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(54) AUTO-AIMING DAZZLER

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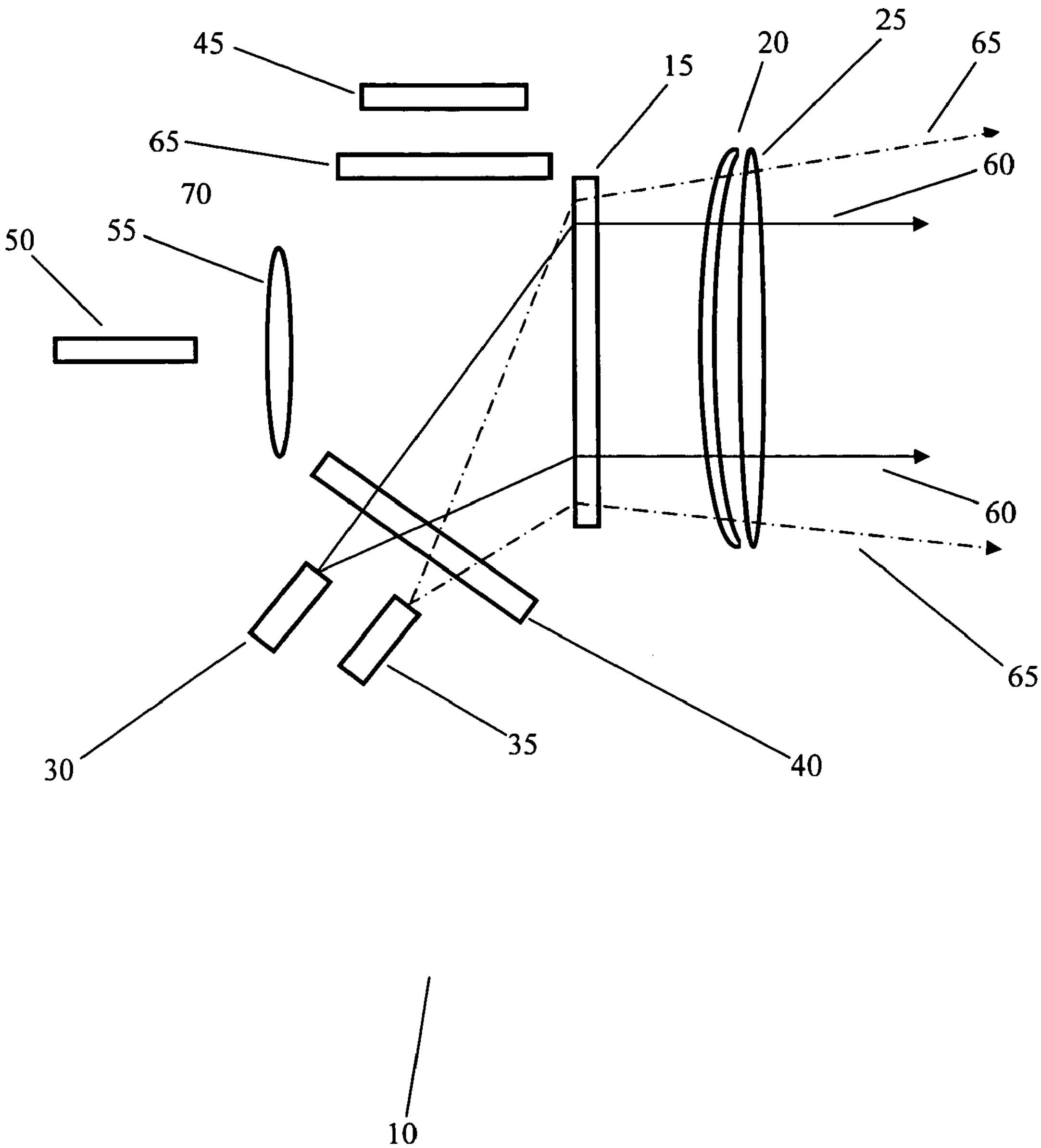
(57) **ABSTRACT**

A method and system is disclosed to aim a light beam at a retro-reflecting target such as an eye by emitting a probe beam through an Alvarez lens pair and detecting a retro-reflected glint on a focal plane array to determine the direction from which he glint is received and move a moving element of the Alvarez lens pair so as to point a light source directly at the retro-reflecting target. A ranging device may be incorporated to adjust the intensity of the light source.



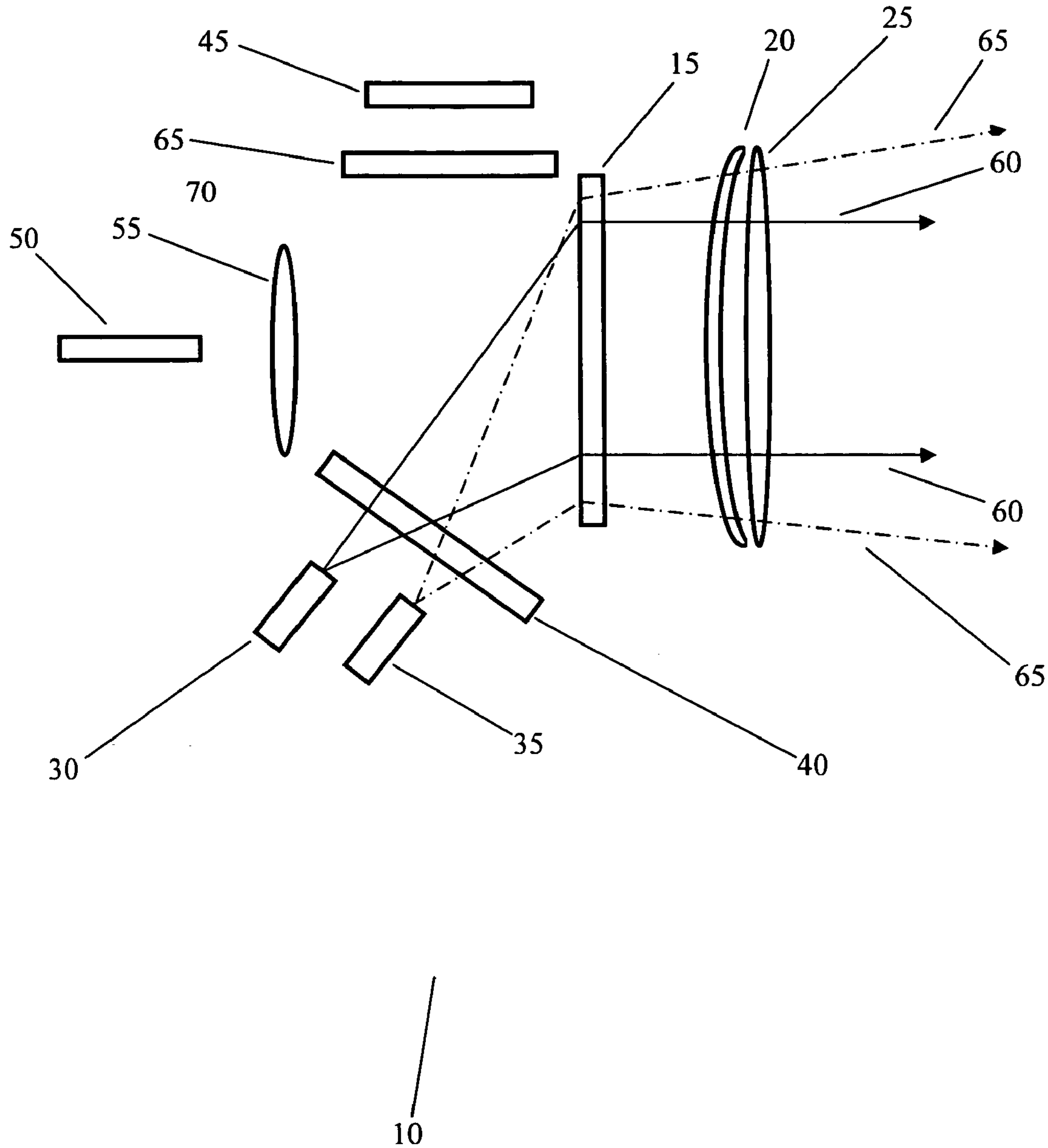


Fig. 1

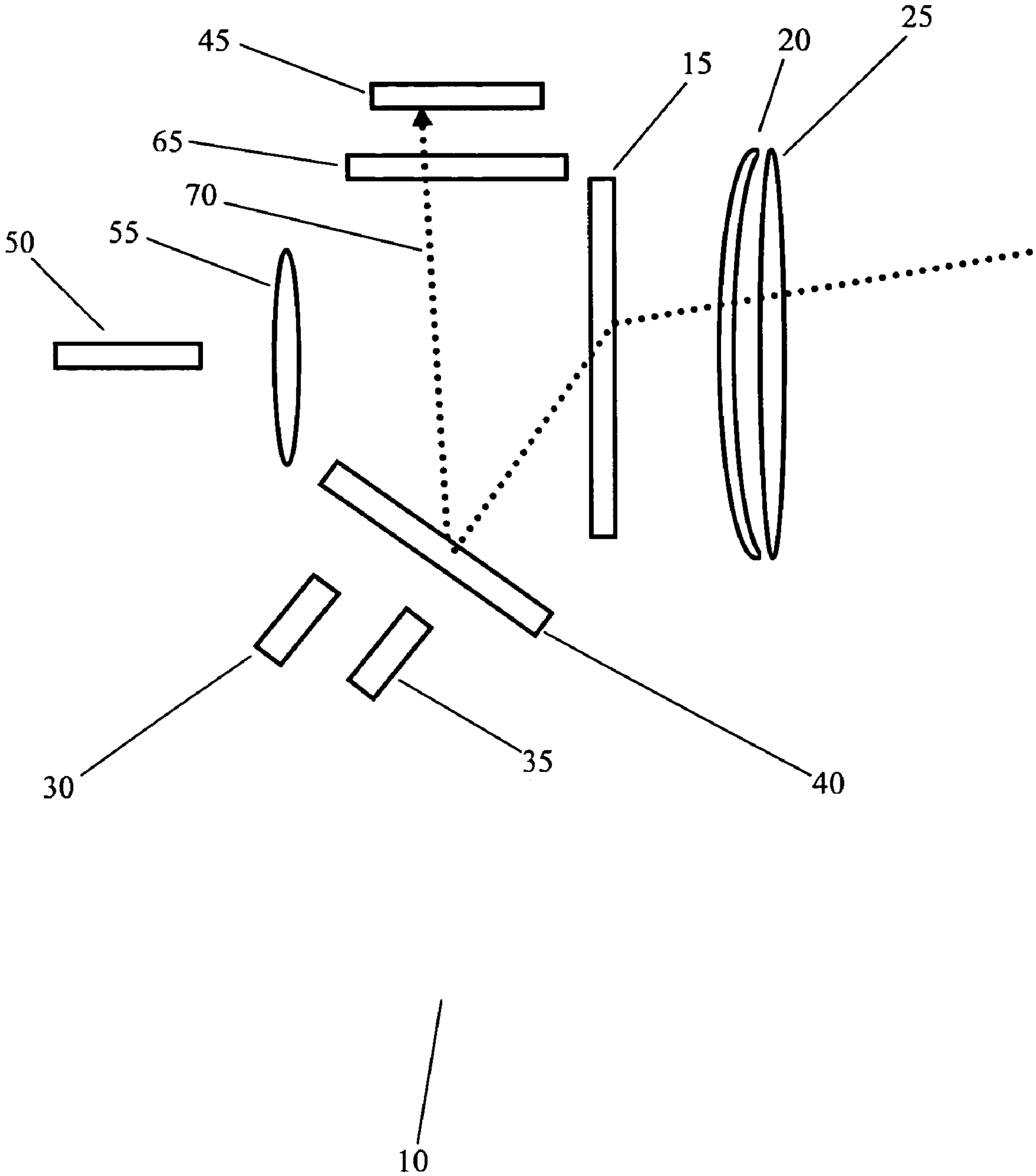


Fig. 2

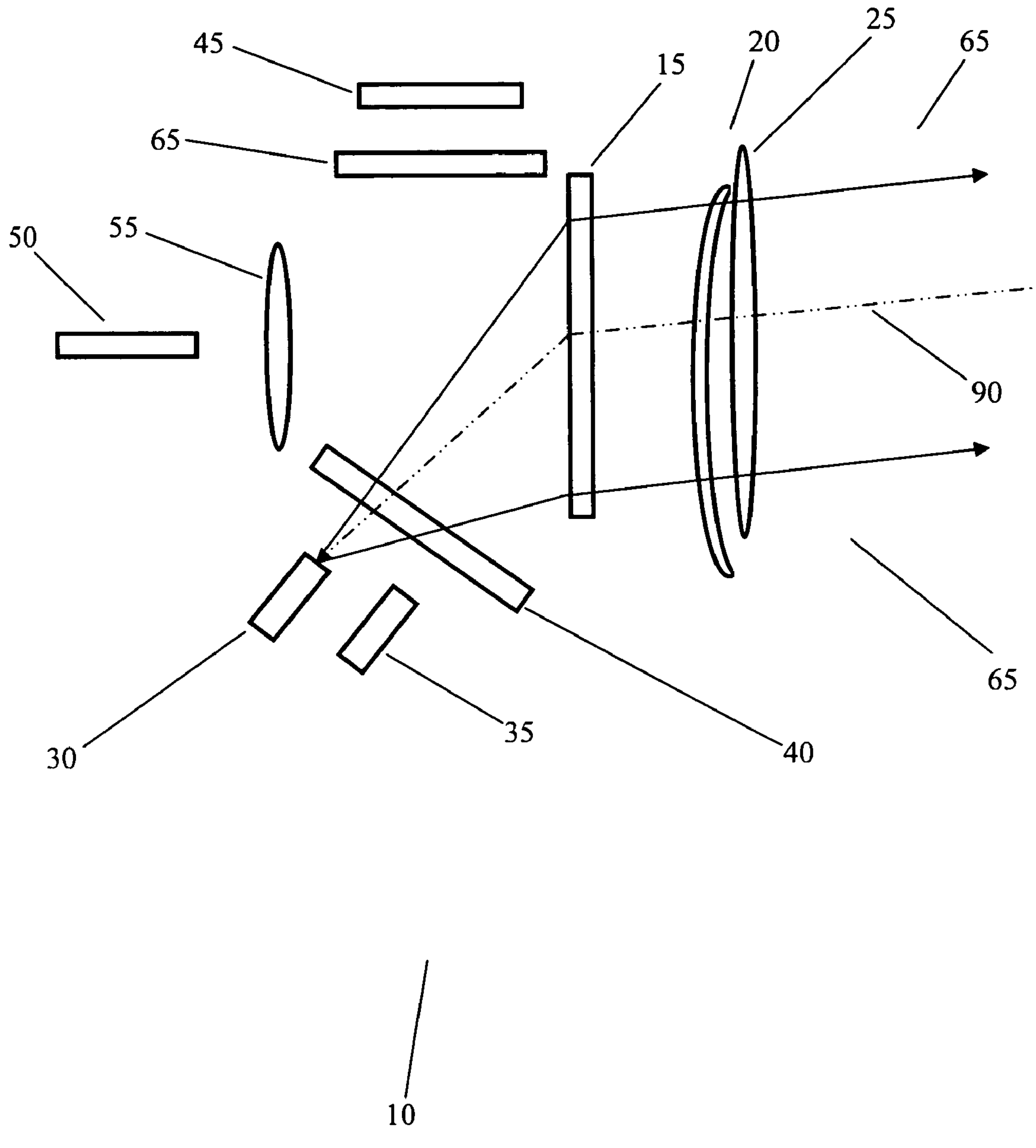


Fig. 3

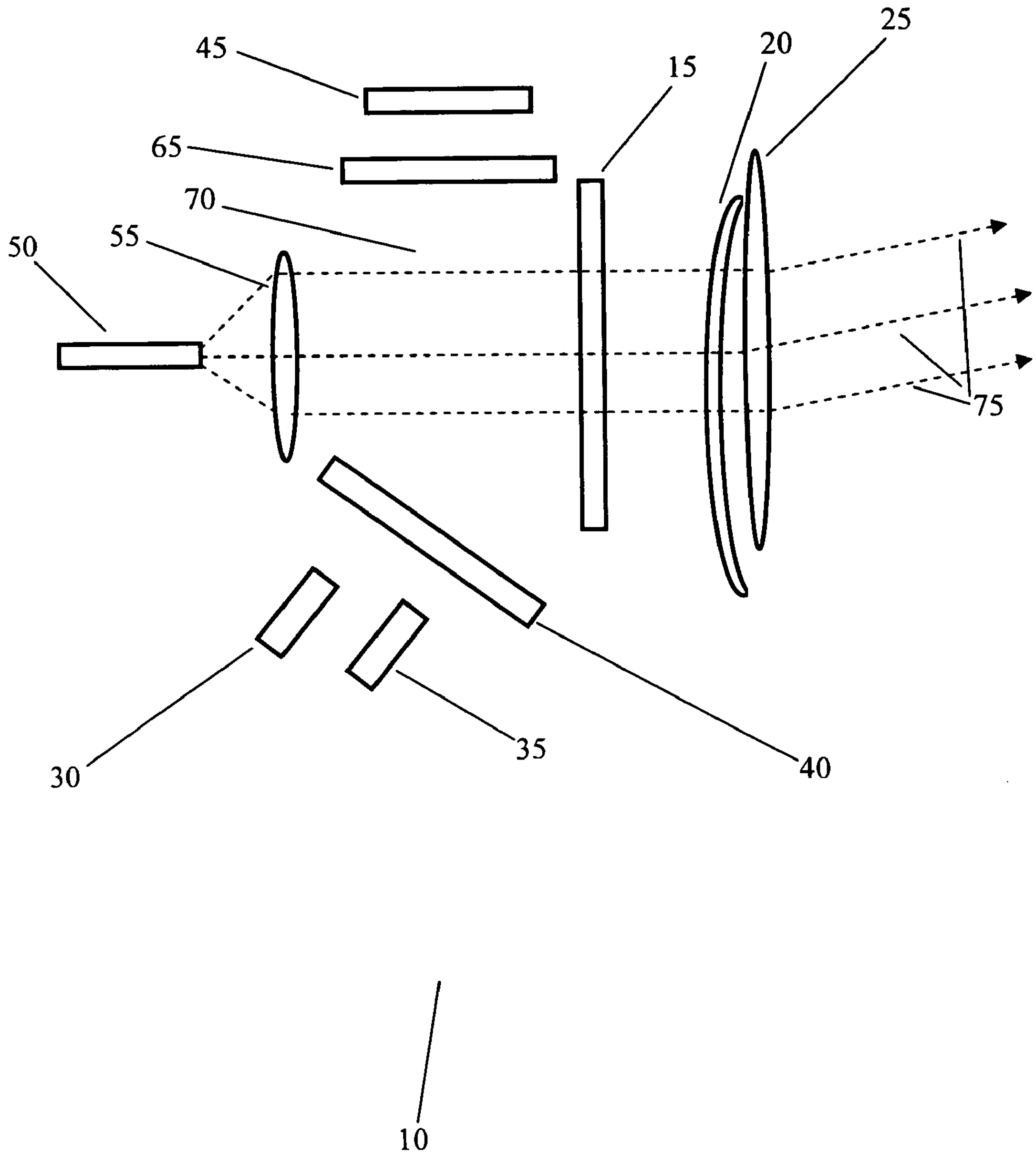


Fig. 4

AUTO-AIMING DAZZLER

TECHNICAL FIELD

[0001] The present invention relates to an aiming device, and more particularly, to a method and system device to aim and deliver a variable strength light pulse, which may be used momentarily to dazzle and incapacitate a desired subject while doing no permanent harm.

BACKGROUND INFORMATION

[0002] Military and law enforcement personnel are often involved in peacekeeping, humanitarian and counter-terrorism missions where the use of lethal force is inappropriate. In these situations non-lethal technologies have appeal for both humane and political reasons. Non-lethal weapons would allow forces to diffuse potentially dangerous situations while limiting casualties. Non-lethal weapons have the promise to revolutionize future armed conflict; however, ethical and operational concerns about their design and function may limit their use.

[0003] Non-lethal weapons are defined as weapons that are explicitly designed and primarily employed so as to incapacitate personnel or materiel, while minimizing fatalities, permanent injury to personnel, and undesired damage to property and the injury to personnel, and undesired damage to property and the environment. NATO has categorized non-lethal weapons into ten groups. These include containment devices, dazzling devices, anti-traction agents, non-penetrating projectiles, combustion modifiers, and odors. The Geneva Protocol, the Biological Weapons Convention, and the Chemical Weapons Convention together prohibit the development, production, acquisition, or retention of biological and chemical weapons, even if the intent of the biological or chemical weapon is non-lethal. Additionally, the Convention on Certain Conventional Weapons and the Blinding Laser Ban prohibit the use of weapons whose primary purpose is to cause permanent blindness.

[0004] The impetus to incorporate and replace the laser in 'Laser Dazzlers' is threefold. One is to avoid simple countermeasures such as wavelength tuned tinted goggles and the another is to avoid the stringent safety limits imposed on lasers (ANSI standards) due to coherence effects, etc. The last consideration is the general repugnance to use laser devices for military purposes even if eye safe.

[0005] In 1980, Sweden first tried to include a ban on blinding lasers in the Convention on Conventional Weapons (CCW) and put forward a draft protocol for that purpose before key meetings in Vienna in 1995. The Swedish draft became Protocol IV of the CCW.

[0006] Despite Protocol IV, Laser dazzler development programs continue in many countries, while keeping the laser energy levels at the aperture of dazzlers within the guidelines of Protocol IV. Since 1995, when the U.S. agreed to the Blinding Laser Protocol of the Convention on Conventional Weapons, the Pentagon has cancelled several blinding laser weapon programs.

[0007] Human Rights Watch identifies and provides details on a host of laser weapon programs of concern, including BOSS, Persuader, LX-5, Maglite, Saber 203, TLOS, Green Laser, Nighthawk and Y-Blue. In some cases, it appears that the very blinding laser weapons that were being developed prior to the 1995 policy (e.g., Saber 203, LCMS/TLOS) are being modified for deployment as dazzlers, with just a less apparent blinding attribute. The United States is not alone in developing such weapons. Other countries such as France, Britain, Russia, Germany and Israel are believed to have pursued antipersonnel laser programs. As early as 1995, China was advertising a similar device as an antipersonnel weapon.

[0008] The technical comparisons are based on the max allowable laser 9-11 intensity (0.4 mW/cm2). The ANSI standard is: CLASS I cannot emit laser radiation at known hazard levels (typically CW: 0.4 milli-watts at visible wavelengths). On the other hand, The maximum limit for white light sources is 1 cd/cm2. This is equivalent to 18 mW/cm2. This is much higher than the laser maximum. By comparison, a 100 watt light bulb is about 18% efficient. It has an intensity of 15 mWcm2 at a distance of 10 cm (4 in). This is uncomfortable and dazzling, but not dangerous.

[0009] To date laser-based dazzler systems have had limited success meeting these goals. For devices having a fixed output power to be eye safe at close range, the output must be reduced to such a low level that at the desired operating distance of 10-100 m the system becomes completely ineffective. At distances of 5 m or more these systems are marginally brighter then a standard flashlight; the intended target can see clearly most of the body of the person holding this conventional laser dazzler. The requirement that the device be nominally eye safe at close range means it is not disabling at all. In fact, eye safety is not guaranteed, as a target using binoculars or a rifle scope might receive a laser dose that would still cause permanent eye damage.

[0010] Other existing devices do permit manual adjustment of the energy of the dazzle pulse in an attempt to account for variables like attenuation by the atmosphere, enhanced collection by binoculars, transmission through sunglasses, target brightness, etc. using measurements of range and illumination and visual observation of target characteristics such as sunglasses or binoculars.

[0011] This is at best a subjective estimate of the optical susceptibility of the target and a difficult and time consuming procedure to undertake during crisis situations. There is a strong possibility that too small or too large a dazzle pulse would be used, and the device either would be ineffective at disabling the target or would permanently harm the eyes of the target or innocent bystanders.

[0012] Ethical and legal guidelines direct and restrict the development of certain non-lethal weapons. For example, dazzling devices which are designed to induce temporary blindness or disorientation using powerful lights, lasers, or stroboscopes must not cause any permanent eye damage.

[0013] What is needed is a smart Auto-aiming dazzler) designed to aim and deliver a dazzling and disabling light flash of maximum eye-safe energy to a selected target. Two desirable features of the Auto-aiming dazzler technology would be for it to be self-aiming and have power-adjusting capabilities so that optical barriers, such as dark glasses, rifle scopes, binoculars, etc., and iris aperture, whether the eyes are light or dark adapted, are automatically taken into account.

BRIEF SUMMARY OF THE INVENTION

[0014] The Auto-aiming dazzler is a non-lethal weapon designed to aim and deliver a dazzling and disabling light flash of maximum eye-safe energy to a selected target. Two key features of the Auto-aiming dazzler technology are its self-aiming and power-adjusting capabilities; optical barriers, such as dark glasses, rifle scopes, binoculars, etc., and iris aperture, whether the eyes are light or dark adapted, are automatically taken into account by using a low-power infrared (IR) light source, such as an IR laser, to probe and return a glint from the eye(s) of the target. Using the retro-reflected glint the dazzle pulse is power adjusted and directed to arrive at the target with maximum allowable non-lethal energy at any range from 1 m to 100 m.

[0015] The collateral risk of this technology is very small. If the weapon is misaimed dramatically, the returned glint may come from an unintended person who will then be dazzled. Although this person will be incapacitated for a short period, he or she will suffer no long-term ill effects.

[0016] The Auto-aiming dazzler adds an important tool to the spectrum of non-lethal responses available for use by military and law enforcement personnel. Applications include dispersing persons in crowd control and disabling terrorists in hijacking situations. The dazzle process may be repeated, choosing the next most susceptible target until a crowd is subdued. One important application in counter-terrorism is onboard planes where a pilot can fire a Auto-aiming dazzler through a cockpit-door window and dazzle a hijacker with no damage to passengers.

[0017] In one embodiment, the invention utilizes an Alvarez lens pair having a moving element adjustable in x and y, a probe beam directed through the Alvarez lens pair, directing retro-reflections from the probe beam to a focal plane array and using the information from the focal plane array to cause the moving element of the Alvarez lens pair to adjust so as to direct a light beam at the retro-reflecting target. Te light beam may be a white light incoherent source or alternatively a laser.

[0018] In another embodiment, a ranging device may be added so as to determine a distance to the retro-reflecting target and adjust the intensity of the light beam accordingly.

[0019] In yet another embodiment, a holographic beam combiner/filter is placed in the optical path between the Alvarez lens pair and the light source, and the probe beam light source is placed off the axis of the light source and the Alvarez lens pair. The holographic beam combiner/filter is designed to pass the light from the light source directly through, while bending the probe beam to become co-linear with the with the light source beam path. The holographic beam combiner/filter may also be constructed so as to perform a similar same function with a ranging beam from the ranging device, the ranging beam and probe beam typically being of different wavelengths.

[0020] These and other features and advantages of the present invention will be better understood by reading the following detailed description, taken together with the drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] **FIG. 1** is a schematic diagram of an Auto-aiming dazzler showing ray traces from outgoing search and ranging beams.

[0022] **FIG. 2** is a schematic diagram of an Auto-aiming dazzler showing a ray trace from a retro-reflected glint of the search beam.

[0023] **FIG. 3** is a schematic diagram of an Auto-aiming dazzler showing ray traces the re-directed outgoing ranging beam and return beam.

[0024] **FIG. 4** is a schematic diagram of an Auto-aiming dazzler showing ray traces for an outgoing dazzle beam re-directed at the target and attenuated based upon range to target.

DETAILED DESCRIPTION

[0025] Retro-reflection occurs in any focusing system, including human eyes. The eyes may be operating as single optical elements, or with glasses, binoculars, telescopes, or the like. In any case, light that reaches the retina is focused to a point, and a fraction of the light scatters off the retina in all directions. A fraction of this light is collected by the lens or lens system and is directed back toward the light source.

[0026] Heuristically, optical augmentation can be understood by considering the visibility of animal eyes in automobile headlights or a flashlight. The eyes of deer or dogs illuminated by automobile headlights at 30 or 50 meters retro-reflect very brightly. If the animal is closer than 30 or 50 meters, the driver will not see the retro-reflection because it is returned within a small area toward the headlight and not toward the driver.

[0027] Two people using a flashlight often find that the one holding the flashlight sees the retro-reflections and his nearby partner does not. It makes no difference whether the deer, dog, or human is looking at the flashlight or in any other direction. The light reflects back to the source.

[0028] The retro-reflections from humans are much more visible in the red. This is often seen in photographs taken using flash lamps which often show red dots for eyes.

[0029] The design and development of the Auto-aiming dazzler involves using optical and electronic control systems the design and construction of which are well known in the art to send a probe beam and a ranging beam, to receive and discriminate the retro-reflected glint, to image the glint and determine its power and direction, to perform two-axis lens control to accurately aim a light pulse and to adjust the power based upon the range to the target and deliver a white-light dazzle pulse.

[0030] A primary requirement for a non-lethal dazzling device is that it will deliver an eye-safe amount of light to a person sufficient to incapacitate him for a significant period of time without causing him permanent damage. The desired effect might be compared to a flash lamp going off at a distance of 30 cm. An almost equally important requirement is that the aiming accuracy be good enough so that the system targets only the intended individual and no collateral injuries can occur.

[0031] Referring to **FIG. 1**, a diagram of an Auto-aiming dazzler **10** is shown. The primary optical elements comprise a holographic beam combiner/filter **15** which is designed to variously pass and refract different wavelengths of light. An Alvarez lens pair, well known in the art, comprising a moving element **20** and a stationary element **25** provides the capability of directing light by two axis motion of the moving element **20**. An outgoing collimated beam may thus easily be directed within a cone whose size is determined by the design of the optics.

[0032] X-Y motion of the moving element **20** may be accomplished in any number of known ways, including use of positioning motors or proportional solenoids or other means well known in the art.

[0033] A ranging sensor **30** having a nearly convergent light source and a search beam source **35** are each aimed so as to pass through a beam splitter **40** and then onto hologram **15**. The ranging source and search source are preferably of different wavelengths so as to be able simultaneously to discriminate between return signals, but alternatively may be of the same wavelength and time multiplexed.

[0034] Referring to **FIG. 2**, the same Auto-aiming dazzler **10** is shown but for clarity's sake only the retro-reflected probe beam **70** is shown. The retro-reflected light (the glint) from the search source **35** is directed back to the beam splitter **40** and reflected to a focal plane sensor array **45**. The sensor array **45** may be of any of a variety well known in the art such as a quadrant detector or imaging array. The position error of the glint from the center of the detector is used in a closed-loop control system to drive the moving element **20** of the Alvarez lens and aim the ranging beam **60**.

[0035] Having located the position of the target (not shown), the moving element **20** of the Alvarez lens pair **20**, **25** is repositioned so as to direct the ranging beam **60** toward the target. The returned ranging beam **90** is received by the ranging sensor **30** and processed (measuring the time between sending the ranging beam **65** and receiving the return reflection **90**) so as to determine the range to the target (not shown). The Auto-aiming dazzler **10** now has target range and position information.

[0036] Lastly, a variable power light source **50** is provided which may be a white light source in the case of a dazzler, in which case an optional collimating lens **55** is provided, positioned such that nearly all of the output power of the white light source **50** is directed through the collimating lens **55**, hologram **15** and then aimed (using the X-Y location derived for the returned glint for direction) at the target by control of the moving element **20** of the Alvarez lens pair **20**, **25**. If a laser (coherent) light source is used then no collimating optics are required. The outgoing dazzle beam **75** is thus directed toward the target.

[0037] Control electronics (not shown) are provided to process the information from the sensor array **45** to discriminate the return glint **70** and determine its X-Y location in the visual field. Techniques of information processing are well known in the art. A filter **65** may optionally be used in the optical path between the beam splitter **40** and the sensor array **45** to pass only the wavelength of light used by the probe beam.

[0038] The ranging beam return **90** is directed to a ranging sensor **30**, which may be any of a number of existing optical and electronic devices well known in the art. In one embodiment, an off-the-shelf range finder was used which measured the time of return of the reflected beam to determine the distance.

[0039] In use, the Auto-aiming dazzler **10** is aimed in the general direction of the intended target, and emits both a ranging beam **60** and a probe beam **65**. In practice, both beams are in non-visible portions of the light spectrum. A retro-reflecting target will return a glint **70** which is passed through stationary element **25** and moving element **20** of the Alvarez lens pair **20**, **25** and directed by the hologram **15** toward the beam splitter **40** and thus sent to the sensor array **45**.

[0040] If a return glint **70** is found by analysis of the information from the sensor array **45**, the moving element **20** is moved in the X-Y place perpendicular to the axis of the Auto-aiming dazzler so as to direct the range source beam **60** toward the X-Y direction of the glint **70** (target). The dazzle pulse is a variable intensity beam, in one embodiment comprising a white light source, such as may be produced by a xenon flash tube, the output beam **75** being passed through collimating optics **55**. However, other embodiments of the invention include using coherent lights sources, such as visible lasers, although not normally for dazzling.

[0041] The ranging device **35** may be of any kind currently commercially available and well known in the art. The divergence of the ranging beam is preferably small so as to be limited as much as may be to the intended target. Range information is utilized by electronic circuitry to determine the appropriate strength of the dazzle pulse, described below, and the dazzle pulse **75** is then triggered. The whole operation from pulling the trigger to delivering the dazzle pulse **75** requires a very small fraction of a second and will appear to the user to be instantaneous.

[0042] The energy delivered in the dazzle pulse **75** and the aiming of the dazzle beam **75** are adjusted and controlled using the retro-reflected glint **70** returned from the target during the probe search.

[0043] Ideally, the return glint **70** would be significantly smaller than the Alvarez lens pair **20**, **25** aperture and accordingly the entire return glint **70** would be collected. Ideal conditions rarely exist. If the size of the return glint is larger than the Alvarez lens pair **20**, **25** aperture then only a portion of the return glint will be collected and measurements of the total power in the entire return glint will be erroneous.

[0044] At 50 meter range, the light adapted eye (2 mm iris) returns a 3.5 cm spot which may be difficult to collect in its entirety. The collection problem becomes much worse if the eye is not perfect (astigmatic, myoptic, hyperoptic) or simply not focused at infinity. Such returns in general would be much larger than the aperture of the dazzler optics and thus will not be totally collected.

[0045] The amount of energy returned as a glint from a dazzler probe reaching an eye is a function of the probe irradiance at the eye, the probe source to distance, the iris diameter and the reflectivity characteristics of the eye. The probe irradiance at the eye can be determined from the eye-dazzler distance and the iris aperture. The iris aperture affects both the incoming radiation and the magnitude of the return glint.

[0046] If one considers simply the factors of range to the eye, the assumption that the eye is focused at infinity will lead to a total power sent by the dazzle beam that will be too high. This is simply because an eye focused at 20 cm sends back a beam so large that only a small fraction is collected. Such a large corresponding dazzle beam would seem normally to produce substantial damage, but the size of the spot on the retina from this close focused eye is 15-20 times larger than a diffraction limited spot. The dazzle power will therefore be distributed over an area 200 times larger. The average power density will then be at acceptable levels if additional conditions are met: the dazzle pulse should be short compared to heat dissipation times in the retina and the total energy deposited must be below acceptable limits.

[0047] More importantly, the eye must not have time to readjust. The dazzle pulse should have a shorter duration than any eye relaxation effects such as blink (250 ms), focus adaptation, and iris changes (250 ms). A maximum pulse length of 100 ms is adequate to prevent any of these problems. It is sufficient then to measure the range to target and the glint power that is collected from the eye and treat those as though this were the entire glint reflection from the eye at that range.

[0048] The Auto-aiming dazzler thus overcomes energy dosage problems and offers several additional desirable features as well. Problems with conventional dazzlers and their solutions using the Auto-aiming dazzler are:

[0049] (i). Misaiming at the target or correctly aiming at the head of the target individual and activating the dazzler while the target has his head turned away or eyes closed. The Auto-aiming dazzler will fire only after it has received a glint from the eyes of the target. Within milliseconds of receiving the glint, the dazzle energy will be adjusted, the output will be directed toward the target, and the dazzle pulse will be delivered.

[0050] (ii). Having a portion of the beam pass the target and reach an individual using an optical device, such as binoculars or telescope, and consequently blinding that individual permanently. The Auto-aiming dazzler uses a white-light dazzle source instead of a laser and will continually readjust its output energy to safely dazzle only the most susceptible target. A probe beam having a larger diameter than the dazzle beam is used to ensure the area receiving the dazzle pulse is thoroughly searched.

[0051] (iii). Missing a target and consequently revealing the dazzler operator's position. Auto-aiming dazzler is fully-automated, firing requiring two triggering events: once by the user and once by the glint. The device will fire only if both triggering events occur, so firing occurs only when a suitable target (return glint) is found.

[0052] (iv) Meeting the requirements of eye safety at the exit aperture while delivering sufficient energy at 100 m Since the Auto-aiming dazzler automatically adjusts its output energy to eye-safe levels at any range, a large exit aperture or diverging dazzle beam is not required. The strength of the retro-reflected glint will provide an accurate measure of the optical susceptibility of the eyes of the target, and the device will adjust the dazzle dosage accordingly.

[0053] For crowd control and area interdiction there may be multiple targets in the probe field-of-view. In this case selecting the strongest return requires a focal plain array with some computational ability. Here a digital control system is used with a microcontroller to acquire the field, determine the strongest return, and position the moving element **20** of the Alvarez lens.

[0054] Modifications and substitutions by one of ordinary skill in the art are considered to be within the scope of the present invention, which is not to be limited except by the following claims. For example, the invention may be used simply to locate the position and/or range to a retro-reflecting target and provide that information for some other purpose the dazzling. A laser may be used as the dazzle beam in applications not intended for humans.

1. A light beam aiming system comprising:

a base;

an Alvarez lens pair further comprising at least one moving element an X-Y motion controller mounted on said base and on which is mounted said moving element;

a probe beam light source capable of emitting a probe beam, said probe beam light source being mounted on said base so as to direct said probe beam thru said Alvarez lens pair;

a second light source capable of emitting a second light beam and mounted on said base so as to direct said light beam through said Alvarez Lens pair;

a focal plane array capable of sensing light of the same wavelength as said probe beam, said focal plane array capable of providing an position signal in response to light of the same wavelength as said probe beam;

a reflector mounted so as to receive at least one reflection from objects illuminated by said probe beam through said Alvarez lens pair and so as to direct said at least one reflection onto said focal plane array;

control electronics configured so as to move said x-y position controller and hence said moving element of said Alvarez lens pair in response to said position signal.

2. The system of claim 1 further comprising a holographic beam combiner/filter disposed between said Alvarez lens pair and said probe beam source, said holographic beam combiner/filter being constructed to variously pass and refract different wavelengths of light.

3. The system of claim 2 further comprising a ranging beam source capable of emitting a ranging beam and mounted on said base so as to direct said ranging beam through said Alvarez lens pair and further comprising a range beam sensor electrically connected to said range beam source and capable of receiving at least one reflection of said ranging beam from an object in a path of said ranging beam, said range beam sensor having electronics so as to be able to measure a time interval between emitting said range beam and receiving said reflection.

4. The system of claim 2 wherein said ranging beam and said probe beam are of different wavelengths and in invisible portions of the electromagnetic spectrum.

5. The system of claim 2 wherein said probe beam and said probe beam are bent in different amounts by said holographic beam combiner/filter.

6. The system of claim 1 wherein said second light source is a laser.

7. The system of claim 1 wherein said second light source produces an incoherent beam.

8. The system of claim 7 further comprising at least one lens disposed between said second light source and said Alvarez lens pair so as to collimate said second light beam.

9. The system of claim 3 wherein said range beam sensor comprises circuitry further comprising the range beam sensor providing a time signal responsive to said measured time interval to said control electronics, and wherein said control electronics is capable of triggering said second light beam source so as to emit a beam with an intensity which varies in response to said time signal.

10. The system of claim 1 wherein said reflector is a dichroic.

11. A method of aiming a beam of light at a retro-reflecting target comprising:

providing a base;

further providing a first light source on said base able to emit a first light beam;

further providing an Alvarez lens pair further mounted on said base comprising at least one movable element and providing an X-Y motion controller on which said moving element is mounted;

providing a search probe source and of emitting a search beam through said Alvarez lens pair;

providing a focal plane array and a reflector mounted on said base so as to receive a retro-reflection of the said search beam; said focal plane array further providing a position signal responsive to the position of said reflection on said focal plane array;

providing control electronics to receive said position signal and to provide a signal to said motion controller to move said moving element of said Alvarez lens pair in response to said signal;

directing the said first light source to emit said first light beam through the said Alvarez lens pair.

12. The method of claim 11 further providing a holographic beam combiner/filter mounted between said Alvarez lens pair and said first light source, said beam combiner/filter constructed so as to variously pass and refract different wavelengths of light.

13. The method of claim 11 further comprising providing a ranging beam source mounted on said base and directing a ranging beam through said Alvarez lens pair; further providing a range beam sensor electrically connected to said range beam source, said range beam sensor positioned so as to receive at least one range reflection of said range beam, said range beam sensor having electronics so as to be able to measure a time interval between emitting said range beam and receiving said range reflection, and further said electronics providing a range signal responsive to said time interval.

14. The method of claim 13 further using said range signal to adjust the intensity of said first light beam responsive to said range signal.

15. The method of claim 13 further providing control electronics to receive said range signal and said control electronics causing said x-y controller to move responsive to said range signal.

16. The method of claim 13 wherein said ranging beam and said probe beam are of different wavelengths and in invisible portions of the electromagnetic spectrum.

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