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Parameter Measurement of Hypersonic Plasma Flow generated by Taper-cone-shaped Plasma Focus Device

テーパー・コーン型プラズマフォーカス装置により生成した極超音速プラズマ流のパラメータ計測

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To observe behaviors of collisionless shocks, dependence of perpendicular magnetic-fields on hypersonic plasma flow generated by a taper-cone-shaped plasma focus device has been evaluated. The velocity of hypersonic plasma flow was observed with a streak camera. The results shows that the perpendicular magnetic-field gradient affects the velocity of hypersonic plasma flow. It also indicates that the acceleration ratio in the perpendicular magnetic-field gradient depends on the plasma beta of hypersonic plasma flow.

1. Introduction

Collisionless shock phenomena, in which are one of the astrophysical phenomena, have unclear mechanism such as energy dissipation process and generation of highly energetic particles. Hypothesis on origin of highly energetic particles are generated by low Mach number flow with the weak perpendicular and/or parallel magnetic-field from numerical simulations [1]. To generate the collisionless shock in the laboratory scale experiments, Drake [2] has considered the required conditions, which depend on the magnetic flux density and the hypersonic plasma flow. The pulsed-power discharge using taper-cone-shaped plasma focus device [3] is easy to generate the hypersonic plasma flow.

In this study, to observe behaviors of collisionless shocks, dependence of perpendicular magnetic-fields on hypersonic plasma flow generated by a taper-cone-shaped plasma focus device has been evaluated. Compared to the magnetic-field gradient, we observed the acceleration/deceleration of hypersonic plasma flow.

2. Experimental Setup

To obtain the one-dimensional shock wave, we use the taper-cone-shaped plasma focus device [3]. Generated plasma was focused and stagnated at the center of cone electrode. The stagnated plasmas were guided by the acrylic tube as a one-dimensional behavior. The velocity of hypersonic plasma flow was observed with a streak camera. The Mach number M, which the sound velocity v_{He} of helium at room temperature $T \sim 300$K standardized by the shock velocity, is estimated to be $M = 10 \sim 20$.

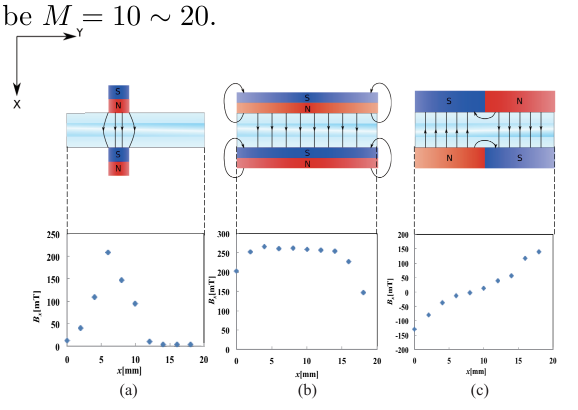

Fig. 1 Perpendicular magnetic-field distribution in the acrylic tube.

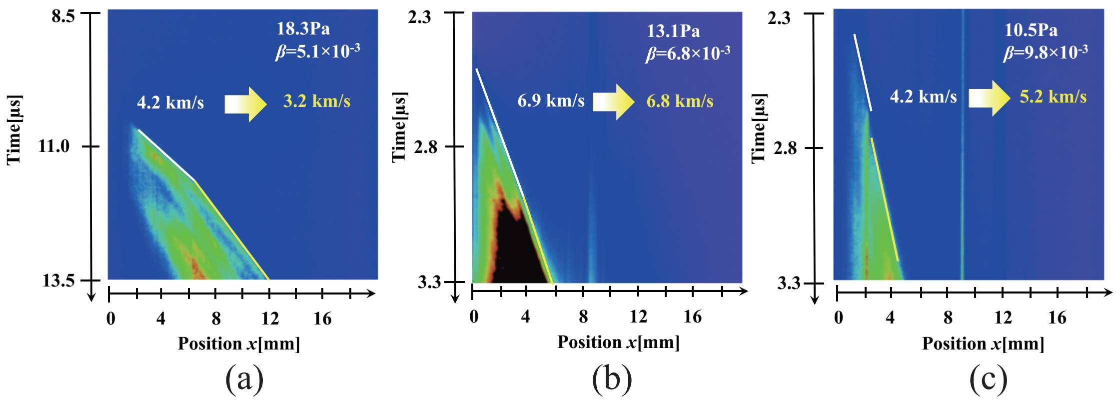

Fig. 2 Streak images of hypersonic plasma flow in the perpendicular magnetic-field. Labels (a)-(c) correspond to the perpendicular magnetic-field distribution in the acrylic tube as shown in Fig. 1

To evaluate an effect of magnetic field on the hypersonic plasma flow, permanent magnets were set on the acrylic tube. The magnetic-flux density distribution of permanent magnets are shown in Fig. 1.

3. Experimental Results and Discussions

Figure 2 shows streak images of the hypersonic plasma flow in the perpendicular magnetic-field with fixed plasma beta. As shown in Fig. 2, we can see a shock front from the visible emission. In the case of localized magnetic-field as shown in Fig. 2(a), the velocity of hypersonic plasma flow decreases from 4.2 km/s to 3.2 km/s. In the case of uniform magnetic-field as shown in Fig. 2(b), the velocity of hypersonic plasma flow is not change in the perpendicular magnetic-field. On the other hand, in the case of perpendicular magnetic-field gradient as shown in Fig. 2(c), the velocity of hypersonic plasma flow increases from 4.2 km/s to 5.2 km/s. The results shows that the perpendicular magnetic-field gradient affects the velocity of hypersonic plasma flow.

We have also demonstrated the different plasma beta with the perpendicular magnetic-field as shown in Fig. 1 (c). The results indicate that the acceleration ratio in the perpendicular magnetic-field gradient depends on the plasma beta of hypersonic plasma flow. These results are suggested that the length of perpendicular magnetic-field gradient contributes the acceleration/deceleration degree of hypersonic plasma flow.

4. Conclusions

To observe behaviors of collisionless shocks, dependence of perpendicular magnetic-fields on hypersonic plasma flow generated by a taper-cone-shaped plasma focus device has been evaluated. The velocity of hypersonic plasma flow was observed with a streak camera. The results shows that the perpendicular magnetic-field gradient affects the velocity of hypersonic plasma flow. It also indicates that the acceleration ratio in the perpendicular magnetic-field gradient depends on the plasma beta of hypersonic plasma flow.

To understand the hypersonic plasma flow with the magnetic field, we should evaluate the time-evolution of the magnetization of plasma flow and its plasma parameters.

Acknowledgment

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