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Ultra-fast Processes in Optically Excited $Ge_2Sb_2Te_5$ by Transient X-ray Diffraction Using a Free-Electron Laser

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1. Introduction

The desire to go beyond the current limits of phase-change memory (PCM) maximum switching speed and energy consumption has lead to increased interest to the investigation of the ultra-fast processes in PCM materials [1]. We present the results of sub-picosecond resolution time-resolved x-ray diffraction studies of the laser-induced structural dynamics in $Ge_2Sb_2Te_5$ as a step towards the non-thermal switching in PCM.

2. Results and discussion

The pump and probe measurements were carried out with an 800 nm 30 fs width laser pump beam and a 10 fs pulse width 11 keV x-ray probe beam, produced by free-electron laser (SACLA) to monitor the optically induced lattice dynamics. The sample consisted of a 30 nm thick epitaxial $Ge_2Sb_2Te_5$ (GST) film. The diffraction signal maps for each time delay up to 2 ns with steps as small as 100 fs were recorded by a CCD camera and plotted as a function of time (Fig. 1).

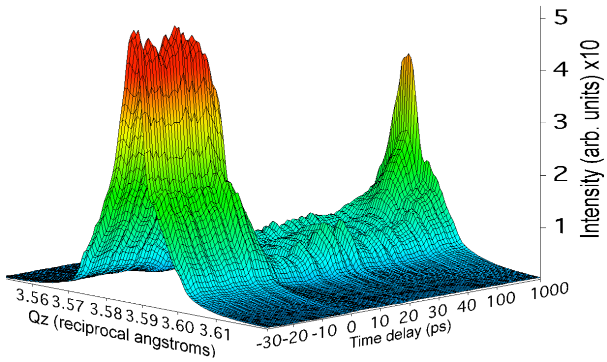

Fig. 1. Transient x-ray diffraction signal map from the epitaxial GST film excited by 24 mJ/cm² laser pulse.

A set of a rocking curves for time delays close to time zero was obtained to determine the crystal strain evolution data. The experimental results show that during a first few picoseconds after the excitation the lattice dynamics are significantly affected by non-thermal processes due to the absence of a Debye-Waller effect induced intensity drop indicated by the constant integrated intensity of the rocking curves (Fig. 2). The data suggest that the majority of the measured GST lattice strain originates from electronic processes due to the change in the bonding symmetry of the Peierls distorted crystal structure of GST [2].

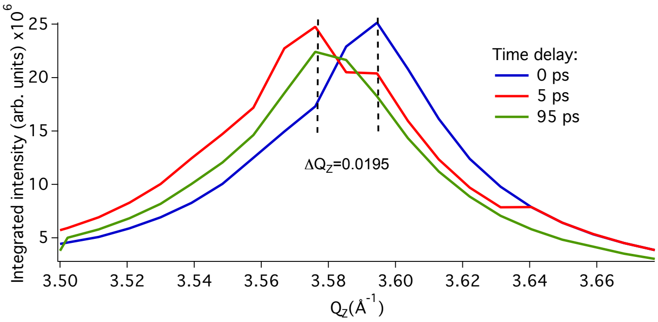

Fig. 2. A set of rocking curves for GST sample at different time delays. Laser pulse fluence is 13.4 mJ/cm².

3. Conclusions

The usage of a short pump laser pulses leads to an increase of the non-thermal effects contribution in GST relaxation process during the first few picoseconds after the excitation, which can be applied for PCM improvement.

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