Thermal and elastic response of Pt metal to a ns laser excitation probed by pump-probe X-ray diffraction

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Optical pump - X-ray probe is the widely used technique to study ultrafast phenomena in solids induced by optical excitations. Ultrashort optical excitation is always associated with the thermal stress generation in the excited volume that, at a later timescales, results in the thermal lattice expansion. Depending on the optical pulse duration, the thermal expansion develops either via elastic waves propagation [1, 2] or quasi-statically.

Modern X-ray free electron lasers like European XFEL produce femtosecond X-ray pulses in the range from soft to hard X-rays with pulse energies of up to several mJ [3]. At the European XFEL impulsive X-ray heating results in beamline optics performance degradation as the number of pulses per burst grows and at a certain number of pulses results in the complete failure of an optic. Therefore, understanding the response of solids to fs optical and X-ray excitations on timescales from fs to milliseconds has important practical value.

Modern area X-ray detectors widely used at most synchrotrons allow for an external triggering, for example, with synchrotron bunch clock [4]. Complementing a synchrotron beamline with a synchronized fs/ps or ns pulsed laser system transforms the beamline into a beamline supporting all kinds of ultrafast diffraction experiments.

We have employed a specially designed mobile nanosecond pump-probe X-ray diffraction setup to understand the thermoelastic response of Pt(110) surface to pulsed ns laser excitations. With the use of Pilatus area detector the X-ray photons from an individual X-ray bunches were collected in the form of slices through reciprocal space. From such a data in our case we have determined all three diagonal components of lattice strain tensor in the probed region on ns to ms timescales. Our experiment clearly shows that on short time scales the lattice expands in the direction normal to the surface, as predicted by our quasi-static thermoelasticity theory. These results suggest that Poisson correction must be applied to the linear thermal expansion coefficient in order to calculate the apparent temperature from the measured Bragg peak shift [5]. The mobile nanosecond setup has been benchmarked at BESSY, ESRF and Petra III synchrotrons.

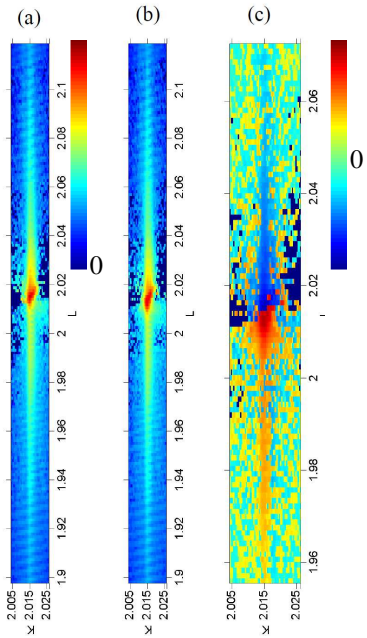

Fig 1.a),b) Measured reciprocal space map along 02L crystal truncation rod for the two pump-probe delays a) -25 ns and b) 25ns.
c) Signal difference b)-a)

References

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