FEMTOSECOND PROBE-PROBE TRANSMISSION STUDIES OF LT-GROWN GaAs NEAR THE BAND EDGE,

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ABSTRACT

We have studied the near-edge optical response of a LT-grown GaAs sample which was deposited at 300 ^{0}C on a Si substrate, and then annealed at 600 ^{0}C. The Si was etched away to leave a 3-micron free standing GaAs film. Femtosecond transmission measurements were made using an equal pulse technique at four wavelengths between 825 and 870 nm. For each wavelength we observe both a multipicosecond relaxation time, as well as a shorter relaxation time which is less than 100 femtoseconds.

INTRODUCTION

Low temperature grown GaAs[1-2] has been of considerable interest in the last few years due to the sub-picosecond recombination times. This increased interest is due both to the possibilities of utilizing the faster response times in electronic devices,[3-8] as well as understanding the basic physics underlying the faster response.[9] In many cases, the faster times are attributed to the presence of As impurities in the annealed samples, though fast times have also been observed in amorphous, unannealed samples.[10] In this paper we report femtosecond transmission spectra on a free standing LT-GaAs film initially grown on a silicon substrate.

EXPERIMENTAL DETAILS

Solid state lasers with short pulses comparable to CPM dye lasers have been recently developed based on Ti-Sapphire.[11-12] In addition to the simplicity of use compared to dye lasers, they provide orders of magnitude higher average power and are tunable over a broad range of frequencies. The laser used in these experiments can provide sub-100 fs pulses with 600 mW average power and is tunable in the current

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configuration from 800 to 900 nm. This wavelength regime brackets the GaAs band gap at 870 nm.

When focused in a GaAs sample, these optical pulses can promote electrons from the valence band to the conduction band, non-destructively creating highly non-equilibrium conditions. In our experiment, we have utilized a probe-probe version[13-14] of the standard pump-probe technique. The beam is split into two equal parts, with one pulse delayed with respect to the second. The reflectivity or transmitivity is then measured as a function of the delay time. The second pulse probes the dynamical process at a given time delay relative to the first. In this way, the time averaged optical properties map out, as a function of delay, the relaxation over the first several picoseconds following excitation. The symmetrical nature of the probe-probe technique

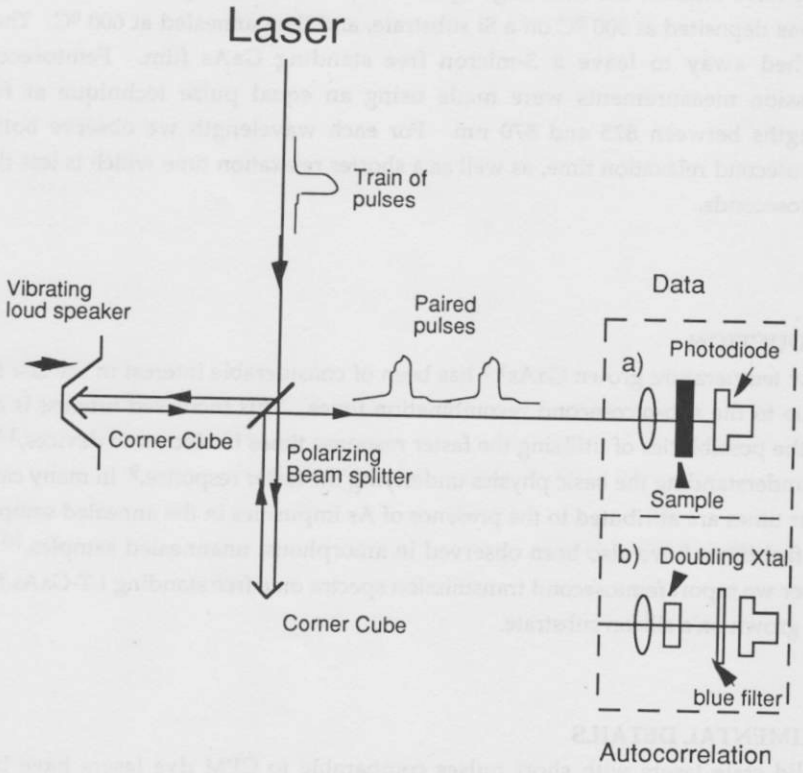

Figure 1 - Experimental set-up for the equal-pulse transmission measurements.

facilitates resolving relaxation times that are comparable or shorter than the pulse width. As a separate feature of the setup, a vibrating speaker is used to sweep through the relevant delays between the pulses many times each second. This allows for both ease in finding the signal, as well as faster collection times. It is analogous to taking a photoluminescence spectra using a scanning spectrometer and a photomultiplier tube, as opposed to using a multichannel analyzer. Both the pump-probe and probe-probe configurations can be used with the vibrating speaker. The diagram for the experimental setup is illustrated in Figure 1.

FILM GROWTH AND CHARACTERIZATION

The GaAs films were grown by MBE on Si substrates. The substrate temperature was 300 ^{0}C. Following growth, the film was annealed for 10 minutes at 600 ^{0}C. It is expected that defects, such as arsenic precipitates, are introduced by the low temperature growth and subsequent annealing.[7-10] The advantage of growth on Si is that this substrate is easy to etch away, leaving a free standing GaAs film , which was 3 microns thick. This thickness corresponds to one optical absorption length at 825 nm, which is the appropriate dimensions for this experiment. The sample was masked prior to etching away the substrate, so that a series of 3-micron, free standing GaAs windows was created.

The GaAs film was characterized by room-temperature photoluminescence, which is shown below in Fig. 2. The film was excited by green 514 nm light from an Ar ion laser. The peak of the spectrum is at 870 nm, corresponding to a gap energy of 1.43 eV. This indicates that the GaAs gap is essentially unchanged from bulk GaAs.[15] (The second peak near 900 nm is likely due to shallow acceptors, not the deep levels associated with the arsenic precipitates.) This would imply that we should see optical absorption even if the excitation energy is equal to or slightly greater than the gap energy. This is indeed what is observed in this sample.

RESULTS AND DISCUSSION

Prior to the availability of Ti-Sapphire lasers, the femtosecond studies of GaAs have relied on laser pump pulses near 2 eV in energy from CPM dye lasers.[13-14,16-17] The new laser sources are now providing the opportunity to study the fast optical response of GaAs using pump beams centered near the band gap energy of 1.43 eV.[18] This is in contrast to studies which use 2 eV pump beams and probe beams with energies close to the band edge.[16-17]

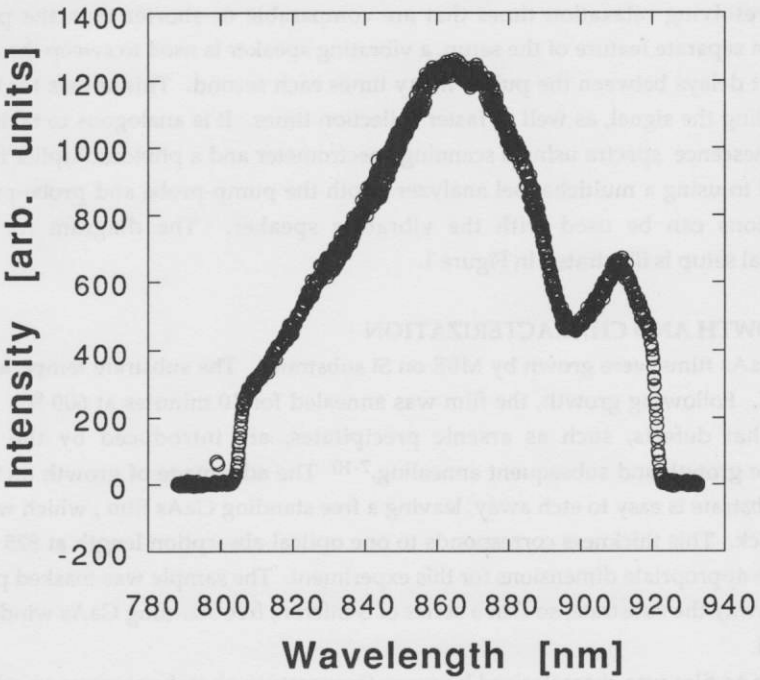

Figure 2. Photoluminescence for the LT-grown GaAs sample.

We show in Figure 3 the transmission correlation peak (TCP)[14] for the LT-GaAs sample taken at 870 nm. Spectra was also obtained at wavelengths of 825, 840, 855 nm. For all four wave lengths we observe two distinct lifetimes. A multipicosecond lifetime (≈ 8 ps) is found to be consistent with literature values for other GaAs films grown at 300 C.[7] This time is take to be the recombination time, and is dependent on the recombination centers which have been introduced into the sample by the low temperature growth. The short lifetime is found to be less than 100 fs, which is consistent with values for pure GaAs.[13-14] Further results will be discussed in detail in a separate publication.[19] It would appear that growth of LT - GaAs on Si substrates

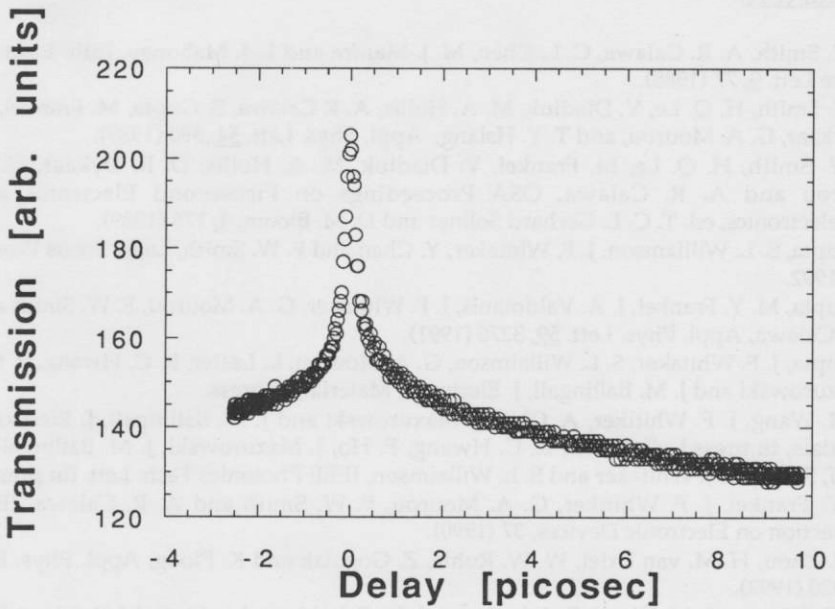

Fig. 3 TCP for LT-grown GaAs at 870 nm.

gives results similar to growth on other substrates, and provides a convenient means to create free standing films and windows.

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