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The development of optical switch of high intensity lasers with plasma grating
プラズマグレーティングを用いた高強度光スイッチの開発

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We propose a new optical switching method using a plasma grating for ejecting the high intensity laser light from enhancement cavity system. To realize ultra-high power laser pulse, the enhancement cavity method is one of the promising method for coherent addition in time scale. Our optical switch will be kick out the accumulated pulse at higher intensity condition than the conventional device. In this switch we use photoexcitation process to change refractivity of the medium of the grating instead of ionization to produce free electrons. This grating has better efficiency in production and has long life time to compare the normal plasma grating.

1. Introduction

How to achieve ultra-high intensity laser pulse is one of the big challenge to go to new scientific field of optical science. There are many proposal to utilize it. The common stance is that the future intense laser pulse is produced with coherent addition because there are already limitation in the present conventional master-oscillator and power-amplifier method of the laser technology. Even though there are many proposals for beam combining in time, space and frequency direction, efficiency of the combining is not enough. If we consider addition of thousand beams to one coherent beam in a single step, efficiency of one-by-one addition process is tremendously high efficiency. Therefore, combination of those method should be selected. Cavity enhancement is one of the adding method to accumulate the laser energy in temporal axis. There are many successful works to accumulate the week laser pulses to create a single pulse in the enhancement cavity [1]. Up to now, conventional optical switch such as an acoustic-optical modulator or an electrooptical modulator is used to extract the laser pulse from the enhancement cavity. However the conventional switches also limit the accumulation factor to avoid optical damage and unfavorite nonlinear process inside switch devise which are always decrease efficiency in the next coherent addition process. To overcome these problems we propose to use our new "plasma grating" instead of the conventional one.

There are several plasma grating to control strong laser pulse. The common modulation method of optical waves in the plasma grating is spatial density modulation of free electrons [2,3]. That is due to the large polarizability in infrared optical wavelength. However there are large energy to use to produce free electrons. In normal ways, we spend several or tens electron-volt energy to produce a single free electrons from atoms. In addition, these method produce large thermal heat and high temperature (at least eV) plasma state are created. The life time of creating density modulation is normally decide with d/v_s, where d is grating period and v_s is the expansion velocity. The v_s will be proportional to square root of temperature so that high temperature plasma device has short life time. Those are main reasons why intense ultra-short pulse laser are used for creating normal plasma grating even though sometimes laser intensity in creation of the grating is larger than the controlled laser intensity.

In this study, we use electronic excitation state to change the optical refractivity. We can keep lower temperature after crating the grating and efficiency is also higher than normal plasma grating.

2. Experiments

Our "plasma grating" system is consisted with (1) production of the initial plasma medium and (2) writing of grating optical refractive index modulation. We use an atmospheric plasma device (APD) to generate the initial stable plasma at atmospheric pressure. The reason why we need "initial plasma" is to achieve efficient production of excitation state which has relatively large difference in optical constants to compare the unwriting condition. The eletro-discharge excitation gas is ejected from the slit of the our APD (length: 5cm, width: 1mm) and uniform initial plasma medium is prepared in free atmosphere space just above the

APD device. Oxygen gas is used in the APD because ozone component has large absorption coefficient in UV light which we use as writing beam to generate grating period. The KrF laser pulse (wavelength is 248㎚ and pulse duration is 10~25ns) used in this study. Fig. 1 shows the configuration of this experiment for making plasma grating. The periodical grating is made by interference fringes created by the UV pulses which are divided into two light paths by a beam splitter. Absorption cross section of ozone in the UV writing wavelength is five orders of magnitude greater than that of the diffracted beam.

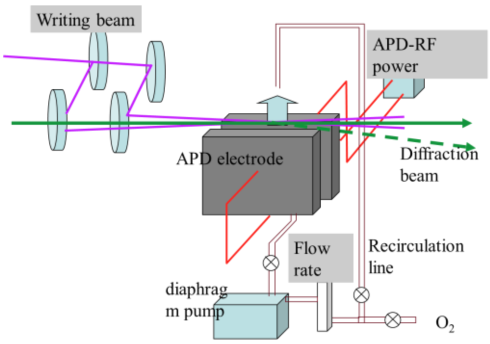

Fig.1 Experimental set up

Fig. 2 shows the photograph of the transmitted beam pattern though this system with (a) and without (b) firing APD operation. The flow rate of operating gas (O2) is also important factor to create this grating. That means we have optimum condition to achieve high density ozone at the top of the APD device.

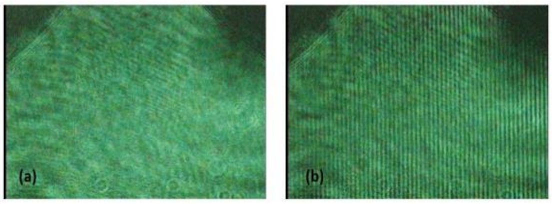

Fig.2 The transmitted beam pattern through "plasma grating" (a) with writing beam and (b) without writing beam.

The life time of the grating is judged by changing delay time between writing and diffractive laser pulses. Up to now, we can keep it for at least several hundreds nanosecond. It is extremely longer life time to compare the normal plasma grating. (normally, picosecond life time) That is also one of the attractive point of our grating because we can decrease intensity of writing beam. (we can write the period of the grating slowly.)

3. Conclusion

We proposed and demonstrated ozone grating. In this method, the writing beam intensity is sufficient to significantly smaller than diffraction beam. And we get relatively high diffraction efficiency can be achieved with asymmetric volume grating method. Development of ozone grating progresses, it will be able to be switched high intensity laser light at enhancement cavity system. Now, we plan to generate ozone gas locally, and varying the thickness of the grating to improve the diffraction efficiency of ozone grating.

References

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