ESRF	**Experiment title:** Investigations of coherent phonons in InSb	**Experiment number**: HS-1122
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Report:

In a joint effort the groups from Lund and Oxford have performed a series of experiments in order to excite and observe coherent acoustic phonons using time-resolved x-ray diffraction. The work was undertaken within the experiments HS-1122 and HS-1123.

The aim was to excite and observe coherent phonons in semi-conductor materials excited by 800 nm radiation from the ultrafast laser (100 fs) at the ID09 beamline.

Studies were performed with two detectors:

a) Photodiodes for long time-scale behaviour (50 ps – 50 ns).

b) ESRF ultrafast streakcamera for high temporal resolution. (1 ps – 100 ps)

Due to an unforseen technical problems that was fixed by the ESRF staff during the cause of the experiment, the streakcamera was not available for the whole experiment.

This report will focus on two aspects:

a) Long time-scale behaviour of acoustic phonons

b) Measurement of the temporal resolution of the jitter-free ultrafast streakcamera developed at ESRF.

Measurements of acoustic phonons using the streakcamera will be described in the report for experiment HS-1123.

A) Long time-scale behaviour of acoustic phonons.

Without using an ultrafast detector, it is posible to implicitly determine if coherent phonons are excited. The temporal structure of this phenomena differs from that of pure heating. If a crystal is rotated to an angle where the reflectivity if within an order of magnitude from that at the rocking curve peak and subsequently heated, the reflectivity would go monotonically to the value for the new lattice spacing of the heated expanded crystal. As can be seen in figures 1 and 2, there is an over- or under- shoot. This is the signature of the shockwave propagating through the wafer. This shockwave can be thought of as built up by phonon oscillitions (see further in report for HS-1123). The overall features of figure 1 can be explained in the following qualitative way. The crystal has been rotated so that the angle is not at the peak of the rocking curve. It has been moved to the low-angle side. As the shockwave enters the crystal there is a thin layer of compressed material, a sharp edge and then expanded material. The thickness of the expanded material will be larger than the amount of compressed material and thus dominate. Hence, the reflectivity will rise rapidly. When the shockwave has passed through the material, the lattice has been heated and thermal expansion will remain until heat diffusion transport the heat. This occur on a 100 ns timescale.

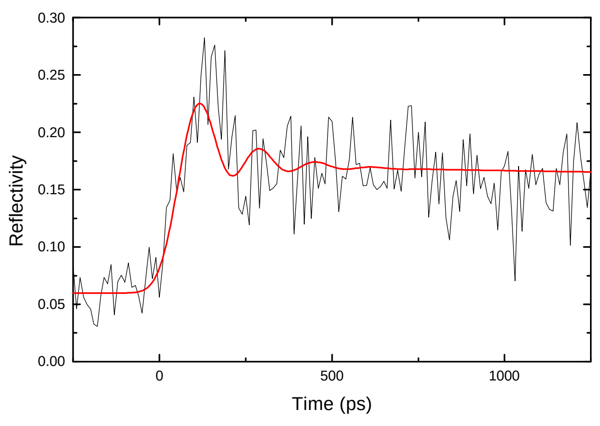

Figure 1. Reflectivity of InSb crystal as function of time. The crystal is oriented to be on the expansion side of the rocking curve. Experimental data as recorded by a photodiode and a simulation assuming the strain profile

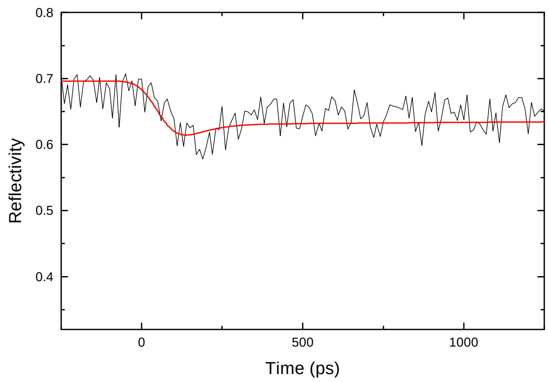

Figure 1. Reflectivity of InSb crystal as function of time. The crystal is oriented to be on the compression side of the rocking curve. Experimental data as recorded by a photodiode and a simulation assuming the strain profile given in ref. 1

We have found that the coherent phonons seem to experience damping which is faster than what is found from the model. This can even be seen in Figure 1 allthough the signal-to-noise ratio is low. We also find that this damping seems to be fluence dependant. We are currently investigating three mechanisms to explain damping: (1) phonon dispersion, (2) phonon decay and (3) surface melting of the crystal. One could imagine both (2) and (3) being fluence dependant.

B) Temporal resolution of the jitter-free streakcamera

In a measurement of the peak reflectivity (peak of rocking curve) of InSb, we observe a rapid drop of the reflectivity. In the raw data this appears to occur in about 1.5 ps (Fig 4.). However, there is a difficulty in extracting time-scales if the signal-to-noise ratio (S/N) is too low. In order to improve the S/N, the data was smoothed and an upper time-limit for the drop in reflectivity was determined to 6 ps. The physics behind this rapid drop in reflectivity is not well understood, but the drop in reflectivity of 15% is consistant with the absorbtion that occurs if a molten layer with the depth of the laser penetration depth is formed at the surface. Theoretical and experimental work has indicated that such a rapid non-thermal melting take place. It should be noted that it is not possible to explain the the rapid intensity drop by the strain/phonon model which provide excellent agreement with experiments for lower fluences.

At fluences of about 5-10 mJ/cm^2, coherent phonons have been detected. In the present study, fluences varying between 30-100 mJ/cm^2 were incident on the sample.

The temporal resolution of the streakcamera was mainly limited by the static focusing and the temporal jitter. At the time of the measurement, the temporal jitter was approximately 1 ps and the effects of static focusing was 1.5 ps . This can be seen by observing the laser generated UV radiation with 100 fs temporal resolution that was measured simultaneously with the x-ray radiation.

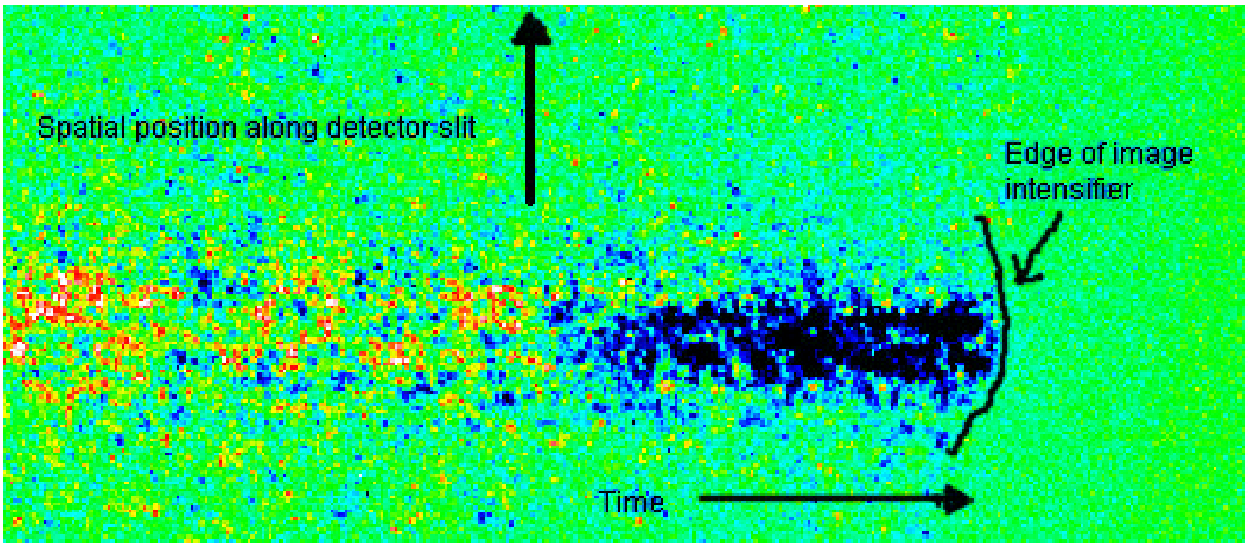

Figure 3. Streakcamera image showing a disordering of the structure of InSb

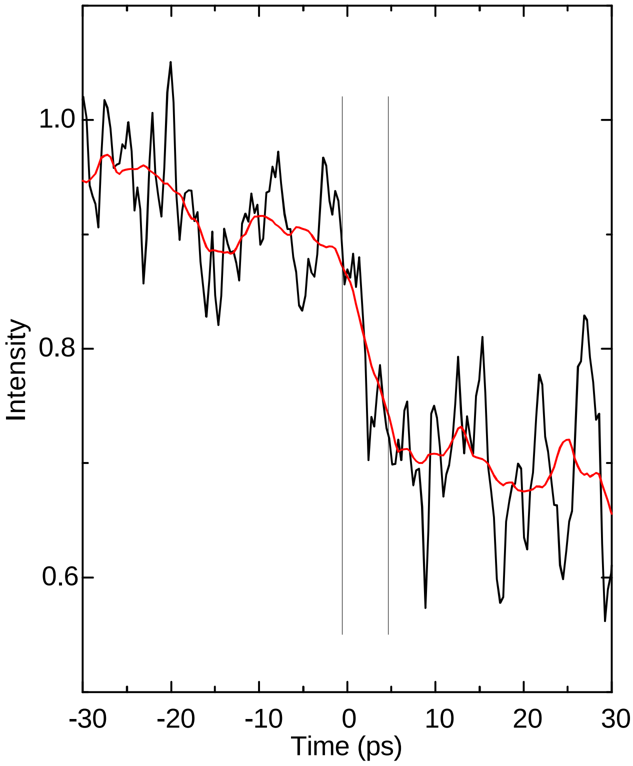

Figure 4. Lineout showing the relative reflectivity as function of time. The laser interacts with the

The image above is derrived from two images of the phosphor of the streak camera. One image was recorded with the laser present and a second was recorded without the laser.

The image shown has been obtained by dividing pixel by pixel, the two images. The linegraph shown is a linout of the image.

References

1. C. Thomsen, H. T. Grahn, H. J. Maris and J. Tauc, Phys. Rev. B34, 4129 (1986)
2. P. Stampfli and K.H. Benneman, Phys. Rev. B **42**, 7163 (1995).