

OPTICAL POINTING AND TRACKING SYSTEM

TECHNICAL FIELD

This invention relates to the field of optical pointing and tracking systems towards a target.

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BACKGROUND

In various technical applications, it is attempted to direct an optical beam, such as a laser beam, towards a target.

In laser applications such as cutting or welding (by melting of material), there is a need for high energy and high-power densities. However, high laser power is a main cause of damage to the optical and laser system components.

An additional challenge is present when the target is a moving target. IL228861 and IL238321 of the Applicant describe a prior art solution to acquire and illuminate a moving target. However, this solution is constrained by the time of flight from the laser to the target and back. For example, an illuminated target located at a range of 6 km is limited by the time of flight at a repetition period of around 40 microseconds.

References considered to be relevant as background to the presently disclosed subject matter are listed below (acknowledgement of the references herein is not to be inferred as meaning that these are in any way relevant to the patentability of the presently disclosed subject matter):

- "*Coherent coupling of laser gain media using phase conjugation*", D. A. Rockwell and C. R. Giuliano, OPTICS LETTERS, Vol. 11, No. 3 1986 pp.147-149;
- "*Laser Beam Combining for High-Power, High-Radiance Sources*", T. Y. Fan, IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS, VOL. 11, NO. 3, 2005 pp.567-577;
- "*Phase conjugate laser optics*", Arnaud Brignon, Jean-Pierre Huignard, Editors A WILEY-INTERSCIENCE PUBLICATION;
- "*Nonlinear optical phase conjugation*", D. M. Pepper, D.A. Rockwell and G. J. Dunning, IEEE Circuits and Devices, 21-48 (1991);

- L. Brillouin, “*Diffusion de la Lumière et des Rayonnes X par un-Corps Transparent Homogène; Influence de l’Agitation Thermique*”, Annales des Physique 17, 88 (1922);
- C. Wolff *et al.*, “*Brillouin scattering—theory and experiment: tutorial*”, J. Opt. Soc. Am. B 38 (4), 1243 (2021).

Therefore, there is a need in the art for a new optical pointing and tracking system that can alleviate the limitations.

GENERAL DESCRIPTION

In accordance with certain aspects of the presently disclosed subject matter, there is provided a system comprising a probe laser device configured to transmit a probe pulse towards an object, thereby obtaining, after reflection of the probe pulse from a reflection area of the object, a reflected probe pulse, an optical subsystem comprising a reorientation module, wherein the reorientation module comprises a film polarizer, a medium, a phase conjugate mirror, wherein a path of the reflected probe pulse from its reflection by the object up to the film polarizer of the reorientation module is designated as a reflected probe path, a pump laser device configured to transmit at least one sequence of pump laser pulses, wherein the pump laser pulses have a wavelength which match a wavelength of the probe pulse according to a matching criterion, wherein the reorientation module is operative to use the phase conjugate mirror to generate a phase conjugated reflected probe pulse, which is phase conjugated with the reflected probe pulse, receive, by the medium, the phase conjugated reflected probe pulse, and sequentially, a plurality of pump laser pulses of the sequence of pump laser pulses, thereby generating, in the medium, a grating, reflect, using the grating in the medium, the plurality of pump laser pulses as a plurality of reoriented pump laser pulses, wherein each given reoriented pump laser pulse of the plurality of reoriented pump laser pulses exits the film polarizer of the reorientation module along a path coinciding with the reflected probe path, to illuminate the object.

In addition to the above features, the system according to this aspect of the presently disclosed subject matter can optionally comprise one or more of features (i) to (xxvi) below, in any technically possible combination or permutation:

- i. an interaction of a given pump laser pulse received by the medium and the phase conjugated reflected probe pulse enables generation of the grating;

- ii. during said interaction, the given pump laser pulse received by the medium coincides in space and time with the phase conjugated reflected probe within the medium;
- 5 iii. some pump laser pulses of the plurality of pump laser pulses received by the medium after said given pump laser pulse are operative to further sustain or enhance said grating in the medium;
- 10 iv. the grating is a Brillouin grating in the medium;
- 15 v. the system is configured to, for a single probe pulse transmitted by the probe laser device towards the object and reflected by the object into a reflected probe pulse propagating along a reflected probe path up to the film polarizer of the reorientation module: reflect, using the grating in the medium, the plurality of pump laser pulses as a plurality of reoriented pump laser pulses, wherein each given reoriented pump laser pulse of the plurality of reoriented pump laser pulses exits the film polarizer of the reorientation module along a path coinciding with the reflected probe path, to illuminate the object;
- 20 vi. a time interval between transmission of at least some of successive reoriented pump laser pulses of the plurality of reoriented pump laser pulses towards the object is shorter than a round-trip time of the probe pulse;
- 25 vii. a power per unit area of each pump laser pulse of the sequence of pump laser pulses is below a damage threshold for which one or more components of the reorientation module, or of the optical subsystem comprising the reorientation module and least one amplifier, is damaged;
- 30 viii. the system is configured to amplify the plurality of reoriented pump laser pulses, wherein a power per unit area of each reoriented pump laser pulse after said amplification is below a damage threshold for which one or more components of the reorientation module, or of the optical subsystem comprising the reorientation module and at least one optical amplifier, is damaged;
- ix. the system is configured to amplify each given reoriented pump laser pulse of the plurality of reoriented pump laser pulses before it exits the optical subsystem, and transmit the plurality of reoriented pump laser

- pulses after amplification towards the object to perform an interaction with the object;
- x. the object is a moving object;
 - xi. the sequence of pump laser pulses transmitted by the pump laser device
5 comprises a plurality of pump laser pulses which are coherent according to a coherence criterion;
 - xii. the medium is operative to receive sequentially a plurality of pump laser pulses of the sequence of pump laser pulses, wherein a time interval between a reception of successive pump laser pulses of the plurality of
10 pump laser pulses by the medium is shorter than a Brillouin Grating lifetime of the medium;
 - xiii. the medium enables Stimulated-Brillouin-Scattering, wherein the pump laser device is configured to transmit a given laser pulse of the sequence of pump laser pulses to the medium in a time interval that is within a
15 lifetime of a Brillouin grating generated by an interaction between a pump laser pulse and the phase conjugated reflected probe pulse;
 - xiv. at least some of the pump laser pulses received by the medium are operative to sustain or enhance a Brillouin grating previously generated in the medium;
 - xv. the system comprises at least one optical amplifier configured to amplify
20 the plurality of reoriented pump laser pulses received by the optical amplifier during an amplification cycle, wherein a total energy of the plurality of reoriented pump laser pulses, after their amplification, for the amplification cycle is equal to or larger than 1 mJ;
 - xvi. the optical subsystem comprises at least one optical amplifier configured
25 to both amplify the reflected probe pulse, and amplify the plurality of reoriented pump laser pulses;
 - xvii. the system is configured to trigger an optical amplifier, during a time-window in which the optical amplifier is operative to perform
30 amplification, perform at least once operations including (1) to (9): (1) transmit, by the probe laser device, a probe pulse towards the object, thereby obtaining, after reflection of the probe pulse on a reflection area of the object, a reflected probe pulse, (2) receive, by the optical amplifier, the probe reflected pulse reflected by the object, (3) receive, by the phase

- 5 conjugation mirror of the reorientation module, the probe reflected pulse after its amplification by the optical amplifier, (4) generate a phase conjugated reflected probe pulse which is phase conjugated with the reflected probe pulse, (5) receive, by the medium the phase conjugated reflected probe pulse, and sequentially a plurality of pump laser pulses of the sequence of pump laser pulses, (6) create, in the medium, a Brillouin Grating, as a result of an interaction of the reflected phase conjugated probe laser pulse and a pump laser pulse of the sequence of pump laser pulses, (7) reflect, by the medium, the plurality of pump laser pulses as a plurality of reoriented pump laser pulses, (8) amplify, by the optical amplifier, the plurality of reoriented pump laser pulses, and (9) use the plurality of reoriented pump laser pulses after their amplification to illuminate the object;
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- xviii. the optical subsystem comprises at least one optical device configured to both receive the probe reflected pulse, and transmit the plurality of reoriented pump laser pulses after amplification to illuminate the object;
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- xix. the probe laser device is configured to transmit a first probe pulse towards the object, thereby obtaining, after reflection of the first probe pulse on a first reflection area of the object, a first reflected probe pulse propagating along a first reflected probe path up to the film polarizer of the reorientation module, the pump laser device is configured to transmit a first sequence of pump laser pulses, wherein the reorientation module is operative to use the phase conjugate mirror to generate a first phase conjugated reflected probe pulse, which is phase conjugated with the first reflected probe pulse, receive sequentially a plurality of pump laser pulses of the first sequence of pump laser pulses, reflect, using the medium, the plurality of pump laser pulses as a plurality of first reoriented pump laser pulses exiting the film polarizer of the reorientation module along a path coinciding with the first reflected probe path, to illuminate the object, the probe laser device is configured to transmit a second probe pulse towards the object, thereby obtaining, after reflection of the second probe pulse on a second reflection area of the object, a second reflected probe pulse propagating along a second reflected probe path up to the film polarizer of the reorientation module, the pump laser device is configured to transmit
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- a second sequence of pump laser pulses, wherein the reorientation module is operative to use the phase conjugate mirror to generate a second phase conjugated reflected probe pulse, which is phase conjugated with the second reflected probe pulse, receive sequentially a plurality of pump laser pulses of the second sequence of pump laser pulses, reflect, using the medium, the plurality of pump laser pulses as a plurality of second reoriented pump laser pulses exiting the film polarizer of the reorientation module along a path coinciding with the second reflected probe path, to illuminate the object, wherein a time interval between reception of a last laser pulse of the first sequence of pump laser pulses by the reorientation module and reception of a first laser pulse of the second sequence of pump laser pulses by the reorientation module is longer than the Brillouin Grating lifetime of the medium;
- xx. the medium is an active Stimulated Brillouin Scattering (SBS) medium;
 - xxi. a frequency of transmission of the pump laser pulses within the sequence by the pump laser device is between 100 MHz and 2 GHz;
 - xxii. the probe laser device is mounted on a first platform, and the pump laser device is mounted on a second platform which is distinct from the first platform;
 - xxiii. the matching criterion the matching criterion is such that the absolute value of a spectral shift between the probe laser device and the pump laser device is smaller than half of the sum of a spectral width of the probe laser device and a spectral width of the pump laser device;
 - xxiv. the phase conjugate mirror comprises a medium comprising a first material, the medium of the reorientation module comprises a second material, wherein the first material and the second material are identical;
 - xxv. the medium of the reorientation module comprises a liquid, wherein the liquid optionally includes at least one of CBrCl_3 , CHCl_3 , GeCl_4 , CCl_4 , C_2Cl_4 , SiCl_4 , $(\text{CH}_3)_3\text{CCl}$, CS_2 , TiCl_4 , ICl , IF_5 , C_6F_{14} , CSe_2 , AsCl_3 , Acetone, H_2O and Freon, or a gaseous material, or a solid crystal; and
 - xxvi. for a first object illuminated by a first probe pulse, a first reflected probe pulse is generated which it is received by the optical subsystem with a first incidence angle α_1 , wherein a path of the first reflected probe pulse from its reflection by the object up to a film polarizer of the reorientation module

is designated as a first reflected probe path, wherein the reorientation module is configured to generate first reoriented pump laser pulses, wherein each given reoriented pump laser pulse of the plurality of first reoriented pump laser pulses exits the film polarizer of the reorientation module along a path coinciding with the first reflected probe path, to illuminate the first object, for a second object illuminated by a second probe pulse, a second reflected probe pulse is generated, which it is received by the optical subsystem with a second incidence angle α_2 different from α_1 , wherein a path of the second reflected probe pulse from its reflection by the object up to a film polarizer of the reorientation module is designated as a second reflected probe path, wherein the reorientation module is configured to generate second reoriented pump laser pulses, wherein each given reoriented pump laser pulse of the plurality of second reoriented pump laser pulses exits the film polarizer of the reorientation module along a path coinciding with the second reflected probe path, to illuminate the object, wherein the system enables maintaining a fixed orientation of the optical subsystem to illuminate the first object with the first reoriented pump laser pulses and the second object with the second reoriented pump laser pulses.

In accordance with certain aspects of the presently disclosed subject matter, there is provided a method comprising transmitting a probe pulse towards an object, thereby obtaining, after reflection of the probe pulse from a reflection area of the object, a reflected probe pulse, receiving the reflected probe pulse by an optical subsystem comprising a reorientation module, wherein the reorientation module comprises a film polarizer, a medium, a phase conjugate mirror, wherein a path of the reflected probe pulse from its reflection by the object up to the film polarizer of the reorientation module is designated as a reflected probe path, generating, by the reorientation module, a phase conjugated reflected probe pulse, which is phase conjugated with the reflected probe pulse, receiving, by the medium the phase conjugated reflected probe pulse, and sequentially, a plurality of pump laser pulses of a sequence of pump laser pulses generated by a pump laser device, thereby generating, in the medium, a grating, wherein the pump laser pulses have a wavelength which match a wavelength of the probe pulse according to a matching criterion, reflecting, using the grating in the medium, the plurality of pump laser pulses as a plurality of reoriented pump laser pulses, wherein each given reoriented pump laser pulse

of the plurality of reoriented pump laser pulses exits the film polarizer of the reorientation module along a path coinciding with the reflected probe path, to illuminate the object.

In addition to the above features, the method according to this aspect of the presently disclosed subject matter can optionally comprise (or implements) one or more
5 of the features (i) to (xxvi) as described above with respect to the system.

According to some embodiments, the method comprises measuring a round trip time of at least one preliminary probe pulse transmitted towards the object to determine a distance to the object, thereby enabling determining arrival time of one or more subsequent probe pulses reflected by the object.

10 According to some embodiments, the proposed solution enables to illuminate a target with a plurality of laser pulses closely spaced in time, thereby reducing the time response of the system.

According to some embodiments, the proposed solution ensures a high energy interaction with the target while preventing damages caused to the optical and laser
15 system components.

According to some embodiments, the proposed solution enables to track a target efficiently and accurately.

According to some embodiments, the proposed solution enables tracking a moving target while ensuring a substantially continuous physical interaction with the
20 target.

According to some embodiments, the proposed solution enables tailoring various parameters of the laser beams reaching the target.

BRIEF DESCRIPTION OF THE DRAWINGS

25 In order to understand the invention and to see how it can be carried out in practice, embodiments will be described, by way of non-limiting examples, with reference to the accompanying drawings, in which:

- **Fig. 1** illustrates an embodiment of a system which can be used to illuminate an object;
- 30 - **Fig. 1A** illustrates an embodiment of a method of illuminating an object using the system of **Fig. 1**;
- **Fig. 1B** illustrates a variant of the embodiment described in **Fig. 1**;
- **Fig. 1C** illustrates an example of time multiplexing of various laser pulses in accordance with the method of **Fig. 1A**;

- **Fig. 2** is a layout of an embodiment of an optical subsystem which can be used in the system of **Fig. 1** or **Fig. 1A**;
- **Fig. 3** illustrates an embodiment of a method of illuminating an object using the optical subsystem of **Fig. 2**; and
- 5 - **Fig. 4** illustrates an example of time multiplexing of various laser pulses in accordance with the method of **Fig. 3**;
- **Fig. 5A** illustrates an example of interaction which can occur in a medium of a reorientation module, in order to generate a grating;
- **Fig. 5B** illustrates another example of interaction which can occur in the
10 medium of the reorientation module, in order to generate a grating; and
- **Fig. 6** illustrates an example of illuminating successively two objects which have a different angular direction with respect to the optical subsystem, without requiring modifying the orientation of the optical subsystem.

15 DETAILED DESCRIPTION

In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it will be understood by those skilled in the art that the presently disclosed subject matter can be practiced without these specific details. In other instances, well-known methods have
20 not been described in detail so as not to obscure the presently disclosed subject matter.

The term “processor and memory circuitry” (PMC) covers any computing unit or electronic unit with data processing circuitry that may perform tasks based on instructions stored in a memory, such as a computer, a server, a chip, a processor, etc. It encompasses a single processor or multiple processors, which may be located in the
25 same geographical zone or may, at least partially, be located in different zones and may be able to communicate together.

Embodiments of the presently disclosed subject matter are not described with reference to any particular programming language. It will be appreciated that a variety of programming languages can be used to implement the teachings of the presently
30 disclosed subject matter as described herein.

Fig. 1 is a schematic representation of an embodiment of a system **100**, that can be used to illuminate an object **110** (target).

According to some embodiments, the object **110** can be a static object.

According to some embodiments, the object **110** can be a moving object. In some embodiments, the moving object is a ground or sea-borne or air-borne moving object.

According to some embodiments, the object does not necessarily move along a known route. According to some embodiments, the moving object rotates (about at least one of pitch, roll or yaw axes).

System **100** includes a probe laser device **115**. According to some embodiments, the probe laser device **115** is configured to transmit a probe pulse **109** towards the object **110**.

At least part of the probe pulse **109** is reflected by an area **114** of the object **110** (the area **114** can correspond to the tip of the object **110**), thereby obtaining a reflected probe pulse **113**.

System **100** further includes an optical subsystem **120**, which includes a reorientation module **130** (also called optical reorientation module **130**).

As explained hereinafter, the reorientation module **130** enables to reorient a sequence **131** of pump laser pulses (which did not previously interact with the object **110**) towards the object **110**.

As explained hereinafter, the reorientation module **130** includes a phase conjugate mirror (see reference **111** in **Fig. 1** or reference **211** in **Fig. 2**) an active medium (see reference **112** in **Fig. 1** or reference **212** in **Fig. 2**) enabling Stimulated Brillouin Scattering.

The reflected probe pulse **113** is collected, at least partially, by the optical subsystem **120**.

An optical path of the reflected probe pulse **113**, from its reflection by the object **110** (as mentioned above, the reflected probe pulse **113** is generated after reflection of the probe pulse **109** by the object **110**) up to a point **152** of the reorientation module **130** (see also **Fig. 1B**), is designated as a reflected probe path **151**. The point **152** can correspond to a film polarizer (located at the entrance of the reorientation module **130** or **230**). This film polarizer is depicted as reference **241** in **Fig. 2**. As explained hereinafter, the film polarizer is operative to receive the reflected probe pulse **113** and pump laser pulses transmitted by a pump laser device **125** (described hereinafter). According to some embodiments, the film polarizer is a thin film polarizer. The term “thin” can include a thickness of about a micrometer per layer, wherein the polarizer can be a single layer polarizer or a multiple layer polarizer.

System **100** further includes (or is operatively coupled with) a second laser device, called pump laser device **125**.

As explained hereinafter, the pump laser device **125** is configured to transmit at least one sequence **131** of pump laser pulses. As visible in the non-limitative representation of **Fig. 1**, each sequence **131** includes a plurality of closely spaced in time distinct pump laser pulses. As explained hereinafter, the pump laser device **125** is operative to generate and transmit a plurality of distinct sequences **131** of pump laser pulses.

According to some embodiments, a wavelength λ_1 of the probe pulse **109** (transmitted by the probe laser device **115**) and a wavelength λ_2 of each pump laser pulse (transmitted by the pump laser device **125**) match according to a matching criterion.

According to some embodiments, the matching criterion is e.g., such that the absolute value of the spectral shift between the two lasers, the probe laser device **115** and the pump laser device **125**, having their peaks respectively at λ_1 and λ_2 , is smaller than half of the sum of the spectral widths of the two lasers $\Delta\lambda(1/e)$, i.e., smaller than $0.5(\Delta\lambda(1/e)_1 + \Delta\lambda(1/e)_2)$, where $\Delta\lambda(1/e)_1$ is the spectral width of the probe laser device **115** and $\Delta\lambda(1/e)_2$ is the spectral width of the pump laser device **125**, each measured between the two 1/e points on the spectral curve of the laser, in which the spectral envelope reaches 1/e of its maximum. This matching criterion allows for at least partial overlap of the spectrum of the two lasers (probe laser device **115** and pump laser device **125**). Note that a matching criterion different from the example provided above can be used.

According to some embodiments, the probe laser device **115** is mounted on a first platform, and the pump laser device **125** (together with the optical subsystem **120**) is mounted on a second platform which is distinct from the first platform (the first platform is therefore separated from the second platform).

This is not limitative, and in some embodiments, the probe laser device **115** and the pump laser device **125** (together with the optical subsystem **120**) can be mounted on the same platform (e.g., on one pedestal).

Time synchronization between the probe laser device **115** and the system including the pump laser device **125** and the optical subsystem **120** can be obtained as explained e.g., with reference to **Fig. 3**.

According to some embodiments, the pump laser device **125** includes a Nd:YAG laser source having wavelength 1.06 microns (this is however not limitative, and other laser types and wavelengths can be used).

According to some embodiments, the pump laser device **125** includes a
5 repetitively pulsed laser, e.g., mode-locked laser or a Q-switched laser.

A non-limitative example of a laser device which can be used as the pump laser device **125** can be found in "*Ultrafast solid-state lasers*", Landolt-Börnstein, Group VIII Advanced Materials and Technologies 1B1 (Laser Physics and Applications) (see in particular chapter 2.1, "*Ultrafast solid-state lasers by U. Keller*", p.70, Table 2.1.4).
10 Content of this document is incorporated by reference herein in its entirety.

According to some embodiments, the probe laser device **115** comprises a pulsed laser having sufficient energy so as to obtain useful returns from the target, and the pump laser device **125** comprises the repetitively pulsed seed for a high energy laser. In particular, in some embodiments, an energy of the probe pulse **112** can be smaller than an
15 energy of each laser pulse of the sequence **131** of pump laser pulses. This is however not limitative.

According to some embodiments, an energy of the probe pulse **109** is in a range between several milli-Joules to several Joules. This is however not limitative. In some embodiments, this energy can be selected depending on the range to the object **110**, to
20 ensure that the optical subsystem **120** receives a reflected probe pulse **113** with sufficient energy (above a detection threshold of the optical subsystem **120**).

According to some embodiments, the different pump laser pulses of a given sequence **131** of pump laser pulses are coherent according to a coherence criterion.

In a non-limitative example, the coherence criterion is such that the coherence
25 length is equal to or greater than the length of an active medium (see for example medium **112** in **Fig. 1** or medium **212** in **Fig. 2** – its length can be measured along an optical axis along which the laser beams counter propagate within the medium) of the reorientation module **130** (note that in **Fig. 2** the reorientation module has reference number **230**).

In a non-limitative example, the length of the active medium **112/212** of the
30 reorientation module **130/230** is between a few centimetres and 100 cm.

The reorientation module **130** is configured to receive the reflected probe pulse **113**. According to some embodiments, the reorientation module **130** receives the reflected probe pulse **113** after its amplification.

In addition, the medium **112** of the reorientation module **130** is configured to receive sequentially a plurality of pump laser pulses of at least one sequence **131** of pump laser pulses transmitted by the pump laser device **125**.

According to some embodiments, system **100** includes (or is operatively coupled to) a processor and memory circuitry (PMC) **126**. PMC **126** can communicate with one or more components of system **100**. In particular, in some embodiments, PMC **126** can control timing of one or more components of system **100**.

According to some embodiments, system **100** can include (or can be operatively coupled with) various sensors/devices **150** enabling e.g., engagement with the object **110** and/or detection of the object **110** and/or acquisition of the object **110**, such as a RADAR, a Forward-looking infrared (FLIR) camera, a visible camera, etc.

Attention is drawn to **Fig. 1A** which describes a method of operation of system **100** of **Fig. 1**. **Fig. 1C** describes an example of a control of the timing of the various laser pulses.

The method includes transmitting (operation **170**) a probe laser pulse (see reference **109** in **Figs. 1, 1B** and **1C**) towards the object **110**. Reflection of the probe laser pulse by the object **110** yields a reflected probe pulse **113**.

The method further includes (operation **171**) collecting, by the optical subsystem **120**, at least part of the reflected probe pulse **113** reflected by area **114** of the object **110**, which is transmitted (optionally after its amplification) to the reorientation module **130**.

As shown in **Fig. 1C** (note that the time scale in **Fig. 1C** is purely schematic and does not necessarily reflect the real time scale), a time interval between transmission of the probe pulse **109** and reception of the reflected probe pulse **113** by the reorientation module **130** (or **230** in **Fig. 2**) is noted Δt_1 . Δt_1 corresponds substantially to the round-trip time of the probe pulse **109**.

In some embodiments, and as depicted in **Fig. 1B**, area **114** corresponds to the area of the object **110** that defines the shortest optical path between the probe laser device **115**, the object **110** and the optical subsystem **120**. For example, in **Fig. 1B**, area **114** corresponds to a tip **114** protruding from the object **110**, or to any other distinct reflective element.

According to some embodiments, the reflected probe pulse **113** is received by the medium of the reorientation module **130**. The medium is particular in that it enables, at

least according to some embodiments, Stimulated Scattering. Stimulated Scattering can include e.g., Stimulated Brillouin Scattering.

The medium can include e.g., a solid crystal, or a liquid or a gas.

According to some embodiments, the medium of the reorientation module **130** includes a liquid such as at least one of (used as a pure component or within a mixture) CBrCl₃, CHCl₃, GeCl₄, CCl₄, C₂Cl₄, SiCl₄, (CH₃)₃CCl, CS₂, TiCl₄, ICl, IF₅, C₆F₁₄, CSe₂, AsCl₃, Acetone, H₂O and Freon. Note that the use of a liquid or gaseous material for the medium reduces the need of cooling the medium. This is not limitative and as mentioned above, the medium can include a solid crystal (e.g., quartz), or a gas.

Since interaction between the reflected probe pulse **113** and the medium **112** (or **212** in **Fig. 2**) have no effect, the reflected probe pulse **113** impinges on a phase conjugate mirror (see reference **111** in **Fig. 1A** or reference **211** in **Fig. 2**) and is reflected (operation **172**) as a phase conjugated reflected probe pulse **137** (or **237** in **Fig. 2**). The phase conjugated reflected probe pulse **137** (or **237** in **Fig. 2**) is then transmitted to the medium **112** (or **212** in **Fig. 2**).

According to some embodiments, the phase conjugate mirror **111** (or **211**) comprises a medium (active medium, which enables e.g., SBS – note that this medium is not represented in the drawings) which contains a material which is identical to a material of the active medium **112** (or **212**). This assures efficient energy transfer from the pump laser pulses to the reoriented pump laser pulses.

According to some embodiments, when the reflected probe pulse **113** enters the optical subsystem **120**, it can have an optical aberration due to atmospheric turbulence disturbances present in the environment between the object **110** and the optical subsystem **120**. This optical aberration can be cancelled by the phase conjugate mirror **111** (or **211**). As a consequence, according to some embodiments, the phase conjugated reflected probe pulse **137** (or **237**) does not include this optical aberration. This is due to inherent properties of the phase conjugate mirror.

The method further includes transmitting (operation **173**) a first pump laser pulse **140** of a sequence **131** of pump laser pulses from the pump laser device **125** to the reorientation module **130** (or **230**). Note that the various pump laser pulses of the sequence **131** do not necessarily have the same energy.

The phase conjugated reflected probe pulse **137** (or **237**) interacts, in the medium **112** (or **212**), with at least one pump laser pulse (e.g., the first pump laser pulse of the sequence **113**, or with one or more of the first pump laser pulses of the sequence **113**)

transmitted by the pump laser device **215** to the medium **112** (or **212**). During the interaction, there is a coincidence in time and space within the medium between the phase conjugated reflected probe pulse **137** (**237**) and the first pump laser pulse **140**.

The interference interaction between the phase conjugated reflected probe pulse
5 **137** (or **237**) and the first pump laser pulse **140** creates an interference grating inside the medium **112** (or **212**), called "Brillouin Grating". The grating causes Stimulated Brillouin Scattering.

Since the grating decays over time, the Stimulated Brillouin Scattering exists only during a given lifetime. In a regular medium (which is not further stimulated), after the
10 given lifetime has elapsed, Stimulated Brillouin Scattering vanishes and ceases to exist. According to some embodiments, in the present system, the given lifetime is extended by the interaction of consecutive pump laser pulse(s) with the medium, which sustains the Brillouin Grating within the medium. This results in a system in which the constraint of the limited lifetime of the Brillouin grating is (at least partially) alleviated. Note that at
15 least some of the pump laser pulses may enhance/stimulate the grating in the medium. In some embodiments, as long as the medium receives pump laser pulses, the grating is sustained or enhanced within the medium.

The given lifetime depends in particular on the material(s) present in the medium, and is known per material. The given lifetime is noted hereinafter "Brillouin grating
20 lifetime". Note that this given lifetime can be also equivalently designated as "phonon lifetime".

Document "*Phase conjugate laser optics*", Arnaud Brignon, Jean-Pierre Huignard, Editors A WILEY-INTERSCIENCE PUBLICATION, provides, for a large variety of SBS materials, the corresponding Brillouin grating lifetime (see p.32-33, τ_B
25 in Table 2.1, Table 2.2 and Table 2.3). Content of this document is incorporated herein by reference in its entirety.

Since the interaction between the first pump laser pulse **140** of the sequence **131** and the phase conjugated reflected probe pulse **137** (or **237**) in the medium **112** (or **212**) creates a grating within the medium **112** (or **212**), the first pump laser pulse **140** is reflected
30 by the medium **112** (or **212**) as a reoriented pump laser pulse **139** (or **239**) which has acquired phase properties (i.e., directional and phase front properties) of the reflected probe pulse **113**.

As a consequence, the first pump laser pulse **140** exits the optical subsystem **120** as a reoriented pump laser pulse **139** (or **238** in the embodiment of **Fig. 2**, in which the

reoriented pump laser pulse **239** exiting the reorientation module **230** is, optionally, amplified before it exits the optical subsystem **220**). The reoriented pump laser pulse **139** exits the film polarizer (visible in **Fig. 2** as reference **241**, but not explicitly represented in **Figs. 1, 1B** and **6** for simplifying the drawings) of the reorientation module **130** along a path which coincides with the reflected probe path **151**. Note that this coincidence also covers the situation in which the optical subsystem **120/220** is moving over time, which may create a neglectable difference between the two paths, since the laser pulses propagate at the speed of light.

If the target is static, the reoriented pump laser pulse **139** (or **238**) impinges the target at the same area at which the probe pulse has been reflected by the object **100**. If the object **100** is mobile, there can be a small shift between the impact area of the reoriented pump laser pulse **139** (or **238**) on the object **100** and the area at which the probe pulse has been reflected by the object **100**.

As depicted in **Fig. 1A**, the method includes transmitting another pump laser pulse (second pump laser pulse **141**, which is generated by the pump laser device **125** after the first pump laser pulse **140** within the first sequence **131** of laser pulses) from the second laser device **125** to the reorientation module **130**.

As depicted in **Fig. 1C**, a time interval between reception of the first pump laser pulse **140** by the reorientation module **130** and reception of the second pump laser pulse **141** by the reorientation module **130** is noted Δt_3 . More generally, a time interval between a reception of successive pump laser pulses of a sequence of pump laser pulses by the reorientation module **130** is noted Δt_3 . Note that Δt_3 is not necessarily a fixed value within a given sequence of pump laser pulses and/or among different sequences of pump laser pulses.

As mentioned above, the Brillouin grating within the medium (which enables Stimulated Scattering within the medium) is initiated by the interaction between the phase conjugated reflected probe pulse **137** (or **237**) and the first pump laser pulse of the sequence **131**, designated as pump laser pulse **140**. Reception of the following pump laser pulses (see pump laser pulses **141**, **142**, etc. of the sequence **131**) by the reorientation module **130** enables sustaining (and may even enhance) this grating (and therefore of the Stimulated Scattering initially generated by the interaction between the phase conjugated reflected probe pulse **137** or **237** and the pump laser pulse **140** within the medium) over time.

Therefore, according to some embodiments, Δt_3 is selected to ensure that the second pump laser pulse **141** is received by the reorientation module **130** (or **230**) while the Brillouin grating within the medium is still present. As a consequence, reception of the second pump laser pulse **141** by the reorientation module **130** (or **230**) enables sustaining the Brillouin grating over time.

This can be ensured by selecting a time interval Δt_3 between a reception of successive pump laser pulses of the sequence **131** by the reorientation module **130** (or **230**) which is shorter than a lifetime of the Brillouin grating generated within the medium.

By the effect of the grating induced by the reorientation module **130** (or **230**), the pump laser pulse **141** is therefore converted into a reoriented pump laser pulse, which has acquired the phase properties of the phase conjugated reflected probe pulse **137** or **237** (and therefore of the reflected probe pulse **113**). As a consequence, the reoriented pump laser pulse exits the film polarizer (see point **152**) of the reorientation module **130** and then the optical subsystem **120** along a path which coincides with the reflected probe path **151**.

According to some embodiments, the reoriented pump laser pulse can be amplified before it exits the optical subsystem **120**. As a consequence, the reoriented pump laser pulse reaches the object **110** after its amplification.

As mentioned above, if the target is static, the reoriented pump laser pulse impinges the target at the same area at which the probe pulse has been reflected by the object **100** (and at which the previously transmitted reoriented pump laser pulse has impinged the object **100**). If the object **100** is mobile, there can be a small shift between the impact area of the reoriented pump laser pulse on the object **100** and the area at which the probe pulse has been reflected by the object **100** (and the area at which the previously transmitted reoriented pump laser pulse has impinged the object **100**).

The method as described above can be repeated for the subsequent pump laser pulses of the first sequence **131** of pump laser pulses. If amplifiers are used (see hereinafter embodiments which use amplifiers), the method can be repeated for the subsequent pump laser pulses of the first sequence **131** of laser pulses as long as the amplifiers are not exhausted.

As mentioned above, each subsequent pump laser pulse of the first sequence **131** received by the medium **112** (or **212**) sustains a Brillouin grating in the medium **112** (or **212**).

As a consequence, the first sequence **131** of pump laser pulses is converted into a sequence of a plurality of reoriented pump laser pulses that have acquired the phase properties of the phase conjugated reflected probe pulse **137** (or **237**).

Each given reoriented pump laser pulse of the plurality of reoriented pump laser pulses exits the film polarizer (see point **152**) of the reorientation module **130** and then the optical subsystem **120** along a path coinciding with the reflected probe path **151**, to illuminate the object. Note that this coincidence also covers the situation in which the optical subsystem **120/220** is moving over time, which may create a neglectable difference between the two paths, since the laser pulses propagate at the speed of light.

Note that, typically, the first reoriented pump laser pulse (generated using the first pump laser pulse **140**) has an intensity which is smaller than the intensity of the second reoriented pump laser pulse (generated using the second pump laser pulse **141**). Indeed, the Brillouin grating in the medium may be further stimulated by at least some of the subsequent pump laser pulses which reach the medium. This is however not limitative.

In some embodiments, the object **110** is a moving target. However, according to some embodiments, the travelling distance of the moving object **110** within the total duration of a given sequence of laser pulses is small, which ensures transmitting the plurality of reoriented pump laser pulses towards the same area of the object **110**.

As apparent from the description above, for a single probe pulse **109** transmitted towards the object **110** (and reflected by the object **110** into a reflected probe pulse **113**), a plurality of reoriented pump laser pulses is generated (which have phase properties of the probe pulse **113**) and transmitted (if necessary, after their amplification) towards the object **110** (in particular, in some embodiments, towards the same area **114**).

It is therefore possible to transmit successively towards the object **110** a plurality of reoriented pump laser pulses which are closely spaced in time.

As a consequence, an interaction with the area of the object **110** is achieved. In particular, according to some embodiments, an interaction which enables removal of material is achieved. The interaction can include (this is not limitative) at least one of cutting, welding, drilling, etc. at the area. This interaction can be used for various applications, such as manufacturing an object (e.g., a car), etc. This is however not limitative.

According to some embodiments, the interval between two successive reoriented pump laser pulses (see e.g., **139**) transmitted towards the object **110** and enabling an interaction with the object **110** is much shorter than the round-trip time of the probe pulse

109 (e.g., 0.5 ns between laser pulses, compared to 40 μ s round-trip time, i.e., 8 thousand times shorter – these values are however not limitative)

This is depicted in **Fig. 1C** in which a time interval Δt_3 between transmission of successive pump laser pulses of the sequence **131** of pump laser pulses (which are converted into reoriented pump laser pulses transmitted towards the object **110**) is shorter than a time interval Δt_1 between transmission of the probe pulse **109** by the probe laser device **115** and reception of the phase conjugated reflected probe pulse by the reorientation module **130**.

According to some embodiments, it is required to obtain a high energy interaction with the object **110**. On the other hand, generating a high energy laser beam may damage one or more components of the system **100**.

Therefore, a power per unit area (also called specific power) of each pump laser pulse of the sequence **131** of pump laser pulses can be selected to be below a damage threshold (also called laser damage threshold, or laser induced damaged threshold) of one or more components (such as optical components, e.g., lenses, mirrors, laser rods, optical coatings, etc., and/or amplifiers) or all components, of the reorientation module **130/230** (or more generally of the optical subsystem **120/220** which includes the reorientation module **130/230**), thereby preventing damage to the one or more components of the reorientation module **130/230** (or more generally of the optical subsystem **120/220**).

In some embodiments, and as explained hereinafter, each pump laser pulse of the sequence of pump laser pulses is (after a process of interacting within an active SBS medium) amplified, to obtain an (amplified) reoriented pump laser pulse having the same properties as the phase conjugated reflected probe pulse **137** (or **237**).

Therefore, power per unit area of each amplified reoriented pump laser pulse can be selected to be below the damage threshold of one or more components (such as optical components, e.g., lenses, mirrors, optical coatings, etc., and/or amplifiers), or all components, of the reorientation module **130** or **230** (or more generally of the optical subsystem **120** or **220**), thereby preventing damage to the one or more components.

Power per unit area of each amplified reoriented pump laser pulse depends in particular on the energy of each pump laser pulse of the sequence **131** of pump laser pulses, on the duration of each pump laser pulse and on the amplitude of the amplification.

According to some embodiments, although each reoriented pump laser pulse does not damage optical components of the optical module **120** or **220**, a useful interaction (see examples above) can be achieved due to the cumulative effect (e.g., heat absorption etc.) of the successive multiple reoriented pump laser pulses impinging the same spot on object **110** during a short period of time, e.g., a few nanoseconds.

A non-limitative example of a damage threshold is provided hereinafter. Assume that a pulsed laser transmits a pulsed laser beam to a Nd:YAG rod. A damage threshold of coatings of the Nd:YAG rod can be, for a pulse duration shorter than 20 ns, around 1.4 GW/cm². This example is not limitative.

On the other hand, as mentioned above, it is required in some applications to generate a high energy interaction with the object **110**. Since the plurality of reoriented pump laser pulses which are transmitted towards the object **110** can be closely spaced in time, the total accumulated energy of the plurality of reoriented pump laser pulses is large enough to ensure the required high energy and sufficient high-power density (note that use of a single laser pulse beam with such high energy and power density would damage one or more components of the reorientation module **130** or **230**, or more generally of the optical subsystem **120** or **220**).

According to some embodiments, a temporal frequency of transmission (as transmitted by the pump laser device **125** – this frequency is substantial equal to the frequency of pump laser pulses reception by the reorientation module **130/230**) of pump laser pulses within a given sequence **131** of pump laser pulses is between 100 MHz and 2 GHz (that is to say that the time duration Δt_3 between two successive pump laser pulses of the sequence **131** is between 0.5 ns and 10 ns). As mentioned above, this value generally depends on the lifetime of the Brillouin grating. The values provided above are therefore not limitative and depend on various constraints, such as the required application, the environment, etc.

According to some embodiments, for a given sequence **131** of pump laser pulses, the pulse duration of the various pump laser pulses of the given sequence is substantially constant among the various pump laser pulses.

According to some embodiments, for a given sequence **131** of pump laser pulses, the pulse duration of each pump laser pulse of the given sequence **131** is shorter than the time duration Δt_3 between transmission of two successive pump laser pulses of the sequence **131**.

As visible in **Fig. 1A** (see reference **175**), the method can be repeated. In particular, once all laser pulses of the first sequence **131** of pump laser pulses have been converted into reoriented pump laser pulses and transmitted towards the object **110**, a second probe laser pulse **117** (see **Fig. 1C** - different from the probe pulse **109**) is transmitted from the pump laser device **115** towards the object **110**, thereby obtaining a second reflected probe pulse.

The method further includes receiving (operation **172**), at the reorientation module **130** (or **230**), the second reflected probe pulse **118** (in some embodiments, the second reflected probe pulse is first amplified before it reaches the reorientation module **130** or **230**).

The method further includes transmitting (operation **173**) successively a plurality of pump laser pulses of a second sequence **132** of pump laser pulses, which are converted into a sequence of reoriented pump laser pulses (which have acquired the phase properties of the second probe laser pulse **117**). The plurality of reoriented pump laser pulses is transmitted towards the same area of the object **110** as illuminated by the second probe laser pulse **117**, or towards an area of the object **110** shifted with respect to the area of the object **110** as illuminated by the second probe laser pulse **117**.

Control of the timing of the various laser pulses can be similar to the first iteration of the method.

As visible in **Fig. 1C**, time multiplexing between the various sequences **131**, **132** of pump laser pulses and the various probe pulses **109**, **117** transmitted by the probe laser device **115** can be obtained.

In particular, a time interval Δt_4 between reception of a last pump laser pulse **144** of the first sequence **131** of pump laser pulses by the reorientation module **130** (or **230**) and reception of a first laser pulse **145** of the subsequent second sequence **132** of pump laser pulses by the reorientation module **130** (or **230**) is longer than a period of time Δt_1 between a transmission of the second probe pulse **117** by the probe laser device **115** and reception of the second probe pulse **117** by the reorientation module **130** (or **230**). In other words, between two consecutive sequences of pump laser pulses, there is sufficient time for a round-trip between the probe laser device **115**, the object **110**, and the optical subsystem **120** (or **220**). This enables recreating a grating within the medium based on the second probe pulse **117**.

In some embodiments, the method of **Fig. 1A** can include an initial phase of acquiring (operation **169**) the object **110**. This can include using e.g., one or more of the sensors **150** mentioned above.

Attention is now drawn to **Fig. 2**, which depicts an embodiment of an optical subsystem **220** (corresponding to a possible embodiment of optical subsystem **120** visible in **Figs. 1** and **1B**).

Optical subsystem **220** includes optics **205**. Optics **205** can be configured to collect light reflected by the object **110** and/or to transmit light towards the object **110**. Optics **205** can include e.g., mirror(s), a telescope, lenses, etc.

Optical subsystem **220** includes at least one amplifier **206** (optical amplifier). In some embodiments, optical subsystem **220** includes a plurality of optical amplifiers **206** arranged in series, or in parallel, or both in series and in parallel.

In a non-limitative example, optical amplifier **206** includes one or more Nd:YAG rod amplifiers (e.g., flash lamp or diode pumped amplifiers). This is however not limitative and other type(s) of optical amplifier(s) can be used, such as e.g., a laser pumped Brillouin amplifier (see “*Demonstration of 2.5 J, 10 Hz, nanosecond laser beam combination system based on non-collinear Brillouin amplification*” by CAN CUI et al, Vol. 26, No. 25 | 10 Dec 2018 | OPTICS EXPRESS 32717 – content of this document is incorporated herein by reference in its entirety).

Optical subsystem **220** can include various optical element(s) which can be used to direct/transmit the various laser beams that travel within the optical subsystem **220**, such as beam splitter(s), mirror(s), polarizer (see **241**), etc.

Optical subsystem **220** further includes a reorientation module **230** (reorientation module **230** is a possible embodiment of the reorientation module **130** of **Figs. 1** and **1B**).

The reorientation module **230** includes a phase conjugate mirror **211** (also called SBS phase conjugate mirror).

Principles and examples of phase conjugate mirrors are described e.g., in “*Stimulated Brillouin Review: Invented 50 Years Ago and Applied Today*”, Elsa Garmire. Content of this document is incorporated herein by reference in its entirety.

The reorientation module **230** further includes a medium **212** which enables (as mentioned above with reference to **Fig. 1**) Stimulated Scattering. Stimulated Scattering can include e.g., Stimulated Brillouin Scattering. Non-limitative examples of materials which can be used in medium **212** have been provided above.

The reorientation module **230** further includes one or more film polarizers (see e.g., film polarizers **241** and **242** in **Fig. 2**). The film polarizers **241** and **242** are arranged such that the medium **212** is located between the film polarizer **241** and the film polarizer **242**.

5 Film polarizer **241** lets the reflected probe pulse **113** (return pulse from the target **110** – note that the reflected probe pulse **113** can be amplified by the optical amplifier **206**, see reference **136** at the output of the optical amplifier **206**) reach the active medium **212** and then the phase conjugate mirror **211**, which is then reflected back towards the active medium **212** (see phase conjugated reflected probe pulse **237**).

10 Film polarizer **241** reflects the pump laser pulses **229** of the pump laser device **125** (these pump laser pulses are also represented as reference **131** in **Fig. 1**) towards the active medium **212**.

The interaction between at least one pump laser pulse **229** (e.g., the first) and the reflected probe pulse **237** within the medium **212** creates a Brillouin grating in the active medium **212**.

15 Once the Brillouin grating has been created, the subsequent pump laser pulses which reach the active medium **212** provide additional energy to the active medium **212** (this operation is also called “pumping”), while the Brillouin grating (previously created as mentioned above) still exists in the active medium **212**.

20 These pump laser pulses are reflected back from the medium **212** as reoriented pump laser pulses **239** that are transmitted, after their amplification, towards the object **110** (see amplified reoriented pump laser pulses **238**). According to some embodiments, film polarizer **242** can be set to deflect the pumping laser pulses (pumping laser pulses of the pump laser device **125** reflected by film polarizer **241**) out of the optical path (e.g. along a direction that does not coincide with the optical path along which the laser pulses propagate) to avoid saturation of the phase conjugate mirror **211** at times that the Brillouin grating does not exist in the medium **212** (this deflection of the pumping pulses out of the optical path is not represented in **Fig. 2**).

30 Optical subsystem **220** can include different and/or additional elements, which are not necessarily depicted in **Fig. 2** (such as amplifiers for additional amplification of the laser pulses transmitted by the pump laser device **125**).

For example, optical subsystem **220** can include in the optical channel Pockels’ cells and/or Faraday rotators as isolators for suppression of photon noise, which are not depicted in **Fig. 2**.

According to some embodiments, optical subsystem **220** can include power supplies, cooling devices, rugged optical benches, etc. (not depicted in **Fig. 2**).

The specific arrangement of the optical subsystem **220** and/or of the reorientation module **230** as described with reference to **Fig. 2** is not limitative, and other
5 architecture(s) (using additional and/or different components) can be used, depending on the needs.

Attention is now drawn to **Fig. 3**, which depicts a method of illuminating an object, using the optical subsystem **220**.

Timing of the various events as described hereinafter can be e.g., managed by
10 the PMC **126**.

The method can include triggering (operation **300**) the optical amplifiers **206**. In particular, the optical amplifiers **206** are generally triggered before the reflected probe **113** (see **Fig. 1**) is collected by the optics **205**.

In some embodiments, in order to be able to trigger in time the optical amplifiers
15 **206**, the method can include a preliminary estimation of the distance to the object **110**. In some embodiments, this can include measuring the round trip of at least one preliminary probe pulse transmitted by the probe laser device **115** (the round trip corresponds to the time for the preliminary probe pulse **109** to hit the object **110**, and to be collected by the optical subsystem **120/220** after its reflection). For a stationary
20 object, or a slow-moving object, this estimation can be performed once. For a fast-moving object, this estimation can be updated periodically. During this preliminary estimation, the preliminary probe pulse **109** is not used to trigger illumination of the object by a plurality of closely spaced in time laser pulses.

This enables determining arrival time of one or more subsequent probe pulses
25 reflected by the object **110**.

Triggering of the optical amplifiers **206** can include triggering of flash lamps or pumping laser diodes which are associated with the optical amplifiers **206**.

The method further includes transmitting (**310**) a probe pulse from the probe laser device **115** to the object **110**, which is reflected by the object **110** into a reflected
30 probe pulse **113**. The method includes collecting the reflected probe pulse **113** and amplifying (**320**) the probe reflected pulse **113** using the optical amplifiers **206** (see amplified probe reflected pulse **136**).

The amplified reflected probe pulse **136** is transmitted to the reorientation module **230**. In particular, the amplified reflected probe pulse **136** is transmitted to the

phase conjugate mirror **211**, which produces a phase conjugated reflected probe pulse **237** (operation **325**).

The phase conjugated reflected probe pulse **237** is transmitted to the medium **212**.

5 The method further includes transmitting (**330**) a sequence **131** of pump laser pulses from the pump laser device **125** to the medium **212**. The laser pulses of the sequence **131** are transmitted sequentially to the medium **212** (as visible e.g., in **Fig. 1C**).

10 The reflected probe phase conjugated pulse **237**, together with the first pump pulse transmitted by the pump laser device **125** to the medium **212**, create a Brillouin grating within the medium **212**.

By virtue of Stimulated Scattering within the medium **212**, each laser pulse of the sequence **131**, after it exits the reorientation module **230** as reoriented pump laser pulse **239** (operation **340**), acquires the phase properties of the phase conjugated reflected probe pulse **237**.

15 Principles of Stimulated Brillouin Scattering are described e.g., in “*Stimulated Brillouin scattering materials, experimental design and applications: A review*”, Z. Bai *et al.*, Optical Materials 75 (2018) 626-645. Content of this document is incorporated herein by reference in its entirety.

20 Each reoriented pump laser pulse **239** is then amplified (operation **340**) using the optical amplifiers **206** to obtain an amplified reoriented pump laser pulse **238** which is transmitted towards the object **110** using the optics **205**.

25 As explained hereinafter, the method can be repeated (see reference **350**). In particular, and as explained hereinafter with reference to **Fig. 4**, within a given time window (amplification cycle) in which the optical amplifiers **206** are operative to perform amplification, operations **310** to **340** can be repeated.

30 An optical path of the reflected probe pulse **113**, from its reflection by the object **110** up to the film polarizer **241** of the reorientation module **130**, is designated as a reflected probe path (see **151** in **Fig. 1**). As mentioned above, by virtue of phase conjugation, the reoriented pump laser pulse **239** (which is subsequently amplified into an amplified reoriented pump laser pulse **238**) exits the film polarizer **241** of the reorientation module along **230** along a path coinciding (in counter-direction) with the reflected probe path. **Fig. 2** represents a portion of each of these two paths as different for clarity reasons, but in practice, they do coincide.

According to some embodiments, the amplified reoriented pump laser pulses **238** are transmitted towards the same area at which the first probe pulse **109** illuminated the object **110**. A reorientation of the pump laser pulses of the sequence **131** of pump laser pulses towards the object **110** is therefore achieved.

5 In this embodiment, the optical amplifiers **206** are operative to amplify both the first reflected probe pulse **113** and each of the reoriented pump laser pulses **239** for illuminating the object **110**.

The ability of the optical amplifiers **206** to perform amplification is limited in time and follows a certain periodicity. Assume that a given time window in which the
10 optical amplifiers **206** can perform amplification has a time duration noted Δt_{amp} (amplification cycle). After this time window, a waiting time has to elapse until the optical amplifiers **206** are ready and can be used again for amplification. Δt_{amp} depends on various factors, such as power supply connected to the optical amplifiers **206**, cooling technology used for the optical amplifiers **206**, etc. Depending on the type of
15 amplifiers and their number, according to some embodiments, within a given time window (of length Δt_{amp}) of amplification, one or more sequences of amplified reoriented pump laser pulse **238** are transmitted towards the object **110**, wherein the total energy of these one or more sequences in the given time window is equal to or greater than 1 millijoule (e.g., between 1 millijoule and 5 Kilojoules). These values are not
20 limitative.

Attention is now drawn to the non-limitative example of **Fig. 4**.

The upper graph of **Fig. 4** depicts cycles of amplification of the optical amplifiers **206**.

During the first period of time Δt_{amp} , it is possible to perform three (this value
25 is not limitative and is provided as an example only) sequences S_1, S_2, S_3 of illumination of the object. In each sequence, a probe pulse (see **412**) is transmitted towards the object and a reflected probe pulse is collected. The reflected probe pulse is amplified and transmitted (see reference **438**) to the reorientation module **230**, which converts the reflected probe pulse into a phase conjugated reflected probe pulse. A sequence **431** of
30 closely spaced in time pump laser pulses is transmitted to the reorientation module **230**. Interaction of a pump laser pulse with the phase conjugated reflected probe pulse creates a Brillouin grating within the medium **212**.

The sequence of pump laser pulses is therefore reflected by the medium into a plurality of reoriented pump laser pulses, which are then amplified and transmitted towards the object **110**.

Similarly, during a second period of time Δt_{amp} , it is possible to perform three
5 (this value is not limitative and is provided as an example only) sequences S'_1 , S'_2 and S'_3 of illumination of the object.

For example, assume that Δt_{amp} is approximately equal to 250 μs (this is not limitative). In some embodiments, the frequency at which a new amplification cycle (see A1, A2, etc. in **Fig. 4**) of the optical amplifiers **206** is triggered is up to 1 KHz.

10 Δt_{amp} is much longer than the round-trip time of light from the system to the object **110**. Therefore, it is possible to illuminate the object **110** with three probe laser pulses **109**, spaced apart e.g., by a time interval Δt_8 of 60 μs . This value is not limitative, and in some embodiments the frequency at which the successive probe laser pulses **109** are transmitted towards the object **110** is up to tens of KHz (e.g., 30 KHz, this value
15 being not limitative). This frequency depends in particular on the distance from the system **100** to the object **110** and the depletion of the amplifiers.

The duration of each sequence **131/431** of pump laser pulses and the time interval between the pump laser pulses within the sequence depend in particular on physical properties of the medium **212**.

20 Various different parameters/patterns can be selected for illuminating the object, in particular the number of pump laser pulses of each sequence, the timing of the pump laser pulses, energy of the pump laser pulses, etc. Selection of these parameters/patterns can be performed e.g., to meet constraints provided e.g., by an operator.

25 For example, in a given sequence **131/431** of pump laser pulses, the number of pump laser pulses can be increased. As a consequence, a higher number of amplified reoriented pump laser pulses is transmitted towards the object. However, power density of each amplified reoriented pump laser pulse is reduced.

Total energy of the pump laser pulses of a given sequence of pump laser pulses
30 is limited e.g., by constraints of heating within the system.

Attention is now drawn to **Fig. 5A**.

According to some embodiments, the phase conjugated reflected probe pulse (represented as **537** in **Fig. 5A**) and the first pump laser pulse(s) **529** which reach the medium **112** or **212** propagate along the same optical path within the medium **112** or **212**

(in counter-(opposite) directions). In this configuration, the interaction in space and time between the phase conjugated reflected probe pulse and the first pump laser pulse(s) is the highest.

This is however not limitative. According to some embodiments, the reflected probe pulse is received with a given angle of incidence α_1 by the optical subsystem **120/220**. As a consequence, the phase conjugated reflected probe pulse **537** is received by the active medium **112** or **212** with this angle α_1 . Therefore, it can occur that the phase conjugated reflected probe pulse **537** and the first pump laser pulse(s) **529** which reach the medium **112** or **212** propagate along optical paths which are not parallel, as visible in **Fig. 5B**. The smaller the angle α_1 , the longer is the distance (and the longer the duration) along which there is an interaction (overlap) of the two pulses **537** and **529**.

Note that even in the configuration of **Fig. 5B**, the reoriented pump laser pulses generated using the grating present in the medium **212** acquire the phase properties of the reflected probe pulse. Therefore, when the reoriented pump laser pulses exit the film polarizer (see **241** in **Fig. 2**) of the reorientation module **130/230**, they propagate along the same path as the reflected probe pulse (along the reverse direction).

This is beneficial, as explained with reference to the non-limitative example of **Fig. 6**.

Assume that a first object **610** is illuminated by a first probe pulse **609**. As a consequence, a first reflected probe pulse **613** is generated, which is received by the optical subsystem **120** with a first incidence angle α_1 .

A path of the first reflected probe pulse **613** from its reflection by the object up to a film polarizer of the reorientation module **130** is designated as a first reflected probe path **651**.

As explained in the various embodiments above, the reorientation module **130** is operative to generate first reoriented pump laser pulses **638**, wherein each given reoriented pump laser pulse of the plurality of first reoriented pump laser pulses **638** exits the film polarizer (see **241** in **Fig. 2**) located at the entrance of the reorientation module **130** along a path coinciding (in counter-direction) with the first reflected probe path **651**, to illuminate the first object **610**.

Assume that a second object **610₁** is illuminated by a second probe pulse **609₁**. As a consequence, a second reflected probe pulse **613₁** is generated, which is received by the optical subsystem **120** with a second incidence angle α_2 different from α_1 .

A path of the second reflected probe pulse **613₁** from its reflection by the object up to a film polarizer of the reorientation module **130** is designated as a second reflected probe path **651₁**.

5 The reorientation module **130** is configured to generate second reoriented pump laser pulses **638₁**, wherein each given reoriented pump laser pulse of the plurality of second reoriented pump laser pulses **638₁** exits the film polarizer (see **241** in **Fig. 2**) located at the entrance of the reorientation module **130** along a path coinciding (in counter-direction) with the second reflected probe path **651₁**, to illuminate the second object **610₁**.

10 Note that the first object **610** and the second object **610₁** are illuminated by the optical subsystem one after the other, and not simultaneously.

In the example above, although the different objects have a different angular direction in the field of view of the optical subsystem **120**, it not required to modify the orientation of the optical subsystem in order to illuminate the first object and the second object using reoriented pump laser pulses. To the contrary, the system enables maintaining
15 a fixed orientation of the optical subsystem to illuminate the first object with the first reoriented pump laser pulses and the second object with the second reoriented pump laser pulses. Note that this does not prevent from changing the orientation of the optical subsystem, but this is not mandatory, as explained above.

The invention contemplates a computer program being readable by a computer
20 for executing at least part of one or more methods of the invention. The invention further contemplates a machine-readable memory tangibly embodying a program of instructions executable by the machine for executing at least part of one or more methods of the invention.

25 It is to be noted that the various features described in the various embodiments can be combined according to all possible technical combinations.

It is to be understood that the invention is not limited in its application to the details set forth in the description contained herein or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Hence, it is to be understood that the phraseology and terminology
30 employed herein are for the purpose of description and should not be regarded as limiting. As such, those skilled in the art will appreciate that the conception upon which this disclosure is based can readily be utilized as a basis for designing other structures, methods, and systems for carrying out the several purposes of the presently disclosed subject matter.

Those skilled in the art will readily appreciate that various modifications and changes can be applied to the embodiments of the invention as hereinbefore described without departing from its scope, defined in and by the appended claims.

CLAIMS

1. A system comprising:
 - a probe laser device configured to transmit a probe pulse towards an object,
5 thereby obtaining, after reflection of the probe pulse from a reflection area of the object, a reflected probe pulse,
 - an optical subsystem comprising a reorientation module, wherein the reorientation module comprises a film polarizer, a medium, a phase conjugate mirror, wherein a path of the reflected probe pulse from its reflection by the object
10 up to the film polarizer of the reorientation module is designated as a reflected probe path,
 - a pump laser device configured to transmit at least one sequence of pump laser pulses, wherein the pump laser pulses have a wavelength which match a wavelength of the probe pulse according to a matching criterion,
15 wherein the reorientation module is operative to:
 - use the phase conjugate mirror to generate a phase conjugated reflected probe pulse, which is phase conjugated with the reflected probe pulse,
 - receive, by the medium:
20 the phase conjugated reflected probe pulse, and
sequentially, a plurality of pump laser pulses of the sequence of pump laser pulses, thereby generating, in the medium, a grating,
 - reflect, using the grating in the medium, the plurality of pump laser
25 pulses as a plurality of reoriented pump laser pulses, wherein each given reoriented pump laser pulse of the plurality of reoriented pump laser pulses exits the film polarizer of the reorientation module along a path coinciding with the reflected probe path, to illuminate the object.
- 30 2. The system of claim 1, wherein an interaction of a given pump laser pulse received by the medium and the phase conjugated reflected probe pulse enables generation of the grating.

3. The system of claim 2, wherein, during said interaction, the given pump laser pulse received by the medium coincides in space and time with the phase conjugated reflected probe within the medium.
- 5 4. The system of claim 2 or of claim 3, wherein some pump laser pulses of the plurality of pump laser pulses received by the medium after said given pump laser pulse are operative to further sustain or enhance said grating in the medium.
- 10 5. The system of any one of claims 1 to 4, wherein the grating is a Brillouin grating in the medium.
- 15 6. The system of any one of claims 1 to 5, configured to, for a single probe pulse transmitted by the probe laser device towards the object and reflected by the object into a reflected probe pulse propagating along a reflected probe path up to the film polarizer of the reorientation module:
reflect, using the grating in the medium, the plurality of pump laser pulses as a plurality of reoriented pump laser pulses,
wherein each given reoriented pump laser pulse of the plurality of reoriented pump laser pulses exits the film polarizer of the reorientation module
20 along a path coinciding with the reflected probe path, to illuminate the object.
- 25 7. The system of any one of claims 1 to 6, wherein a time interval between transmission of at least some of successive reoriented pump laser pulses of the plurality of reoriented pump laser pulses towards the object is shorter than a round-trip time of the probe pulse.
- 30 8. The system of any one of claims 1 to 7, wherein a power per unit area of each pump laser pulse of the sequence of pump laser pulses is below a damage threshold for which one or more components of the reorientation module, or of the optical subsystem comprising the reorientation module and least one amplifier, is damaged.
9. The system of any one of claims 1 to 8, configured to amplify the plurality of reoriented pump laser pulses, wherein a power per unit area of each reoriented pump laser pulse after said amplification is below a damage threshold for which one or

more components of the reorientation module, or of the optical subsystem comprising the reorientation module and at least one optical amplifier, is damaged.

10. The system of any one of claims 1 to 9, configured to:
- 5 amplify each given reoriented pump laser pulse of the plurality of reoriented pump laser pulses before it exits the optical subsystem, and
- transmit the plurality of reoriented pump laser pulses after amplification towards the object to perform an interaction with the object.
- 10 11. The system of any of claims 1 to 10, wherein the object is a moving object.
12. The system of any of claims 1 to 11, wherein the sequence of pump laser pulses transmitted by the pump laser device comprises a plurality of pump laser pulses which are coherent according to a coherence criterion.
- 15 13. The system of any of claims 1 to 12, wherein the medium is operative to receive sequentially a plurality of pump laser pulses of the sequence of pump laser pulses, wherein a time interval between a reception of successive pump laser pulses of the plurality of pump laser pulses by the medium is shorter than a Brillouin Grating
- 20 lifetime of the medium.
14. The system of any of claims 1 to 13, wherein the medium enables Stimulated-Brillouin-Scattering, wherein the pump laser device is configured to transmit a given laser pulse of the sequence of pump laser pulses to the medium in a time interval that
- 25 is within a lifetime of a Brillouin grating generated by an interaction between a pump laser pulse and the phase conjugated reflected probe pulse.
15. The system of any of claims 1 to 14, wherein at least some of the pump laser pulses received by the medium are operative to sustain or enhance a Brillouin grating
- 30 previously generated in the medium.
16. The system of any of claims 1 to 15, comprising at least one optical amplifier configured to amplify the plurality of reoriented pump laser pulses received by the optical amplifier during an amplification cycle, wherein a total energy of the plurality

of reoriented pump laser pulses, after their amplification, for the amplification cycle is equal to or larger than 1 mJ.

17. The system of any of claims 1 to 16, wherein the optical subsystem comprises at least one optical amplifier configured to both:

amplify the reflected probe pulse, and
amplify the plurality of reoriented pump laser pulses.

18. The system of any of claims 1 to 17, configured to:
trigger an optical amplifier,
during a time-window in which the optical amplifier is operative to perform amplification, perform at least once operations including (1) to (9):

- (1) transmit, by the probe laser device, a probe pulse towards the object, thereby obtaining, after reflection of the probe pulse on a reflection area of the object, a reflected probe pulse,
- (2) receive, by the optical amplifier, the probe reflected pulse reflected by the object,
- (3) receive, by the phase conjugation mirror of the reorientation module, the probe reflected pulse after its amplification by the optical amplifier,
- (4) generate a phase conjugated reflected probe pulse which is phase conjugated with the reflected probe pulse,
- (5) receive, by the medium:
 - the phase conjugated reflected probe pulse, and
 - sequentially a plurality of pump laser pulses of the sequence of pump laser pulses,
- (6) create, in the medium, a Brillouin Grating, as a result of an interaction of the reflected phase conjugated probe laser pulse and a pump laser pulse of the sequence of pump laser pulses,
- (7) reflect, by the medium, the plurality of pump laser pulses as a plurality of reoriented pump laser pulses,
- (8) amplify, by the optical amplifier, the plurality of reoriented pump laser pulses, and

(9) use the plurality of reoriented pump laser pulses after their amplification to illuminate the object.

19. The system of any of claims 1 to 18, wherein the optical subsystem comprises at least one optical device configured to both:

receive the probe reflected pulse, and

transmit the plurality of reoriented pump laser pulses after amplification to illuminate the object.

20. The system of any of claims 1 to 19, wherein:

the probe laser device is configured to transmit a first probe pulse towards the object, thereby obtaining, after reflection of the first probe pulse on a first reflection area of the object, a first reflected probe pulse propagating along a first reflected probe path up to the film polarizer of the reorientation module,

the pump laser device is configured to transmit a first sequence of pump laser pulses,

wherein the reorientation module is operative to use the phase conjugate mirror to generate a first phase conjugated reflected probe pulse, which is phase conjugated with the first reflected probe pulse, receive sequentially a plurality of pump laser pulses of the first sequence of pump laser pulses, reflect, using the medium, the plurality of pump laser pulses as a plurality of first reoriented pump laser pulses exiting the film polarizer of the reorientation module along a path coinciding with the first reflected probe path, to illuminate the object,

the probe laser device is configured to transmit a second probe pulse towards the object, thereby obtaining, after reflection of the second probe pulse on a second reflection area of the object, a second reflected probe pulse propagating along a second reflected probe path up to the film polarizer of the reorientation module,

the pump laser device is configured to transmit a second sequence of pump laser pulses,

wherein the reorientation module is operative to use the phase conjugate mirror to generate a second phase conjugated reflected probe pulse, which is phase conjugated with the second reflected probe pulse, receive sequentially a plurality of pump laser pulses of the second sequence of pump laser pulses, reflect,

using the medium, the plurality of pump laser pulses as a plurality of second reoriented pump laser pulses exiting the film polarizer of the reorientation module along a path coinciding with the second reflected probe path, to illuminate the object,

5 wherein a time interval between reception of a last laser pulse of the first sequence of pump laser pulses by the reorientation module and reception of a first laser pulse of the second sequence of pump laser pulses by the reorientation module is longer than the Brillouin Grating lifetime of the medium.

10 21. The system of any of claims 1 to 20, wherein the medium is an active Stimulated Brillouin Scattering (SBS) medium.

22. The system of any of claims 1 to 21, wherein a frequency of transmission of the pump laser pulses within the sequence by the pump laser device is between 100 MHz and 2
15 GHz.

23. The system of any of claims 1 to 22, wherein the probe laser device is mounted on a first platform, and the pump laser device is mounted on a second platform which is distinct from the first platform.

20

24. The system of any one of claims 1 to 23, wherein the matching criterion is such that the absolute value of a spectral shift between the probe laser device and the pump laser device is smaller than half of the sum of:

25 a spectral width of the probe laser device, and
 a spectral width of the pump laser device.

25. The system of any of claims 1 to 24, wherein:

 the phase conjugate mirror comprises a medium comprising a first material,
 the medium of the reorientation module comprises a second material,
30 wherein the first material and the second material are identical.

26. The system of any of claims 1 to 25, wherein the medium of the reorientation module comprises:

a liquid, wherein the liquid optionally includes at least one of CBrCl₃, CHCl₃, GeCl₄, CCl₄, C₂Cl₄, SiCl₄, (CH₃)₃CCl, CS₂, TiCl₄, ICl, IF₅, C₆F₁₄, CSe₂, AsCl₃, Acetone, H₂O and Freon, or

a gaseous material, or

5 a solid crystal.

27. The system of any one of claims 1 to 26, configured to:

for a first object illuminated by a first probe pulse, a first reflected probe pulse is generated which it is received by the optical subsystem with a first incidence angle α_1 ,
10 wherein a path of the first reflected probe pulse from its reflection by the object up to a film polarizer of the reorientation module is designated as a first reflected probe path,

wherein the reorientation module is configured to generate first reoriented pump laser pulses, wherein each given reoriented pump laser pulse of the plurality of first reoriented pump laser pulses exits the film polarizer of the reorientation module along
15 a path coinciding with the first reflected probe path, to illuminate the first object,

for a second object illuminated by a second probe pulse, a second reflected probe pulse is generated, which it is received by the optical subsystem with a second incidence angle α_2 different from α_1 ,

wherein a path of the second reflected probe pulse from its reflection by the object
20 up to a film polarizer of the reorientation module is designated as a second reflected probe path,

wherein the reorientation module is configured to generate second reoriented pump laser pulses, wherein each given reoriented pump laser pulse of the plurality of second reoriented pump laser pulses exits the film polarizer of the reorientation
25 module along a path coinciding with the second reflected probe path, to illuminate the object,

wherein the system enables maintaining a fixed orientation of the optical subsystem to illuminate the first object with the first reoriented pump laser pulses and the second object with the second reoriented pump laser pulses.

30

28. A method comprising:

transmitting a probe pulse towards an object, thereby obtaining, after reflection of the probe pulse from a reflection area of the object, a reflected probe pulse,

receiving the reflected probe pulse by an optical subsystem comprising a reorientation module, wherein the reorientation module comprises a film polarizer, a medium, a phase conjugate mirror, wherein a path of the reflected probe pulse from its reflection by the object up to the film polarizer of the reorientation module is designated as a reflected probe path,

generating, by the reorientation module, a phase conjugated reflected probe pulse, which is phase conjugated with the reflected probe pulse,

receiving, by the medium:

the phase conjugated reflected probe pulse, and

sequentially, a plurality of pump laser pulses of a sequence of pump laser pulses generated by a pump laser device, thereby generating, in the medium, a grating,

wherein the pump laser pulses have a wavelength which match a wavelength of the probe pulse according to a matching criterion,

reflecting, using the grating in the medium, the plurality of pump laser pulses as a plurality of reoriented pump laser pulses, wherein each given reoriented pump laser pulse of the plurality of reoriented pump laser pulses exits the film polarizer of the reorientation module along a path coinciding with the reflected probe path, to illuminate the object.

20

29. The method of claim 28, wherein an interaction of a given pump laser pulse received by the medium and the phase conjugated reflected probe pulse enables generation of the grating.

25 30. The method of claim 29, wherein, during said interaction, the given pump laser pulse received by the medium coincides in space and time with the phase conjugated reflected probe within the medium.

30 31. The method of claim 29 or of claim 30, wherein some pump laser pulses of the plurality of pump laser pulses received by the medium after said given pump laser pulse further sustain or enhance said grating in the medium.

32. The method of any one of claims 28 to 31, wherein the grating is a Brillouin grating in the medium.

33. The method of any one of claims 28 to 32, comprising, for a single probe pulse transmitted by the probe laser device towards the object and reflected by the object into a reflected probe pulse propagating along a reflected probe path up to the film polarizer of the reorientation module:
- 5 reflecting, using the grating in the medium, the plurality of pump laser pulses as a plurality of reoriented pump laser pulses,
- wherein each given reoriented pump laser pulse of the plurality of reoriented pump laser pulses exits the film polarizer of the reorientation module
- 10 along a path coinciding with the reflected probe path, to illuminate the object.
34. The method of any one of claims 28 to 33, wherein a time interval between transmission of at least some of successive reoriented pump laser pulses of the plurality of reoriented pump laser pulses towards the object is shorter than a round-trip time of the probe pulse.
- 15
35. The method of any one of claims 28 to 34, wherein a power per unit area of each pump laser pulse of the sequence of pump laser pulses is below a damage threshold for which one or more components of the reorientation module, or of the optical subsystem comprising the reorientation module and least one amplifier, is damaged.
- 20
36. The method of any one of claims 28 to 35, comprising amplifying the plurality of reoriented pump laser pulses, wherein a power per unit area of each reoriented pump laser pulse after said amplification is below a damage threshold for which one or more components of the reorientation module, or of the optical subsystem comprising the reorientation module and at least one optical amplifier, is damaged.
- 25
37. The method of any one of claims 28 to 36, comprising amplifying each given reoriented pump laser pulse of the plurality of reoriented pump laser pulses before it exits the optical subsystem, and transmitting the plurality of reoriented pump laser pulses after amplification towards the object to perform an interaction with the object.
- 30
38. The method of any one of claims 28 to 37, wherein the object is a moving object.

39. The method of any one of claims 28 to 38, wherein the sequence of pump laser pulses transmitted by the pump laser device comprises a plurality of pump laser pulses which are coherent according to a coherence criterion.

5

40. The method of any one of claims 28 to 39, wherein the medium receives sequentially a plurality of pump laser pulses of the sequence of pump laser pulses, wherein a time interval between a reception of successive pump laser pulses of the plurality of pump laser pulses by the medium is shorter than a Brillouin Grating lifetime of the medium.

10

41. The method of any one of claims 28 to 40, wherein at least some of the pump laser pulses received by the medium sustain or enhance a Brillouin grating previously generated in the medium.

15 42. The method of any one of claims 28 to 41, using at least one optical amplifier to amplify the plurality of reoriented pump laser pulses received by the optical amplifier during an amplification cycle, wherein a total energy of the plurality of reoriented pump laser pulses, after their amplification, for the amplification cycle is equal to or larger than 1 mJ.

20

43. The method of any one of claims 28 to 42, comprising:

transmitting, by the probe laser device, a first probe pulse towards the object, thereby obtaining, after reflection of the first probe pulse on a first reflection area of the object, a first reflected probe pulse propagating along a first reflected probe path up to the film polarizer of the reorientation module,

25

transmitting, by the pump laser device, a first sequence of pump laser pulses,

wherein the reorientation module uses the phase conjugate mirror to generate a first phase conjugated reflected probe pulse, which is phase conjugated with the first reflected probe pulse, receives sequentially a plurality of pump laser pulses of the first sequence of pump laser pulses, reflects, using the medium, the plurality of pump laser pulses as a plurality of first reoriented pump laser pulses exiting the film polarizer of the reorientation module along a path coinciding with the first reflected probe path, to illuminate the object,

30

transmitting, by the probe laser device, a second probe pulse towards the object, thereby obtaining, after reflection of the second probe pulse on a second reflection area of the object, a second reflected probe pulse propagating along a second reflected probe path up to the film polarizer of the reorientation module,

5 transmitting, by the pump laser device, a second sequence of pump laser pulses,

wherein the reorientation module uses the phase conjugate mirror to generate a second phase conjugated reflected probe pulse, which is phase conjugated with the second reflected probe pulse, receives sequentially a plurality of pump laser pulses of the second sequence of pump laser pulses, reflects, using
10 the medium, the plurality of pump laser pulses as a plurality of second reoriented pump laser pulses exiting the film polarizer of the reorientation module along a path coinciding with the second reflected probe path, to illuminate the object,

wherein a time interval between reception of a last laser pulse of the first sequence of pump laser pulses by the reorientation module and reception of a first
15 laser pulse of the second sequence of pump laser pulses by the reorientation module is longer than the Brillouin Grating lifetime of the medium.

44. The method of any one of claims 28 to 43, wherein a frequency of transmission of the
20 pump laser pulses within the sequence by the pump laser device is between 100 MHz and 2 GHz.

45. The method of any one of claims 28 to 44, wherein the probe laser device is mounted on a first platform, and the pump laser device is mounted on a second platform which
25 is distinct from the first platform.

46. The method of any one of claims 28 to 45, wherein the matching criterion is such that the absolute value of a spectral shift between the probe laser device and the pump laser device is smaller than half of the sum of:

30 a spectral width of the probe laser device, and
a spectral width of the pump laser device.

47. The method of any one of claims 28 to 46. wherein:
the phase conjugate mirror comprises a medium comprising a first material,

the medium of the reorientation module comprises a second material,
wherein the first material and the second material are identical.

48. The method of any one of claims 28 to 47, wherein the medium of the reorientation
5 module comprises:
a liquid, wherein the liquid optionally includes at least one of CBrCl₃, CHCl₃,
GeCl₄, CCl₄, C₂Cl₄, SiCl₄, (CH₃)₃CCl, CS₂, TiCl₄, ICl, IF₅, C₆F₁₄, CSe₂, AsCl₃,
Acetone, H₂O and Freon, or
a gaseous material, or
10 a solid crystal.
49. The method of any one of claims 28 to 48, comprising:
for a first object illuminated by a first probe pulse, a first reflected probe pulse is
generated which it is received by the optical subsystem with a first incidence angle α_1 ,
15 wherein a path of the first reflected probe pulse from its reflection by the object up to
a film polarizer of the reorientation module is designated as a first reflected probe path,
wherein the reorientation module generates first reoriented pump laser pulses,
wherein each given reoriented pump laser pulse of the plurality of first reoriented
pump laser pulses exits the film polarizer of the reorientation module along a path
20 coinciding with the first reflected probe path, to illuminate the first object,
for a second object illuminated by a second probe pulse, a second reflected probe
pulse is generated, which it is received by the optical subsystem with a second
incidence angle α_2 different from α_1 ,
wherein a path of the second reflected probe pulse from its reflection by the object
25 up to a film polarizer of the reorientation module is designated as a second reflected
probe path,
wherein the reorientation module generates second reoriented pump laser pulses,
wherein each given reoriented pump laser pulse of the plurality of second reoriented
pump laser pulses exits the film polarizer of the reorientation module along a path
30 coinciding with the second reflected probe path, to illuminate the object,
wherein the method comprises maintaining a fixed orientation of the optical
subsystem to illuminate the first object with the first reoriented pump laser pulses and
the second object with the second reoriented pump laser pulses.

50. The method of any one of claims 28 to 49, comprising measuring a round trip time of at least one preliminary probe pulse transmitted towards the object to determine a distance to the object, thereby enabling determining arrival time of one or more subsequent probe pulses reflected by the object.

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