Ultrafast, Time-Resolved Dynamics of Carriers, Spins, and Phonons in Solid-State Materials Studied by Femtosecond Optical Spectroscopy

Roman Sobolewski

Departments of Electrical and Computer Engineering and Physics and Astronomy,
Materials Science Program, and Laboratory for Laser Energetics
University of Rochester, Rochester, NY 14627-0231, USA
e-mail: roman.sobolewski@rochester.edu

Femtosecond optical pump-probe spectroscopy is the most versatile and most frequently used method for time-resolved studies of the ultrafast nonequilibrium phenomena in solid-state materials. The technique uses femtosecond laser pulses for both optical excitation and probing, simultaneously providing a timing gate for measured events, and acts as a precise clock to control the generation and detection of tested events. In all pump-probe experiments, absorption of pump photons changes optical properties of a tested material by one or several optically-induced effects, such as band-filling, electron-hole recombination, phonon or thermal relaxation, electron-phonon interaction, spin polarization, Cooper-pair breaking in superconductors, etc. Next, a second beam (probe beam) of much weaker intensity and time-delayed with respect to the pump, is incident on the material overlapping the pump-excitation region. The reflected and/or transmitted probe signal is collected with a photodetector and the corresponding normalized differential reflectivity and/or transmissivity change as a function of the pump-probe time delay is a measure of the nonequilibrium dynamics of the excited subsystem in the studied material. Jitter-free time resolution of ~100 fs or better is routinely obtained in the sampling-type, pump-probe measurements. We will review the current state-of-the-art and the advancement of the femtosecond pump-probe spectroscopy and demonstrate its unique usefulness in studying nonequilibrium, time-resolved dynamics of carriers, spins, and coherent phonons in condensed-matter systems varying from semiconductors to spintronic materials and superconductors.

Roman Sobolewski is a Professor of Electrical and Computer Engineering, Physics and Materials Science, and a Senior Scientist of Laser Energetics at the University of Rochester, Rochester, NY, USA. He received his Ph. D. and D. Sc. (Habilitation) degrees in Physics from the Institute of Physics, Polish Academy of Sciences, Warszawa, Poland, in 1983 and 1992, respectively. In 2006, he was granted the State Professorship of the Republic of Poland. His current interests are concentrated on ultrafast phenomena in condensed matter, novel nanostructured electronic and optoelectronic semiconducting and superconducting materials and devices, single-photon quantum detection, and on generation and detection of THz radiation transients. He has published almost 400 peer-reviewed publications and communications, and presented over 100 invited talks, lectures, and colloquia worldwide. Dr. Sobolewski is the Representative of Poland for the EU Cooperation in Science and Technology (COST) Action: Nanoscale Superconductivity: Novel Functionalities through Optimized Confinement of Condensate and Fields.