EXCITATION INTENSITY DEPENDENCE OF ULTRAFAST CARRIER DYNAMICS IN GAAS

David Simonne
Graduate School of Science
Tohoku University
davidsimonne@gmail.com

Shinichiro Iwai
Graduate School of Science
Tohoku University
s-iwai@m.tohoku.ac.jp

February 2017

While studying ultrafast temporal evolution, for instance the motion of photo-excited carriers in semiconductors [1], the optical pump probe method is a powerful technique [2]. We can measure the evolution according to the time delay between the pump and the probe beams. Thus, yielding information about the relaxation of electronic states in the sample. Therefore, we can compute the recovery time in the sample using the reflectivity changes. In this paper, we will investigate the exponential profile of the plasma density, given the excitation intensity, in a photo-doped GaAs sample.

The primary pulse with an 800 nm wavelength and 100 fs width is generated by an Ti:Al_2O_3 pulse laser. As described in Figure 1, our experimental setup is also constituted of one Optical Parametric Amplifier (OPA) that is providing us with the probe beam, and allowing us to access a wide wavelength range. Both pump and probe beams have the same path lengths. A cube corner is used to control the delay time. Figure 3 shows the time profile of differential reflectivity spectra (ΔR/R) detected by 100 fs pulses with a probing energy of 1.55 eV, at room temperature. For weak excitation, 0.064 mJ/cm^2, the time delay is 2.0 ps. For 1.44 mJ/cm^2, the time delay is 10.0 ps. For 6.7 mJ/cm^2 the time delay is 3.1 ps.

GaAs being a direct gap semiconductor, intrinsically the radiative recombination prevails and causes the fast reduction of the plasma resonance at the surface. We proceed to the fitting of an exponential model that allows us to determine precisely the delay time τ. However, we can observe that the evolution of the decay time is not linear given the intensity. If beforehand τ increases from 2.0 ps to 10.0 ps in parallel with the excitation density, it then decreases from 10.0 ps to 3.1 ps while the excitation density still increases. The behaviour changes from the weak excitation limit where only several isolated carriers are generated (figure 3 a), to the strong excitation limit where the plasma emerges (figure 3 b). In the future, we would like to extend to the mid-IR and examine the transient reflectivity spectra.

***K*eywords** Ultrafast Spectroscopy, Carrier Dynamics

Acknowledgement I would like to thank A. Takayuki and Y. Yuto for their very much appreciated help.

References

[1] J. Shah, *Hot Carriers in Semiconductors : Physics and Application*. Academic Press, 1992.

[2] M. Nagai and M. Kuwata-Gonokami, "Time-resolved reflection spectroscopy of the spatiotemporal dynamics of photo-excited carriers in si and gaas," *Journal of the Physical Society of Japan*, vol. 71, 2002.

[3] J. P. Walter and M. L. Cohen, "Calculation of the reflectivity, modulated reflectivity, and band structure of gaas, gap, znse, and zns," *Phys. Rev.*, vol. 183, 1969.

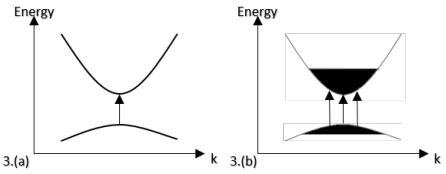

Figure 1: Band Structures of GaAs for (a) weak excitation and (b) strong excitation [3].

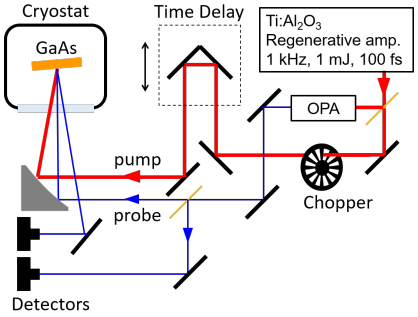

Figure 2: Setup of the experiment.

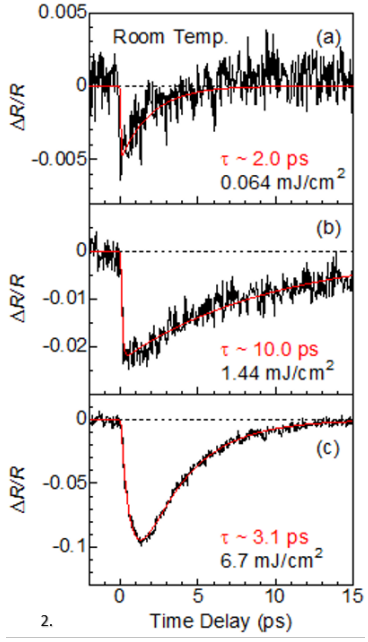

Figure 3: (a)-(b)-(c) Temporal evolution of reflectivity changes ΔR/R in GaAs at several excitation densities.