Coherent Optical Spectroscopy of Semiconductors

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09.00-10.00 Tut5 - Femtosecond Photobiology
Presider: W. Hogervorst, *Vrije Universiteit, Amsterdam, THE NETHERLANDS* **LOMOND**

09.00 Tut5

Femtosecond Photobiology

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This tutorial will discuss techniques and applications of femtosecond photobiology. First, ultra-short pulse generation, detection and measurement techniques will be briefly reviewed. Then, several examples of ultrafast dynamics in biological systems will be discussed. Ultrafast spectroscopy has provided a wealth of new information about the dynamics and function of many biological systems. As examples we will discuss the energy and electron transfer processes in photosynthetic and artificial light-energy converting systems and isomerization reactions of retinal chromophores in poroteins used by nature in energy converting and signaling systems.

Ultrashort pulses for dynamics in biology. Reactions forming the functional basis of biological systems are elementary chemical reactions like energy and charge *transfer, bond breaking and forming, isomerizations, proton transfers, etc. The direct* study of these reactions in real time frequently requires sub-100 femtosecond time resolution. Widely tunable and low-intensity pulses are often advantageous in order to facilitate the study of sensitive biological systems absorbing light over a broad range of wavelengths. How ultrashort-pulse Ti:Sapphire technology can be used to accomplish this will be discussed.

Photosynthetic energy conversion. Energy and electron transfer reactions are the basis of the photosynthetic light-energy converting processes. The availability of structural information to atomic resolution of many photosynthetic pigment-proteins has made it possible to study in great detail the dynamics and function of these systems. Topics of current interest that will be discussed are: The nature of light excitations in photosynthetic antenna proteins; the mechanism of energy relaxation and transfer in antenna proteins and how electronic and nuclear coherence contribute to the function; the mechanism of primary charge separation in the photosynthetic reaction center; photosynthetic pigment systems as models for artificial photosynthesis and photonic systems.

A light-driven cis-trans isomerization reaction is extensively used by nature in several pigment-proteins for light-energy conversion (bacteriorhodopsin, photoactive yellow protein) and signaling (rhodopsin and phytochrome). The nature of the primary photoreaction and how it is related to the function of the proteins will be examined and compared with a model dye system.

08.00-10.00 QThA - Time-Resolved Optical Interaction with Semiconductors
Presider: M. Aeschlimann, *ETH, Zürich, SWITZERLAND* **GALA**

08.00 QThA1 (Invited)

Coherent Optical Spectroscopy of Semiconductors

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Coherent optical spectroscopy in the form of transient four-wave mixing (TFWM) has been used extensively to investigate the exciton and biexciton dynamics in semiconductor materials, alloys, and low-dimensional heterostructures. The dephasing times of excitons and biexcitons is determined from the decay of the spectrally resolved non-linear signal as a function of the delay (positive and negative) between the incident pulses in a two-beam TFWM experiment.

From the temperature dependence of the dephasing times the exciton-phonon is determined, and the exciton-exciton interactions (collisions) are revealed by the exciton density dependence the dephasing times. The polarization selection rules of the TFWM signal are used to identify the biexciton contribution to the signal, as well as to identify the other origins of the non-linear signal, such as phase-space filling, local-field effects and excitation-induced dephasing.

Randomly fluctuating potentials, due to either alloy disorder or interface roughness in low-dimensional structures, tend to localize excitons and biexcitons and give rise to an inhomogeneous broadening of the excitonic resonances. At the same time the TFWM signal changes from a free-polarization-decay in the homogeneously broadened system to a photon echo in the inhomogeneously broadened system.[1]

The localization alters the exciton-exciton and the exciton-phonon interactions and thereby changes the dephasing rates of the excitations. Further, the localization changes the exciton and biexciton binding energies, and in particular their ratio. Biexciton binding energies are determined from spectral resolution of the nonlinear signal, as well as by nonlinear quantum-beat spectroscopy. The latter is useful, or necessary, when the broadening is comparable to the biexciton binding energy.

The ratio between the binding energies of the biexciton and the exciton depends strongly on the dimensionality of the confined structure and/or the degree of localization by random fluctuations. It changes from about 0.1 in homogeneous bulk semiconductors (Haynes' rule) over about 0.2 in quasi two-dimensional quantum wells[2] *to about 0.4 in strongly localized/confined zero-dimensional structures (quantum dots). Again, the crucial parameter is the localization energy (broadening) compared to the biexciton binding energy.*

In strongly inhomogeneously broadened systems, the random fluctuations cause an inhomogeneous distribution of biexciton binding energies, which again results in the observation of a fast decay of the biexciton signal as a function of the delay between the incident pulses. This has falsely been interpreted as a fast (homogeneous) dephasing of the biexcitons, but it only reflects destructive interference due to the distribution of biexciton binding energies.[3]

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[1] J. Erland, K.-H. Pantke, V. Mizeikis, V.G. Lyssenko, and J.M. Hvam, Phys. Rev. B **50**, 15047 (1994).
[2] D. Birkedal, J. Singh, V.G. Lyssenko, J. Erland, and J.M. Hvam, Phys. Rev. Lett. **76**, 672 (1996).
[3] W. Langbein, J.M. Hvam, M. Umlauff, H. Kalt, B. Jobst, and D. Hommel, Phys. Rev. B **55**, R7383 (1997).