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DESIGN AND TEST OF THE GAS-DYNAMIC CARBON DIOXIDE LASER EXPERIMENTAL SETUP

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Abstract

An experimental gas-dynamic laser apparatus based on acetylene-in-oxygen combustion has been designed and tested. Main setup volume was designed as a modular type for flexibility. A vacuum system, electrical and measuring elements were attached to the volume. Tests of the gas supply, vacuum system, electronics and lasing have been performed. They have shown reliable functionality and durability of all units.

Introduction

In principal, the gas-dynamic laser (GDL) is based on rapid cooling of a hot gas by expanding it through a supersonic nozzle to obtain the *gas-dynamic* flow. The gas must be previously heated in the *stagnation* chamber in front of the nozzle using a suitable method. While its translational temperature significantly drops, it remains the vibrational temperature at a sufficiently high level to reach population inversion and to lase. The gas-dynamic flow of the escaping gas can be controlled by the combustion parameters and slit dimensions.

Although the first GDL laser was built more than thirty years ago [1] it still retain significant interest between researchers and especially in practice. These are typical high power lasers operating in either cw or (long) pulse regime. In the case of the CO_2 laser, as here, they do not need electricity for operation because they are *fuel powered*, thus very convenient for mobile units. Beside military interest great practical importance can be found in the material processing [2].

The main purpose of this work is to present the design and testing of an apparatus, built for the gas-dynamic CO_2 laser, based on the acetylene combustion in oxygen. Thus, carbon dioxide and water are formed in that reaction. A certain fraction of nitrogen is added to the mixture to control the explosion and improve the laser emission. We want to use this apparatus rather to investigate physico-chemical processes and mechanisms in the gas than only to measure pure laser effects, since a variety of non-solved physico-chemical problems still remain in this area [3].

Setup Design

The experimental setup consists of two main parts:

a) The *process volume* with attached gas mixture supply, vacuum equipments and gas exhausts, to make a unique system, all shown in Figure 1. This system was assembled from many segments for several reasons: (i) The modular unit offers flexibility in operation; (ii) It is easier for manufacturing and more convenient when making inspection, repairing or cleaning the apparatus. Disadvantages are vacuum problems due to many points to seal.

Central part of the apparatus is the supersonic two-dimensional slit nozzle separating *high pressure/high temperature* combustion (stagnation) chamber from the expansion volume, in which the gas-dynamic flow is established due to the transfer of thermal energy of molecules into the energy of the directional beam. The nozzle slit height was typically 0.35 mm and the *cavity-to-slit* ratio above 50. The expansion to the combustion volume ratio was about 187. First part of that volume consists of four two-centimeter thick segments with side holes to attach laser mirrors, in order to investigate the distance dependence of the laser action. The role of the diffuser is to shock down the supersonic flow to subsonic speeds before exhausting gaseous products to the atmosphere. All heated parts of the system are water cooled.

b) Driving electronics: (i) The stagnation chamber shutter. It controls the moment and duration of opening the door to the nozzle. It consists of an electromagnet pushing the rods carrying the shutter plate. This unit can be programmed to trigger a defined period before or after the spark firing. (ii) Spark firing takes place at a programmable moment in regards to the shutter opening. It starts ignition of the fuel (acetylene) by the same type of plug as those used in automobiles. (iii) A pyroelectric detector (Gentech, ED200) along with a digital oscilloscope (Gould 4050) are used to monitor the optical signal from the laser cavity. Copper made mirrors, the output one having a hole covered with the NaCl window, were used to form the laser resonator.

Test Measurements

Firstly, the vacuum pumps and accompanied units were adjusted to work properly and reach pressure below 1 mbar at the low-pressure side.

Typical gas mixture contained acetylene, oxygen and nitrogen. The mole ratio was varied around the stoichiometric one, $C_2H_2/O_2/N_2 = 2/5/5$, to get as stronger explosion as possible for the given amount of nitrogen. The apparatus behaved as a good and safe machine under all experimental conditions. The supply system, opening mechanisms, pumps etc. responded in a proper way. After about one thousand or more pulses the apparatus had to be opened for cleaning.

We looked at the optical signal through the output mirror and saw some good indications of the lasing.

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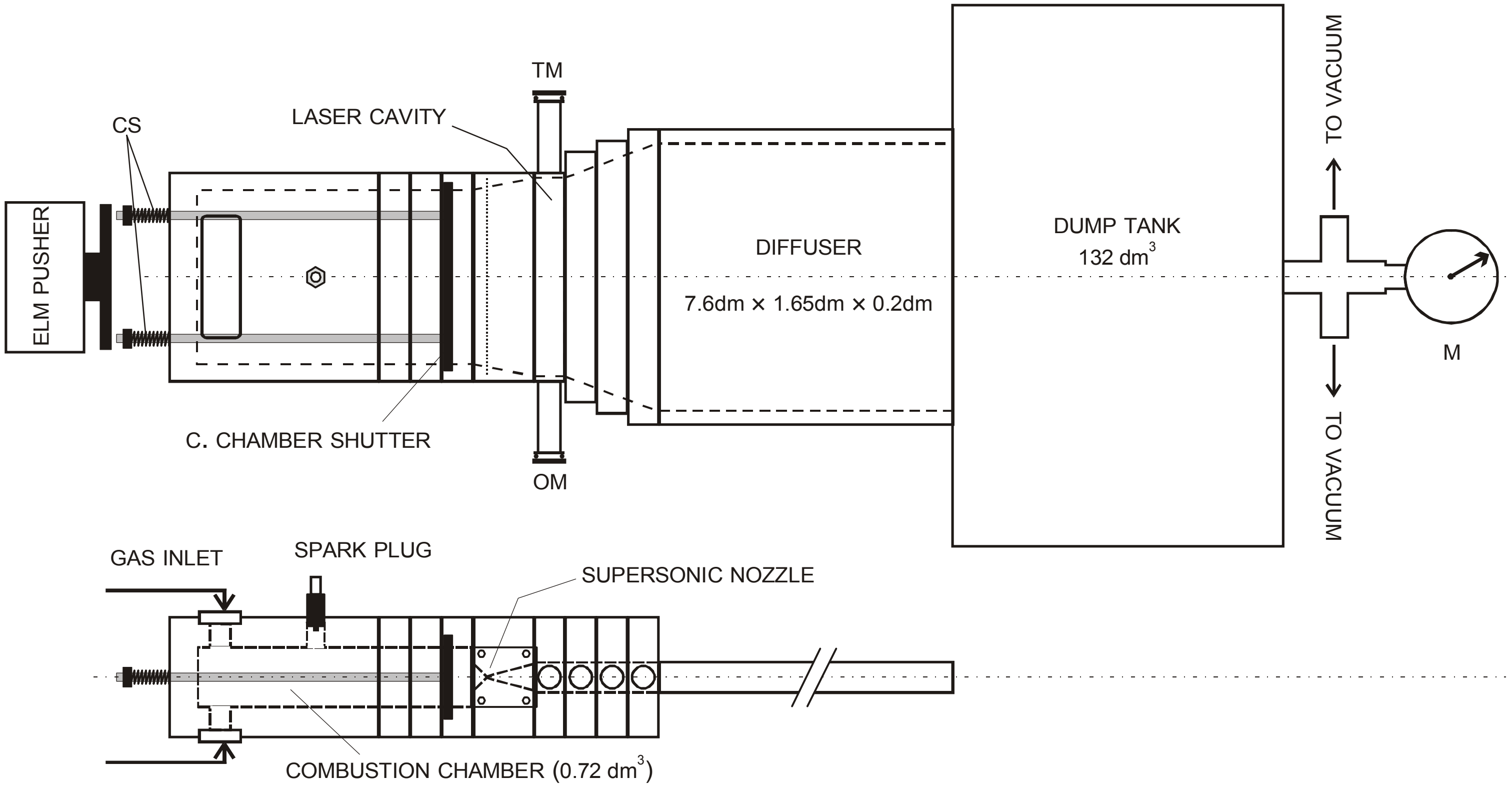

Figure 1. Schematic diagram of the experimental setup for the gas-dynamic laser, top view (upper) and side view (lower): CS – Counter-recoil springs, ELM PUSHER – Electromagnet for the combustion chamber shutter, TM – Total reflector (back laser mirror), OM – Output mirror, M – Vacuum meter. Electrics and electronics not included.