23P168-B

Formation of a Transient Plasma Micro Optics for Laser Wake Field Acceleration
レーザー航跡場加速のためのプラズママイクロオプティクス形成

Yoshio Mizuta[1], Akinori Nishida[1], Shinichi Masuda[2,3] ,Keigo Makito[1], Shohei Kajino[1], Nobuhiko Nakanii[2,3],Masaki Kando[4], Michiaki Mori[4], Hideyuki Kotaki[4], Yukio Hayashi[4], Alexei Zhidkov[5], Sergei Bulanov[4], Tomonao Hosokai[2,3], and Ryosuke Kodama[1,2,3]

水田好雄[1]、西田明憲[1]、益田伸一[2,3]、牧戸啓悟[1]、梶野祥平[1]、中新信彦[2,3]、神門正城[4]、森　道昭[4]、小瀧秀行[4]、林由紀雄[4]、アレクセイジドコフ[5]、セルゲイブラノフ[4]、細貝知直[2,3]、兒玉了祐[1,2,3]

[1]*Graduate School of Engineering, Osaka University, 2-1 Yamadaoka, Suita-shi, Osaka 565-0871, Japan*
[2]*Photon Pioneers Center, Osaka University, 2-8 Yamadaoka, Suita-shi, Osaka 565-0871, Japan*
[3]*Japan Science and Technology Agency (JST), CREST,*
[4]*Kansai Photon Science Institute, Japan Atomic Energy Agency, Umemidai 8-1, Kizu, Kyoto 619-0215, Japan*
[1]大阪大学大学院 工学研究科 〒565-0871　吹田市山田丘 2-1
[2]大阪大学 光科学学センター 〒565-0871　吹田市山田丘2-8
[3]科学技術振興機構 (JST), CREST
[4]日本原子力研究開発機構 〒619-0215　京都府木津川市梅美台 8-1

The transient plasma micro optics (TPMO) is important part of the two-staged laser wake- field acceleration scheme, because the electron self-injection and acceleration can be controlled independently. We have observed TPMO structures created by laser pulses with the pulse duration of nanoseconds and picoseconds using interferometry. A density profile of plasma cavities created by the nanosecond pulse pedestal was measured. In addition, temporal evolution of a plasma channel created by a picosecond pulse was also observed. The channel length exceeded 600μm, which was three times the Rayleigh length.

1. Introduction

We study laser wake-field acceleration (LWFA) for aiming at a repeatable and high quality electron source. By controlling the waveform of intense laser pulse with nanoseconds and picoseconds pre-pulses, we have demonstrated generation of quasi-monoenergetic, hundreds MeV electron beams with excellent emittance by laser wake field acceleration[1,2]. Nanosecond pre-pulse may produce plasma cavity in a gas target. The plasma cavity acts like optical element of focusing or defocusing laser light. Picosecond pre-pulse propagates in the cavity and it creates long plasma channel. We called this process as a transient plasma micro optics (TPMO). Femetosecond pulse is guided in the long plasma channel. As a result, high quality electron beam is generated. TPMO plays important role in LWFA. Until now, it has not been studied much. In this paper, we investigated the cavity and channel creation in details. We measured the density profiles of plasma created by laser pulses with the pulse duration of nanoseconds and picoseconds in a high-density gas jet target using picoseconds time-resolved interferometer.

2. Experimental Setup

The experiment was performed at JLITE-X 800nm Ti:Sappire CPA laser system at the JAEA-KPSI (Kansai Photon Science Institute, Japan Atomic Energy Agency) [3,4]. An outline of the experimental setup is given in Fig. 1.A laser pulse with a diameter 30 mm is focused to the position of the ~100μm front edge of the slit gas jet height of 1.5 mm form nozzle exit with f/5.9 off-axis parabolic mirror. In order to study the effects of the TPMO formation by the laser pulse, we controlled the nanosecond order laser pre-pulse by tuning the Pockels cell behind the regenerative amplifier of the laser system [4]. We also controlled pulse duration 300 fs~6 ps by turning the distance of the grating pair in the pulse compressor, to observe the effect of pulse duration. The focal spot size is 16μm in full width at $1/e^2$ of maximum with 186μm Rayleigh length. The maximum laser intensity on the target is estimated to be 3.5×10^{15} W/cm^2 .We used an Ar gas jet target, which was provided through a supersonic nozzle by a pulse valve (Smartshell Co.Ltd). The stagnation pressure of the pulse valve was 2.00 MPa. The neutral gas density is estimated to be 1.5×10^{19} cm^{-3} .

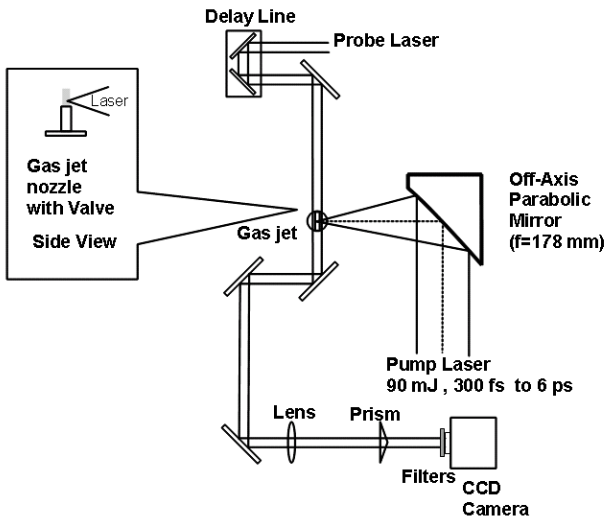

Fig.1 Schematic diagram of the experimental setup

To observe the formation process of a TPMO, we used time-resolved interferometer. The length of the probe laser is 400 nm. The interferograms were taken by a CCD camera.

3. Experimental Results

Fig.2 shows interferogram taken during the propagation of a CPA pulse through the gas jet. Laser pulse comes from the left side.

The corresponding electron density distribution is also shown Fig.3. We are calculating about the absolute number of the electron density now. The electron density distribution can be calculated from the phase shift. IDEA code was used to obtain a phase shift map. A fast Fourier transform technique was used to retrieve the plasma-imposed phase shift. The phase-shift map is processed then with an Abel inversion algorism [5]. The maximum channel length was 600μm. It was three times the Raleigh length.

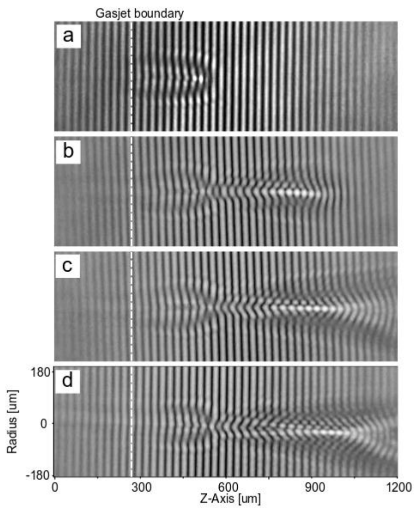

Fig.2 Interferogram

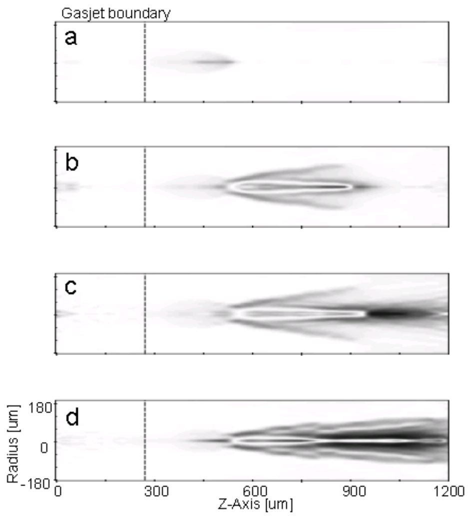

Fig.3 Electron density distribution

4. Conclusion

In conclusion, we have studied the formation process of a TPMO useful for laser wake field acceleration. We have investigated the TPMO creation in detail upon using the picoseconds time-resolved interferometry. The density distribution of a TPMO was measured. The channel length was 600μm, which was three times the Rayleigh length. Our measurements prove the plasma behavior as TPMO.

Acknowledgments

This work supported by the Japan Society for the Promotion of Science Global Centers of Excellence program(GCOE). This work was also supported by CREST (Core Research for Evolutional Science and Technology) of the Japan Science and Technology Agency(JST). We also are grateful to JAEA for providing the laser system.

References

[1] T. Hosokai, A. Zhidkov, A. Yamazaki, Y. Mizuta, M. Uesaka, and R. Kodama, Appl. Phys. Lett. **96**, 121501 (2010)

[2] T. Hosokai, K. Kinoshita, A. Zhidkov, A. Maekawa, A. Yamazaki, and M. Uesaka, Phys. Rev. Lett. **97**, 075004 (2006)

[3] M.Mori,A.Pirozhkov,M.Nishiuchi,K.Ogura,A.Sagisaka,Y.Hayashi,S.Orimo,A.Fukumi,Z.Li,M.Kando,and H.Daido Phys. Rev. Lett . **97**,075004(2006)

[4] M.Mori, *et al* IEEE TRANSACTIONS ON PLASMA SCIENCE, VOL. **36**, NO.4 AUGUST 2008

[5] P.Tomassini,andA.Giulietti,Opt.Commun.199,143(2001)