A Newly Developed Large Diameter Diaphragmless Shock Tube for Studies on CO_2-N_2 Gas-Dynamic Laser

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A large diameter diaphragmless shock tube has been recently developed and designed to perform detailed studies of CO_2-N_2 gas-dynamic laser (GDL). This large diameter diaphragmless shock tube offers various advantages over the conventional shock tubes (diaphragm-type) as longer test times, higher degree of reproducibility of shock-tube data, and especially low-impurity operation condition. The latter advantage is experimentally demonstrated herein, which is very critical issue in the CO_2-N_2 GDL studies. A supersonic nozzle section was mounted at the end wall of the shock tube and instrumented for simultaneous measurement of laser output power and energy. The GDL action in a CO_2-N_2 mixture under low impurity condition has been obtained by using the large diameter diaphragmless shock tube for the first time.

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Conventional shock tubes have been used in gas-dynamic laser (GDL) experiments [1–3] for compressing and pre-heating instantaneously a mixture to elevated temperatures and pressures and delivering it to a nozzle station from which the shocked gas is turned into a laser medium (i.e., a population inversion is created) during the process of rapid cooling of the hot gas therein. However, in general the utilization of a conventional shock tube results in (i) uncontrollable amount of impurities as water vapor and hydrogen inside the shock tube and (ii) relatively large scattering of shock-tube data. These two together may impact badly the study of basic processes in CO_2-N_2 GDL (e.g. study of kinetic rates involved). In order to overcome these difficulties, a large diameter diaphragmless shock tube [4], based on the double piston-actuated structure developed by H. Oguchi *et at.* [5], has been recently developed and designed to study basic processes in CO_2-N_2 GDL. The main advantage of using such a unique shock tube in terms of GDL research is the cleaner operation condition attained by avoiding the exposure of inside shock tube to the ambient air after each and every test. Hence, impurities as water vapor and H_2, which may excite and de-excite the upper and lower laser levels of CO_2 molecule quite sensitively depending on their concentration in the mixture [6, 7], could be decreased to a large extent. This condition, which cannot be achieved in diaphragm-type shock tubes, would benefit doubtless such a research. In addition to this, the relatively good degree of reproducibility of shock-tube data and longer test times count positively. The lowered concentration of impurities mentioned is experimentally demonstrated herein. This shock tube was equipped with a supersonic nozzle section at its end wall and instrumented for simultaneous measurement of laser power and energy. The first GDL action (at mid-infrared wavelengths) in a CO_2-N_2 mixture driven by the large diameter diaphragmless shock tube was successfully achieved under low-impurity condition.

The recently developed double piston-actuated structure is shown in Fig. 1. The auxiliary piston is quickly actuated when the high-pressure actuating gas at its rear is very rapidly purged by means of the fast-opening valve. As such a piston slides backwards, the high-pressure actuating gas at the rear of the main piston, which

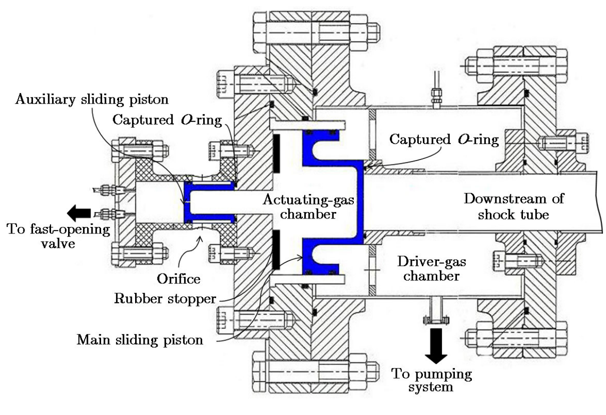

Fig. 1 Scale drawing of the double piston-actuated structure.

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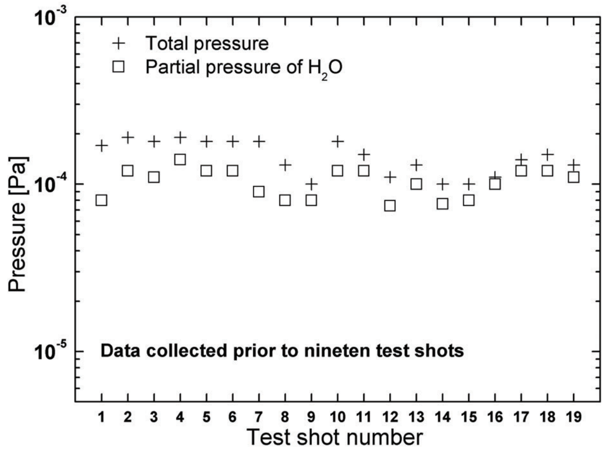

Fig. 2 Partial pressure of residual H_2O and total pressure of gases. Data collected prior to nineteen test shots.

separates the driver-gas chamber from the shock tube, is massively released through the orifices. This actuates the main piston which slides rapidly backwards driven by the high-pressure driver gas. Simultaneously, the driver gas discharges massively in the shock tube, thereby forming a shock wave therein, whose operation has been reported separately in Ref. [4]. Lowered and controllable concentrations of residual H_2O and H_2 were achieved, as shown in Fig. 2. The partial pressure in the evacuated shock tunnel was measured before filling the tunnel with the investigated mixture (driven gas) in a series of nineteen test shots. Partial-pressure reading was accomplished by using a quadrupole partial pressure transducer. The first test shot was taken after four hours of pumping down in order to bring the partial pressure of residual H_2O to an acceptable level. In general, the partial pressure of residual H_2O was approximately 10^{-4} Pa and that of residual H_2, helium and other gases was two order of magnitude lower than this. It is worth pointing out that from the first test shot, the pumping time necessary to reach the acceptable partial pressure of residual H_2O was 19 minutes only or less. Such a cleaner environment resulted in part from the fact that the inside shock tunnel was not repeatedly exposure to the ambient air after the diaphragmless shock tube was fired. The output power and energy of laser radiation available in the supersonic gas flow was measured by using the experimental arrangement as shown in Fig. 3 (a). Oscilloscope images of the first GDL laser action in a $0.3\,CO_2 + 0.7\,N_2$ mixture and post-shock pressures are plotted in Fig. 3 (b). Post-shock pressures were monitored by two piezoelectric sensors 50 cm

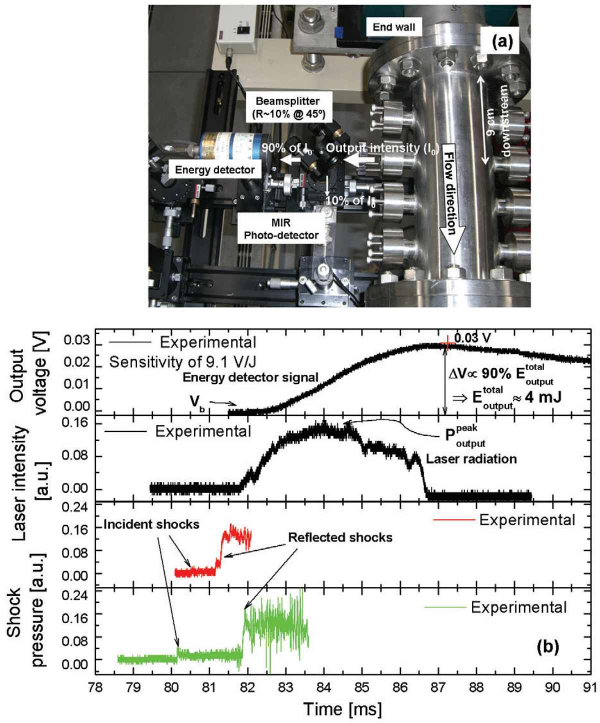

Fig. 3 (a) Shock tube end wall, nozzle, and resonator arrangement for the test shots. (b) Traces of post-shock pressures, laser intensity and energy as detected during a test shot.

apart (where the furthest downstream sensor stays 25 cm away from the end wall).

The GDL action reported above was obtained under concentrations of H_2O and H_2 (typical contaminants that affect the molecular kinetic involved) of 0.01 and 0.001 ppm by mass, respectively and relatively good degree of reproducibility of incident-shock Mach numbers (typically, uncertainty of 1 % only).

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