Experiment title: 2D shock focusing	Experiment number: HC-5095
Beamline: ID09	**Date of experiment:** from: Februaru 14 to: February 20, 2023	**Date of report:** March 24, 2023
Shifts: 18	**Local contact(s):** Matteo Levantino, Céline Mariette	*Received at ESRF:*

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Report:

Objectives. This proposal aimed at studying in-plane shock stresses characteristics of surface acoustic waves excited by a laser-driven 2D shock focusing technique. Prior to the proposed time-resolved X-ray studies at ID09, stroboscopic 1D laser-excited SAWs studies on SrTiO3:Nb substrates were carried out in our laboratory. Experiments performed in our lab revealed that these substrates can bear quite high strains, that we estimate in the range of 1%-2%, before showing mechanical failure. We expect that with the 2D focusing technic, the pressure will be even higher and that the synchrotron x-ray source is perfectly suited for solving the shock discontinuity and quantitatively access the shock characteristics imprinted on the crystalline sample from the 2D focusing technique.

The uncompressed output (~ 300 ps) of the 800 nm Ti:Sapphire laser at the repetition rate of 10 Hz was shaped on the sample surface (1) as a ring with the combination of a 3 cm focal length microscope objective and a 0.5º axicon and (2) as a line of some definite thickness with the combination of a 3 cm focal lens and a cylindrical lens (f = 1 m), see Figure 1(a and b). A commercially available blank SrTiO3:Nb crystalline substrate with (111) cut (10 mm x 10 mm x 500 µm) was used. A specific experimental set-up, based on caged systems from Thorlabs, was designed and mounted for the beam-time (cf. figure 1 (c)). It allowed to have an optical beam at normal incidence on the sample which is mandatory to create an homogeneous shock and to get an imaging system allowing to align correctly the optical beam on the sample.

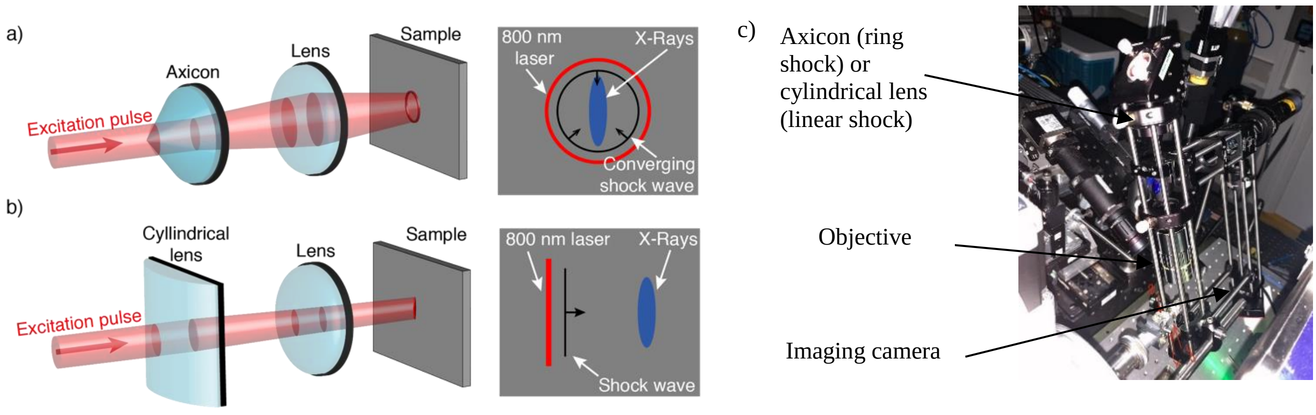

Figure 1 : (a) Schematic representation of 2 D shock focusing scheme. (b) 1 D laser-excitation scheme. (c) Cage system.

Experiments performed and main results

We have performed time-resolved X-ray diffraction on SrTiO3:Nb (111) substrate at different times during shock propagation on the sample and at different laser energies:

(1) With a ring shaped laser beam (d ~ 160 µm, thickness ~8 µm). At 3 ns delay, a change in the signal can be noticed. The two wings shape of the profile indicate a displacement of the ray line to the small value of q which is compatible with a dilatation. At 1 µs, the signal has still not go back to zero. We observe only thermal wave because the X-ray footprint is ~ 40x80 μm^2 and intergrate the signal on a too large area of the schocked zone.

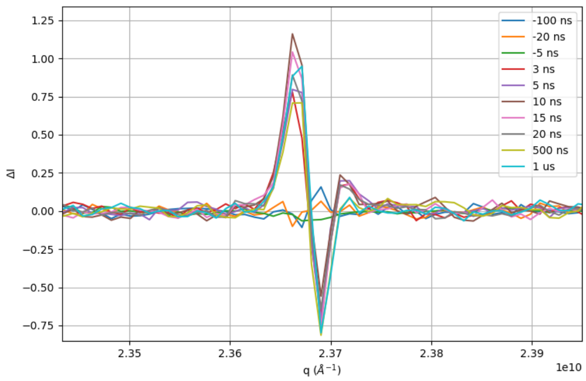

Figure 2 : Differential XRD pattern measured at various. Differential XRD pattern measured with a ring shaped pump with a 16 µJ energy at various time delays.

(2) With a line shaped laser beam (thickness ~ 40 µm) at 40 µJ (under a damage threshold), at the distances of 250 µm from X-Rays. Here we observe two waves (see figure 3(a)) : 1) at 35 ns and 2) at 60 ns. These time values correspond to longitudinal wave and SAW. To confirm this, we have increased the distance between laser excitation and X-ray detection to 320 µm. Indeed, in figure 3(b) we see that the arrival time has shifted to 40 ns for longitudinal wave and to 80 ns for SAW.

(3) With a line shaped laser beam (thickness~10 µm) at 35 µJ (under a damage threshold) at a distance of 370 µm. As expected, the observation of the longitudinal and SAW are shifted toward longer delays, and their amplitude is higher as the excitation fluence is much higher (cf. Figure 3(c)).

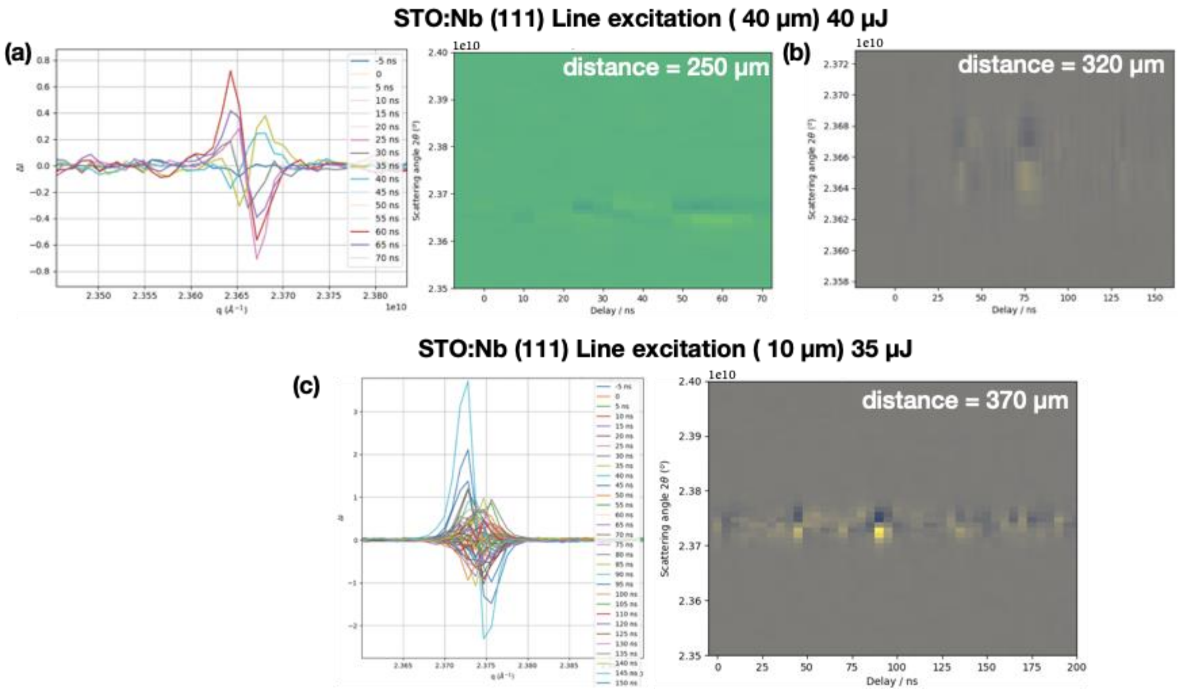

Figure 3 : Differential XRD pattern measured at various delays and associated time dependence. (a) XRD pattern measured with a 40 µm thick line shaped pump with a 40 µJ energy at a distance of 250 µm from X-rays. (b) Same with 320 µm distance from X-rays. (c) XRD pattern measured with a 10 µm thick line shaped pump with a 35 µJ energy at a distance of 370 µm from X-rays.

Overall, the results obtained on the sample with line shaped excitation beam are clear. We indeed detect the propagation of SAW and longitudinal acoustic waves. In order to get more promenent effect, the next should be the optimization of the ring shaped excitation since the 2D shock focusing should lead to higher strain/pressure. It can be achieved either by optimization of the X-Rays incidence angle to decrease its footprint on the sample, either by working with thinner (<20 µm) sample at normal incidence of X-Rays in transmission mode. Another important advantage would be to use the motorized goniometer in order to change probe position on the sample more precisely.