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Upgrade of single-shot time-resolved X-ray diffraction system using high-power Nd:glass laser at AR-NW14A

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1 Introduction

Time-resolved X-ray diffraction, combined with the shock-wave driven laser pulse and short X-ray pulse, is a powerful tool for understanding the high-speed structural change of condensed mattes under shock wave loading. Usually, the measured signal from the shock compression state of material cannot be accumulated repeatedly because the sample was completely broken after strong shock compression. Therefore, high-flux X-ray pulse is extremely useful to observe the irreversible structural change under shock wave loading. The PF-AR is operated in the single-bunch mode through a whole year. The flux of single X-ray pulse is higher than that of multi bunch mode operation of the other synchrotron sources. Combination of a nanosecond high-power laser and picosecond X-ray pulse from the PF-AR are suitable for studying the shock-wave induced structural dynamics, such as the shock-induced phase transition and elastic-plastic deformation in high strain rate. We have studied the shock-induced elastically structural change of various materials using the two staged amplified Nd:YAG laser with a maximum energy of 1 J/pulse[1-3]. The laser intensity per pulse depends on the shock pressure. Further study of these structural dynamics under shock compression is needed in order to increase the laser energy per pulse.

We have installed the high-power Nd:Glass laser with 16 J/pulse in the X-ray hutch of the AR-NW14A beamline. We developed to synchronize an amplified nanosecond laser pulse to X-ray pulse which is crucial for performing single-shot time-resolved X-ray diffraction experiment under shock wave loading.

2 Installation of Nd:Glass laser system and synchronization of an amplified laser pulse with X-ray pulse

The high power Nd:Glass laser system with 16 J/pulse (NPG 760, Continuum Co. Inc.) was installed at the experimental X-ray hutch of the AR-NW14A beamline, as shown in Fig.1. The Nd:Glass laser was composed of the Q-switch Nd:YAG laser for laser oscillator system and three staged Nd:Glass amplifier components. The amplifier system consisted of ϕ9, ϕ16, ϕ25 mm rods of Nd-doped laser glass surrounded by many flushlamps. The pulse width, wavelength, repetition rate, and energy of the Nd:YAG oscillator of a seed laser were 12 ns, 1.06 μm, 9.46 Hz, and 0.2 J/pulse, respectively. The Nd:YAG oscillator is synchronized with a divided 508 MHz rf

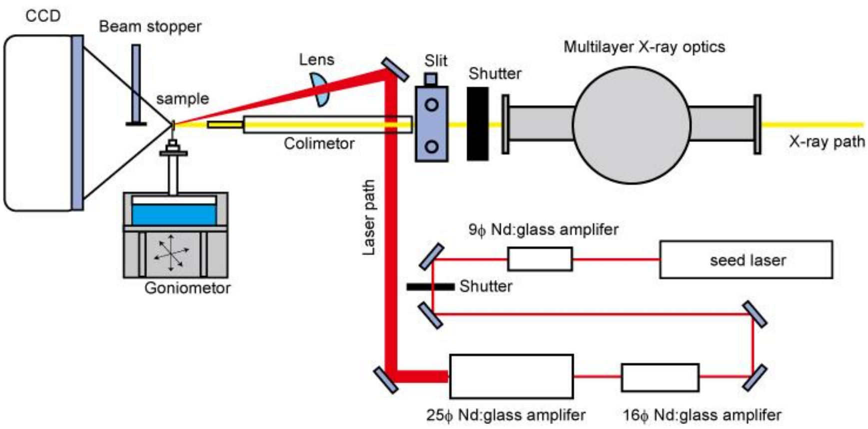
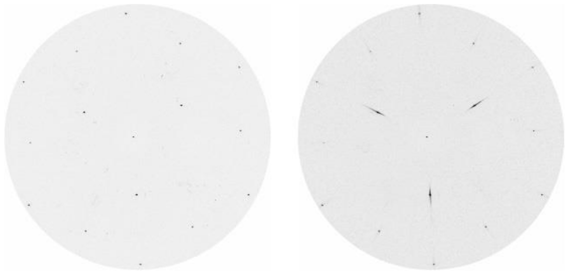


Fig.1 Schematic drawing of the single-shot time-resolved X-ray diffraction system. The red line and yellow line are the laser and X-ray path. The seed laser is Nd:YAG laser synchronized with the divided rf master clock from 794 kHz to 9.46 Hz. Single amplified laser pulse of 16 J was taken by the solenoid shutter.

master clock at 9.46 Hz. Single laser pulse in the 9.46 Hz was amplified by the three staged Nd:Glass medium. The amplified laser pulse from 0.2 J/pulse to 16 J/pulse was taken by a solenoid shutter. A delay time timing between the laser pulse and the X-ray pulse is changed by a digital delay generator (DG645, Stanford Research System, Inc.).



(a) (b)

Fig.2 Laue diffraction patterns of Si(111) single crystal at before laser irradiation (a) and at 1.4 ns after the high-power Nd:Glass laser irradiation (b).

The beamline provides a white X-ray pulse in the 13-18 keV energy range using an undulator with a period length of 20 mm and a pulse duration of 100 ps. The single X-ray pulse was taken using a X-ray pulse selector and a solenoid X-ray shutter [3].

3 Experimental demonstration of elastic-plastic deformation of Si(111) single crystal under shock wave loading

We demonstrated to observe the elastic-plastic deformation of Si(111) single crystal of 50 μm thickness under shock compression. We observed the shock-wave induced structural change of Si(111) single crystal using single-shot time resolved Laue diffraction with the high-power Nd:Glass laser, as shown in Fig.2. At 1.4 ns, the diffraction peaks was obviously broadened and shifted. The crystal structure of Si(111) was changed with increasing the defect and dislocation by shock-induced elastic-plastic defromations. We will describe in details elsewhere.

References

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