

[54] **LASER-GUIDED PROJECTILE SYSTEM**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 214,619, Jan. 3, 1972, abandoned.

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[51] Int. Cl. ... **F42b 15/10, F42b 15/02, F42b 15/00**

[58] Field of Search **244/3.13, 3.21**

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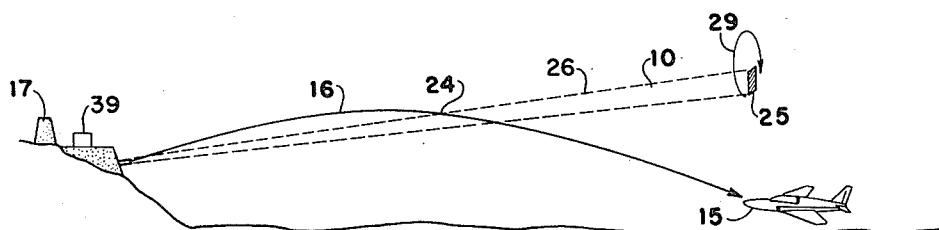
Attorney, Agent, or Firm—Fitch, Even, Tabin & Luedeka

[57]

ABSTRACT

A method and system is disclosed for guiding a spinning in-flight projectile by determining the deviation of the projectile from an optimum trajectory along which the projectile would impact a target, and transmitting a signal to the projectile to subject the projectile to a correctional impulse acting substantially through the center of gravity of the projectile of sufficient magnitude to translate the projectile toward the optimum trajectory.

20 Claims, 8 Drawing Figures



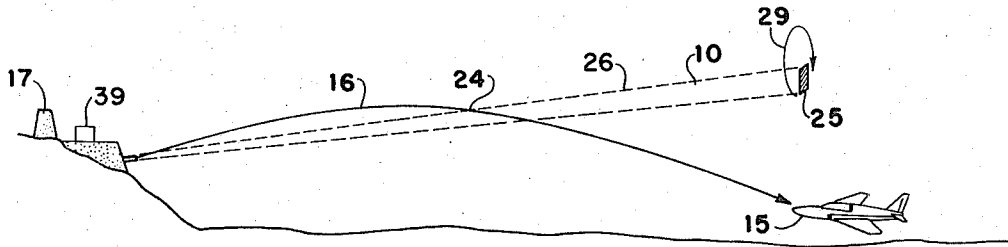


FIG. 1

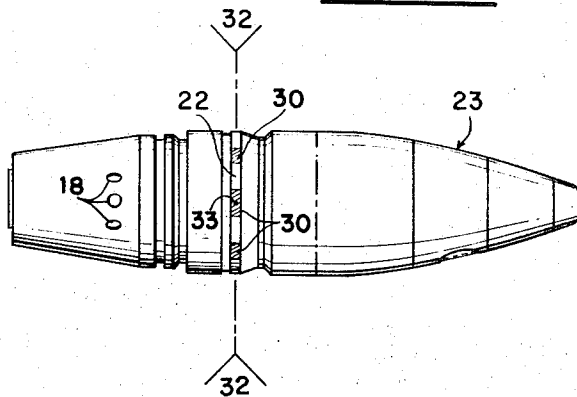


FIG. 2

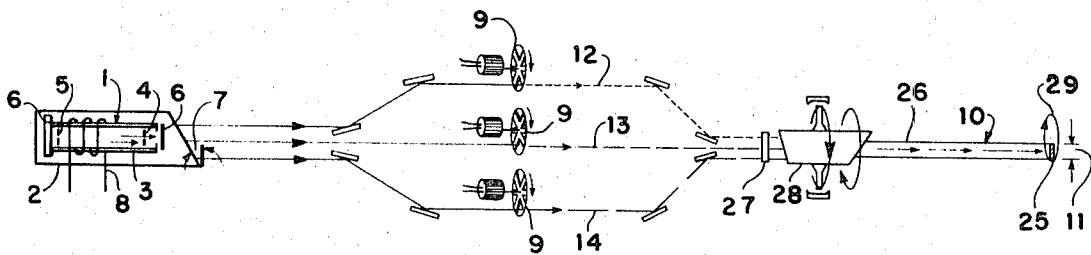


FIG. 3

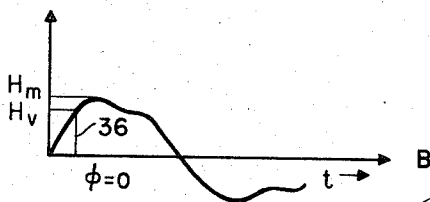
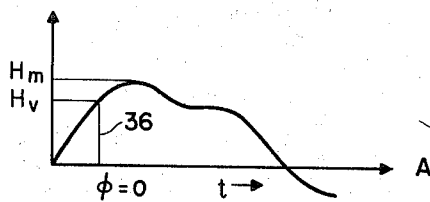


FIG. 4

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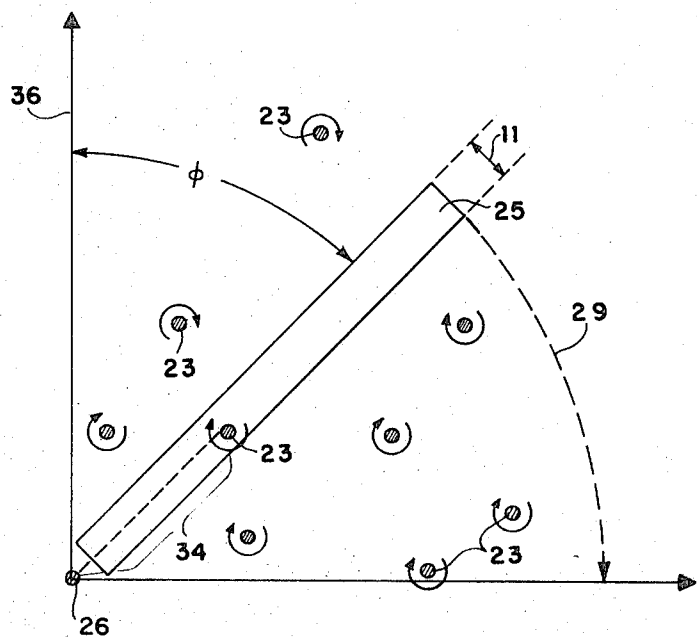


FIG. 5

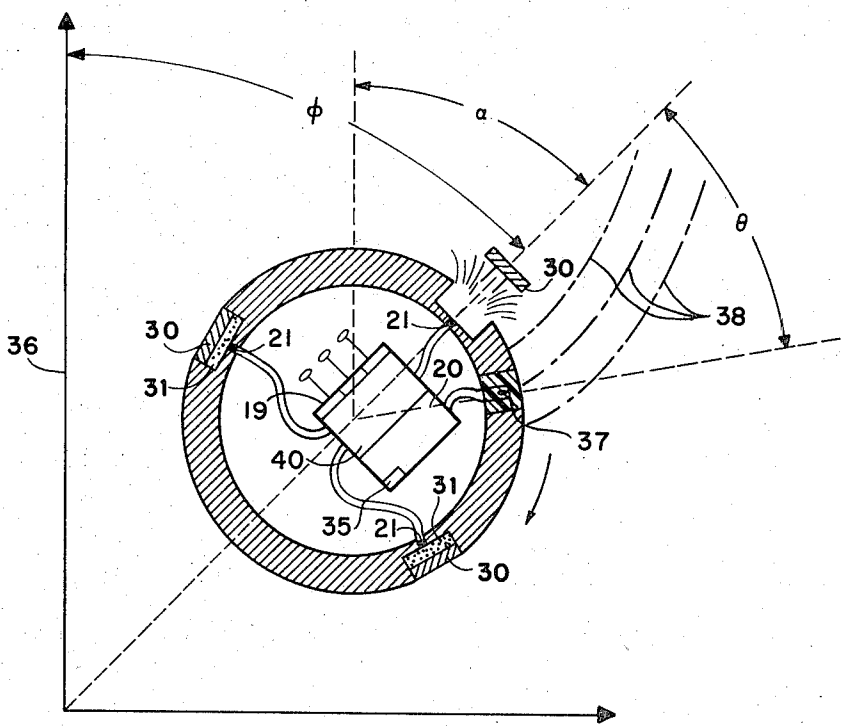
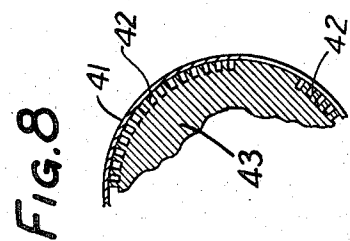
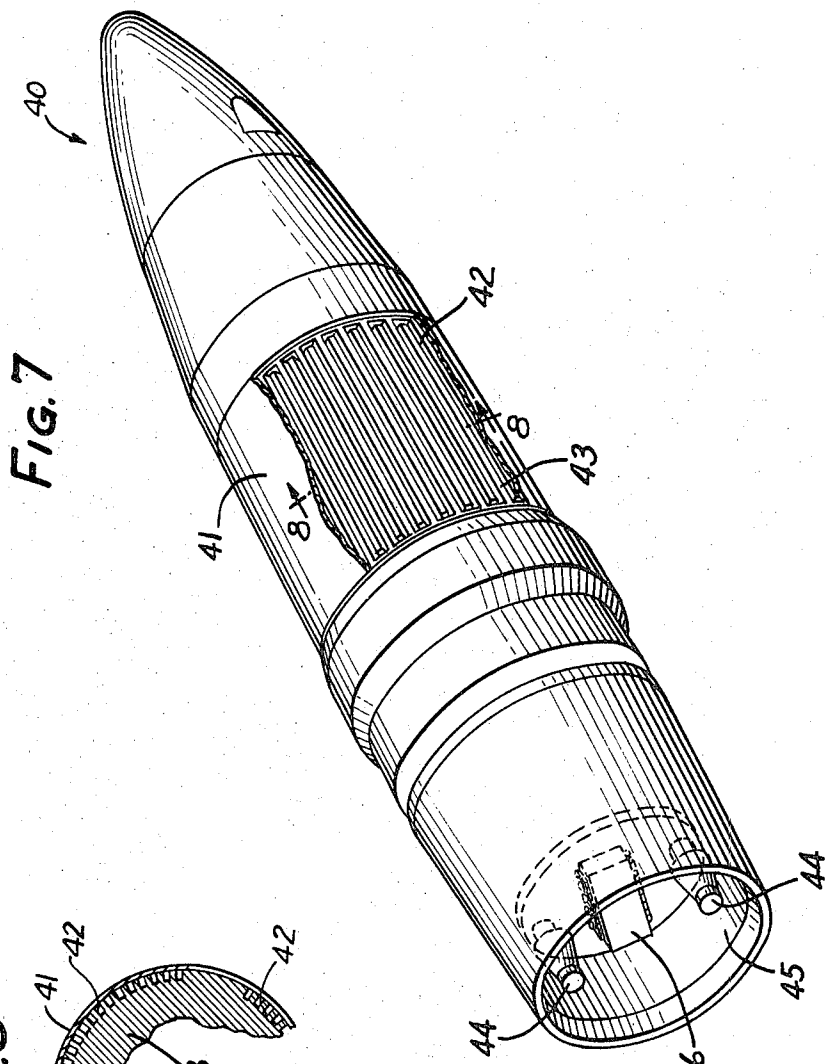


FIG. 6

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LASER-GUIDED PROJECTILE SYSTEM

This application is a continuation-in-part from my copending application, Ser. No. 214,619, filed Jan. 3, 1972 now abandoned.

The present invention relates generally to guided projectile systems, and more particularly to a novel laser guided projectile system capable of guiding a spinning in-flight projectile toward an optimum trajectory along which the projectile would impact a target.

The use of various types of projectiles against manned and unmanned aircraft targets has a long tradition. The advent of guns with high firing rates during World War II signalled a change in weapon effectiveness. Guns firing projectiles of 20 and 40 millimeter caliber became quite useful against all types of aircraft targets.

In recent times, however, the effectiveness of such guns against manned aircraft, pilotless ramjet or liquid-rocket-propelled aircraft has diminished.

This arises from three factors. First, the speed of the various aircraft is significantly higher than in World War II (namely about 650 mph vs. about 300 mph.) Second, the aircraft are sometimes pilotless, have automatic terminal homing systems and are of considerably heavier construction, thus rendering them more invulnerable to projectile impact. Third, even with the high firing rates presently obtainable with modern Gatling guns, the dispersion, or average angular error of a statistical sample of projectiles fired from the gun, is ordinarily too large in magnitude to allow sufficient hits to be scored.

This invention relates to a relatively simple, yet effective projectile or missile guidance system which is designed to reduce the dispersion error and hence allow more hits to be scored on any target, thus providing a more effective means for destroying such targets. While aircraft targets are one type against which the guidance system would be particularly useful, ground and naval targets could also be more effectively attacked.

Many guidance systems have been proposed for missiles and projectiles. In the case of projectiles, most of these are useful only for larger calibers, (greater than 3 inches in diameter), whereas the optimum calibers for the high-rate-of-fire guns are generally less than 40 millimeters. Thus there is a need for a guidance system which would be feasible with both large and small calibers, and yet sufficiently compact, light-in-weight, simple and reliable in design, and low enough in manufacturing cost to be a practical improvement. In the following description, the system is particularized to a projectile fired from a gun. The invention, however, is also applicable for the guidance of a spinning rocket, or missile, and the word 'projectile' when used in the following description, should be understood to include such spinning rockets or missiles.

This invention, then, relates to a method and system for guiding a projectile in flight so that the natural dispersion or scatter of a number of sequentially-fired projectiles is reduced substantially, so that more hits are registered on the target. The principal object of the invention is to provide a sufficiently simple, small and lightweight system so that a reasonably small caliber, such as a 20, a 35, or a 37 millimeter diameter projectile, can be effectively guided to a target by the use of a laser beam.

It is assumed that means are provided for tracking the projectiles to the target, such as by the use of doppler radar, or passive optical or infrared tracking of the projectiles by the use of radiation sources in the projectiles, which tracking system would provide the information for the proper positioning of the guiding laser beam, by a servo-actuation device, so as to enable calculation of the correct lead angle for the optimum interception of the target by the projectile or projectile stream. Such systems are in a practical state of development. The computation of the trajectory of the projectile, including deceleration due to air drag, and calculation of the target position, including lead angle, and so forth, and the determination of the optimum aiming direction is straightforward and reduced to practice and would require no further explanation to those reasonably skilled in this art.

Another object of the invention is to utilize light from a narrow, rectangular or other suitably-shaped cross-sectioned, collimated, circularly-sweeping laser beam to provide directional information to a compact sensing system in a projectile in such a way that sufficient guidance can be imparted to the projectile so that it will more probably impact with the intended target.

A further object of the device is to provide a system by the use of a circularly-sweeping, collimated laser beam with rectangular or other suitable cross-sectional area and a computer which is programmed with the specific ballistic data of a given projectile and measured initial velocity of the projectiles so that optimum guidance is given to the projectile, taking account of the statistical spread or scatter of the projectiles about the given aim direction of the barrel or barrels of the firing gun system.

A still further object of the invention is to provide a countermeasure-proof guiding laser beam by the use of an intermittent modulation or pulsation of various wavelengths within the laser beam, by either an amplitude modulation or a coded sequence.

Such signals would be transmitted through the earth's atmosphere at the ranges of interest with a high probability. Included in this information would be the angle of the projectile from the center of the laser beam, said angle being measured from the projected vertical in a plane perpendicular to the beam and passing through the projectile; also a reference vertical by sensing the earth's magnetic field intensity at both the laser and the projectile by the use of a rotating Helmholtz coil at each location.

A still further object of the invention is to provide, by means of small optical detectors, filters, light-sensitive cells, and a magnetic intensity coil, coupled with suitable, compact, and reliable integrated or miniaturized circuitry to activate one or more discrete radial impulses, which are produced by the acceleration of small masses, employing propellant or high explosive energies so as to provide small changes in velocity of the projectile in a direction normal to or perpendicular to the direction of motion of the projectile along its trajectory or flight path.

Yet another object of the invention is to provide a projectile having novel impulse reaction means thereon responsive to a predetermined signal to effect a net impulse force on the projectile which passes substantially through the center of gravity of the projectile.

These and other objects of the invention will become apparent to persons skilled in the arts and techniques

of lasers, gunnery, rocketry, and gun control systems by reference to the following description when taken with the accompanying drawings which illustrate the inventive principle.

FIG. 1 illustrates a projectile firing system in accordance with the present invention having a rectangular laser guidance beam scanning in circular fashion about a chosen point on an optimum trajectory for projectile impact;

FIG. 2 is a side elevational view of one embodiment of a projectile containing a guidance system in accordance with the present invention, windows to accept the laser signals being shown on the boattail, and three guidance masses being located on a plane passing through the center of mass of the projectile;

FIG. 3 is a diagrammatic view illustrating the method of generation of the beam, encoding various guidance information, and development of the circular scan of the rectangular laser beam;

FIG. 4 depicts a pair of graphs. In the graph denoted by (A), the waveform shown is a voltage across a spinning Helmholtz coil, which cuts the earth's field lines. This coil is located in the projectile. In graph (B), the voltage across a similar coil mounted at the laser beam source is shown. The vertical line on each graph represents the electrical signal when the coil is in the reference vertical position;

FIG. 5 is a 90° sectional view looking down-range toward the target. The spinning projectiles are statistically scattered about their optimum trajectory (at the origin of the coordinates in this figure). The intercepted rectangular laser beam transmits to the projectiles information as to their individual coordinates, as well as the range to the target and information as to true reference vertical;

FIG. 6 is a cross-sectional view of the projectile, looking down-range. A small mass is shown being explosively projected at an appropriate spin angle of the projectile causing it to translate toward the origin, which represents the optimum trajectory for target impact;

FIG. 7 is a perspective view of a projectile containing a guidance system in accordance with another embodiment of the invention; and

FIG. 8 is a partial transverse sectional view taken substantially along the line 8—8 of FIG. 7.

In order to simplify the description of the system, a particular projectile will be chosen, and a particular laser beam system, and also a particular number of guiding wavelengths and impulses and so forth, however, it is understood that the system may be usefully employed with other projectile calibers, lasing wavelengths, number and coding of the guiding impulses, particular geometries of the guiding laser beam, and so forth. The caliber described in the following description is 37 millimeters, because such a round has sufficient size and weight to easily accommodate the guidance system, although smaller or larger projectiles could also be used if desired. The type of round chosen to describe the present invention is basically a high-explosive-filled shell, with a shell-destroying tracer and a point-detonating fuze.

For a given gun aiming situation, the ballistics of the projectiles are quite accurately known, but due to the random processes, involving small differences in effects of powder load, projectile shape and mass, frictional forces as the projectile leaves the gun, small differences

in effects of cloud water, small differences in frictional force due to fluctuations in wind and air density, the stream of projectiles will tend to scatter about the aim direction, such scatter being known as the dispersion of the projectiles and is an accurately measurable quantity, by the performance of a test with many rounds. It is of importance for the proper description of the guidance system to estimate the magnitude of this dispersion. In general, for a practical gun or missile system, it will be an angle of about 5 to 15 milliradians, by which is generally meant that in travel along its trajectory, the projectile or missile will tend to deviate in a statistical manner about 5 to 15 feet in every 1,000 feet of travel. Thus, if a small velocity can be imparted in some simple and accurate and reliable manner which is of magnitude 5 to 15 thousandths of the instantaneous projectile velocity, the projectile course could be corrected.

For clarity of exposition and description, the component systems of the laser guidance system are separately described. These are, first, the laser guidance beam, second, the projectile laser illumination sensing system, and third, the projectile detonation impulse system. A specific system is chosen, which may or may not be optimum, in order to better demonstrate the workability, feasibility, and utility of the guidance method and hence some of its advances over the present state of the art.

With the goal of providing a useful beam with the minimum of equipment, a specially-modified argon-ion laser is employed. The laser tube 1, consists of a gas reservoir 2, connected to a precision-bore, air-cooled quartz tube 3, having an inside diameter of about 5 centimeters and a length of about 75 centimeters. Electron flow for the unit is from a hot cathode 4, through the active lasing region to the anode 5. A bypass tube on one end of the laser tube is connected to a reservoir to equalize the gas pressure and to improve the pumping efficiency. A ground, located near the bypass tube forces the electrons to flow through the quartz tube. Confocal optical resonators 6, are externally mounted so that the laser light may pass through the end quartz window which is mounted at the Brewster's angle 7. The voltage required to pass the current through the tube is about 12 kV and is supplied through a resistor. A coil of wire, 8, wrapped around the quartz tube 3, supplies a continuous radio-frequency energy required to produce ionization of the argon gas contained within the quartz tube.

Gas pressure can be varied to effect optimization of the lasing action. Light output from such a laser is given by the following table:

TABLE 1

SPECTRAL OUTPUT OF ARGON ION LASER		
Wavelength (A)	Color	Relative Power Output (% of Total Beam)
4658	Very Faint Violet	1
4765	Dark Blue	13
4880	Blue	35
4965	Blue-Green	11
5017	Blue-Green	8
5145	Green	32

The power which is scattered out of the beam reduces the propagation power of the primary beam from

about 0.02 decibels per kilometer to about 3 decibels per kilometer for a clear to a light-hazy atmosphere. Because of the fact that the scattering losses depend on the inverse fifth power of the wavelength, it is preferably to operate the system at wavelengths in the optical region rather than in the ultraviolet. Use of the near infrared region is also possible since there are room-temperature detectors which operate in this region. Continuous gas lasers such as those employing carbon dioxide, nitrogen, helium or water vapor, which produce monochromatic light at 10,600 Å, have attenuation losses which are larger than those for wavelengths in the visible spectrum, but these could also be employed. To achieve a system which is nearly impossible to countermeasure, three or more wavelengths may be employed simultaneously. In the case of the argon-ion laser, these might be the 5145 Å, 12; the 4965 Å, 13; and the 4880 Å, 14 lines. These are produced with high efficiency as shown in TABLE 1.

Spectral filters 19, using interference layers can be utilized to absorb other wavelengths. The above three wavelengths would then transmit, in a manner extremely difficult to counter-measure, the various necessary input data to the projectile.

To effect pulse coding of the laser beam, the laser itself may be pulsed at high rates, electrically. Pulses of length between 0.4 and 3 microseconds are easily produced with an argon-ion laser. The output power is related, in such a mode of operation, to the gas pressure and the peak anode current.

An alternate method for producing a train of pulses, either coded or uncoded, is by the use of three or more mechanical beam choppers or sectored filter discs 9 which are rotating at various angular rates and through which the beam passes.

The light energy from the laser can be concentrated into a very narrow beam 10. The angle subtended by the beam at the ranges of interest for this device is primarily dependent upon the quality of the optics in the laser apparatus, but also upon fluctuations in the density in the atmosphere, (refractive or bending effects), and to energy loss due to interactions from scattering processes with small density fluctuations or particulate matter such as dust or water droplets as the scattering centers. The angular width 11, of the rectangular laser beam can be quite small. For the application described here, an angle of one milliradian would be easily obtainable.

Since the laser beam intercepts air density fluctuations or concentrations of particulate matter suspended within the atmosphere, a certain fraction of the beam power is scattered out of the beam and lost, however the scattered intensity is in the generally forward direction of propagation.

As the projectile moves outward in the general direction of the target 15, it will be in the circularly sweeping rectangular laser beam, the center of rotation of this beam being directed toward some point on the optimum trajectory 16 to the target, as calculated by the system computer 17. Some radiant energy is attenuated or scattered out of the laser beam, as has been discussed previously. However, a sufficient fraction of the laser beam energy is intercepted and transmitted through a small window or windows 18, located, for example, on the projectile boattail. Such a window or windows may be constructed from any number of materials including glasses, fused silica, or quartz. The optical ra-

diation is focused on the sensitive photodetector element 19. This again could be chosen from among a wide variety of currently available materials. Lead selenide, or lead sulphide photoconductive cells are two detectors which would be responsive to radiation from the argon-ion laser, and could be used at room temperatures, not ordinarily requiring cooling. The electrical signals from such light sensitive cells are then amplified by microcircuit amplifiers, then processed by state-of-the-art modular circuits 20 which may be presently obtained from many industrial sources and are easily interconnectable to produce the functions required by the system. Such circuit elements are extremely lightweight, use very low electrical currents, and are extremely compact, because of the recent advances in this art, now including many extremely complex and very small circuits employing what is known as large-scale-integration. This is mentioned because this invention is only possible in practice by the use of advanced modular or other microcircuit techniques.

If the laser radiation is of the appropriate wavelength and modulation, and a certain pulse length as determined by the rate of spin of the projectile and the narrowness of the rectangular beam and distance away from the center of rotation of the primary axis of the laser beam, then an electrical firing pulse is appropriately delayed and then conducted to a particular miniature detonator 21, in the guidance band 22, the detonator being chosen so as to effect the optimum discrete change in the radial impulse delivered to the projectile. The correctional impulse needs to be chosen in such a way that the projectile will impact the target with a much improved probability. This can be done by the use of different correcting masses in the guidance band, or different amounts of explosive which propel said masses or possibly both. Because of the fact, as was pointed out earlier, that the laser radiation is mainly at small angles to the direction of the optimum trajectory, it is advantageous for the small window or windows of the guidance system in the projectile to accept radiation from the direction opposite to the direction in which the projectile is moving. Such a window or windows could be easily mounted on the rear end or boattail of the projectile.

In the following, consideration is given of how this guidance might be effected in practice. It is assumed that the guidance system is installed into a 37 millimeter projectile 23. A typical velocity of this projectile is 3,000 feet per second. It is assumed in this analysis that the target is fixed at a range of 2,000 feet. The projectile will take approximately 0.66 seconds to reach the target if the latter is fixed and the gun will have to be elevated about 4 mils, if the target and gun are approximately at the same elevation, to compensate for the effect of gravity during the projectile flight. As shown in FIG. 1, the laser beam will be directed at an appropriate angle so that at or near the midpoint of the projectile flight 24, for example, any corrections in azimuth or elevation angle can be applied to the projectile by the discrete radial impulse system to bring it more nearly onto the optimum trajectory.

In order to determine the radial distance of the projectile away from the optimum trajectory at the half range position, the laser beam, of rectangular cross section 25, in a plane perpendicular to the direction of the propagating light beam, is rotated at a frequency f_0 . This can be accomplished simply in practice by passing

the beam through an aperture 27 to render it rectangular in shape, then through a device known as a beam expander, if necessary, to increase the long dimension of the rectangle, and then through a rotating dove prism 28, or equivalent mirror array, which will rotate the whole rectangular beam about the center of rotation 26, which, for the example chosen, is placed on the trajectory midpoint. (FIG. 1)

The small window or windows located on the boattail of the projectile intercept and filter the various wavelengths providing signals to the various amplifier channels and microcircuit decision elements within the projectile.

The pulse length of the green line at 5145 Å depends upon the frequency of rotation of the dove prism 28, the width of the scanning rectangle, 11, and the radial distance from the point of optimum trajectory, r.

In order to effect a small correctional velocity small masses 30, are ejected radially from the projectile at an appropriate time. Because of the requirements of small space, weight, complexity and fabrication cost, only a limited number of correcting impulses are given to the projectile.

Let us assume, for the purposes of this description that there are three masses, perhaps made of steel or brass, and accelerated by small amounts of propellant or high explosive 31. Explosive weights of perhaps twice to three times the weights of the guidance masses would be appropriate. The explosive might be a secondary type initiated by a microdetonator which may have a wide variety of component explosive compounds, such as lead styphenate, as a primary explosive, followed by a train of a more sensitive booster explosive material, such as tetryl, followed in turn by the secondary explosive, such as HMX, RDX, or PETN. The secondary explosive is generally quite brisant, and for this reason a thin layer of a buffer material, such as a soft plastic, would ordinarily be interposed between said secondary explosive and the guidance mass, to insure smooth and reproducible acceleration of the latter. However, it is important to note that the guidance mass is accelerated and out of contact with the projectile in a very short time interval, 2 microseconds or less being typical, and in this time the projectile would only rotate around its spin axis about 1° in angle. The detonation of the guidance mass accelerating explosive would produce some shock effect in the body of the projectile. If the high explosive fill of the projectile is proximate to the guidance mass, a thin layer of shock-absorbing material, such as rubber, or a plastic, such as polyethylene, can be interposed between the explosive fill and the metal projectile body to prevent shock waves of any appreciable magnitude from intercepting said explosive fill.

A simplified way of considering the correcting impulse required is contained in the following simple analysis. It is first assumed that the dispersion of the projectile is denoted by τ . The radial velocity of the projectile away from the optimum trajectory (Δv) can then be related to the projectile velocity, (v) through the following relation:

$$\Delta v / v = \tau$$

(1)

Typical projectile velocities at the target would be approximately 2,500 feet per second. The velocity at

which the small guidance masses can be projected, v_g , by the use of a microdetonator and a small high explosive charge is in the neighborhood of 5,000 feet per second. The following equation gives the guidance mass, m_g , to effect the required correction to a projectile of mass m .

$$2\Delta v m = v_g m_g$$

(2)

The guidance mass, m_g , can be calculated from the above equation and Equation 1.

$$m_g = 2\Delta v m / v_g = 2\tau v m / v_g$$

(3)

As was previously pointed out, in typical practice, the guidance mass speed will be approximately twice the projectile speed. Thus

$$m_g = \tau m$$

(4)

Since the value of the total dispersion τ is about 7×10^{-3} , while m is approximately 600 gm, thus

$$m_g = 4.2 \text{ gm.}$$

(5)

This mass is an acceptably small fraction of the total projectile mass and hence will not deteriorate the terminal fragmentation or penetration effectiveness of the round.

The projectile is spinning in free flight at a rate determined by the twist of the rifling. For example, with a rifling twist of 1 in 17 calibers, the spin rate would initially be approximately 1,430 rps, or about 1.4 revolutions for every millisecond of flight. For a velocity of 3,000 feet per second, this yields a single revolution for each 2 feet of projectile travel along the trajectory.

If the axis of a spinning mass is rotated in a direction normal to the axis, the mass will suffer a gyroscopic precession, by which is generally meant that the spin axis tends to rotate in a direction perpendicular to the direction of the applied force. Likewise, if the projectile is rendered an impulse at a position off the plane 32 normal to the axis and passing through the center of mass of the projectile, the axis of the projectile will undergo precession; it will describe a cone, and the resulting aerodynamic forces on the projectile will cause it to yaw or stray off course in an uncontrolled manner. Thus, one of the essential features of this invention is the location of the guidance masses on a 'guidance band' which is at or very near a plane perpendicular to the projectile axis and which passes through the projectile center of mass 33. Depending upon the projectile flight time to the target, a radial impulse would be chosen which would optimize the probability of interception with the target. Thus, the radial correction impulse applied, for a given error in distance 34, from the predicted trajectory, might be small at the initial segments of the trajectory, but then increase as the time interval to correct the course grows shorter, with decreasing distance to the target. For this purpose, a microcircuit computational element is employed; this circuitry being powered, for example, by a small electric generator taking its power from the spin-up of the pro-

jectile during acceleration in the barrel, or a lightweight, compact battery 35, activated by setback forces during projectile acceleration in the gun barrel, as is commonly practiced in proximity or VT fuzes.

The angle ϕ (FIG. 5) is communicated to the projectile sensing system by an amplitude-modulated signal superimposed on the argon-ion laser green line at 5,145 Å, the modulation having, for simplicity, a frequency relation to the angle ϕ of direction, a proportionality as follows:

$$f_1 = K_1 \phi \quad (6)$$

The projection of the true vertical 36, can be established within the projectile as follows: A dielectric material in the side of the projectile in the form of a small cylindrical plug, carries embedded within it a small Helmholtz coil 37. As the projectile spins, a voltage is developed across the terminals of this coil, said voltage depending on the direction of the intercepted magnetic lines of the earth's field 38. Since the intensity of this field is generally about 0.2 gauss, the voltage developed by the coil is sufficient for the operation of this sensor. A typical voltage waveform across the coil as a function of angle of rotation is shown in FIG. 4A. Because the earth's field varies in dip, or vertical angle, and declination, or horizontal angle, the angle at which the magnetic field maximum occurs from the projected vertical will vary. This angle is shown as $\phi=0$ in FIG. 4.

At the laser, another Helmholtz coil 39 is located, with its geometry and rotational axis nearly coaxial with the projectile magnetic-field-sensing Helmholtz coil. Thus the two voltage signals will be similar in waveform to one another irrespective of the direction of aim of the gun and the guiding laser beam. However, at the laser, a reference projection of the true vertical is readily available; a simple damped pendulum would provide, with sufficient accuracy, a reference projected vertical. This data could also be provided from fire control systems.

The voltage signal at the laser magnetic sensing system is shown in FIG. 4B. It may have a different amplitude and frequency, but the ratio H_m , the maximum value, to the value at the vertical plane H_v , will be nearly the same as that on the projectile. This may be written as follows:

$$\gamma = H_m / H_v (\text{Projectile}) = H_m / H_v (\text{Laser}) \quad (7)$$

Thus, the signal amplitude at the projectile which represents the projection of the true vertical can be easily determined. Hence the angle $\alpha + \epsilon$ is also determined.

The variable γ can then be transmitted to the projectile by the laser beam employing an amplitude-modulated signal of frequency f_2 on the blue (4,880 Å) line.

$$f_2 = K_2 \gamma \quad (8)$$

Normally, the earth's magnetic inclination will be between useful limits and the magnetic field strength (about 0.2 gauss) will be sufficient so that the projectile vertical-sensing system will be simple, accurate, reli-

able, and nearly impossible to countermeasure by the enemy.

The spinning Helmholtz coil on the projectile also supplies pulses to a microcircuit counter 40 which totals the number of projectile revolutions to a given range. Thus, knowing the number of revolutions, the initial projectile velocity, and the rate of decrease of the spin rate, due to frictional forces in the air, allows the range to be determined with excellent precision.

Amplitude-modulated signals of frequency f_3 can be sent down the laser beam on the 4,965 Å blue-green line to specify the range at which the correction impulse should be initiated. For purposes of illustration, we specify here that this correction would begin at mid-range, or halfway to the target, which is at range R.

$$f_3 = K_3 R \quad (9)$$

The angle ϵ is known by the design of the projectile. Since the angle $\alpha + \epsilon$ is known from the projected vertical sensing Helmholtz coil in the projectile, with the normalizing signal sent down the laser beam by the modulation of the 4,880 Å line. When the angle α is nearly equal to the angle ϕ , the detonator on an appropriate guidance mass is fired, projecting this mass out at an angle ϕ thus imparting to the projectile a correcting impulse toward the optimum trajectory (at the co-ordinate origin in FIG. 6).

Appropriate logic or computational elements in the subminiaturized computing circuitry would select the optimum discrete impulse, of the three available to effectuate the optimum trajectory correction, which would depend upon the following factors: the range from the gun, as determined by the magnetic field spin counter of the projectile, which initiates action upon firing setback or acceleration; the distance error from the correct trajectory, determined by f_0 and the time that the scanning rectangular laser beam intercepts the projectile.

Various components of this system can also be utilized in a further-developed system to provide improved fuze function. For example, many of the components of an active infrared or visible light proximity fuze are already included in the system, such as windows, detectors, detector circuitry, filters, power supplies, and so forth. Also, updated range data is available within the projectile with this system, so the projectile can be detonated at this range to substantially increase the damage radius.

FIGS. 7 and 8 illustrate another embodiment of a projectile, indicated generally at 40, which may comprise a rocket or missile constructed in accordance with the present invention. The projectile 40 differs from the projectile illustrated in FIG. 2 primarily in its impulse reaction means for establishing a net impulse force to effect lateral movement of the projectile toward a desired trajectory in response to a predetermined signal applied to the projectile. The peripheral configuration of the projectile 40 is generally similar to the peripheral configuration of the projectile illustrated in FIG. 2. The projectile 40 includes an intermediate section having an annular generally cylindrically shaped peripheral wall 41 which overlies a long groove 42 formed in a cylindrical housing portion 43 of the projectile body. The long groove 42 may take the form of a plurality of U-shaped grooves which are connected

in end-to-end relation such that the ends of the legs of each U-shaped groove are each connected to one end of an adjacent U-shaped groove to form a long groove disposed peripherally about the housing 43. The long groove 42 is positioned such that a plane intersecting the groove 42 at the midpoint of each longitudinal leg portion of the groove and disposed perpendicular to the longitudinal axis of the projectile 40 passes through the center of mass of the projectile 40, the long groove being connected to a microdetonator by an explosive train.

The groove 42 in the projectile 40 contains a high explosive material which completely fills the groove 42. The high explosive material may comprise a secondary type explosive capable of being initiated by a microdetonator and may have a wide variety of components of explosive compounds, such as lead styphenate, as a primary explosive, followed by a train of more sensitive explosives such as tetryl, followed in turn by the secondary explosive, such as HMX, RDX, or PETN. The explosive material may be bound together by various binding materials to effect an optimum detonation speed by variance of the density of the binder material. The high explosive, if bound in a form initially having low viscosity, can be then easily injected into the long groove, later hardening into a more rigid consistency. The high explosive material disposed within the groove 42 is capable of high order detonation and, upon being selectively detonated with respect to the angular position of the point of detonation relative to vertical, will effect a very rapid rate of detonation along the length of the groove. An explosive material is selected having a rate of detonation, considered along the length of the groove 42, which will maintain the "point" of detonation in a fixed angular position relative to a true vertical even though the projectile is spinning about its longitudinal axis at a relatively high rotational speed. In this manner, when the high explosive material within the groove 42 is detonated, a high order detonation will be effected which will act against the inner surface of the annular peripheral wall 41 accelerating it so as to effect a net impulse force acting perpendicular to the longitudinal axis of the missile 40. The materials which surround the groove may be of a friable nature so that after detonation the resulting underlying surface is smooth, thus, reducing the air drag forces due to projectile spin. The rate of detonation of the high explosive material within the groove 42 and the balanced geometry of the groove 42 relative to the center of mass of the projectile 40 are such that the impulse force created by detonation of the explosive material will create an average net impulse force which acts through the center of mass of the projectile 40 in a chosen direction perpendicular to the longitudinal axis of the projectile.

As an alternative to employment of small windows on the projectile boattail, as employed in the projectile illustrated in FIG. 2, the projectile 40 may employ a pair of laser light sensor elements 44 which are positioned within an axial recess or opening 45 in the base portion of the projectile 40. The recess 45 may be covered with a thin cover plate when the projectile is being accelerated in the gun barrel so as to protect the sensor elements 44 from the high temperature propellant gases and smoke which could cause obscuration, this cover plate being dropped off in flight after the projectile exits from the gun barrel. The laser light sensor elements 44 serve to transmit optical radiation from the

laser guidance beam to a photodetector element (not shown) housed within the projectile 40, such photodetector element being similar to the above referenced photodetector element 19 mounted within the projectile illustrated in FIG. 2. As an alternative to the use of the earth's magnetic field as a method for determining the true vertical of a fiducial point on the projectile, as is illustrated in FIGS. 4 and 6, the center of the angle of acceptance of the laser light sensor elements 44 may be canted at various angles to the longitudinal axis of the projectile so that they accept light from the guiding laser beam only at a certain rotational angle, thus providing a vertical electrical reference pulse, since the longitudinal axis of the projectile on its ballistic trajectory is always at a slight angle to the direction of the guiding laser beam, as is shown in FIG. 1.

The projectile 40 includes guidance microcircuitry which may be housed within a suitable encasement housing 46 carried within the recess 45 in the tail end of the projectile 40. The guidance micro-circuitry within the encasement housing 46 is similar to the above referenced modular circuits 20 described with respect to the projectile illustrated in FIG. 2. In other respects, the projectile 40 is guided in identical fashion to the guidance of the projectile illustrated in FIG. 2, the net impulse reaction force being effected to cause a lateral translation of the projectile 40 from an actual trajectory toward a theoretical trajectory which would cause impact with a selected target.

Various other modifications may be made in the disclosed method and apparatus without departing from the spirit and scope of the invention.

Various features of the invention are set forth in the following claims.

What is claimed is:

1. A method for guiding a spinning projectile or the like having at least one discrete mass releasably mounted in the projectile with the center of gravity of said mass located in a plane substantially normal to the axis of the projectile and passing proximate to the center of gravity of the projectile, said method comprising the steps of; determining the deviation of the projectile from an optimum trajectory along which the projectile would impact a target, transmitting a predetermined signal to said projectile, receiving said signal by said projectile, and releasing at least one of said masses from said projectile in response to receipt of said predetermined signal by said projectile in a manner to impart a correctional momentum to said projectile sufficient to translate said projectile toward said optimum trajectory.

2. The method as defined in claim 1 wherein said projectile includes chemical propellant means cooperative with said discrete masses to effect release of said masses from said projectile upon selective detonation of said chemical propellant means, and wherein said predetermined signal to said projectile is transmitted and received in a manner to selectively detonate a propellant means and release at least one of said discrete masses to impart said correctional momentum to said projectile.

3. The method as defined in claim 1 wherein said correctional momentum applied to said projectile is imparted in a radial direction relative to the axis of said projectile.

4. The method of claim 2 wherein said chemical propellant means comprises high explosive means cooper-

ative with said masses to selectively release at least one of said masses from said projectile upon selective detonation of said explosive means, and wherein said step of transmitting said predetermined signal to said projectile and receiving said signal by said projectile are sequenced in a manner to effect said selective detonation and release at least one of said masses to impart said correctional momentum to said projectile.

5. A method for making an in-flight correction of the trajectory of a spinning projectile, comprising the steps of selectively subjecting the projectile to a correctional impulse essentially at a right angle to the axis of the missile and passing adjacent the center of gravity of the missile, said impulse being created by a detonation of sufficient magnitude and direction to change the trajectory traveled by the projectile at the time of impulse to a desired trajectory thereby to substantially improve the probability of the projectile hitting a predetermined target.

6. The method as defined in claim 5 wherein said projectile has high explosive impulse reaction means thereon, and wherein said correctional impulse is created by selectively detonating said high explosive impulse reaction means.

7. A method for guiding a spinning projectile to a target, said projectile having at least one discrete guidance mass mounted thereon with the center of gravity of said guidance masses located substantially in a plane normal to the projectile axis and passing substantially through the center of gravity of the projectile, said discrete masses being adapted to be accelerated outwardly from said projectile in a generally radial direction to provide a correctional momentum to the spinning projectile and translate it laterally into an optimum trajectory so that the probability of impact with a chosen target is improved, said method comprising the steps of transmitting to said projectile a signal representative of the angular position of a predetermined surface point on said projectile relative to a projected vertical, transmitting to said projectile a signal representative of the instantaneous angle of the projectile relative to said projected vertical, transmitting to said projectile a signal representative of the distance of the projectile from an optimum trajectory path, transmitting to said projectile a signal representative of the distance that the projectile is along its trajectory path, receiving said transmitted signals by said projectile and effecting release of at least one of said guidance masses from said projectile in response to receipt of said signals, thereby effecting lateral translation of said projectile in a manner to establish a trajectory which increases the probability of impact of the projectile with the intended target.

8. The method as defined in claim 7 wherein said projectile includes a plurality of discrete guidance masses, and repeating the sequence of steps as required to maintain the desired trajectory of said projectile.

9. A missile guidance system for guiding a spinning projectile or the like having impulse reaction means mounted in the projectile with the center of gravity of said impulse reaction means located in a plane substantially normal to the axis of the projectile, said system including laser beam means for transmitting a predetermined signal to said projectile, said projectile having means therein responsive to receipt of said predetermined signal for determining the deviation of the projectile from an optimum trajectory along which the projectile would impact a target and for effecting an

impulse reaction by said impulse reaction means in a manner to impart a correctional momentum to said projectile and cause said projectile to translate toward said optimum trajectory.

10. A system as defined in claim 9 wherein said impulse reaction means includes one or more discrete masses releasably mounted in said projectile, and high explosive means cooperative with said discrete masses to effect release of said masses from said projectile upon selected detonation of said high explosive means, and wherein said predetermined signal is effective to selectively detonate said high explosive means and effect release of at least one of said discrete masses.

11. A system for guiding and reducing the aim dispersion of a spinning projectile or the like to a target, comprising, in combination, at least one small discrete guidance mass mounted on the projectile with the center of gravity of said guidance mass located substantially in a plane normal to the projectile axis and passing through the center of gravity of the projectile, each of said guidance masses being capable of being accelerated outwardly in a generally radial direction to provide a correctional momentum to the projectile and bring it into a more optimum trajectory so that the probability of impact with a chosen target is improved, computer means contained within the projectile and capable of receiving input data signals transmitted to the projectile, laser beam means capable of transmitting input signals from a source to the projectile, means for transmitting to said projectile along said laser beam means a signal representative of the vector from the optimum trajectory point to the projectile, measured in a plane perpendicular to the direction of propagation of the laser beam, means for transmitting to said projectile along said laser beam means a signal representative of the direction of the true vertical, means for transmitting to said projectile along said laser beam means a signal representative of the distance that the projectile is along its trajectory, said computer means being operable to effect acceleration of at least one of said guidance masses outwardly from the projectile in response to receipt of said signals to impart a correctional impulse momentum to the projectile sufficient to bring it into a trajectory which increases the probability of impact of the projectile with a predetermined target.

12. A missile guidance system as defined in claim 9 wherein said means in said projectile responsive to receipt of said predetermined signal includes microcircuit computational element means disposed within said projectile.

13. A projectile for use in a system operative to guide a projectile between a guidance laser source and a predetermined target substantially along an optimum trajectory, said projectile having impulse reaction means mounted thereon including means capable of being detonated in a manner to effect a net impulse force on the projectile which acts substantially in a plane normal to the projectile axis and passes through the center of gravity of the projectile, and means cooperative with said impulse reaction means and responsive to a predetermined signal to effect detonation of said detonation means to provide a correctional momentum to the projectile to bring it into a trajectory which will increase the probability of impact of the projectile with the predetermined target.

14. A projectile as defined in claim 13 wherein said impulse reaction means includes at least one discrete

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guidance mass releasably mounted in said projectile substantially in a plane normal to the axis of the projectile and passing substantially through the center of gravity thereof, said detonation means being capable of effecting release of at least one of said masses from said projectile to provide said correctional momentum.

15. A projectile as defined in claim 14 wherein said detonation means includes high explosive means selectively detonatable to effect release of at least one of said discrete masses.

16. A projectile as defined in claim 14 wherein each of said discrete masses is selectively releasable outwardly relative to the center of gravity of said projectile to effect an impulse momentum force which acts in a corrective manner to provide said momentum to said projectile.

17. A projectile as defined in claim 13 wherein said impulse reaction means includes a long groove formed in a housing portion of said projectile, and high explosive means disposed within said long groove and capable of being detonated in a manner to establish a net

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impulse force on the projectile which acts substantially in a plane perpendicular to the longitudinal axis of the projectile and passes substantially through the center of gravity of the projectile.

18. A projectile as defined in claim 17 wherein said long groove extends about the periphery of said projectile housing and is balanced relative to a plane perpendicular to the longitudinal axis of the projectile and passing through the center of gravity thereof, said high explosive means including a high explosive material capable of high order detonation upon selective detonation thereof.

19. A projectile as defined in claim 17 wherein said projectile includes a plurality of said long grooves, the explosive contained therein being detonable in a sequence of steps as required to maintain the desired trajectory of said projectile.

20. A projectile as defined in claim 17 including an annular generally cylindrically shaped wall overlying said long groove.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,860,199
DATED : January 14, 1975
INVENTOR(S) : Brian B. Dunne

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 48 "Helmholz" should be --Helmholtz--
Column 5, lines 4-5 "preferably" should be --preferable--
Column 9, line 16 "a follows" should be --as follows--
Column 9, line 54 "the angle $\alpha + \iota$ " should be -- $\alpha + \phi$ --
Column 10, line 20 " ι " should be -- θ --
Column 10, line 21 " ι " should be -- θ --
Column 14, line 64 "biring" should be --bring--

Signed and Sealed this

twenty-ninth Day of July 1975

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

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