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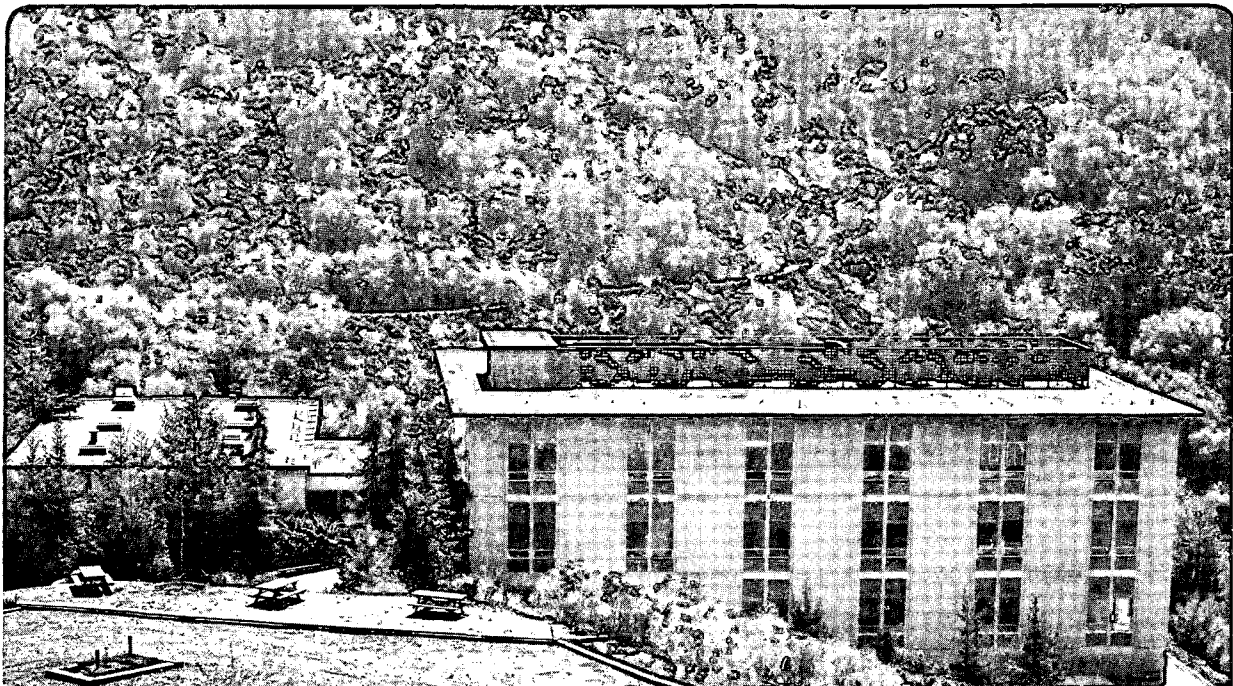
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CARRIER DYNAMICS IN InGaAs: QUANTUM WELLS VS. BULK

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Carrier Dynamics in InGaAs: Quantum Wells vs. Bulk

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Abstract

Using femtosecond infrared continuum, we investigate carrier thermalization in $L=100\text{\AA}$, 600\AA & 6000\AA InGaAs layers. Surprisingly, we find that the thermalization time, ~ 400 fs, is independent of L . In contrast, the initial dynamics for <100 fs exhibits significant L -dependence.

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Carrier Dynamics in InGaAs: Quantum Wells vs. Bulk

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InGaAs heterostructures are widely used in high speed devices such as lasers, modulators, and HBTs. Optimization of these devices' performance requires a detailed understanding of carrier relaxation dynamics. It has been predicted, however, that due to quantum confinement effects, carrier relaxation depends critically on the width of ultra thin layers, L . Gain recovery dynamics have been studied in InGaAs traveling-wave optical amplifiers using single wavelength femtosecond optical pump-probe measurements [1,2]. As these were single wavelength measurements interpretation of the results is difficult. As shown in Figure 1, using an ultrashort pulse infrared broad band continuum probe [3] to follow the carrier location in k -space, we have measured, with 150 fsec resolution, the dynamics of optically injected carriers in InGaAs vs L , from the almost 2D case, $L \ll a_0$, to the 3D case, $L \gg a_0$, where $a_0 \sim 290 \text{ \AA}$ is the exciton Bohr radius.

Twelve InGaAs/InAlAs samples varying from $L=75 \text{ \AA} \sim a_0/4$ to $L=6000 \text{ \AA} \sim 20a_0$ were grown by MBE, all containing 6000 \AA of InGaAs. Figure 2 shows the absorption spectra of the $L=100 \text{ \AA}$ and 6000 \AA samples at 7K. Excitonic features are clearly visible in the QW samples. The bulk sample shows no clear resonance, but is well described by a

3D density of states with a Sommerfeld enhancement factor, suggesting that Coulomb effects are important. Pump probe measurements on resonance reveal an excitonic character of the bulk band edge.

Femtosecond, differential absorption spectra (DAS) were obtained using a "narrow band" ($\Delta\lambda = 30\text{nm}$) pump and a broad band probe. (Fig. 1.) Carriers were excited at energies just below the LO-phonon threshold, so that carrier-carrier scattering dominates the thermalization. The DAS of the bulk sample, Fig 2(b), shows nearly complete thermalization to a carrier temperature $T \sim 550\text{K}$ at $t \geq 400\text{ fs}$. At early times the spectral hole is red shifted as compared to the pump spectrum and the DAS shows an induced absorption at higher energies. We attribute this to many-body non-equilibrium Fermi edge effects similar to those seen in GaAs [4,5]. However, they are expected to be stronger in InGaAs due to the larger ratio of m_{hh}/m_e . There is also a strong induced absorption at the band-edge near 800meV , due to the combined effects of screening and coherent scattering.

Surprisingly, the quantum wells show thermalization times $t \approx 400\text{ fs}$ as well. (Fig. 2(d)) At early times, $t \leq 100\text{ fs}$, the DAS for the 100\AA and 200\AA samples show a more pronounced hole burning near the pump than the bulk sample, and reduced effects at the band edge. This indicates that the relative effects of screening versus phase-space filling are stronger in 3D than 2D [6]. Note that coherence effects are strong in these samples due to the narrow excitonic lines (long T_2).

The $L=500\text{\AA}$ sample, which is truly intermediate between 2D and 3D (Figure 3) also shows a thermalization time $t \approx 400\text{ fs}$, however in this case coherence effects due to the energetic proximity of the subbands cause very complicated DAS.

In conclusion, although the density of states and the subband separation show extreme variations among the samples we have investigated, thermalization seems unaffected. This observation has important consequences for device applications and needs theoretical explanation.

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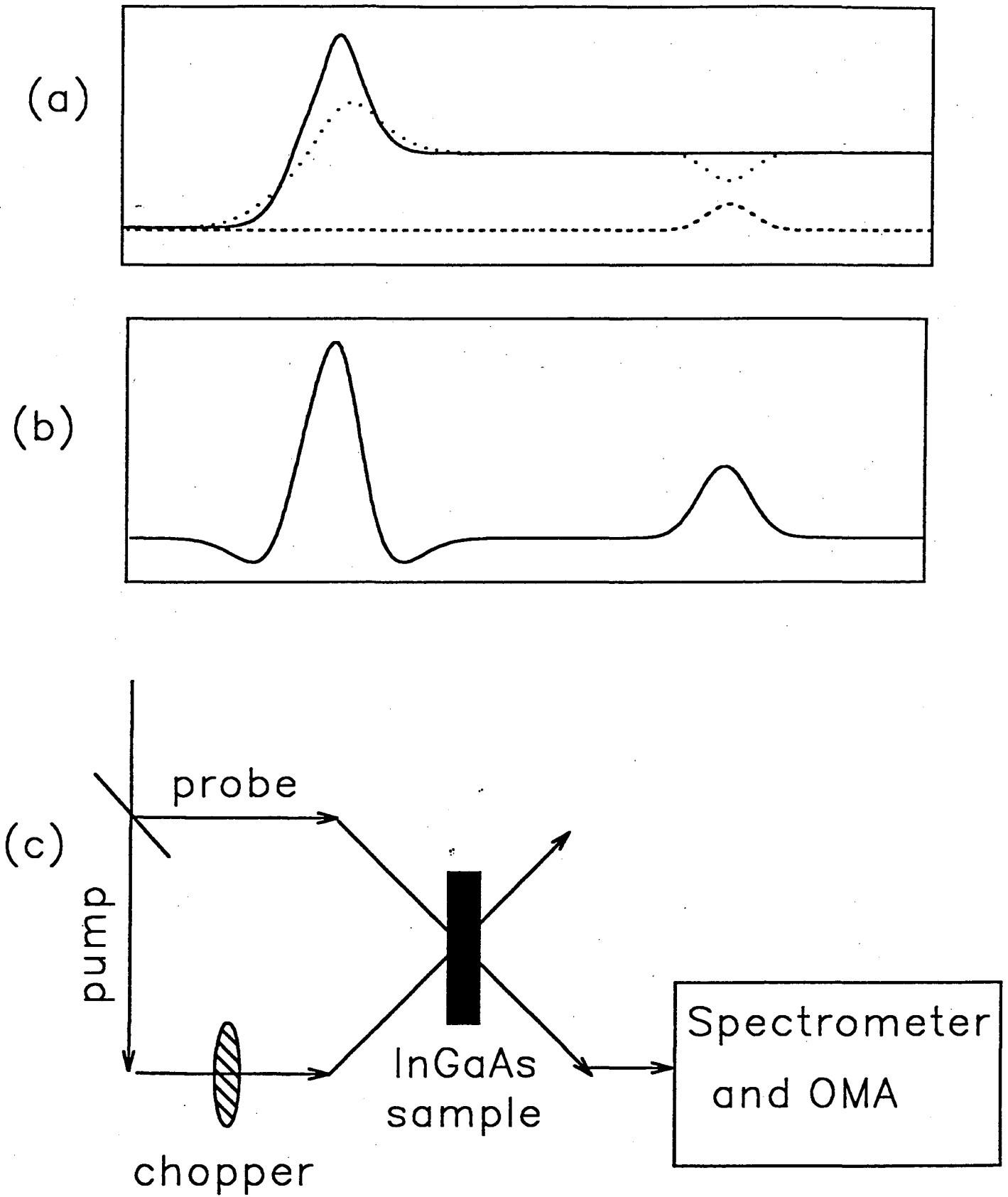
Figure Captions

Figure 1. Principle of the Experiment. (a) Schematic absorption spectrum of sample with and without pump beam. (Absorption without pump—solid. Absorption in presence of pump—dotted. Pump—dashed.) (b) Differential absorption spectrum. (DAS) (c) Experimental setup.

Figure 2. Absorption and DAS of 6000Å and 100Å samples. (a) 6000Å absorption spectrum (solid) and pump spectrum (dotted). (b) DAS for 6000Å sample. (c) Absorption spectrum and DAS of 100Å sample. (d) DAS for 100Å sample.

Figure 3. (a) DAS for 500Å sample. (b) Absorption spectrum (solid) and pump spectrum (dashed) for 500Å sample.

FIGURE 1



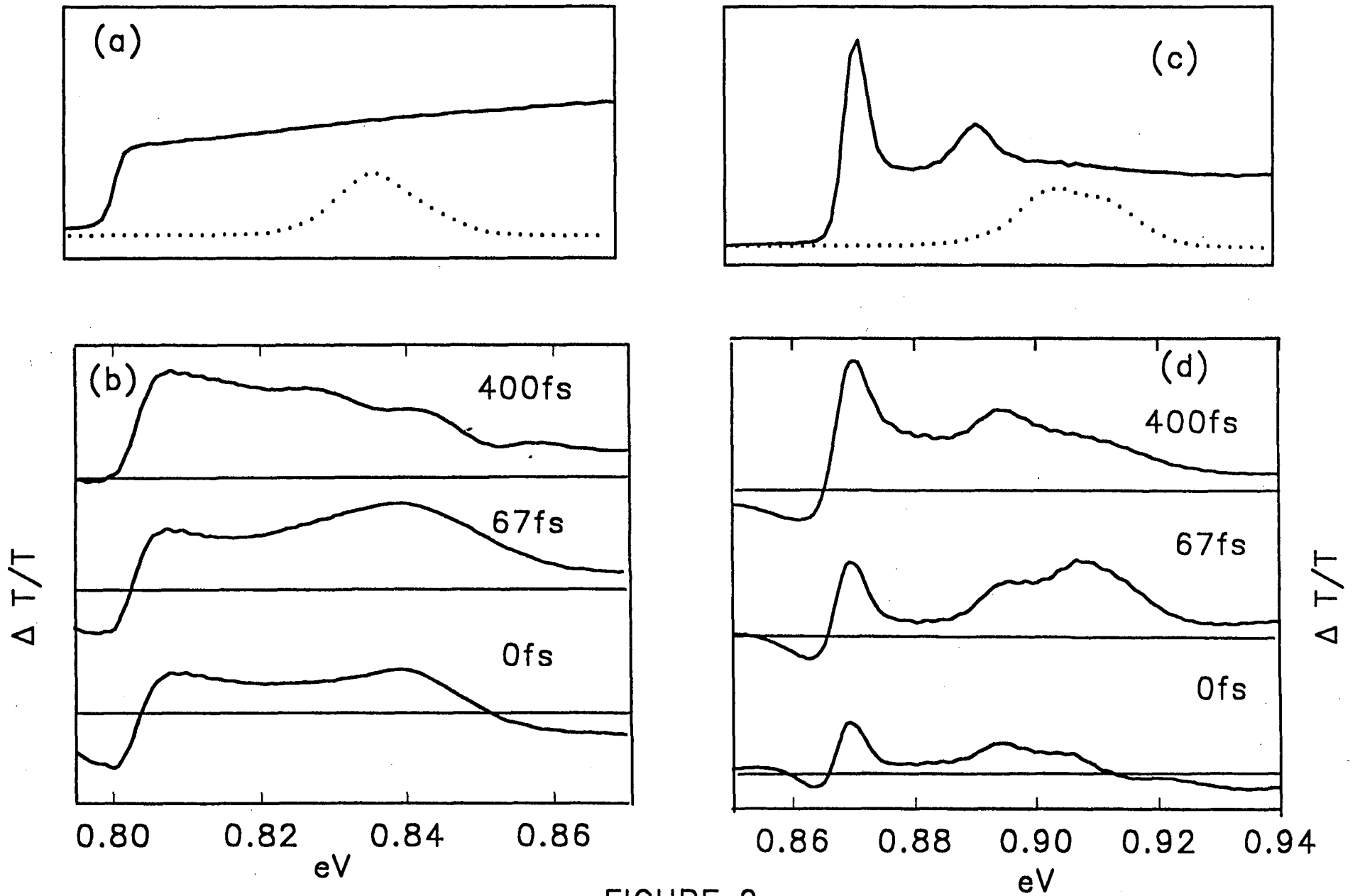
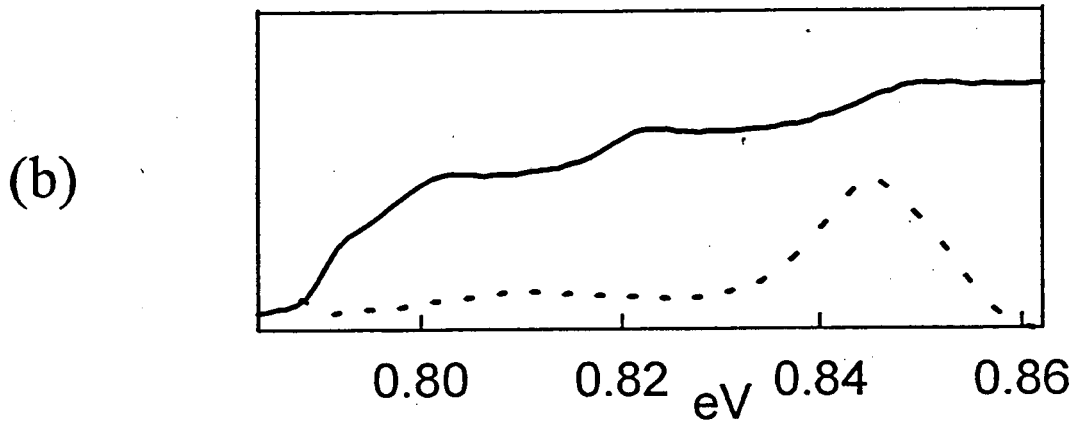
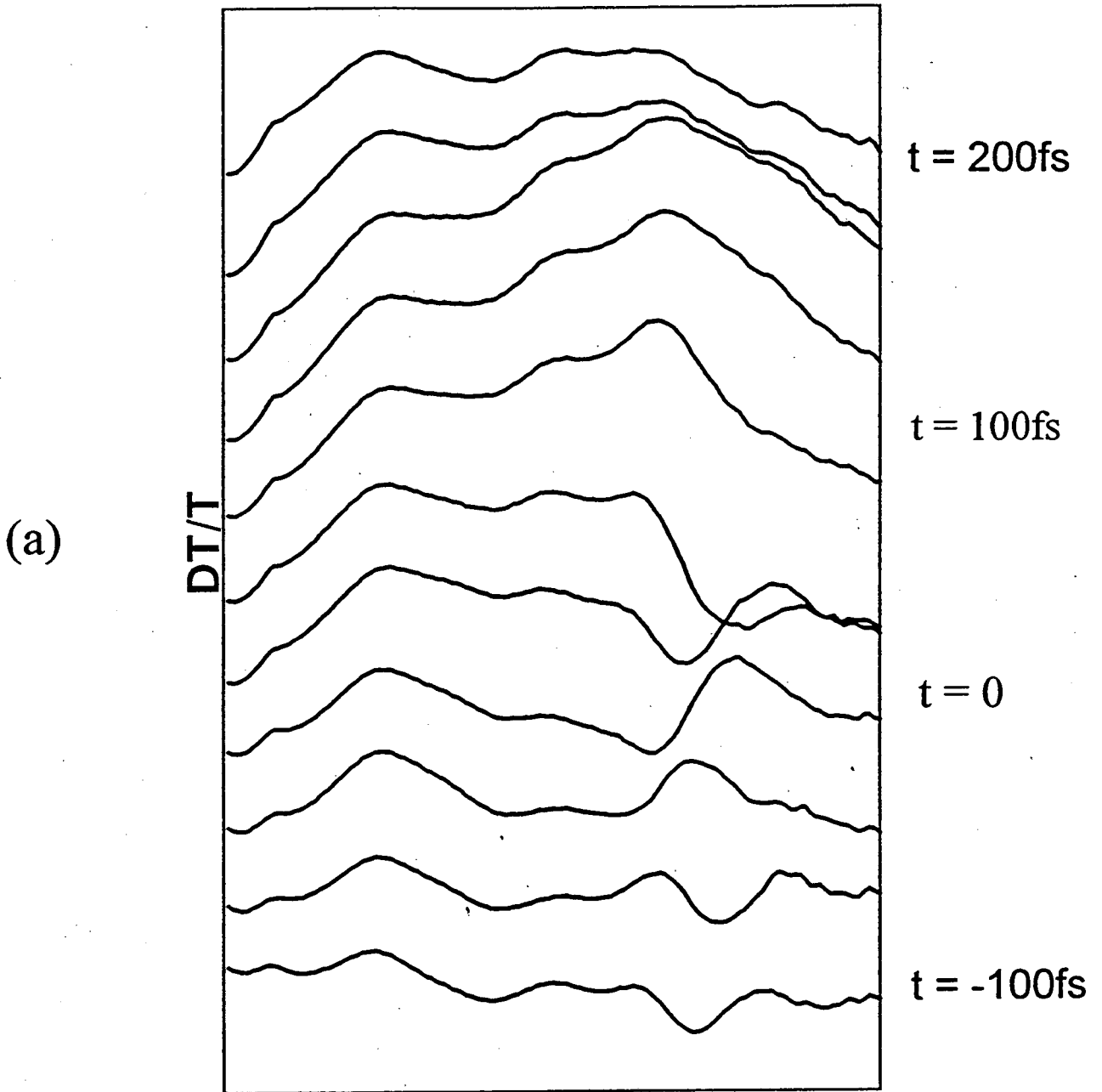


FIGURE 2



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