Propulsion for Spacecrafts using on-board Laser Reflection and Absorption

*Jivesh Adhlakha**

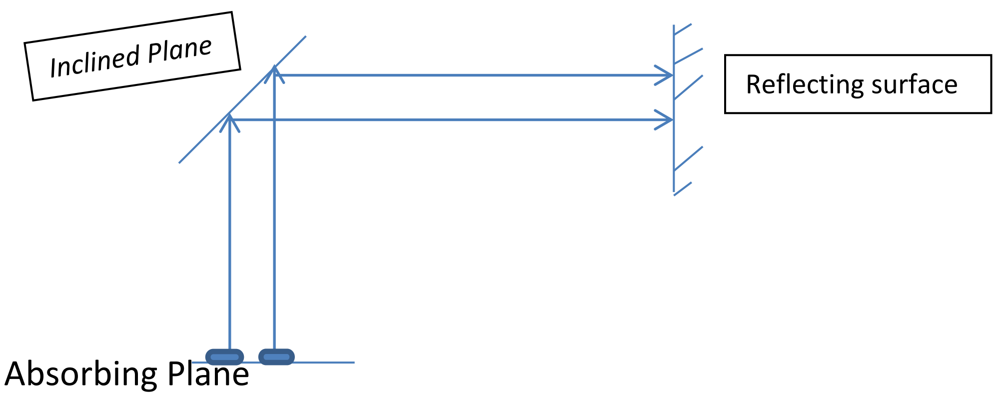
Abstract

In this paper, a new laser-based, on-board propulsion system has been produced. This system utilizes Laser reflection and absorption to obtain a net momentum. The proposed system is also unique in the sense that no on-board propellant is required. Further, the power consumed can be ideally recycled 100%. This makes it a viable mode of propulsion for long distance trips to planets or solar systems. Further, it has been calculated that depending upon the lasers used, this system can propel a 4000kg spacecraft with an acceleration of 100-10000 ms^{-2}. This means, a 4000kg mass can be propelled to one-third the speed of light in just $5*10^4$ seconds, or 13.8 hours roughly. This is a big jump from current technology, which cannot achieve sub-luminal speeds, that too so quickly. This makes this system of propulsion our best bet for sub-solar system travel. Further, the setup proposed is expected to be improved.

*E-mail – jiveshadhlakha@gmail.com

Theory and Setup

The proposed system uses lasers as the mode of propulsion. It uses concept developed and discussed by R.L. Forward in a 1984 paper [1]. Proposed setup includes one absorbing surface, an inclined reflecting surface, and another reflecting surface in front of inclined plane, as shown below:



The idea is to plant lasers on one surface which is ideally made of an ideal Laser absorber. Lasers are fired normal to this surface producing force F_1 on surface (actually, space craft) as shown in diagram 1. The lasers are reflected by ideally reflecting inclined plane, which produces a force F_2 on inclined plane, normal to it. The lasers then fall on third surface, which is again a perfect reflector. This

*E-mail – jiveshadhlakha@gmail.com

produces a Force F_3 normal to this surface. Due to reflection, a force F_4 is again applied on this reflecting surface, which is equal to F_3. This reflected beam again falls on reflecting inclined surface; again apply a force F_5 perpendicular to surface. Finally, the lasers reach absorbing surface applying Force F_6 equal to F_1. The absorbed lasers are again converted to electric potential and stored in batteries.

This all is illustrated in following diagrams:

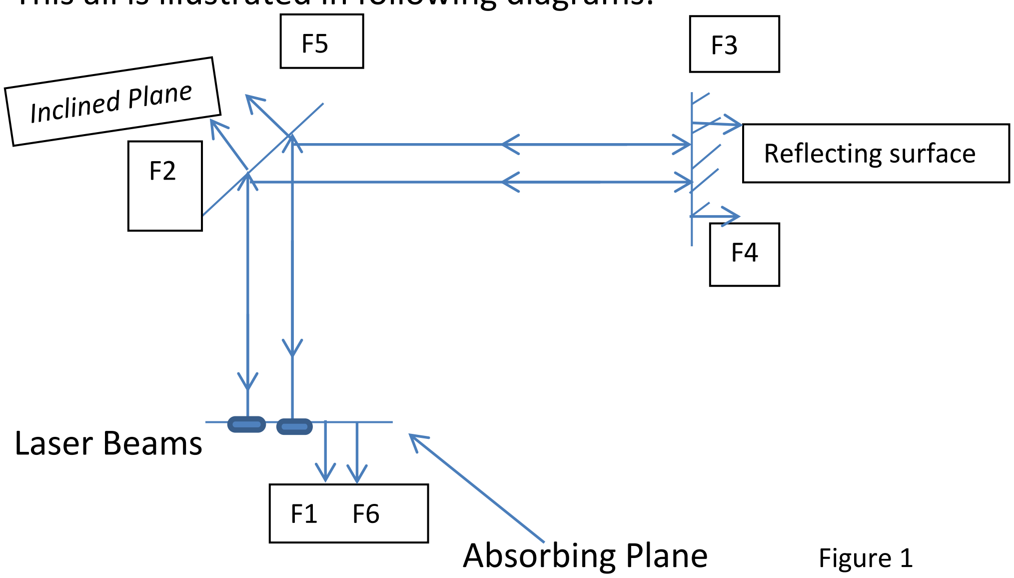


Figure 1

In the calculation part, it has been calculated that there is a net force propelling the system, whose magnitude and direction depends upon the angle of inclined plane and power of lasers.

*E-mail – jiveshadhlakha@gmail.com

Calculations

Let

F_1 be the Force produced on surface one due to firing of lasers

F_2 be the net Force produced when lasers hit inclined plane and reflect

F_3 be the Force produced on third surface

F_4 be the force produced on third surface upon reflection of lasers

F_5 be the net Force produced when lasers hit inclined plane and reflect

F_6 be the force on absorbing surface when lasers are absorbed

Now, This all is illustrated in following diagrams:

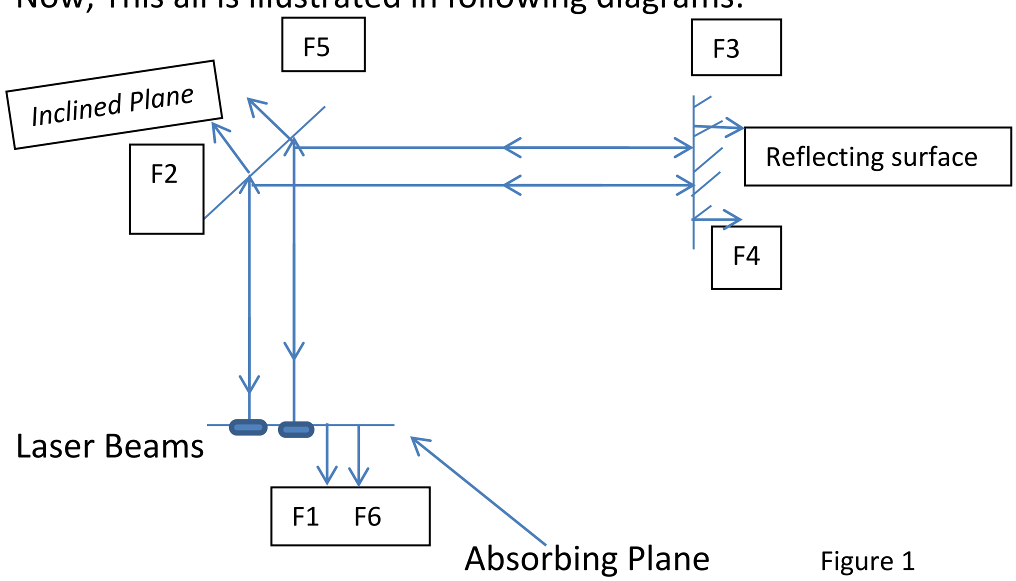


Figure 1

*E-mail – jiveshadhlakha@gmail.com

Force produced upon firing, reflecting, and absorbing of lasers normal to plane will be equal in magnitude. This gives:

$$F_1=F_6=F_3=F_4=F$$

Force normal to inclined plane can be given as $\mathbf{F\cos^2\alpha}$

α is the angle of inclined plane with respect to lasers from surface

As laser is reflected, so the net force will be $2\mathbf{F\cos^2\alpha}$

Now,

The lasers reflected from the third surface will fall on inclined reflecting plane to further apply a force $\mathbf{2F\cos^2(90-\alpha)=2F\sin^2\alpha}$

Net force on the absorbing surface after one complete cycle of laser reflection will be

$$F_1+F_6=2F$$

Net force on the reflecting surface (third surface) after one complete cycle of laser reflection will be

*E-mail – jiveshadhlakha@gmail.com

$$F_3+F_4=2F$$

To maximize the net force on inclined plane, let $\alpha = 45°$

Therefore, net force will be

$$2F\cos^2\alpha + 2F\sin^2\alpha = \frac{2F}{2} + \frac{2F}{2} = 2F$$

Resolving the force vector into its components gives:

Magnitude of force along x-axis**= $2F\cos 45° = \sqrt{2}F$**

Direction will be exactly opposite to the force applied on third surface, as shown in figure 2.

Magnitude of force along y-axis= **$2F\cos 45° = \sqrt{2}F$**

Direction will be exactly opposite to the force applied on first surface, as shown in figure 2.

Therefore, net force on the system after one laser cycle will be:

Component along x-axis

$$F_r = 2F - \sqrt{2}F = F(2-1.4) = .6F \text{ (approx..)} \qquad \sqrt{2} = 1.4$$

*E-mail – jiveshadhlakha@gmail.com

Component along y-axis

$$F_p=2F-\sqrt{2}F=F(2-1.4)=.6F(\text{approx..})$$

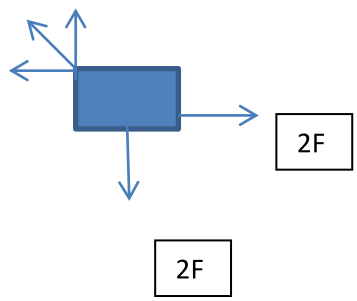
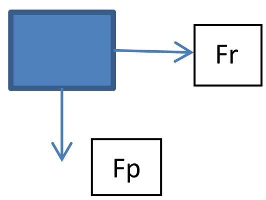


Figure 2



Net Force

Note that angle between F_r and F_p is 90°

Therefore magnitude of net force on space craft will be

$$F_n=\sqrt{F_r^2+F_p^2+2F_rF_p\cos 90^\circ}$$

$$F_n=\sqrt{.6F^2+.6F^2}$$

*E-mail – jiveshadhlakha@gmail.com

$F_n = \sqrt{.72F^2}$

$F_n = .8485F$

$F_n = .85F$ (approx.)

Now, this gives 85% force to space craft, as opposed to direct laser propulsion. However, this makes it more viable because in ideal setup, the lasers fired are being again converted to electrical potential and stored again, while still giving a net force of .85F.

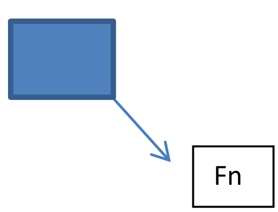
For the direction,

Let net force be in β direction

$$\beta = \tan^{-1}\left(\frac{Fpsin90}{Fr + Fpcos90}\right)$$

$$\beta = \tan^{-1}\left(\frac{Fp}{Fr}\right) = \tan^{-1}(1)$$

$$\beta = 45 \text{ degrees off the y-axis}$$



*E-mail – jiveshadhlakha@gmail.com

Calculations for 300 Trillions watt lasers system

If lasers used are of combined power $3*10^{14}$ watts, Force F will be

$$F=\frac{P}{c}=3*10^{14}/3*10^{8}=10^{6}\text{ Newtons}$$

Net force on space craft $\mathbf{F_n=.85*10^6=8.5*10^5\ N}$

Let mass of space craft be around 8500kg

This will give an acceleration of $100ms^{-2}$ to a spacecraft of 8500kg mass.

$$a=10^2\ ms^{-2}$$

Using classical non-modified equation of motion v=at

To reach one third the speed of light, the given system will take

$\mathbf{t=10^8/10^2=10^6}$ seconds, which is almost 11 and a half days.

*E-mail – jiveshadhlakha@gmail.com

Calculations for 3000 Trillions watt lasers system and 4250 kg mass

$$F=\frac{P}{c}=3*10^{15}/3*10^{8}=10^{7}\text{ Newtons}$$

Net force on space craft $\mathbf{F_n=.85*10^7=8.5*10^6\ N}$

This will give an acceleration of 2000ms^{-2} to a spacecraft of 4250kg mass. (F=ma)

$$a=2*10^{3}\ ms^{-2}$$

Using classical non-modified equation of motion v=at

To reach one third the speed of light, the given system will take

$$\mathbf{t=10^{8}/2*10^{3}}$$

t=50,000 seconds or 13.89 hours

*E-mail – jiveshadhlakha@gmail.com

Results

The Laser based Jet Propulsion system suggested in this paper can propel a space craft of 8500 kg to sub-luminal speeds in matter of 10-15 days. However, more powerful laser systems can make it quicker – to a matter of few hours.

Implications and Conclusion

The propulsion systems using on-board fuel right now or proposed alternatives like ion-propulsion are both limited by material requirement and can not propel to sub-luminal velocities currently. This has also been discussed in detail in review article published in Journal of Aerospace Technology and Management [2].Ion propulsion though, as discussed by John Brophy [3] may provide acceleration of 11km/s – better than system discussed in this paper – it is limited by propellant. The photonic repulsion systems, like the one used in this case, are great for faster

*E-mail – jiveshadhlakha@gmail.com

propulsions. However, they will also be limited by power requirements on-board. The space-based laser system discussed by Colin Robert [4] also is limited by reach of laser systems. On the other hand, the proposed used of Laser Propulsion in this paper is not only a propulsion system promising sub-luminal velocities, but also viable method due to ideally one-time power requirement. This makes this system our best bet for interstellar travel as it can quickly propel spacecraft to high velocities, while recycling its power.

References

1) R.L. Forward **Roundtrip Interstellar Travel Using Laser-pulsed Lightsails** Journal of Spacecraft and Rockets, 21 (1984), pp. 187-195
2) **Space Propulsion: A Survey Study about Current and Future Technologies** Journal of Aerospace Technology and Management, 10, Feb 26 2018, page 1-10
3) Brophy J. **The Dawn Ion Propulsion System** Springer, New York, Ny. https://doi.org/10.1007/978-1-4614-4903-4_11

*E-mail – jiveshadhlakha@gmail.com

4) Mclnnes C.R. (1999) Laser Driven Light Sails. In: Solar Sailing, Astronomy and Planetary Sciences, Springer, London. https://doi.org/10.1007/978-1-4471-3992-8_7

*E-mail – jiveshadhlakha@gmail.com