
Illumination device and method for controlling the illumination
device

Description

The present invention relates to an illumination device and a method for illuminating a target using this illumination device.

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Multiple active laser target illumination devices and also laser target illumination methods are known from the prior art, in which a target object is illuminated by means of laser radiation. In particular, the range gating method is known, in which pulsed laser radiation is used to illuminate a target surface, so that suitable cameras can register the reflected radiation of this illumination. By way of the pulsing of the laser radiation, it is possible to determine a distance to the target surface. Furthermore, the laser target illumination is used in the prior art in active optical tracking methods of rapidly moving targets.

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15 However, as a result of the coherence of the laser radiation typically used in laser target illumination and the effect of the atmospheric turbulence occurring on the beam path and also the nonideal flat surface structure of the target, interference-related disturbances can occur, which are also called speckle effects. These speckle effects arise due to strong local intensity variations of the reflected light, wherein the image quality is thus strongly decreased. Such a decreased image quality makes subsequent electronic analysis more difficult, however, which often makes an optical tracking method impossible in particular.

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It is the object of the present invention to provide an illumination device, which allows a high image quality of the illuminated objects with simple and cost-effective production and assembly and with reliable and low-maintenance operation. It is a further object of the invention to specify a method for illuminating a target, which allows the recording of high-quality images of an illuminated object with simple and cost-effective application.

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30 The object is achieved by the features of Claims 1 and 8. The dependent claims have preferred refinements of the invention as content.

The object is therefore achieved by an illumination device, which is suitable in particular for illuminating a target to be combated. The illumination device according to the

invention comprises a light source, which is preferably a laser light source. The light source is configured to emit light along a beam path. Furthermore, a first modulator is introduced into the beam path, wherein the modulator is configured to manipulate a direction of the beam path in a first plane. It is therefore preferably provided that the modulator can deflect the light radiation originating from the light source by a predefined angle. In particular, it is provided that the first modulator is an active optical element. In addition, a phase plate is provided in the beam path, which has a variety of optical thicknesses. The phase plate is preferably arranged downstream of the first modulator, so that the light of the light source can initially be deflected by the modulator before it is incident on the phase plate. The variety of different optical thicknesses of the phase plate can preferably be implemented in that the phase plate has an uneven surface. Therefore, preferably statistically distributed optical path differences of the light arise within the beam path. It is particularly preferably provided that these optical path differences on average make up small fractions of the wavelength of the light emitted by the light source. A control device is connected to the light source and the first modulator, so that the control device can activate the first modulator using different frequencies. In this manner, the beam path can be deflected over a first control period of time up to a first angle. The extent of the first duration and the first angle can be individually established by the control device. However, it is particularly preferably provided that the first angle is at most 5 millirad, while the control period of time is in the range from 1 to 10 ns (inclusive).

It is preferably provided that the light source emits light pulses. It is particularly preferably provided that a light pulse has the duration of the control period of time, so that the first modulator can be activated synchronously to the emission of light pulses. In this manner, it is advantageously possible to deflect each of the emitted light pulses up to a predetermined angle. A broad scattering of the illumination is therefore possible. Alternatively, it is also particularly preferably provided that the light source emits multiple light pulses during the control period of time. In any case, it is particularly preferably provided that at least one complete light pulse is emitted during the control period of time. It is therefore preferably ensured that each light pulse can be deflected completely by the first modulator.

Furthermore, it is preferably provided that the first modulator is an acousto-optical modulator. The first modulator is particularly preferably a Bragg cell. Therefore, the first modulator comprises in particular a transparent carrier material, through which a wave, in particular an acoustic wave, is conducted. Different optical densities arise within the carrier material due to the acoustic wave, so that a diffraction of the beam path can be executed on an optical lattice resulting from the different optical densities. The beam path can be manipulated in this manner. The degree of the deflection can be varied by the activation of the first modulator using various frequencies, which means the emission of different sound waves. It is therefore preferably possible to design the manipulation of the beam path to be greatly variable. The first modulator is particularly preferably activated using frequencies of at least 100 MHz.

The difference of the optical thicknesses and the beam plate advantageously has a value which does not fall below 1 μm , in particular 5 μm . Alternatively or additionally, it is preferably provided that the value of the difference of the variety of the optical thicknesses of the beam plate does not exceed 50 μm , particularly preferably 10 μm . Therefore, the beam path deflected by the first modulator can pass various optical thicknesses of the beam plate, wherein statistically distributed optical path differences arise due to the various optical thicknesses. It is nonetheless ensured by the above-mentioned values of the differences of the optical thicknesses that these path differences are on average small fractions of the laser wavelength, which represents optimum conditions for effective target illumination.

In an advantageous embodiment of the invention, the illumination system comprises a second modulator, which is implemented as identical to the first modulator in particular. The second modulator is preferably configured to manipulate a direction of the beam path in a second plane. The second plane is arranged in particular perpendicularly to the first plane. The use of the second modulator therefore advantageously allows the beam path to be deflected in all spatial directions. The variety of the possible deflection directions can therefore be increased, which allows an effective variation of the path differences of the light.

Furthermore, the illumination device preferably has an optical sensor, which can be a camera in particular. The optical sensor is preferably configured to detect the light which

is emitted by the light source and reflected from the target. Since the light source emits light pulses in particular, it is furthermore particularly preferably provided that a determination of a distance of the target to the illumination device is possible by means of the detection of the reflected light pulses by the optical sensor.

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The illumination device according to the invention as described above allows an effective reduction of the speckle effect described at the beginning. The beam path is conducted through various optical thicknesses of the beam plate by the deflection of the beam path by means of the first modulator. Therefore, as already described, statistically distributed optical path differences arise. In this manner, it is possible to generate local and chronological variations of the phase fronts of the emitted light pulses in the cross section of the beam path. Interactions with atmospheric disturbances or a nonideal flat target surface can therefore result in chronologically and locally varying speckle effects. It is possible by way of a time averaging of these local and chronological variations to reduce the influence of the speckle effect on the overall measurement.

Furthermore, the illumination device according to the invention or according to a preferred refinement of the invention allows an illumination of the target in which an intensity profile over the beam path is similar to a plateau. In contrast thereto, in conventional illumination devices, a Gaussian distribution would occur, wherein the intensity decreases toward the edge of the beam path. Therefore, the illumination device according to the invention allows uniform and therefore optimized illumination of the target.

The invention furthermore relates to a method for illuminating a target, wherein an illumination device having the above-described features is used. According to the invention, the following steps are executed in the specified sequence: Firstly a light pulse is emitted by the light source. Subsequently, the first modulator and/or the second modulator is activated in such a manner that the light pulse just emitted is deflected in a randomly determined direction. The light pulse therefore runs through a randomly determined region of the phase plate, so that statistically distributed optical path differences arise over the cross section of the beam path. The light pulse thus manipulated is preferably oriented onto the target, so that it can illuminate the target.

In one preferred embodiment, the above-mentioned steps are executed in continuous repetition. It is therefore particularly preferably provided that the light source continuously emits light pulses, wherein the light pulses are deflected in randomly determined directions. Therefore, the above-described chronological and spatial
5 variation of the phase front distribution results over the cross section of the beam path in the different emitted light pulses.

Furthermore, it is preferably provided that the additional following steps are executed: Firstly, each emitted light pulse is received, which is performed in particular by the
10 optical sensor. Subsequently, the intensities of the received light pulses are determined, wherein preferably the phase front distribution over the cross section of the reflected beam path can also be determined. A chronological mean value of the intensity of each pulse is determined. In this manner, it is possible to reduce the influence of speckle effects, since the speckle effect is spatially and chronologically varied by way of the
15 above-described emission of the light pulses and manipulation of the direction of the emitted light pulses. Finally, it is preferably provided that an image is generated from the averaged intensity data. This image allows in particular an optical tracking method to be carried out, using which a rapidly moving target can be tracked by an active unit, for example.

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The invention will now be described in greater detail on the basis of exemplary embodiments with reference to the appended drawings. In the drawings:

Figure 1 is a schematic illustration of the illumination device according to a first
25 exemplary embodiment of the invention,

Figure 2 is a schematic illustration of the beam plate of the illumination device according to the first exemplary embodiment of the invention, and

30 Figure 3 is a schematic illustration of a part of the illumination device according to a second exemplary embodiment of the invention.

Figure 1 shows an illumination device 1, which comprises a light source 10, wherein the light source 10 emits pulsed laser beams along a beam path 4. An optical system 2 is

provided, to focus the beam path 4 on a target 3 to be illuminated. A target region 31 can be illuminated by the light source 10 in this manner.

5 A first modulator and also a phase plate 9 are arranged between the optical system 2 and the light source 10. The first modulator 7 is configured to deflect the beam path 4, so that the deflected beam path 41 is incident on the phase plate 9. From the phase plate 9, the beam path 4 reaches the target 3 by way of the optical system 2.

10 A control device 8 is provided and is configured to activate the light source 10 and the first modulator 7 in chronological synchronization with one another. For this purpose, the first modulator 7 is in particular an acousto-optical modulator, which has a main body 70, which is transparent to the beam path 4. On one edge of the main body 70, an acoustic, in particular an ultrasound-based actuator 71 is attached, which can transmit an acoustic wave 73 to an absorber attached to an opposing side of the main body 70.

15 In particular, it is provided that the acoustic wave 73 transmitted between actuator 71 and absorber 72 runs perpendicularly to the beam path 4. The acoustic wave 73 therefore generates different optical densities within the main body 70, so that the modulator 7 is capable of deflecting the beam path 4, since the beam path 4 can be diffracted by the resulting optical lattice. By establishing different frequencies of the

20 acoustic wave 73, it is possible to determine a first angle 40, up to which the beam path 4 is deflected at maximum. It is provided that the deflection angle 40 can be determined by the control device 8, wherein the control device 8 furthermore ensures that a complete light pulse of the light source 10 is always deflected. It is therefore preferably provided that the control device 8 establishes the duration of a light pulse on a control

25 period of time, on the one hand, wherein the same control period of time is used to transmit the acoustic wave 73 through the main body 70. Alternatively, it is also preferably provided that the control device 8 emits multiple complete light pulses by way of the light source 10 during the control period of time.

30 The beam path 41 deflected by the first modulator 7 is incident on the phase plate 9. The phase plate 9 has a variety of optical thicknesses, which vary over a surface 90 of the phase plate 9. A more detailed view of the phase plate 9 is apparent from Figure 2.

Figure 2 shows the phase plate 9, wherein a first optical thickness 91, a second optical thickness 92, and a third optical thickness 93 are shown as examples. The first optical thickness 91, the second optical thickness 92, and the third optical thickness 93 result due to an irregular surface 90. The light must therefore cover optical paths of different lengths as a function of the position through which it passes through the phase plate 9.

As is apparent from Figure 1, the first modulator 7 can force different paths through the phase plate 9 by the deflection of the beam path 4. Therefore, a chronological and spatial variation of the phase fronts arises over the cross section of the deflected beam path 41. The light pulses thus varied are finally focused by the optical system 2 on the target 3.

However, it is possible that the light pulses are incident on atmospheric disturbances, which can result in phase shifts of the light pulses, between the optical system 2 and the target 3. Furthermore, a surface 30 of the target 3 cannot be ideally flat, so that phase shifts can also occur here. Therefore, disturbances in the form of speckle formations occur in the image of a camera 5, which can register reflected light radiation from the target 3. However, since the phase front distribution of the light pulses is chronologically and spatially varied over the cross section of the beam path 4, as described above, the speckle effect also occurs in a chronologically and spatially varied manner. Therefore, the camera 5 can noticeably reduce the effects of the speckle effect by chronological averaging of the intensities of the received light radiation.

In particular, every light pulse can be deflected to scan an angle range which extends from the deflected state up to the maximally deflected state at the first angle 40. The light pulse can particularly preferably be deflected from the non-deflected state up to the first angle 40, to subsequently be deflected back into the non-deflected state. By scanning the described angle range, a variety of speckle effects arises, which are reduced or cancel out upon chronological averaging.

Figure 3 shows a second exemplary embodiment of the invention, which represents an additional refinement of the first exemplary embodiment. For the sake of simplicity, only a part of the illumination device 1 is shown here. A light source 10 emits light pulses along the beam path 4, wherein the beam path 4 is firstly incident on the first modulator

7. The first modulator 7 is configured to deflect the beam path 4 in a first plane 100. The first plane 100 is shown as the vertical direction in Figure 3. Subsequently, the deflected beam path 41 is incident on a second modulator 75, which is implemented identically to the first modulator 7 in particular. The second modulator 75 is preferably implemented in such a manner that it can deflect the deflected beam path 41 in a second plane 200. In Figure 3, the second plane 200 is shown as the horizontal plane. It is therefore apparent that the first plane 100 and the second plane 200 are arranged perpendicularly to one another. It is therefore possible to deflect the beam path 4 of the light emitted by the light source 10 in all spatial directions, by combining the deflections of the first modulator 7 and the second modulator 75. A greater spatial and chronological variation of the speckle effect is therefore possible, whereby it can be reduced further. Overall, very high-quality data are therefore available about the illuminated target 3, so that these data are also suitable in particular for optical tracking methods.

List of reference numerals

	1	illumination device
	2	optical system
5	3	target
	30	surface of the target
	31	illuminated target region
	4	beam path
	40	first angle
10	41	deflected beam path
	5	optical sensor
	6	atmospheric disturbance
	7	first modulator
	70	main body
15	71	actuator
	72	absorber
	73	shaft
	75	second modulator
	8	control device
20	9	phase plate
	90	surface of the phase plate
	91	first optical thickness of the phase plate
	92	second optical thickness of the phase plate
	93	third optical thickness of the phase plate
25	10	light source
	100	first direction
	200	second direction

Patent Claims

1. An illumination device (1), in particular for illuminating a target (3) to be combated, comprising
 - 5 – a light source (10), in particular a laser light source, for emitting light along a beam path (4),
 - a first modulator (7), which is introduced into the beam path (4) and is configured to manipulate a direction of the beam path (4) in a first plane (100),
 - a phase plate (9), which is introduced into the beam path (4) and has a variety of different optical thicknesses (91, 92, 93), and
 - 10 – a control device (8), which is connected to the light source (10) in the first modulator (7) and is configured to activate the first modulator (7) using different frequencies, so that the beam path (4) can be deflected over a control period of time up to a first angle (40).
- 15 2. The illumination device (1) according to Claim 1, characterized in that the light source (10) emits light pulses.
3. The illumination device (1) according to Claim 2, characterized in that the light
20 source (10) emits at least one complete light pulse during the control period of time.
4. The illumination device (1) according to one of the preceding claims, characterized in that the first modulator (7) is an acousto-optical modulator, in particular a Bragg cell.
- 25 5. The illumination device (1) according to one of the preceding claims, characterized in that a difference of the variety of the optical thicknesses (91, 92, 93) of the beam plate (9) does not fall below a value of 1 μm , in particular a value of 5 μm , and/or does not exceed a value of 50 μm , in particular a value of 10 μm .
- 30 6. The illumination device (1) according to one of the preceding claims, characterized by a second modulator (75), which is implemented identically to the first modulator (7) in particular, wherein the second modulator (75) is configured to manipulate a direction of the beam path (4) in a second plane (200), wherein the first plane (100) and the second plane (200) extend perpendicularly to one another in particular.
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7. The illumination device (1) according to one of the preceding claims, characterized by an optical sensor (5), in particular a camera, which is configured to detect light radiation emitted by the light source (10) and reflected from the target (3).

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8. A method for illuminating a target (3), using an illumination device (1) according to one of the preceding claims, comprising the following steps, which are executed in the specified sequence:

- emission of a light pulse by the light source (10),
- 10 – activation of the first modulator (7) and/or the second modulator (75) to deflect the light pulse in a randomly determined direction,

9. The method according to Claim 8, characterized in that the steps are executed in continuous repetition.

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10. The method according to Claim 9, comprising the additional steps:

- reception of each emitted light pulse,
- determination of a chronological mean value of the intensity of the received light pulse.

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