be chirp dependent, and is explained quantum mechanically in terms of coherent population transfer. According the wave-packet engineering, a design principle of the device using semiconductor coupled quantum nanostructures is also discussed.