Proposal for a Solar-Laser-Driven Vehicle

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We propose an automobile engine driven by water-laser coupling without fuel. The automobile can load a solar-pumped fiber laser or can be driven by ground-based lasers. The vehicle will be useful on other planets because the piston is in a closed system and the water will not be exhausted into a vacuum. In the preliminary experiment, we succeeded in driving a cylindrical piston of 0.2 g on top of water placed inside an acrylic pipe of 8 mm in inner diameter.

Keywords:

laser propulsion, automobile, engine, fiber laser, experiment

The possible use of laser propulsion for launching a rocket has been intensively studied for last two decades [1]. With the advent of new lasers, the use of laser propulsion is not necessarily limited to such expensive applications. As suggested by one of the authors, a micro-airplane driven by a relatively small laser can be used for various atmospheric and volcanic observations. In such a system, the metal target is covered with water which is transparent to a YAG laser. We have previously demonstrated that a very high thrust can be produced by means of this overlay structure [2,3]. In this paper, we propose a new concept for driving vehicles by using similar mechanism.

About forty years ago, the possibility of pumping a laser by means of solar energy was discussed and a one-watt cw (continuous wave) laser was constructed [4]. The theoretical estimation [5] of such an experiment predicted that 30% of the received solar energy can be converted into a cw laser, with this having been confirmed by recent experiments. In the near future, a pulse laser of 20% or more efficiency will be possible. Therefore, a laser producing a few kW from 10 m^2 solar energy could be installed in the car. If we combine this laser with laser propulsion concept, we can realize an engine that uses only water and solar energy.

Since a laser can be made of fiber, its weight is negligibly smaller than car itself. A few kW is not sufficient for accelerating the car in a short period but it can be combined with battery that accumulates the excessive energy. In addition to this, the boosting laser can be placed outside the car, for example, together with traffic signals or on the side of the road. Since the laser light can be transported along a tube or in open atmosphere, construction of such system is relatively non-problematic. Such a ground-based laser can be generated either by solar energy with a much larger receiving area or by other methods. In the latter case, the energy can be supplied even at night and on cloudy day.

Several mechanisms are capable of converting the thrust produced by laser propulsion to wheel drive. One is the laser-driven turbine shown in Fig.1 which was proposed by one of the authors [6]. The basic principle of this system is to rotate the turbine half-submerged in water by means of the laser ablation. This system can automatically replenish water on the target by its rotation as shown in Fig.1(a). The fin covered with water droplets is then irradiated by the laser generating rotational powers. For demonstration, we tried to lift a 1 yen

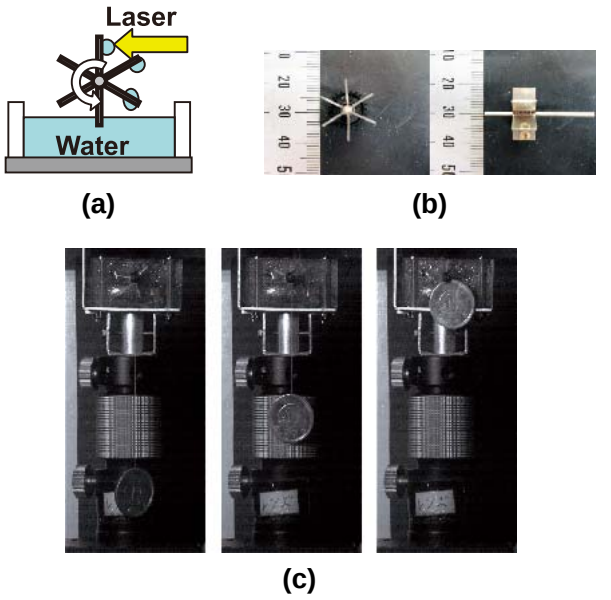

Fig. 1 (a): Schematics of micro turbine. (b) The fins of the turbine. (c) Lifting experiment from left 0, 0.54, 1.34 sec.

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coin (1 g-weight) using this turbine of 0.7 g-weight shown in Fig.1(b) and a 10 Hz 640 mJ/5ns YAG laser. Unfortunately the fin's motion was not synchronized with the laser shots and most of the laser missed the target.

Another interesting mechanism is the piston like automobile engine as shown in Fig.2. In the actual system, water is injected onto the wall of the cylinder and the laser illuminates the water's inner region just below the surface as shown in Fig.2. Although the water is transparent to near infra-red and visible lasers, a high intensity laser can induce the breakdown of the water if the laser is focused onto the inner region of the water, with the resulting explosion causing water to be ejected from the cylinder's surface.

In this case, we do not need metal as an ablator. We call this system "metal-free water cannon (MFWC)" [7] and succeeded in gaining thrust comparable to a metal target covered by water. The maximum coupling coefficient was 2444.4N.s/MJ, which is comparable to 3536.1N.s/MJ for the metal-water target proposed in ref. [2,3]. With the present system, metal is not ablated and hence metal vapor which is harmful to the environment will not be exhausted. Furthermore, the metal can be used for a long time since the piston experiences no wear.

Most water is exploded in the form of liquid without vaporizing. Therefore, after the explosion we can recycle the water and only a small amount of vapor is exhausted into the air. Furthermore, the present water engine can be proven to be more effective than the above-mentioned turbine. The turbine is driven by the reaction force of the ejected water . In contrast, the piston is driven by the ejected water. Usually the latter is much more effective. This can be easily understood as follows. Suppose the mass and the velocity of the target are M and V, and those of water are m and u. From momentum conservation, $MV = mu$. The ratio of the kinetic energy is then $mu^2/MV^2 = M/m$. If the target mass M is much larger than water mass m, then most of the energy is transferred to the water jet. In the turbine, energy gained by the reaction is m/M ($\ll 1$) of water ; however, the piston can be driven by water itself since the water inelastically collides with the piston and moves with the piston.

In the preliminary experiment shown in Fig.2, a piston of 0.2 g (6 mm in diameter) rests on water filling an acrylic pipe of 8mm in inner diameter. The laser is incident from the bottom and focused onto the upper part of the water by a lens (f = 8 mm) attached to the bottom edge. The breakdown

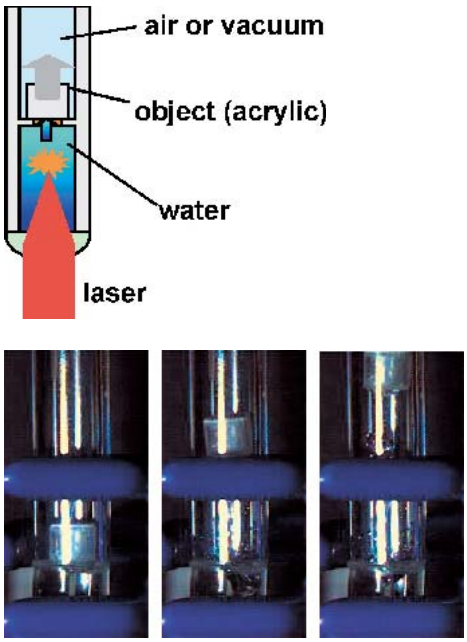

Fig. 2 (Top) Schematics of laser-driven water engine. (Bottom) The preliminary experiment. From left to right, the time is 0, 25, 50 msec.

of water induces the explosion of a thin layer of water at the top of surface and thus drives the cylindrical piston.

Since the explosion is triggered at a very high temperature and water condensates at the contraction phase, we can expect very high efficiency according to the theory of Carnot cycle. Thus the laser-driven car can provide an alternative mode of locomotion, whose most important near-future application could be in vehicles designed for use on other planets.

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