Study on surface processing process by using femto-second pulse train beam with excitation of coherent phonon

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INTRODUCTION

When a laser pulse interacts with metal or semiconductor target, the coherent phonon, which is the coherent motions of lattice and molecule vibrations in solids, is excited by the interaction of electrons and high latitude electric field[1]. It has unique properties of decaying in approximately several picoseconds and substance specific frequency.

The femtosecond laser processing is the local processing with little heat diffusion and little thermal damage to the target, due to the ultrafast time scales. We propose a novel femtosecond pulse ablation process with oscillation of the coherent phonon by femtosecond pulse train.

PULSETRAIN BEAM PROCESSING

The pulse train is shaped by using spatial light modulator (SLM), which shift the phase of the passing light[3]. The coherent phonon oscillations enable to activate the lattice motion on the sample surface. The target is ablated efficiently without thermal damage.

Figure 1 shows single pulse oscillation process for the lattice. Pulse interval of femtosecond Ti: Sapphire laser (repetition rate: 80 MHz) is 12.5 nanosecond. The coherent phonon, which is stimulated by single femtosecond pulse, is dumped before the next pulse irradiation. Figure 2 shows the pulse train oscillation process with repetitive oscillation in single pulse train. The coherent phonon is repetitively amplified by using pulse train beam whose decay is within a few picoseconds.

We describe the novelty of the proposed method in the case of irradiation the pulse train beam, which consists of the double pulse irradiation in ps time range.

When the first pulse is oscillate coherent phonon, the interval change of double pulses caused the change of the timing of coherent phonon oscillation.

When the timing of the amplification is matched, the amplitude of the coherent phonon is increased. In this case, the exceeding the ablation threshold is easily occurred and the ablation rate is expected to be increased.

Furthermore, the phase of the phonon is matched in the area where the coherent phonon is generated. In this case the energy transfer from free electron to lattice vibration (phonon) is unified. It has advantage to decrease the validation of processing volume.

Experimental Setup
The phase control system to shape the pulse train beam in time domain is reported by e.g. Hase and Weiner[1,2]. The system consists of a pair of gratings and lenses and liquid crystal spatial light modulator (LC-SLM). Each element is placed on the focal distance of lens, and Fourier transform plane is formed in left side of SLM and inverse Fourier transform plane is formed right side. The first grating disperses an incident pulse and each frequency component of pulse is spatially spread before SLM. That is, each lens performs a spatial Fourier transform between the plane of the grating and SLM.

Figure 5 shows the pulse train measurement system, which can integrate with femtosecond pulse processing system. The shaped pulse and reference pulse is passing through the second harmonic generation by using BBO crystal.

When input sine wave phase pattern to SLM for femtosecond pulse shaping, the femto pulse is shaped in the pulse train as shown in figure 5. The pulse shape is measured by using cross-correlation method by using femto second reference pulse[3]. The femtosecond pulse consists of discrete and a series of frequency modes.

We integrate the system as shown in fig. 5 into the pulse train processing system as shown in figure 6. We change the optical path by using beam splitter (BS) in fig. 5. The shaped pulse is introduced in the pulse train processing process as shown in Figure 6.

**Summary**

We proposed a novel laser processing method by using coherent phonon oscillation. In order to achieve the laser processing with coherent phonon oscillated surface, we need to develop the femto pulse shaping system to generate the pulse train beam. In this paper we test and evaluate the pulse shaping system and pulse shape measurement system in time domain. It is possible to generate the pulse train beam, which repeats pulse irradiation in the duration with 1.3 ps. Then we integrate the pulse processing system with the pulse train beam shaping system.

We will investigate the processing property by using pulse train beam as compared to the single femto-pulse processing results.

**REFERENCES**

