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(54) Benævnelse: **Lasersystem med beskyttelsesindretning**

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WO-A1-2007/039473
FR-A1- 2 753 898
FR-A1- 2 993 971
US-A1- 2016 062 148
US-B1- 8 051 761

DESCRIPTION

Laser system having protective apparatus

The invention relates to a protective apparatus for a laser system for creating a laser system which protects the eyes. The laser system comprises at least one effective laser with at least one beam guide. The protective apparatus is provided for a laser weapon. The protection or eye safety of people who may be at risk is provided by at least one additional safety device. This safety device is intended to bring about or cause at least the eyes to be closed and/or optionally the line of vision to be averted away from the point of incidence of the effective laser beam on a target. The safety device can comprise a further laser as a warning laser which is used in a visible spectral range shortly before the use of the effective laser.

Laser effectors can be designed as very precise weapons which can concentrate the effect on a very small spot, referred to as a point of incidence, on the target object. Furthermore, depending on the laser power and the material and surface condition of the target object, directional and diffuse reflection of the laser radiation can occur around the point. This laser radiation may also be harmful to the eyes under certain circumstances.

The laser power density for irradiation (exposure limit value, ELV) of the eye permitted according to international standards is 50 W/m^2 at a used wavelength of 1.06 µm.

In the case of some deployment scenarios discussed for laser weapons (combat against pick-ups, speedboats, jet skis, etc.), it cannot be ruled out that the ELV for the eye is exceeded in the case of soldiers, combatants and civilians located in the immediate vicinity of the point of incidence and/or looking in the direction of the reflection or scattering of the laser beam (effective laser beam) by the point of incidence. Looking at the direct beam/laser beam or at the point of incidence from a short distance can result in the ELV being exceeded and thus in damage.

WO 2007/039473 A1 discloses a laser system having an effective laser with at least one beam guide and an effective range around an object/target when

the effective laser is used. A method and a device are described for successively and repeatedly illuminating a number of remote regions, together defining a larger region, with light in the form of a beam or beams in order to induce a physiological blinking response or an optical blinking reflex in the illuminated region.

FR 2 753 898 A1 discusses a device for protecting the eyes of a user from light beams which are emitted by a pulsed light source, in particular a laser source. This is to ensure that each time a light beam is emitted from the light source the view of the user is closed so that the eyes are effectively protected. The closure can be a mechanical closure or an optoelectronic closure. Acousto-optical crystals or a ceramic closure element are also specified.

FR 2 993 971 A1 defines an illuminating device having an emitter of electromagnetic radiation and an observation system. The aim is to provide an apparatus for illuminating a scene that makes it possible to hinder some of the people present and not to disturb others.

DE 693 06 078 T2 already covers the topic of eye protection. It describes an optical laser targeting device with alternating darkening of the laser beam path and observation beam path. A movable element darkens the laser beam when the target beam is not darkened by the movable element. In this case, the laser beam and the target beam are alternately darkened at such a frequency that the persistence of the retinal image of the operator is maintained.

DE 601 08 174 T2 (EP 1 391 014B1) proposes allowing a laser weapon to operate in the eye-safe waveband.

DE 10 2012 221 164 A1 relates to an apparatus and a method for detecting laser radiation. DE 14 97 569 A is cited therein, in which the user of a periscope is shown via a warning lamp that the periscope is aligned with a light source with eye-damaging radiation. The protective device can be applied in optical instruments against laser radiation. However, because only directly incident laser radiation can be detected, DE 10 2012 221 164 A1 proposes using an apparatus to

monitor incident light from a larger solid angle for the presence of coherent, monochromatic or polarized laser radiation and to output a warning signal.

Although these proposals appear to be practical, their use is not practical for the present problem of eye protection while ensuring functional reliability as a laser weapon (or a weaponized laser). The aforementioned eye-safe lasers do not meet the demands placed on a weaponized laser or have significant disadvantages compared, for example, to a Yb:YAG laser (weaponized lasers) with respect to the available laser power, achievable beam quality, illumination duration, stability, efficiency (electrical to optical), or availability, etc.

The object of the invention is that of preventing eye damage resulting from looking into the direct high-intensity beam of an effective laser, or at least minimizing it.

The object is achieved by a laser system according to claim 1 and a method according to claim 9. Advantageous embodiments are contained in the dependent claims.

The invention is based on the idea of protecting a person from eye-damaging light radiation of an effective laser and warning said person. In addition to this warning, eye safety is to be provided by either the eye-closing reflex being stimulated to close the eye, and/or averting the line of sight of the person or people away from the point of incidence and thus away from the scattered radiation or the direct irradiation. Provision is made for providing a protective device against laser beams impinging on a target/object directly or indirectly (e.g., diffuse scattered radiation).

The background of the idea is to shift the ELV for the scattered radiation from a low limit value of the (open) eye to a high limit value of the skin (closed eye). When the eye is closed, the ELV is 1,000 W/m^2 (for human skin) and is thus larger by a factor of 20.

As a protective device, a laser that operates in a visible spectral range is operated in addition to the effective laser. Said laser is used shortly before the

effective laser is used. This use is intended to cause the eyes of the person(s) to close and/or the line of vision to be averted away from the point of incidence of the effective laser beam.

Alternatively, the view to the point of incidence can be interrupted or the line of sight to the point of incidence can be perceived by selecting the area to be irradiated by this laser. A laser that operates in the green spectral range is preferred.

However, it is also possible to indicate the danger to the person or the people by emitting a red laser beam. This can then be pulsed for the purpose of signaling to the people, for example. Such pulsed red laser radiation can be used, for example, if only averting is to be brought about.

This laser is used in addition to the effective laser and is used primarily to warn that the effective laser will be used in a time-offset manner. The warning laser can be a dazzling laser (dazzler), such as a GLOW (Green Laser Optical Warner). The effective laser can be a fiber laser (approximately 1-100 kW/cm^2). A person skilled in the art is familiar with alternative lasers.

The additional laser preferably irradiates at least the same area on the target as the effective laser. Depending on the vignette (military: minor situation, deployment scenario), the area on the object/target irradiated by the additional laser can, however, also be significantly larger than the area irradiated by the effective laser so that the line of sight to the point of incidence can be perceived by the person or people. The at least one person in the effective range of the effective laser perceives this irradiation. In an intuitive manner, this irradiation is classified as a hazard. Due to the visibility of the laser beam of the additional laser, the at least one person will follow the human reflex referred to as the corneal reflex and/or avert their line of vision away from the beam direction of the additional laser (dazzling laser) or from reflections from the irradiated object/target.

Only after a predetermined time, generally after approximately 250 ms (corneal reflex or time for averting), the actual effective laser is then applied to the object/target.

As a result of this temporal preliminary warning by the additional laser or the time delay of the use of the effective laser after the activation of the additional laser, it is possible to prevent damage to people due to the radiation of the effective laser or scattered radiation thereof from the point of incidence, or at least to minimize said damage. Damage can thereby be significantly reduced. In particular, in the successful case of eye closure, (permanent) damage is avoided because now the significantly higher ELV affects the skin (closed eyes).

By means of this solution, effective lasers can be used in vignettes and the risk for people (such as soldiers, combatants, civilians, etc.) can be significantly reduced.

The additional laser (dazzling laser) can be used both in an axially parallel manner in the optical axis and offset from the effective laser. The additional laser can additionally be used as an illuminating laser for the effective laser.

With the additional laser, a gradation of the escalation is achieved because the people are visually warned in advance.

The invention is to be explained in more detail on the basis of an embodiment with reference to a drawing. Fig. 1 to 3 show a sketch of a target 10 that is intended to be controlled by at least one laser system, in this case by an effective laser 1. A beam guide 1.1 is assigned to the effective laser 1. In this embodiment, the effective laser 1 is a laser weapon for combating the target 10.

14 denotes an effective range which arises around the target 10 when the effective laser 1 is used. As can be seen in the figures, at least one at-risk object 12, in this case at least one person 12, is located in the effective range 14 of the effective laser 1 or in the effective range 14 of this laser radiation.

In order to prevent eye injuries, etc., in the person 12 caused by the laser radiation of the effective laser 1, a protective device 100 is provided. Said protective device 100 has the task of signaling a dangerous situation to the person 12. In the preferred embodiment, this signal should result in the person 12 closing their eyes automatically (human reaction, e.g., to brightness).

In the preferred embodiment, an additional laser 2 having a beam guide 2.1 is provided as a protective device 100. Said laser 2 is predominantly operated as a warning laser.

According to Fig. 1, this additional laser 2 can work offset relative to the effective laser 1. The effective laser 1 and the additional laser 2 are spaced apart from one another and from the target 10.

According to Fig. 2, the effective laser 1 and the additional laser 2 are aligned axially parallel to one another. Both are preferably located in the immediate vicinity of one another.

In the embodiment according to Fig. 3, the effective laser 1 and the warning laser 2 use the same beam guide 3. The separate beam guide 1.1 or 2.1 can be omitted because the additional laser 2 and the effective laser 1 are not operated simultaneously but in succession. Switching to the beam guide 3 can be provided.

The effective laser 1 can be a fiber laser (e.g., a Yb:YAG laser). The additional laser 2 can be a dazzling laser. This dazzling laser can operate in the green spectral range. While the effective laser 1 preferably operates in the range of 1-100 kW/cm^2, the power of a dazzling laser is preferably 1-100 mW/cm^2.

The mode of operation is as follows:

The effective range 14 of the effective laser 1 should be determined, which effective range can be different depending on the structure of the effective laser 1 if this is not known.

At least said effective range 14 of the effective laser 1 is then monitored for people 12. The monitoring can be carried out visually or by means of sensors (not shown in more detail). If at least one person 12 is detected within said effective range 14 of the effective laser 1, visually or by means of the sensors, the additional laser 2 is switched on before a possible actuation of the effective laser 1. This switching on can be performed manually. Automatic switching on, for

example on the basis of the sensor data processed in a control unit (not shown in more detail), is also possible.

As a result of the additional laser 2 emitting a visible light beam, the at least one person 12 is alerted to the fact that they are located in a hazardous region. In this case, the visible light beam is emitted as a warning signal. The warning signal can be a green, red or a differently colored light beam.

With this information, the person 12 is warned of a danger. As a result, it can be achieved that the at least one person 12 is stimulated at least to close their eye and/or to avert their line of sight away from the point of incidence 13 and thus away from the scattered radiation or the direct irradiation of the subsequently switched on effective laser 1.

Only after a predetermined time, i.e., after the additional laser 2 is switched on, generally after approximately 250 ms, is the actual effective laser 1 then applied to the object/target 10. This application can preferably be initiated by the control unit.

Additionally or alternatively, the additional laser 2 can be used as an illuminating laser of the effective laser 2.

Patentkrav

1. Lasersystem omfattende et laservåben med en effektiv laser (1) med mindst en stråleføring (1.1, 3) og et effektivt område (14) ved anvendelse af den effektive laser (1) omkring et objekt/mål (10), **kendetegnet ved** en beskyttelsesindretning (100) med mindst en yderligere laser (2), der arbejder i et synligt spektralområde, hvor beskyttelsesindretningen (100) er konfigureret således, at den yderligere laser (2) tilkobles, når der er fastslået mindst en person (12) i den effektive lasers (1) effektive område (14) før anvendelse af den effektive laser (1).

2. Lasersystem ifølge krav 1, **kendetegnet ved, at** den effektive laser (1) og den yderligere laser (2) er anbragt separat fra hinanden.

3. Lasersystem ifølge krav 1, **kendetegnet ved, at** den effektive laser (1) og den yderligere laser (2) er orienteret akseparallelt med hinanden.

4. Lasersystem ifølge et af kravene 1 til 3, **kendetegnet ved, at** den effektive laser (1) og den yderligere laser (2) har adgang til en fælles stråleføring (3).

5. Lasersystem ifølge et af kravene 1 til 4, **kendetegnet ved, at** den effektive laser (1) er en fiberlaser.

6. Lasersystem ifølge et af kravene 1 til 5, **kendetegnet ved, at** den yderligere laser (1) er en dazzlinglaser.

7. Lasersystem ifølge krav 6, **kendetegnet ved, at** dazzlinglaseren arbejder i det grønne spektralområde.

8. Lasersystem ifølge et af kravene 1 til 7, **kendetegnet ved, at** sikkerhedsindretningen (100) også kan fungere som belysningslaser.

9. Fremgangsmåde til beskyttelse mod laserstråling med et lasersystem ifølge krav 1, **kendetegnet ved** de følgende trin:

- at bestemme det effektive område (14) omkring objektet/målet (10),
- at overvåge i det mindste det effektive område (14) for personer (12),
- at udsende en synlig lysstråle ved hjælp af den yderligere laser (2) efter detektering af mindst en person (12),
- at aktivere den effektive laser (1) mod objektet/målet (10).

10. Fremgangsmåde ifølge krav 9, **kendetegnet ved, at** aktiveringen af den effektive laser (1) sker tidsforskudt i forhold til tilkoblingen af den yderligere laser (2).

11. Fremgangsmåde ifølge krav 9 eller 10, **kendetegnet ved, at** den yderligere laser (2) bestråler mindst den samme flade på objektet/målet (10) som den effektive laser (1), hvor fladen på objektet/målet (10), der bestråles af den yderligere laser (2), også kan være større end fladen, der bestråles af den effektive laser (1).

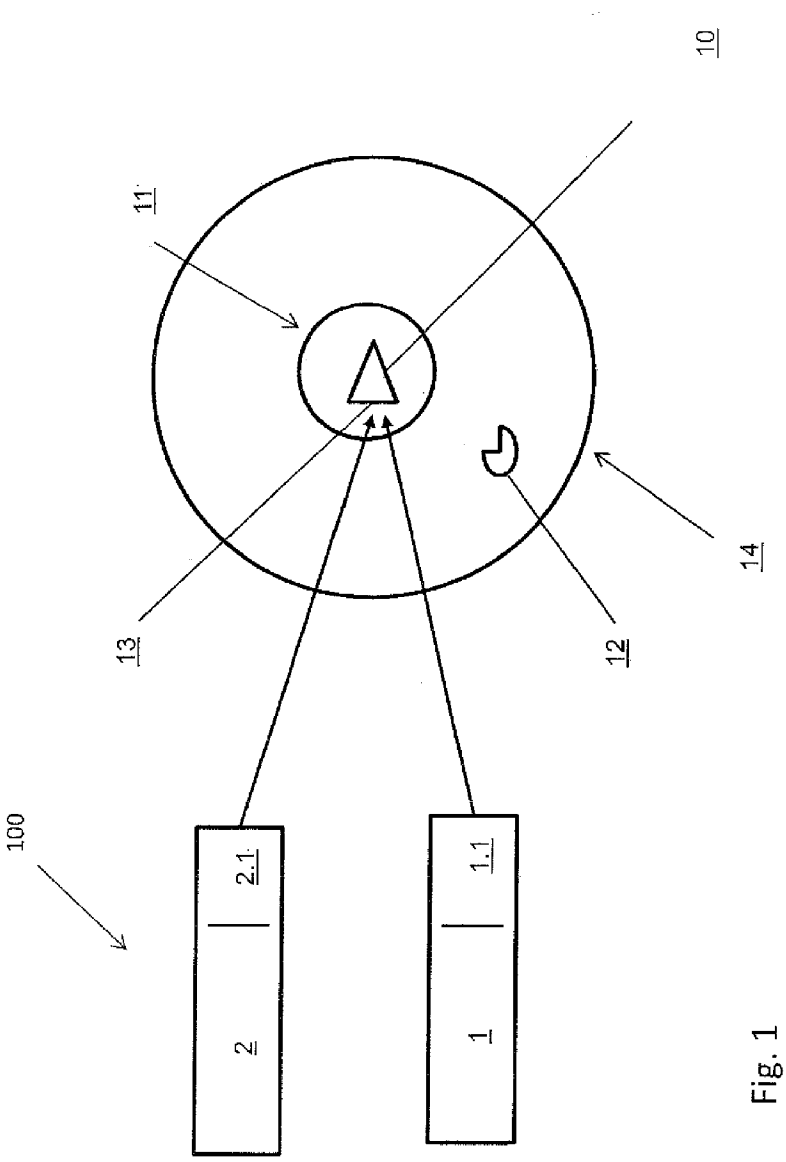

Fig. 1

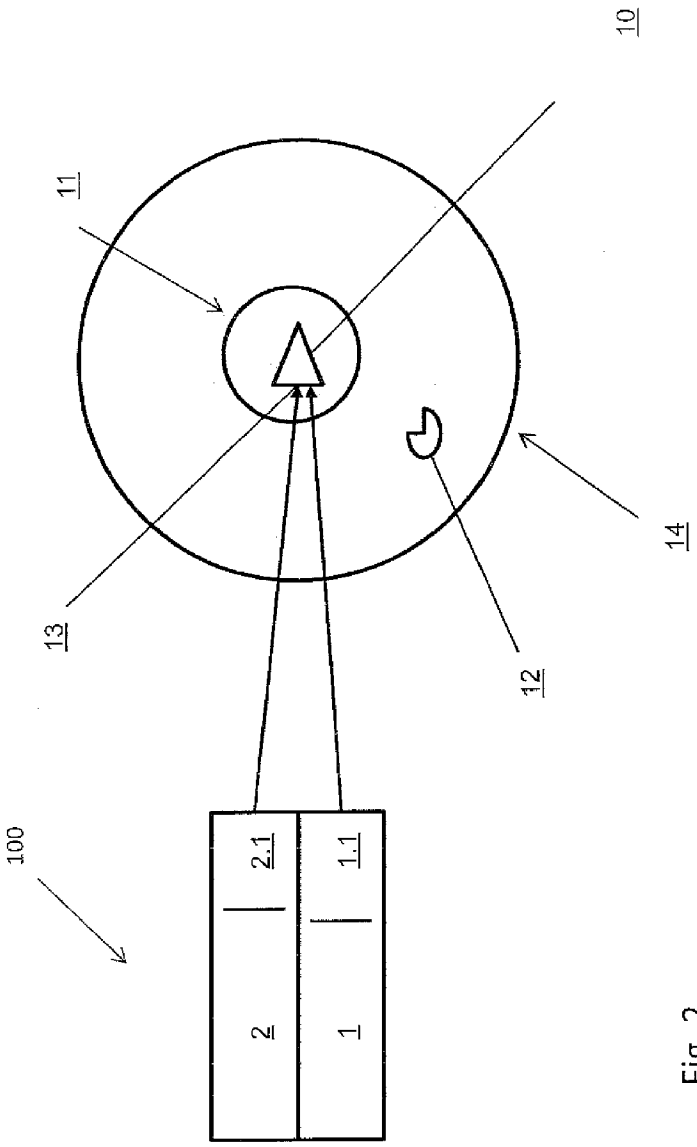

Fig. 2

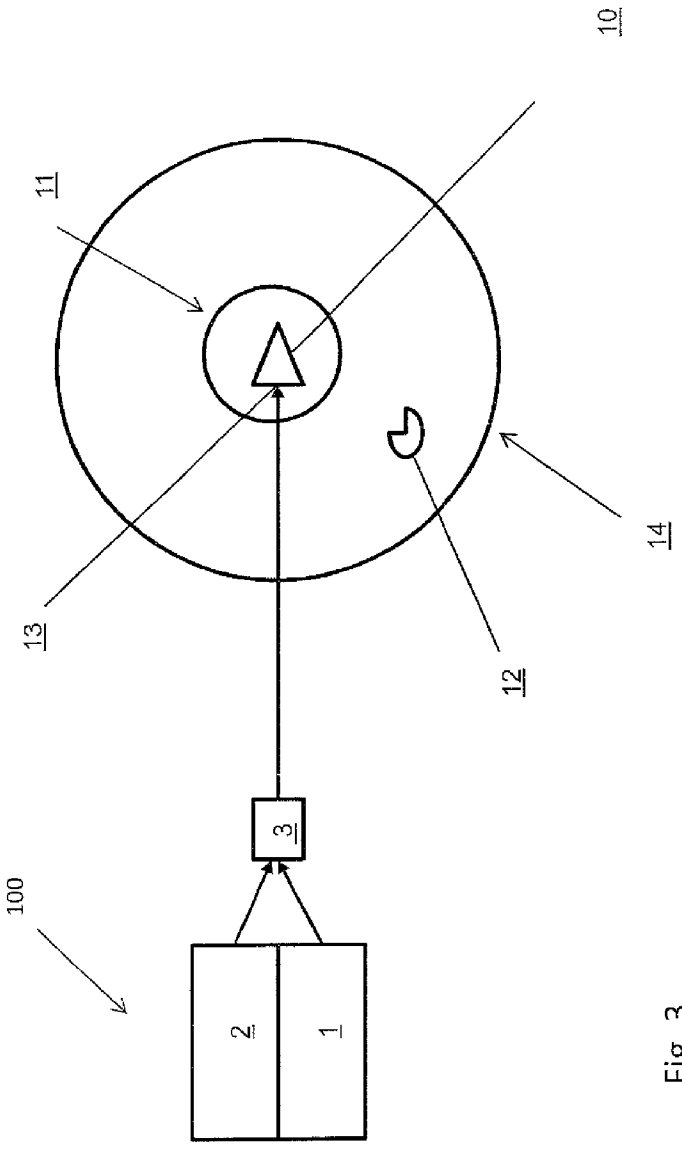

Fig. 3