Observation of stress dynamics after fs laser irradiation inside diamond

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1. Introduction

Recently, diamond has attracted great interest as a platform for quantum information, because it has nitrogen vacancy (NV) centers, which can be exploited as quantum bits, since the electron spin at the NV center has a long coherence time and be controlled with light [1]. Therefore, the precise three-dimensional fabrication inside diamond is a great challenge for realization of integrated diamond-based quantum devices. One of the key components in diamond-based quantum devices is an optical waveguide, which can be written by fs laser direct writing. Previously, we found that a single-pulse irradiation with 100-300 fs laser pulses cannot induce any permanent modification inside diamond, but double-pulse irradiation with 200-400 fs laser pulses was effective to induce larger permanent modification [2]. However, the difference in the dynamics after fs laser irradiation between single- and double-pulse irradiation has remained unclear. In this study, we observed stress dynamics using a time-resolved interferometer to investigate the difference between single- and double-pulse irradiation.

2. Methods

Fs laser pulses (single or double pulses, central wavelength = 800 nm, pulse duration 0.1-0.4 ps) were focused inside a diamond by a 50× objective lens (NA = 0.80) to induce nonlinear photoexcitation at the focus. The focus was 50 μm below the surface. At the same time, the SHG of the fs laser pulse was transmitted through the photoexcited region as a probe pulse, and the transmitted light images were detected by a charge coupled device (CCD). For the detection of the phase distribution in the probe pulse, the probe light was passed through a Michelson interferometer before detection by the CCD.

3. Results

Figure 1 shows transient phase distributions after irradiation with a 300 fs laser pulse inside diamond. We can see double ring patterns with opposite phase changes, which is due to the interference of two identical probe lights after passing through the sample and interferometer. Therefore, we focused on the left ring pattern for the analysis. The phase change in the photoexcited region did not change from 300 ps to 400 ps, while the phase change in the outer region propagated away from the center. Since the propagation velocity was similar to the sound velocity in diamond, the outer phase change is due to a laser induced stress wave. Figure 2 shows radial distributions of the phase change plotted against the position from the center of the photoexcited region. The phase changes of the stress wave by double-pulse irradiation was slightly larger than that by single-pulse irradiation, while the phase change at the periphery of the photoexcited region by double-pulse irradiation was smaller. This difference suggests that the double-pulse irradiation can generate a large stress wave with less stress around the photoexcited region.

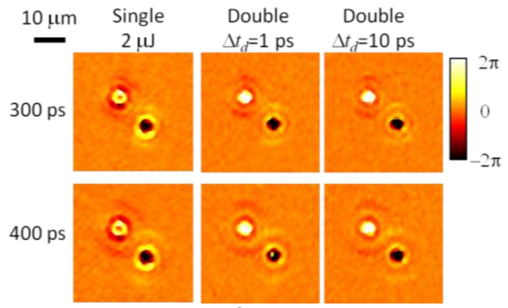

Fig. 1 Phase distributions after laser irradiation inside a diamond.

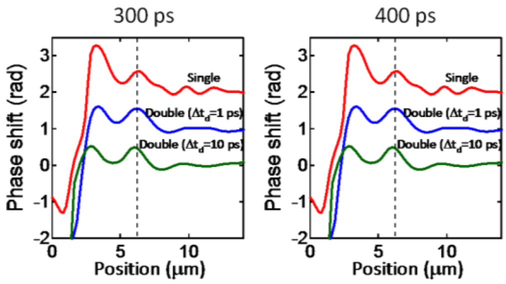

Fig. 2. Radial distributions of phase change from the center of the photoexcited region.

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References

[1] L. Childress et al., Phys. Today, **67** (2014) 38.
[2] M. Sakakura et al., JSAP2016 Spring meeting; LPM2016 proceedings, under review.