Re: Solar powered lasers in space

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- *From*: Willie.Mookie@xxxxxxxxx
- *Date*: Sun, 23 Sep 2007 15:24:14 −0000

On Sep 21, 11:21 am, Ian Parker <ianpark...@xxxxxxxxx> wrote:

> On 20 Sep, 22:35, Willie.Moo...@xxxxxxxxx wrote:
>
> > > I doubt that. If you are going to travel at 0.03c you want an
> > > ion
> > > drive that accelerates to 0.05c (say)
>
> > Why do you doubt it? What's the basis? You state a conclusion and provide absolutely no technical data to back it up. I find that maddening! lol. The way to look at this is propellant fraction, power level and thrust.
>
> > A 1 gee acceleration is convenient for interplanetary travel for a variety of reasons. First off, you have gravity aboard ship during the transit. Secondly, you get to where you're going pretty fast. You fly halfway to your destination, carry out a powered pitchover, and arrive at zero altitude and zero speed at your destination. With clever programming the gee forces slide linearly from your start to your finish so that you are acclimated to the destinations gravity by the time you get there.
>
> > So, lets look at a 1 gee spaceships performance. You may remember these from elementary physics
>
> > d = 1/2 a t^2
> > v = a t

So,

t = v / a

and so

d = v^2 /(2a)

Where d= distance travelled
a = acceleration
t = time
v = velocity

So, the velocity needed to attain the halfway point is

v = sqrt(d * a)

And the total delta vee to achieve the trip is

V = 2 * v

and the time in hours needed to make the trip is

t = V / 9.82 / 3600

So, we can construct the following chart

	m	kps	hours	LSD
Earth to	d	sqrt(d*a)	t	u
Moon	3.86E+08	61.60	1.74	2.03%
Mars−close	7.50E+10	858.20	24.28	24.88%
Mars−far	3.75E+11	1,918.98	54.28	47.25%
Venus−close	4.50E+10	664.76	18.80	19.88%
Venus−far	2.55E+11	1,582.43	44.76	40.99%
Ceres−close	2.70E+11	1,628.31	46.06	41.89%
Ceres−far	5.70E+11	2,365.88	66.92	54.55%
Mercury−close	9.00E+10	940.11	26.59	26.90%
Mercury−far	2.10E+11	1,436.04	40.62	38.04%
Jovia	8.55E+11	2,897.60	81.96	61.93%

So sailing the inner solar system in a 1 gee spaceship would be like sailing the Pacific in a cruise ship. You'd have islands like the moon, that are only hours a way. You'd have nearby territories like Mars and Venus that are only a day or two away. Then you'd have the outer planets that are weeks away.

The factor u is the propellant fraction for a Laser Sustained Detonation (LSD) rocket operating with an exhaust velocity of 3000 km/sec (kps)

Now, lets look at the power levels needed to achieve that, and the propellant fractions. The first thing we realize is that to have reasonable propellant fractions we need exhaust speeds to match the flight speeds.

Vf = Ve * LN(1/(1−u))

so

u = 1 − 1/EXP(Vf/Ve)

So, Vf/Ve must be less than or equal to 1 to have reasonable u. 3,000 kps − is a specific impulse of 30,000 − which is damned difficult to achieve. And power to weight of the engine must be tremendous. So, an ion rocket with 5,000 sec Isp − won't cut it for this application. (it would do fine for 1/10th gee or 1/100th gee operation) some sort of laser sustained detonation of inert working fluids would be needed. This is nearly an exact analogue of nuclear pulse propulsion, but the energizing force comes from pulses of laser energy accurately directed at a thrust structure.

The power level to produce 1 kgf is

F = mdot * Ve
P = 1/2 mdot * Ve ^2

So,

mdot = 2 * P / Ve^2

and so

F = 2 * P / Ve

This is in newtons and 1 kgf = Newton / 9.82

so..

F(kgf) = P / (4.91 * Ve)

And with Ve = 3,000 kps = 3e6 m/sec we need 14.73 MW per kgf of thrust. That's 7.37 quadrilion watts of power. And this is the low

> > power solution!!! haha.. The world has a few thousand super tankers. To operate a few thousand interplanetary freighters with this capacity requires tapping into 1e20 watts of power. Such capacity would tie humanity together across the interplanetary frontier.
>
> > At 1MW per sq meter − the sun centered laser array would have to cover 1e8 sq km of area. A disk 11,283 km in diameter − about the size of the Earth − a very small fraction of the sun's total surface. Four disks 6,000 km in diameter equally spaced around the plane of the ecliptic would provide adequate power for a fleet of such spacecraft.
>
> I am afraid I was simply thinking about energy. To go to 0.03c with minimal energy you need ion drive. If you have plenty of energy you indeed don't need to worry about that.

You are right that when you reduce Isp you are reducing power levels and energy use. But you won't be travelling at 1 gee though. Something far less.

Check it out

first,
The sun puts out lots of energy and capturing it and transmitting it efficiently provides all the energy we need. So, this is part and parcel of a space program. Not only is sunlight the first extra−terrestrial resource humanity has used, making efficient use of it along the lines I have describe is part of a rational commercial space program.

second,
Lets review a little rocket basics shall we? haha..

Ion rockets have specific impulses of around 5,000 sec − that's approximately 50 km/sec exhaust speed. .Awesome performance. Thrust to weight is low, and so, accelerations of 1 gee won't be achieved. 1/100th gees are doable. Which is fine, because it reduces top speeds from 0.03c − or 9,000 km/sec to 1/100th this value or 90 km/sec.

So, you won't be reaching 3% light speed with ion rockets we can build today. Because this is 180x the exhaust speed. A rocket man has to keep this in mine. Look at the rocket equation. If your delta vee, or final velocity is 0.03c or 9,000 km/sec and your exhaust speed if 50 km/sec then your propellant fraction will be;

u = 1 − 1/EXP(9000/50) = 1 − 6.7e−79 ~ 1 = 100%

Which doesn't leave much for ion rockets, tanks, and payload!

But what you need to do is reduce accelerations to about 1/2% of 1 gee − 5 milligees − which can be done by an ion rocket. So, the equations I gave above are linear, so that means your acceleration times and top speeds will be 1/2% of those given. That means you'll have a constant gee ion spaceship, but it will accelerate at 5 milligees, instead of 1,000 milligees − and its top speed will be around 45 km/sec not 9,000 km/sec − and it will take hundreds of days to navigate the inner solar system, instead of days, and hundreds of weeks to navigate the outer solar system, instead of weeks. Power levels are 1% too − and so total energy per kg is 1% − if energy is costly, and payloads are easily stored and not time critical, then this approach is perfectly doable. Either as an early stage,or at later stages for low value freight − like building materials..

Lets check out the propellant fraction of an ion rocket whose delta vee is 45 km/sec and exhaust speed is 50 km/sec

u = 1 − 1/EXP(45/50) = 0.5934 = 59.34%

So, now you have a doable vehicle. You've got 60% propellant, say 25% structure (mostly ion engine and power supply) and 15% payload. Not as nifty as an ultra high powerful laser light wing − but doable and very similar to the interplanetary probes being launched by NASA today − toward asteroids and jupiter.

> There is one other point. If you have polulated the ecliptic with lasers, you will (presumably) be able to phase lock them. You will have a telescope 300million kilometers in diameter. In earlier postings I have said how a number of problems are all tied together. Now let us see what sizes you can see 10 parsecs distance.

Well we were talking about power beaming...

You're now talking about two large aperture telescopes exchanging laser information and doing aperture synthesis like we now do with radio telescopes − but in the optical realm. Of course with a very accurate time reference you can record information at two telescopes and combine the recordings to do your synthesis off line. What would it take for two optical telescopes to achieve that? lol. I've often wondered about that. All they need is a common reference. A quasar or something might do − or a seed laser as you mentioned earlier. So these are uses of space laser technology certainly.

Of course Bob Forward's idea of using laser light sails for interstellar distances requires filled in apertures to get sufficient energy to the light sails efficently.

> Now a
> parsec is by definition 1sec of arc with observations separated by 6 months. Therefore 10 parsecs means that viewed from the target the telescope is subtending 1/10 sec of arc. 50 deg per radian 3600sec per degree. That is 1/180000 radian. This means we see objects some 7cm across. Clearly the gas in interstellar space + gravitational lensing will prevent us getting anywhere near that figure. We should have little difficulty though in seeing any planets.

Once the gas and dust and gravity lenses are mapped, we can use computers to adjust the distortions − and once we have clear maps and images and so forth, compare new images with old to look at changes in the dust gas and gravity lenses!

> We will know fairly quickly whether or not we are in a race, another possible explanation of the Fermi paradox.

Yes, I read a science fiction book that had that as a premise. When you look out into the cosmos you are looking back and time. So, if the universe looks like its devoid of technical life, all that means is that is was devoid before NOW. Think of the universe as a desolate desert plain − in the Kalahari say. But it could be like the Kalahari desert, these is a season − and in that season all the seeds of living things that are not apparent other times of the year − spring to life filling the entire plain with a riot of flowers, grasses, insects, small animals of all types.. and then they all die out when the season passes.

How like life to be this way. We wouldn't see evidence of technical life in such a cosmos by looking at the Andromeda Galaxy which is 2 million light years away. Because 2 million years ago − using our Earth as a reference − no one had technology.

It is only by looking at nearby stars that we will get an idea of how common life is, and how common technology is in the cosmos.

We may get a very surprising result!

So, its worth doing certainly.

Of course what would synchronize evolution so closely across the cosmos? We don't know. We don't know if it is. But it might be. And its worth figuring out.

Haha.. if we found that there were dozens of technical civilizations within 50 light years of earth among the 10,000s stars in that distance, military planners would go apeshit. If some were slightly more advanced, some would argue we'd have to figure out how to deal with them. If others were less advanced − but growing rapidly − some would argue we'd have to try to figure out how to infiltrate them and slow them down. The interesting thing is that this is what the crazy UFO folks are saying is happening right now! lol. So, the universe is stranger than we can imagine if this is true.

> > Humanity today consumes 10 TW of power − 1/10,000,000th the power level postulated here. Needless to day, any industrial activity we wanted to carry out on the planets or in free flying space colonies, could easily be provided as well. This might also form the basis of maintaining government control over this far flung array of humans, to keep them from using high tech to attack one another − and stopping the possibility of interplanetary war.

> You are assuming that war is the result of competition for resources. I say it is saying your prayers the wrong way.

No, I'm saying something else entirely. Just as police routinely cut off power to a home where there is a hostage situation, power may be cut off to a region or for an activity that threatens folks. This is possible. Not inevitable.

A common device used widely to provide limitless amounts of energy across the entire span of human activity − more cheaply than any other form of energy − provides a means, a hook, by which that activity can be controlled. Whether it is used that way, and the degree of control exercised is a matter for people to decide. And if abused, can be counted as a cost of use. Which means those being abused will find other approaches.

> > A laser light sail requires no propellant, but power levels go way up for both high thrusts, small sail size, and for ton of payload moved.

> > There are two ways to do this. One is to heat a body to very high temperatures and use the black body radiation for propulsion − this requires some sort of plasma containment system that can't be built. The other (if we are to have high gee forces) is to use a mirror to reflect nearly all the energy incident on it. In order to limit the size of the mirror.
> >
> > To make logistics simple, it would be nice to have the mirrors operate like wings do on aircraft − exerting 100 kg/m2 or more. A disk like spacecraft that had multi−mode capabilities would be interesting. That is, a spherical payload encircled by a mirror disk, that might also operate as a radiator propulsor short term − for landing and operating out of sight of the sun...
>
> A laser is monochromatic.

One laser is monochromatic. A collection of lasers is not.

One laser pumped by a thermal light source is profoundly inefficient. 20 lasers pumped by a thermal light source, segmente into 20 bands of color, is not.

> This means you can use simple dielectric sails which do not heat up.

Or a collection of dielectrics... Yes, this is the basis of GBO film. But dielectrics, are not 100% efficient. But they can be nearly so. One part per billion absorbed − for example, means that 1 billion watts per square meter on the film will have only 1 watt of heating. (but don't get in the way of the beam!) haha..

> A metal sail is hopeless at anything like a high energy.

Agreed. This is what I'm saying.

> > Black body thrustor

Pr = 1/3 ar T^4

Where ar = radiation constant = 7.57e−16 J/m3/K4
T = temp K
Pr = radiation pressure (watts/m2)

To exert 100 kg/m2 requires a temperature of 45,000 K − and the power output of that square meter is

j = sigma * T^4

Where j = watts/m2
T = temp K
sigma = stephan boltzman constant = c * ar / 4
= 5.67e−8

j = 5.67e−8 * 45,000^4 = 232.5e9 W/m2

So, 1/100th of a meter squared, would be a square 10cm on a side, would produce 1 kg of thrust, and consume 2.32 GW of power!!! Compare this to 14.7 MW of power needed for 1 kgf in the LSD rocket!! But the great advantage here is that no propellant is needed.

This is a black body radiator, some sort of cavity containing a magnetically stabilized plasma − that efficiently absorbs powerful laser energy. By encasing the cavity in a reflective parabolid that transmits the laser energy but reflects the bulk of the plasma radiation in a desired direction, the surface can absorb laser energy from one direction and emit radiation in another direction. By having a certain amount of plasma that stores a goodly amount of energy − thrust can be maintained for a period of time − without direct illumination. Excellent for landing and takeoffs, where laser energy may be a hazard (the plasma itself would be a hazard if the cavity developed any leaks! − and the exhaust itself would also be a hazard − it may be possible to use the plasma energy directly by venting it for landing and take off.

A mirror based system has the following relation;

Pressure = 2 U / c

Where U = power per unit area, c = speed of light, Pressure = N/m2

So, 100 kg /m2 = 982 N/m2 implies U = 3e8 m/sec * 982 N/m2 / 2 = 147.3 GW/m2 − which is less than that required for the radiation pressure mode − and actually, the radiation pressure mode above, doesn't include the momentum that is obtained from absorbing the light energy in the first place.. which can help or hinder the thrust effects depending on how the cavity is arrayed relative to the energy being beamed in.

Of course to keep temperatures under control requires VERY VERY highly reflective mirrors. Before the invention of GBO films I would say such things would be impossible. But the advent of GBO films that have reflectivities in excess of aluminized coatings − suggest that continued development along this path would allow mirrors that absorb less than 1 part per million of the incident energy. This means that the wings need only

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I think I missed the rest of your commentary. What is happening to Google? They really suck these days. Ah well.

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