Extended abstract for 18th ICDERS

Dynamics of Laser-Driven Blast Wave Generated in Space Propulsion Configuration

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1. Background and motivation

Recently, application of blast wave generated by focusing a high-energy laser beam to space propulsion attracts intense interests from the view points both of fundamental physics and practical application. Myrabo et al. (1997) developed the 'Lightcraft Technology Demonstator (LTD) and demonstrated its operation. Bohn et al of DRL, Germany, developed a similar device. In those devices, a light object is driven by a blast wave driven by repetitively-supplied pulsed CO_2 laser beam in open atmosphere.

Sasoh proposed another type of laser-driven propulsion device utilizing an internal flow system. This is applicable as a laser-driven ram accelerator (Sasoh 2000a), laser-driven in-tube accelerator (LITA, Sasoh 2001) and a laser-driven pulse detonation engine (Sasoh 2000b). The propulsion performance is expected to be increased by confinement of the working fluid in the tube.

However, basic physics on the laser-driven blast wave still warrants further basic investigations. In particular, process of breakdown needs to be better understood in order to increase coupling coefficient. Also, behavior of the blast wave which propagates with absorbing the laser energy, that is the laser-supported or –assisted blast wave needs to be further studied experimentally and theoretically. The purpose of this study is to quantitatively understand the above-mentioned issues.

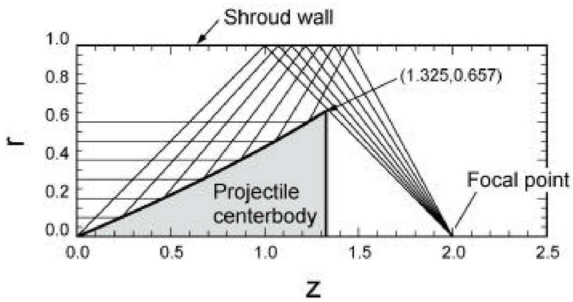

Fig. 1 Optical design for LITA or laser-driven RAMAC

2. Apparatus

Figure 1 shows the shape of the device. This configuration can be used both as a projectile launcher and as an engine. In the latter case, the projectile is fixed to the shroud and acts as a centerbody. An incident pulse-laser beam is supplied upstream of the nose, and is reflected on the nose, then on the inner surface of the shroud, finally is focused behind. The focused beam causes breakdown at the focal point, then its energy is transferred to the working fluid enthalpy. A blast wave is generated, and a momentum is transferred through overpressure exerting on the base.

In the experiment, a CO_2 TEA laser (5J/pulse, 100 Hz maximum) is used. The nominal cross-section of the beam is 33mm X 30 mm rectangle. Its dimensions are reduced half through a beam reducer lens system, and is supplied to a 25-mm-bore tube or a shroud. In the experiment, both of the launcher and the engine mode are investigated.

An overpressure around the focal point is measured using a piezo-electric pressure transducer. The spectra of the radiation emission is measured using a streak spectroscopy system, in which a CCD array is utilized to record the time variation of the spectra.

3. Preliminary results

Figure 2 shows an example of measured time variation of the overpressure. This is a record after a single laser beam shot. The first peak corresponds to the primary blast wave. Then, another small peak corresponding to the secondary shock wave is observed. The

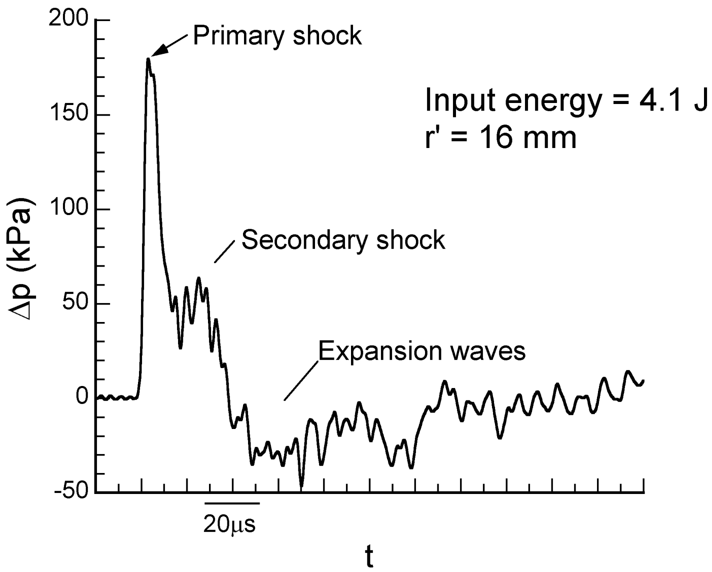

Fig. 2 Time variation of overpressure

underpressure observed after the secondary shock is caused by expansion waves.

In Figure 3, the radial distributions of the peak overpressure are summarized. The fitted value of the exponent ranges from –1.70 to –1.63.

An example of the streak spectroscopic image is shown in Fig. 4. The duration time of the strongest emission pulse equals around 2 μs. Currently, identification of the spectra and the determination of the temperature are under investigation.

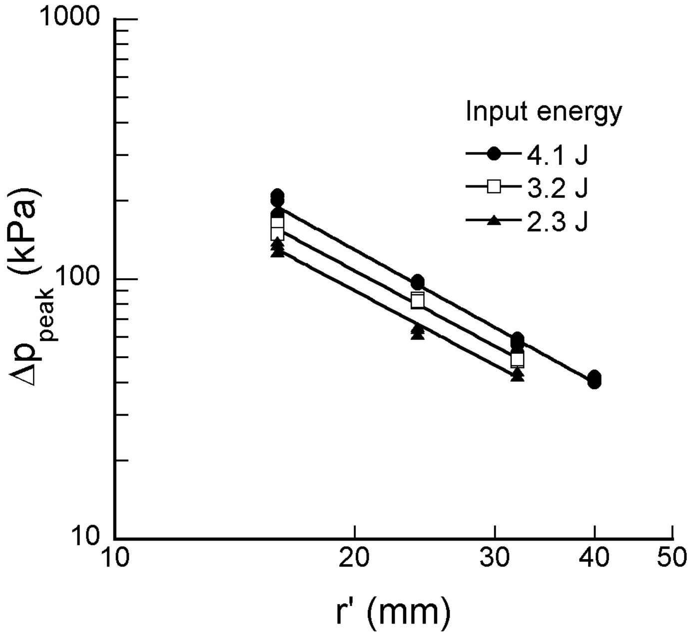

Fig. 3 Peak overpressure vs. radial position

4. Summary

A system of laser propulsion device which can be applied as a ram accelerator, pulse detonation engine and a zero-velocity start launcher has been developed. Preliminary measurements of the over pressure and emission spectroscopy were conducted. Further diagnostics as well as operation performance experiments are currently conducted.

5. References

Myrabo LN, Messitt DG, Mead Jr FB (1997) Ground and flight tests of a laser propelled vehicle, AIAA paper 98-1001

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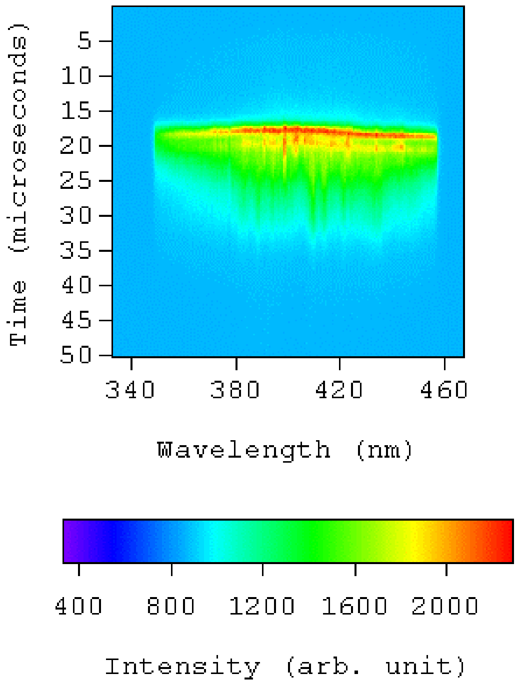

Fig. 4 Streak spectroscopy measured at focal point