ANTI-BALLISTIC LASER SATELLITE

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Abstract- It is very important for a country to have a defense against ballistic missiles. The anti-ballistic missiles used till date requires many ground stations and the nearest ground station launches the missile. The system is very expensive and requires resources which when used once cannot be replenished. Majority of anti-ballistic missiles destroy the ballistic missile in the earth atmosphere, hence leads to pollution. Hence there comes a need to protect a country against ballistics by minimum utilization of resources and money. Hereby, we propose a design of Anti-ballistic laser satellite which can be used to destroy the ballistic missile. The idea is to follow the trajectory of ballistic missile using a high intensity laser and destroying the ballistic missile at apogee. The laser beam is focused on the ballistic from its burnout point till the apogee where the warhead is destroyed. This laser is a result of multiple reflections which are guided by hexagonal shaped mirrors of which the main reflecting surface is made up of. These multiple lasers hit the ballistic missile and generate a large amount of heat. This heat destroys the ballistic missile. This is a pollution free and one time investment procedure for defense against intercontinental ballistic missiles.

I. INTRODUCTION

Defense systems are very crucial for a country. Having a satellite which can destroy inter-continental ballistic missile launched on a city (particular co-ordinates) provides advantage in war and helps in saving lives of millions of people. There is a satellite launched by Russia named SSTS which is used to track ballistic missiles launched from any country. This paper gives details of a satellite, one of its own kind, which will instantaneously locate as well as destroy any ballistic missile.

Inter-continental Ballistic missile mainly has three stages in a trajectory; missile has to travel a long distance, hence it is designed to travel most of the distance in mesosphere, as it will face low drag. Missile is designed to gain velocity in first stage till the burnout and is left to free fall into the atmosphere which helps in saving fuel and reduces the missile weight. Satellite destroys the missile during its second stage trajectory, where air density is low which reduces the refraction or loss of intensity of laser launched to destroy the missile. The procedure is pollution free to earth’s environment; moreover ozone layer is also not affected as this is happening above the stratosphere. This satellite is a onetime investment, unlike other anti-ballistic missiles which once used cannot be replenished. Satellite uses laser to heat the secondary fuel tanks which will destroy the missile. There are many challenges to do this. First task is locating the position of the missile. With present technology we are able to locate the missile during its first stage of trajectory because it is using busters which can be located by the infrared satellites. But during the second stage, the missile does not have any type of propulsive system which makes it difficult to locate. This satellite has the algorithm which can give the co-ordinates of the missile when provided with its first stage information. Other challenge is to aim at a moving object from a long distance with a high intensity laser. Most of the satellites use Orbital maneuvering system (OMS) to change the direction of the satellite which in-turn will move the laser but with OMS it’s hard to make very accurate and small change in direction hence a system of changing the orientation of various hexagonal mirrors has been developed to aim and change the direction of laser as the missile moves. This particular system takes care of point to point movement of the Ballistic missile.

II. DESIGN OF SATELLITE
III. PART DESCRIPTION

This section will describe the parts of anti-ballistic laser satellite:

1. Ion thruster: Xenon will be used as an ion thruster as its atomic number is 131 and atomic mass 21.8×10^-26. This will give high thrust, though cesium and mercury have high atomic number and atomic mass than xenon but mercury has contamination problems of the optical surface of the spacecrafts by mercury vapors and cesium is readily ionized by tungsten. So xenon would be used as a propellant, which will give high thrust which could be derived by the equation of

\[ F = \frac{I(2Vm/q)^{1/2}}{\sqrt{2}} \]

where I= Current (Amps); V= Voltage (Volts); m= Mass of charged particle (Kg); q=Charge (coulombs)

2. OMS: There will be eight OMS placed just below the ion thruster module, they will orient the laser satellite accordingly. The propellant used in OMS system is LOX ethanol as it is lighter and produces small amount of thrust which would help the satellite to precisely align itself.

3. Antennas: There are two antennas on board which are used for receiving signals from SSTS (i.e. Space Based Surveillance and Tracking system) and from the infrared ballistic detection satellites.

4. Electronic annular module: This electronic annular module consists of the electronic system onboard computers and the power generation and storage circuits along with the receiver circuit of the signals sent by ballistic detection infrared satellite.

5. CO2 Tanks: There are 4 tanks of Carbon dioxide which is used as a laser.

6. Solar Arrays: There are four solar panels to provide power to the satellite for various operations. The solar array used is GaAs Triple junction, it is also known as astrium solar array as it can be used in all environments.

7. Coolant tank: The tank consists of a coolant which is used for maintaining the working temperature of the laser module. The coolant that would be used is Lead Bismuth Eutectic. The tank is maintained at a temperature of 130°C (melting point of the alloy). The boiling point is 1670°C. Hence the fluid moves over the laser module to keep the laser module at a low temperature.

8. Reflecting mirrors: This is a slightly concave structure with numerous hexagonal shaped mirrors made up of galvanized alumina coated with gold. Alumina is light in nature and is durable with high thermal resistance of around 2000°C. On the other hand gold absorbs very less energy. The mirror is used for reflection of laser beam. These mirrors can align themselves with the use of robotic quad-pressurizing hand fixed at the backside of each mirror.

Fig. Hexagonal shaped mirror with robotic hand
9. Laser module: it contains many reflecting surfaces. Laser will be emitted towards the reflecting surfaces and then the rays will be reflected towards the reflecting mirrors by only movement of the reflecting surfaces. The Module is made of galvanized alumina coated with gold.

Materials for various satellite parts-

<table>
<thead>
<tr>
<th>S.no</th>
<th>Parts</th>
<th>Materials</th>
<th>properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Electronics system Hg.</td>
<td>Internal insulation Alumina</td>
<td>• It is electrical insulator but has high thermal conductivity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External insulation by MLI</td>
<td>• It’s in soluble in water.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Melting point 2072°C.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Reduces heat loss by thermal radiation.</td>
</tr>
<tr>
<td>2</td>
<td>CO₂ gas tanks</td>
<td>Internal insulation Alumina</td>
<td>• It is electrical insulator but has high thermal conductivity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Um provide</td>
<td>• It’s in soluble in water.</td>
</tr>
<tr>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Reduces heat loss by thermal radiation.</td>
</tr>
<tr>
<td>3</td>
<td>Solar array</td>
<td>Astrium</td>
<td>• Astrium provides turnkey solar arrays for all environment.</td>
</tr>
<tr>
<td>4</td>
<td>Coolant module insulation</td>
<td>MLI</td>
<td>• Reduces heat loss by thermal radiation.</td>
</tr>
<tr>
<td>5</td>
<td>Reflecting mirrors (Hexagonal)</td>
<td>Alumina coated with gold</td>
<td>• Gold does not absorb much heat energy.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• The material is a good reflector.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Strong and has a very high melting point</td>
</tr>
</tbody>
</table>

**IV LASER DESCRIPTION**

A device that generates an intense beam of coherent monochromatic light (or other electromagnetic radiation) by stimulated emission of photons from excited atoms or molecules. Lasers are used in drilling and cutting, alignment and guidance, and in surgery; the optical properties are exploited in holography, reading barcodes, and in recording and playing compact discs.

A) Different Types Of Lasers.

Solid state laser: Have lasing material distributed in a solid matrix (such as the ruby or neodymium: yttrium-aluminum garnet “YAG” lasers). The neodymium-YAG laser emits infrared light at 1,064 nanometers (nm). A nanometer is 1x10⁻⁹ meters. Gas lasers: Helium and helium-neon, HeNe, are the most common gas lasers, have a primary output of visible red light. CO₂ lasers emit energy in the far-infrared, and are used for cutting hard materials. Excimer lasers: The name is derived from the terms excited and dimmers use reactive gases, such as chlorine and fluorine, mixed with inert gases such as argon, krypton or xenon. When electrically stimulated, a pseudo molecule (dimer) is produced. When lased, the dimer produces light in the ultraviolet range.

Dye lasers: Use complex organic dyes, such as rhodamine 6G, in liquid solution or suspension as lasing media. They are tunable over a broad range of wavelengths. The laser we are using is CO₂, Due to its low weight and it produces laser which lies in the range of infrared and microwave region. Infrared radiation is basically heat energy, hence this laser basically melts through whatever it is focused upon.

B) Mechanism of CO₂ laser:

The carbon dioxide laser is a gas laser that uses the energy difference between rotational-vibrational energy levels. Within the vibrational levels of CO₂ there are rotational sub-energy levels. A mixture of N₂ and CO₂ gas are placed inside a chamber. The N₂ atoms are excited through an electrical pumping mechanism. The excited atoms then collide with the CO₂ atoms transfer energy.

This transfer of energy causes the CO₂ to go into a higher vibrational level. The excited CO₂ molecules then go through spontaneous emission when they are relaxed to lower rotational-vibrational levels increasing the signal of the incident light. Carbon dioxide lasers are extremely efficient, around 70%, and powerful compared to other gas lasers making them useful for welding and cutting.

Laser unit contains a tube in which the gas mixture is released from the tanks. Electrical pumps are used to excite the nitrogen atoms and the structure is show in the figure.

The laser falls on the semi-spherical laser module and is reflected back to reflecting surface. The reflecting surface thus reflects the beam finally towards the ballistic missile.
Calculation for laser:

Taking the specific heat of the missile material to be $= 0.91 \text{KJ/kg} \text{k}$. Beam released out of the laser has the diameter of 0.5cm the impact area is 0.785 cm$^2$. Temperature at which the missile material melts is 2500 degree Celsius.

Amount of energy required to melt the substance in 5min is 1.6 KW. As the material won’t absorb whole energy so laser needs to generate 2KW of energy. Assuming effective pumping speed to be 15 cubic ft/min we calculate the parameters of the laser unit length, diameter and energy required. The laser unit has 10 sub-tubes generating total energy required. We start with a rough assumption that the length required for each tube is $= \text{P}0/60$ (power required to be generated). Using this length and material properties we start optimization of parameters. From length we get required radius from the graph shown in figure-6.

<table>
<thead>
<tr>
<th>Length (per tube)</th>
<th>4 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (per tube)</td>
<td>3 cm</td>
</tr>
<tr>
<td>Electrical energy (per tube)</td>
<td>24 Kv</td>
</tr>
</tbody>
</table>

Some of the data collected are from graph show in figure-6.

Pressure ratios needed to be maintained is:

$\text{CO}_2$: $\text{N}_2$: $\text{He}$

0.6: 1.5: 6.8

V. MECHANISM

The Ballistic trajectory can be detected by SSTS (i.e. Space Based Surveillance and Tracking system a satellite of Russia). It emits Infrared radiations which follow the path of ballistic missile till the burnout point is reached. The Infrared emitting satellite will give the signal to the ABLS (anti Ballistic Laser Satellite) which will start generating its laser. The ABLS is a geostationary satellite. As the ballistic missile reaches the burnout, the co-ordinates at the burnout co-ordinates are transferred to ABLS and the satellite emits laser. The laser follows the flight of ballistic missile and continuously hits it. With the motion of the ballistic missile the satellite also tilts required degrees so that the ballistic always remain focused. The equations along with a MATLAB program are follows-Known parameters at the burnout-

$$GM = \mu = 3.986 \times 10^{14} \text{ m}^3\text{kg}^{-1}\text{sec}^{-2}$$

Rotation of earth ($\omega$) = 3.038208495 $\times 10^{-6}$ rad/sec

The parameters to be used in equations are-

- $\theta$ = azimuth
- $\theta$ = Angle of elevation from burnout point to the satellite (library of angles for various co-ordinates on earth)
- $r_{bo}$ = Burnout Radius
- $V_{bo}$ = Burnout velocity
- $\theta$ = True anomaly
- $\lambda_{bo}$ = Latitude of ballistic (projected above the surface of earth)
- $N_{bo}$ = Longitude of ballistic (projected above the surface of earth)
- $V_{n}$ = normal velocity
- $\lambda_{apogee}$ = latitude of apogee (projected above the surface of earth)
- $N_{apogee}$ = longitude of apogee

The formulas to be used in the same order

$$Q = V_{bo}^2 + r_{bo} / \mu$$

$$a = \frac{\mu}{2-\mu}$$

$$\cos \theta = \frac{1}{2}$$
VI. MATLAB PROGRAM

```matlab
u = 3.986*10^14;
w = 3.038208495*10^-6;
velocity = input('Velocity: ');
theta = 30;
r_bo = input('rbo: ');
v_bo = input('vbo: ');
L_bo = input('lbo: ');
N_bo = input('nbo: ');

q = (v_bo^2*r_bo)/u;
a = r_bo/(2-q)
si = 2*cos(-1)

phi_ap = acos(sqrt(abs((2*q+q(q-2)*si) + (sqrt(2*q+q(q-2)*si))^2 - 4*(q*q))/2*(q*q)));
phi_an = acos(sqrt(abs(2*q+q(q-2)*si) - (sqrt(2*q+q(q-2)*si)^2 - 4*(q*q))/2*(q*q)));

phi = phi_ap + phi_an;
if phi > 0 && phi < 180
    phi = max(phi_ap + phi_an);
    if phi > 90
        phi_a = 180 - phi;
    else
        phi = phi_a;
    end
else
    phi = min(phi_ap + phi_an);
    if phi < 0
        phi = abs(phi_a);
    if phi > 90
        phi = 360 - phi;
    end
end

e = sqrt(1+(q(q-2)*cos(phi)));
R_a = a(1+e);
vn = v_bo*sin(phi);
v_ns = v_bo * cos(phi) * sin(b);
v_ew = v_bo * cos(phi) * sin(b);
v_true_a = vn^2 * v_ns^2 * v_ew^2;
v_true = sqrt(v_true_a);
phi_act = asin(vn/velocity);
b_act = atan(-v_ew/v_ns);
Range_angle_a = (2/q)*(csc(2*phi_act) - cot(phi-act));
Range_angle = 2*acot(Range_angle_a);

cosE = e*cos(range_angle/2);
sinE = sqrt(1 - cosE^2);
T = 2* sqrt((a^3/u)*(pi - E - esinE));
Lapogee = (sin(L_bo)*cos(Range_angle/2)) +
        (sin(range_angle/2)*cos(L_bo)... *cos(360 - b_act));
```

Fig. Angle shift to hit a ballistic missile
Naço = N_0 + del_N

d = Re * sin*(range_angle/2);
cosdel = x/(Rsat - Ra);
p = Ra/tan(del);
alpha = del - V;

disp(alpha);
disp(Naço);
disp(Lapogee);

CONCLUSION

The design of anti-ballistic laser satellite is unique and technically very feasible. Care has been taken for orientation with the use of OMS (orbital maneuvering system). The system uses CO2 laser above all lasers because of its low weight and high intensity. Satellite takes 5min to destroy the missile. The use of multiple reflections of laser from the reflecting surface (as per the design) rule out the chance of melting of various satellite parts. The destruction of ballistic missile takes place at apogee. Hence procedure is totally pollution free, with no harm to ozone layer. This is onetime investment, unlike other anti-ballistic missiles which once used cannot be replenished.

REFERENCES


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