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Candidate of final focusing system for high power lasers

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With advances in laser technology, the trend toward higher power and higher repetition rate lasers has accelerated in recent years. Lasers in the PW and kJ class lasers are now available, and research and development of applications utilizing high intensity lasers such as EUV generation and laser particle acceleration is underway. However, in contrast to this increase in laser power, there has not been rapid progress in optics, which is one of the factors preventing further increases in laser power. For example, laser systems used in inertial fusion energy programs must have many meter-sized optics to avoid damage. Another problem in applications such as laser processing and laser particle acceleration is contamination of the final focusing optics by debris produced when focusing an intense laser beam on a target.

To solve these problems, we have proposed a new optics using a mixture of ozone and oxygen as the medium. When using solids, as in the case of conventional optics, damage cannot be repaired, whereas gases are easily replaceable. In addition, gaseous media, which in principle have a damage threshold that is an order of magnitude higher than that of solids, are useful in many high-energy laser applications.

As one example of a gas optics, we have demonstrated a gas diffraction grating. This gas diffraction grating utilizes a refractive index modulation $\Delta n \geq 10^{-5}$ generated transiently in a neutral gas containing a few percent ozone (1 atm). It diffracts the laser light like a volume phase diffraction grating. The refractive index modulation in this gas is generated by ultraviolet pulsed laser (266 nm, 6 ns pulse). By irradiating the gas with UV laser, which is resonantly absorbed by ozone, large-amplitude dense waves are excited in the gas. The periodic density modulation by these dense waves is the refractive index modulation source. Figure 1 shows an image of an actual gas diffraction grating generated in ozone gas. A typical system is shown in Figure 2. The period of the diffraction grating corresponds to the spatial frequency of the UV laser radiation pattern. The refractive index modulation is gradually generated with a rise time of several 10 ns, reaches a maximum density modulation amount, and then gradually disappears.

Recently, we have succeeded in creating gas lenses by introducing unequally spaced curved large amplitude density modulation structures into ozone gas. This gas lens functions like a Fresnel zone plate, diffracting and focusing the incident laser light. Typical ozone gas thickness is only a few mm.

To date, we have realized gas optics with a damage threshold of 1.6 kJ / cm^2, an average diffraction efficiency of 96%, and a diffraction wavefront accuracy of $\lambda/10$ for nanosecond pulse lasers [1]. Almost ideal focusing conditions of $M^2 = 1.1$ have been achieved with the gas lens. The UV laser energy required to generate it is only about 70 mJ/cm^2. These new gas optics are expected to be used as the final focusing system for many laser applications.

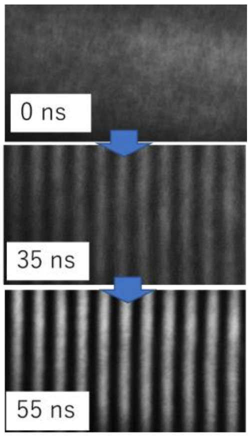

Figure 1. Absorption measurement image of a gas diffraction grating. The grating period is about 20 micrometers. The numbers indicate the delay time from the time when the UV laser pulse light was irradiated.

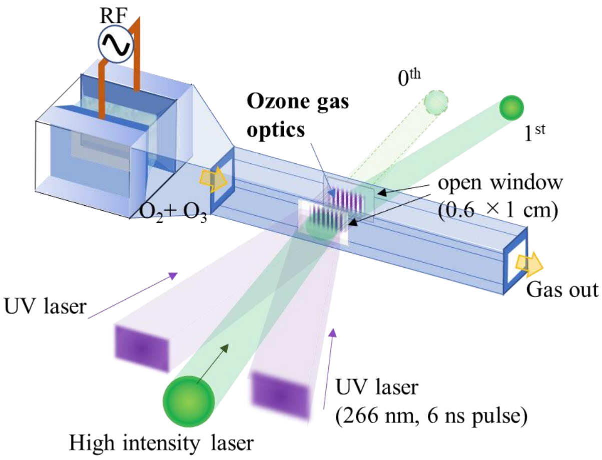

Figure 2. Conceptual figure of gas optics.

Reference
[1] Y.Michine and H.Yoneda, Communications physics 3, 24 (2020).