Time-Resolved Reflectivity Measurements to Characterize Novel Semiconductor Materials

Benjamin Ecker[1], Robinson Kuis[1, 2], Dr. Anthony Johnson[1, 2, 3]

[1] Department of Physics, University of Maryland Baltimore County, Baltimore, MD 21250, United States of America

[2] Center for Advanced Studies in Photonics Research, University of Maryland Baltimore County, Baltimore, MD 21250, United States of America

[3] Department of Computer Science and Electrical Engineering, University of Maryland Baltimore County, Baltimore, MD 21250, United States of America

email: bec1@umbc.edu

One of the main goals of MIRTHE is to develop high quality but low cost sensors which make use of Quantum Cascade Lasers (QCLs). The performance of the sensors depends upon the characteristics and quality of the semiconductor layers which make up the QCLs. Layers grown from new materials, different techniques, and varying compositions demand characterization. A measure of the quality of the semiconducting material is the lifetime of optically generated carriers excited by short pulses of light. Typically, a short lifetime corresponds to a poor quality sample; the photo-excited carriers become trapped rapidly by defects in the sample. While a long carrier lifetime usually corresponds to a high quality sample. These lifetimes can be as short as several picoseconds (ps).

The laser system used for these time-resolved reflectivity measurements was a modelocked Nd:Vanadate operating at a wavelength of 1064-nm. This SESAM (semiconductor saturable absorber modelocking) modelocked laser had a nominal pulsewidth of 8 ps and a repetition rate of 76 MHz. The infrared wavelength of the Nd:Vanadate laser was frequency-doubled to a green visible wavelength of 532-nm using a nonlinear optical crystal of potassium titanyl phosphate (KTP). The time-resolved reflectivity measurements were performed at 532-nm with pulses of 8 ps duration.

To perform a pump-probe reflectivity measurement, the 532-nm laser beam was divided into two beams, the pump and probe, where the probe was significantly weaker than the pump. The pump beam's polarization was rotated ninety degrees relative to the probe's polarization to reduce coherent coupling between the pulses. The probe beam is variably delayed relative to the pump using a stepper motor and retroreflector combination. The modulated signal of the pump was transferred to the probe, and the change in the reflected probe signal was detected using a lock-in amplifier. The general idea behind the time resolved reflectivity measurement is that the 532-nm pulses generate a distribution of photo-excited electrons and holes that alter the refractive index of the material for a time period corresponding to the carrier lifetime. This resultant time-dependent refractive index is thus a measure of the carrier lifetime.

Initial experiments are being done on an Indium Phosphide (InP) substrate which is expected to have a long lifetime of optically generated carriers. After validating the setup, lifetime measurements of II-VI semiconductor samples from CCNY will be performed. The data at 532 nm will be presented at the MIRTHE Summer Workshop.