Light–Firing Coupling

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***Abstract*—Hypersonic missile poses a great challenge to defensive system. Knowing the fact that light travels faster than sound, it is reasonable to develop laser weapon. However, the laser strength diminishes in atmosphere and diverge in a long distance. Moreover, the track of hypersonic missile can be altered. Although high power laser gun can be mounted on aircraft carrier, it is not flexible enough. It will be logical to carry less power laser gun by a lighter drone or fighter. The traditional coordinate positioning is not possible.**

We know the missile emits light energy and photo-diode can convert light energy to electrical energy. A device can be made to locate the target. The jerky motion of missile can be tackled by a swinging stick system. And the plane of lens system can face directly to the target using the new advance in electroactive polymer that expands 300 times on passing current such that the opposite diagonal photodiode detectors will set the plane perpendicular to the target.

Swinging stick system responds quickly to the target motion and can even predict the next milliseconds motion of the target according to the Newton's first law—moment of inertia. The range of swinging stick system can cover the whole sphere around meaning that it can attack several flying objects sequentially with minimal time in between.

Electromagnetic pulses (EMPs) generated from laser coupling with polymer targets doped with 7% titanium can damage the electronics of missile.

Keywords—hypersonic missile, photo-diode, swinging stick system,electromagnetic pulses, spectral beam combining, electronic solid-gel switching.

I. Introduction

The automation sector depends on object detection, e.g. an object moving by on a conveyor, the closing of a door, or the arrival of a carrier puck at a stop. Engineers and software developers need to be aware that an object or target has arrived at a specific area.These inputs are necessary for event-based programming at specified points in the ladder logic program for the machine's computer or Programmable Logic Controller. The control system receives an electronic signal from the sensing devices Electromechanical, Pneumatic, Capacitive, and Photoelectric are sensing technologies.

When the recognized object shifts a mechanical actuator, a sensitive micro electro-mechanical switch modifies its state. Magnetic sensors are actuated by the presence of a permanent magnet within their sensing range. The presence of a magnetic field produces a change in the electrical signal—Hall effect transducer operating principle. Metallic objects cause a disruption in the electromagnetic field emanating from the body of the inductive proximity sensor. Proximity capacitative switches detect wood, paper, fabric, liquid and plastic that have different dielectric constant. They are electrostatic field sensors. Photoelectric sensors project a light beam and track the return light variation. The sensing distance will be impacted by the light sources employed, which may include visible, infrared, LED, or laser light. Diffuse reflection of the beam occurs in diffuse sensors when an item enters the optical field of view. Any opaque object that deflects the beam is detected by reflective and through-beam sensors. A 50-meter-long or longer light beam can be produced by laser sensors. Problem can be seen in transparent items with different surface finishes. Ultrasonic sound is sent toward a target, and the sensor receives the reflected sound. The target can be metal, wood, plastic, glass, liquid, but not foam-like materials, which will absorb sound waves.

Based on the articles 'Can You Hit What You See? JMESS. ISSN: 2458-925X Vol. 5 Issue 7, July – 2019' and 'High Power Laser in Intercepting the 'Flash', JMESS. ISSN: 2458-925X Vol. 8 Issue 2, February – 2022', further refinement is performed. A streamlined flying jet with swinging stick system mounted on. Protecting shield with mirror, restriction block to the swinging stick, or computer programmed firing avoid accidental damage to the jet itself.

Several problems need to face with this design, such as the light-electricity coupling, electro-mechanical coupling. We know the object is moving fast. We know it emit light and heat –infrared radiation. How can we convert this into an aiming lens to move in the correct direction? Will the angulation of the plano-concave lens affect the distance length? How the flying object triggers laser response—the rate of change of light intensity? As we have laser in hand, will it be possible to use electromagnetic pulse by coupling with polymer targets doped with 7% titanium to destroy the semiconductors? Is AI better than human control? Is unmanned flying jet better than the manned fighter? As laser has a limited range of effective attack, the design is primarily for defensive purpose.

II. Main Body

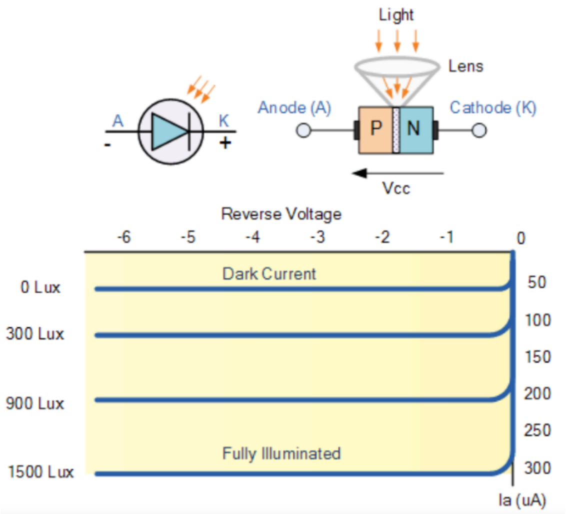
A. *How to convert light energy into an electrical signal?*

Photodiode light sensor has a clear lens to focus the light onto the PN junction for increased sensitivity. The junction will respond to light with long wavelengths such as red and infra-red.

All PN-junctions are used in a photo-conductive unbiased voltage mode with the PN-junction of the photodiode in "Reverse Biased" so that only the diodes leakage or dark current can flow.

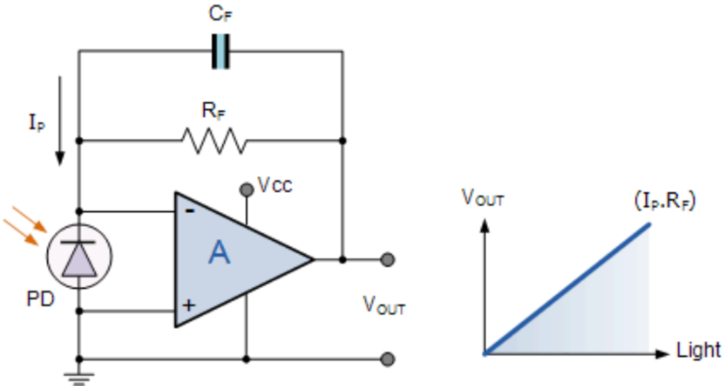
The current-voltage characteristic (I/V Curves) of a photodiode without light on its junction (dark mode) is very similar to a normal signal or rectifying diode. When the photodiode is forward biased, there is an exponential increase in the current. When a reverse bias is applied, a small reverse saturation current appears which causes an increase of the depletion region, which is the sensitive part of the junction. Photodiodes can also be connected in a current mode using a fixed bias voltage across the junction.

B. *Photo-diode Construction and Characteristics*



When used as a light sensor, a photodiodes dark current (0 lux) is about 1uA for silicon type diodes. When light falls upon the junction more hole/electron pairs are formed and the leakage current increases. The photodiodes current is directly proportional to light intensity falling onto the PN-junction. Photodiodes has fast response to light, but has relatively small current flow.

C. *Photo-diode Light Sensor Circuit*



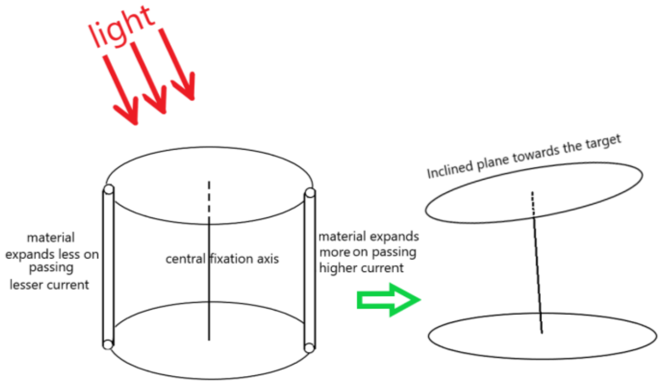
A photo-current-to-voltage converter circuit uses an operational amplifier as an amplifying device. The output voltage V_{out} = I_P*R_f is proportional to the light intensity. It can turn its current flow both "ON" and "OFF" in nanoseconds.

An operational amplifier with two inputs at zero voltage to operate the photodiode without bias. Zero-bias op-amp configuration gives a high impedance loading to the photodiode resulting in less influence by dark current and a wider linear range of the photocurrent relative to the radiant light intensity. Capacitor C_f prevents oscillation, gains peaking , and set the output bandwidth (1/2πRC).

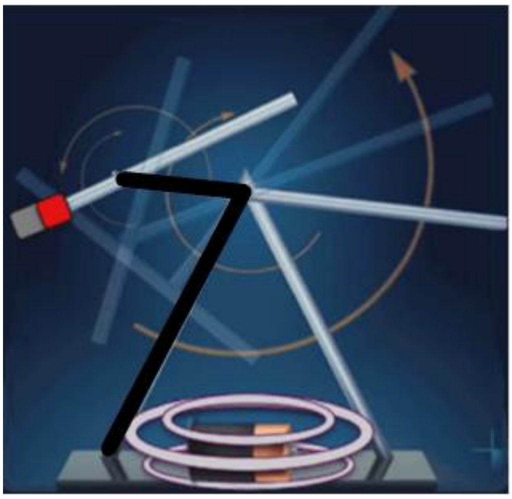
D. *How difference in current generated alters the angle of inclination of plano-concave lens?*

Researchers in Sweden and Britain synthesized a polymer that expands and contracts dramatically in response to a weak electrical signal due to phase change in response to electricity—Reversible electronic solid-gel switching of a conjugated polymer. When placed in an electrolyte solution, the material expands by a factor of 100 in response to a weak positive electrical pulse. A negatively charged pulse causes the material to return to its original volume. The underlying mechanism is that the material can manipulate via electricity to control the passage of different sized particles. The pore size of this filter can be controlled electronically. If the material is bounded circumferentially, the material tube will be lengthened according to the current passing through.

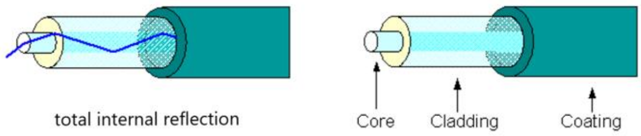
Because the buddy photo-diodes at the ends of diagonal receives different light energy, the buddy tubings will be lengthened disproportionately. If the centre of the plane is fixed by an unexpandable wire, the plane of lens will direct towards the flying object without change in the object distance.



E. How the pendulum motion can keep tracking with the flying object?



Consider the swinging-stick system works in 2D. One end will swipe the southern hemisphere, the other end will swipe the northern hemisphere. The base can be rotated to cover the 3D situation. The sudden jerky motion of the swinging-stick system locks the position of target closely. Through the fixed parts of sculpture, fiber optic cables allow laser to travel with little loss of energy by means of total internal reflection. The fibre carries the light in its core, whose refractive index is greater than that of cladding.



The Acousto-Optical Beam Splitter - Leica TCS SP8 AOBS can then divide the laser beam into a left and a right beam.

A laser light beam is partially transmitted and partially reflected as it collides with a prism. The incoming beam's direction is not the same as the direction of the reflected or transmitted beams. Due to the action-reaction law and the force operating on the prism, this direction change results in a change in the momentum of the light beam.

F. Manufacturing Process

Swinging Sticks is a perpetual motion device created by two Germans in 1996. Each Swinging Sticks sculpture is custom made and takes skilled craftsmen almost a full day to complete the perfect the balance , and to assure maximum level of excellence. The pin of sculpture can get misaligned pin during shipping. To guarantee excellence, the sculpture is tested again after shipping

G. How the Swinging Sticks Works?

The swinging sticks should operate in a vacuum-sealed glass hollow sphere so that the laser will emit perpendicular to the spherical surface in order to eliminate air resistance.

It employs electromagnetism to generate a moving kinetic sculpture, that arouses curiosity about its workings. The magnets in the sculpture's arms are calibrated by skilled craftsmen to enable exact mobility.

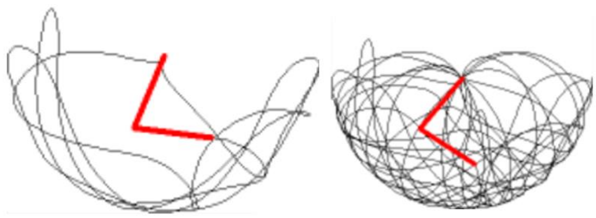
H. Physics

Electromagnetic fields and electrical currents are used to operate the Swinging Sticks sculpture. Although friction prevents the creation of true perpetual motion machines, we may engineer moving electrons to produce a magnetic field that powers the entire sculpture.

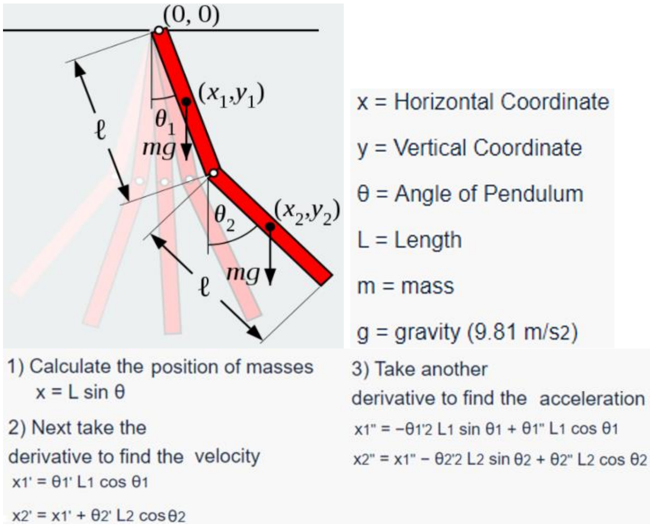
Three coils are present in the Swinging Sticks and have different purposes. The rotational speed of the revolving sticks is measured by two of the electrical coils. Depending on the speed determined by the first and last electrical coils, the intermediate electrical coil is utilized to change the pace either quicker or slower.

The Swinging Sticks have strong neodymium magnets built in their arms. The magnetic field produced by the electrical coils repels the magnets, giving them a "boost" of kinetic energy that causes them to shoot upward before effortlessly spinning back down. As long as a magnetic field is produced, this process keeps going back and forth.

I. Mathematics



A set of calculus equations in physics relating to double pendulums govern the Swinging Sticks. According to the Runge-Kutta methods of numerical analysis, it is regarded as a compound double pendulum that swings in a 2D plane.

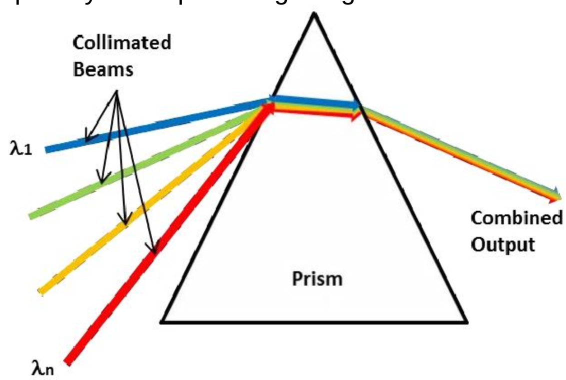


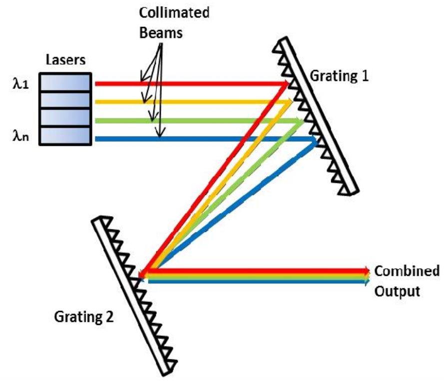
J. How to generate a high power laser?

Consider how a prism divides white light into seven different colors. Since light can move in either direction, we can apply seven distinct colors at various angles to one side of a prism, and we can anticipate receiving a mixed white light on the other side.

The process of combining several laser emitter outputs at various wavelengths into a single beam using a prism and diffractive gratings is known as spectral beam combining (SBC).

Each laser's wavelength is controlled by the architecture's external resonant cavity. The dispersive element in this method is a diffraction grating. A collimating optic is housed in the exterior cavity, a focal length from the laser emitters. The grating is then placed on the opposite side of the collimating optic, another focal length distant. The grating is then positioned another focal length away, on the other side of the collimating optic. This shape enables the diverging beams from each laser are collimated and spatially overlap at the grating.





The external resonant cavity is formed by an output coupler that returns a fraction of the power back to each laser with a second reflection from the grating. The design is shown in above figure.

The angles at which each beam leaves the grating are the same, making them collinear. The design of an SBC cavity can be derived directly from differentiating the grating equation where *d* is the distance between the grating grooves, W_{Array} is the width of the array of lasers to be combined, θ_g is the grating angle, and f is the focal length of the collimating optic.

$$\Delta\lambda_{LaserArray} = \frac{dW_{Array}Cos(\theta_g)}{f}$$

The needed bandwidth is between 5 and 10 nanometers for a 30 cm focal length, a 2400 line-per-mm grating, and a laser array width of a few centimeters.

Aculight is a circular arc of seven diode bars designed to lessen off-axis aberrations. 200 single-mode emitters were present in each diode bar, resulting in a total of 1,400 lasers in the combined beam. They collaborated to produce 27 watts of power that was almost diffraction-limited. A few hundred watts of power could be delivered by such configurations.

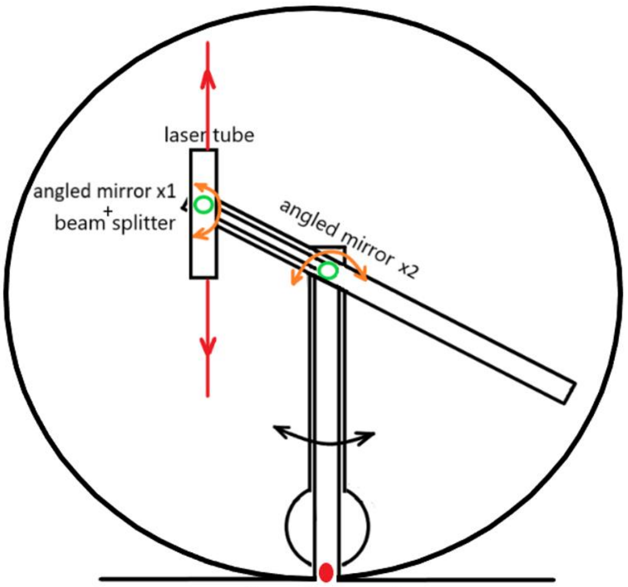
Yb:YAG lasers have been spectrally coupled to generate power levels of over 100 watts as opposed to a semiconductor laser's milliwatts. A 4-cm linear aperture can accommodate 160 high power fibers. To counter anti-aircraft missiles, a small directed energy weapon—pod weapon—had been installed on a fighter plane.

The thermal issue with laser weapons has now mainly been fixed. Additionally, lithium-ion batteries produce the energy reservoirs required to refuel and store laser light. Other ground fires are being targeted using weaker lasers as sensors.

A powerful burst of electromagnetic energy – electromagnetic pulse (EMP) can damage the delicate elements like semiconductors. This phenomenon occurs in nuclear explosions, lightning, and solar geomagnetic storms. The pulses generate harmful currents and voltage surges that damage the electronic systems.

When strong lasers engage with solid targets, significant electromagnetic pulses result (EMPs). EMPs generated at the XG-III laser facility by a pulsed laser (1 ps, 100 J) firing at CH targets doped with various titanium contents are studied. A doping concentration of 7% Ti yields the highest intensity of EMPs. Analysis based on the target-holder-ground equivalent antenna model confirms that EMP emission is closely related to the hot electrons ejected from the target surface. The EMPs have wide frequency bands ranging from a few megahertz to 1.6 GHz, and their energy is 200 times lower outside the target chamber than it is inside.

III. Final Design



The circumferentially restricted, diagonal polymer tubes will lengthen differently because the buddy light detectors receive different light intensity. The swinging sticks swings in a 2D plane. Beam splitter allows firing at both ends of the laser tubes. But usually, hypersonic missile flies at a lower orbit to evade from radar detection. So the splitter may not be required and we need to fire about the southern hemisphere. This couples with rotation about the vertical axis of the ball and socket joint at the base, and will cover the 3D territory. The fibreoptic delivering laser entry site is indicated at the red spot.

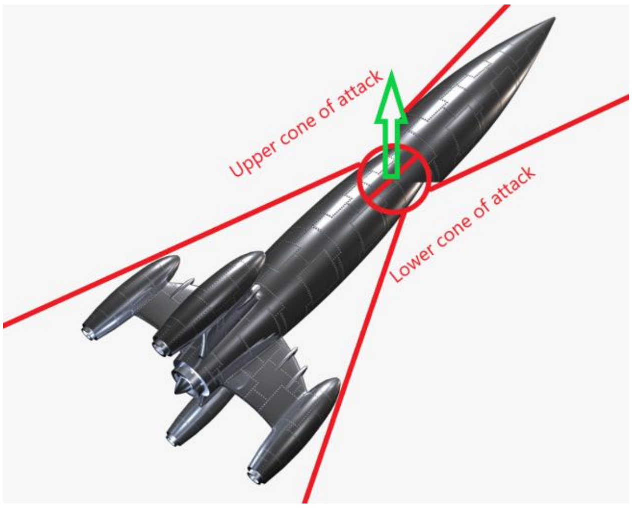
The problem is how to prove this aiming device will finally perpendicular to the flying object.

Calculation is difficult but we can see the locus of one end of swinging tube and deduce the locus of the other end of the tube. Think when will the buddy diagonal polymer tubes will be equal in length and will not struggle to bending left or right. It is when the plane of plano-concave lens is perpendicular to the flying object such that the buddy photodiodes receive the same amount of light.

So the scenario will be the swinging tubes will move and adjust by itself. The thing we do is to provide movable joints such that it corrects itself freely in tracing the infrared releasing flying object(s).

Noting that the device continues to move and fires whenever the rate of change of light intensity suits our entry criteria. Even though the flying object lies outside the range, we can rotate the symmetric fighter and the target will fall on the firing range again. The point is whether we can have strong laser.

Alternatively, we can use laser to hit on the polymer doped with 7% titanium to create electromangnetic pulse to affect the electronics of the missile. For example, we can released powder of doped polymer into the vicinity of target and use laser to strike the polymer in air.



III. Conclusion

Energy conversion and coupling occurs in our daily lives. Use of them can solve problems. A hypersonic missile can be seen as a light and infrared releasing flying objects. By means of optical, electronic, and chemical, physics, mathematics, and laser knowledge, here I suggest a solution. There may be other answers depending on the advance in science in future. Of course, making use of these techniques for people and our earth is far more worthwhile than use for military purposes.

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