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(71) Applicant: MKS INSTRUMENTS [US/US]; 2 Tech Drive,

Suite 201, North Andover, MA 01810 (US).

(72) Inventors: KIRKHAM, Kevin; 134 South State Street,

Richmond, UT 84333 (US). FERREE, Kenneth; 3266

North 1730 East, North Logan, UT 84341 (US).

(74) Agent: SWIENTON, Brian; Newport Corporation, 1791

Deere Avenue, Irvine, CA 92606 (US).

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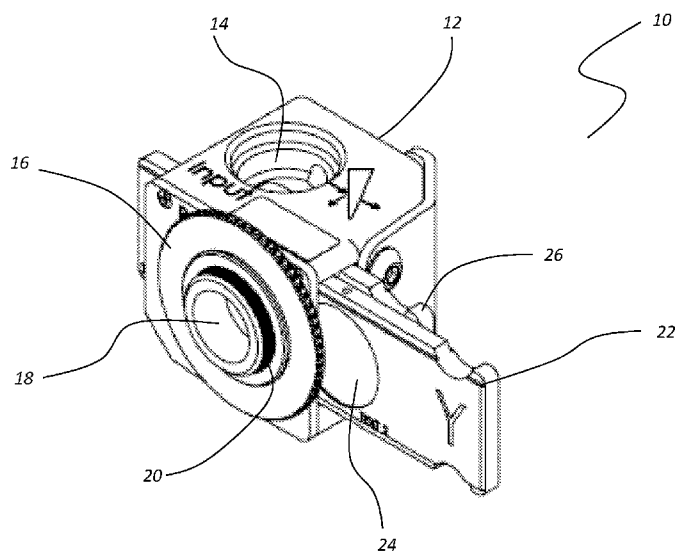
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(54) Title: NANO-TEXTURED ATTENUATOR FOR USE WITH LASER BEAM PROFILING AND LASER BEAM CHARACTERIZATION SYSTEMS AND METHOD OF USE

Fig. 1



(57) Abstract: The present application discloses a nano-textured attenuator which includes a body defining in the aperture, a measurement aperture, at least one beam dump aperture, at least one coupling fixture may be formed on or positioned on the body, a first nano-textured beamsplitter is positioned within the body and configured to transmit 85% to 99.9999% of an input signal therethrough while reflecting 0.0001% to form at least one partially attenuated signal, at least a second nano-textured beamsplitter is positioned within the body and is configured to transmit 85% to 99.9999% of an input signal therethrough while reflecting 0.0001% to form at least one attenuated measurement signal, and at least one camera in communication with the measurement aperture be configured to measure at least one optical characteristic of the attenuated measurement signal.

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**Nano-Textured Attenuator for Use with Laser Beam Profiling and Laser
Beam Characterization Systems and Method of Use**

Cross-Reference to Related Applications

[0001] The present application claims priority to United States Provisional Patent Application Serial Number 62/865,160, filed on June 22, 2019 and entitled “Nano-Textured Attenuator for Use with Laser Beam Profiling and Laser Beam Characterization Systems and Methods of Use,” the entire contents of which are incorporated by reference herein.

Background

[0002] Increasingly, laser systems offering high output powers from about 500 W to 5000 W or more are being implemented in various fields. Often, laser measurement is used to monitor the performance of laser systems. Typically, these measurements, which include beam profiling, spectral observations, temporal observations, or intensity observations are performed by creating a sample of the intensity map at a plane transverse to the propagation axis of the laser beam.

[0003] While laser output measurements including beam profiling and laser beam characterization has proven useful in monitoring the performance of low power laser systems, a number of shortcomings have been identified when these systems are used to monitor the performance of high power laser systems. For example, 2-D matrix sensors such as CCD devices, CMOS devices, pyroelectric devices, and/or InGaAs devices are saturated at fluences several magnitudes less than the fluences of the output signals of the high-power laser systems under test. As a result, presently available beam profiling systems, high laser power measurement systems, and similar laser power measurement systems utilize one or more thin-film coated attenuators to reduce output signal fluence. Unfortunately, the power densities of many high-power laser system output signals exceed the damage threshold of thin-film reflective coatings used in making thin-film coated attenuators. As such, the performance of thin-film coated attenuators tends to degrade thereby permitting potentially damaging fluence to be incident

on sensitive cameras and sensors used in laser beam profiling systems and/or measurement systems.

[0004] In light of the foregoing, there is an ongoing need for durable attenuator devices for use in high laser power beam profiling systems and laser beam characterization systems.

Summary

[0005] The present application discloses various embodiments of a nano-textured attenuator for use with a variety of laser beam profiling systems, laser power measurement systems, and various other systems configured to measure or otherwise characterize laser output signals or beams. In one embodiment, the nano-textured attenuators disclosed herein are well-suited for use with laser outputs in excess of about 200 W to 5000 W (i.e. high power) or more, although those skilled in the art will appreciate that the various embodiments of the nano-textured attenuator disclosed herein may be used at any variety of laser powers.

[0006] In one embodiment, the nano-textured attenuator includes a body defining in the aperture, a measurement aperture, at least one beam dump aperture. At least one coupling fixture may be formed on or positioned on the body. In one embodiment, the coupling fixture is positioned proximate to the measurement aperture. A first nano-textured beamsplitter is positioned within the body. During use, the first nano-textured beamsplitter is configured to transmit 85% to 99.9999% of an input signal therethrough while reflecting 0.0001% to form at least one partially attenuated signal. At least a second nano-textured beamsplitter is positioned within the body. During use, the second nano-textured beamsplitter is configured to transmit 85% to 99.9999% of an input signal therethrough while reflecting 0.0001% to form at least one attenuated measurement signal. At least one camera communication with the measurement aperture be configured to measure at least one optical characteristic of the attenuated measurement signal.

[0007] In another embodiment, the nano-textured attenuator includes a body defining in the aperture, a measurement aperture, at least one beam dump aperture. At least one coupling fixture may be formed on or positioned on the body. In one embodiment, the coupling fixture is positioned proximate to the measurement aperture. A nano-textured beamsplitter is positioned within the body. During use, the nano-textured beamsplitter is configured to

transmit 85% to 99.9999% of an input signal therethrough while reflecting 0.0001% to form at least one partially attenuated signal. A at least one nano-textured optical component is positioned within the body. During use, the nano-textured optical component is configured to transmit 85% to 99.9999% of the partially attenuated signal therethrough while reflecting 0.0001% to form at least one attenuated measurement signal. At least one camera communication with the measurement aperture be configured to measure at least one optical characteristic of the attenuated measurement signal.

[0008] In still another embodiment, the present application discloses a nano-textured attenuator which includes a body defining in in the aperture, a measurement aperture, at least one beam dump aperture. At least one coupling fixture may be formed on or positioned on the body. In one embodiment, the coupling fixture is positioned proximate to the measurement aperture. A first nano-textured beamsplitter is positioned within the body. During use, the first nano-textured beamsplitter is configured to transmit 85% to 99.9999% of an input signal therethrough while reflecting 0.0001% to form at least one partially attenuated signal. At least a second nano-textured beamsplitter is positioned within the body. During use, the second nano-textured beamsplitter is configured to transmit 85% to 99.9999% of an input signal therethrough while reflecting 0.0001% to form at least one attenuated measurement signal. At least one attenuator/filter body having at least filter coupled thereto may be selectively positionable within the optical beam path of the attenuated measurement signal. Thereafter, at least one camera communication with the measurement aperture be configured to measure at least one optical characteristic of the attenuated measurement signal

[0009] the present application also discloses a method of measuring high laser power optical signal which includes directing at least one input laser signal to a first nano-textured beamsplitter. A portion of the input laser signal is reflected with the first nano-textured beamsplitter to form at least one partially attenuated signal. The partially attenuated signal has 0.0001% to 15% of the power of the laser input signal while transmitting 85% to 99.9999% of the laser input signal through the first nano-textured beamsplitter. Thereafter, a portion of the partially attenuated signal from the first nano-textured beamsplitter is reflected by at least a second nano-textured beamsplitter to form at least one attenuated measurement signal. The

attenuated measurement signal has 0.0001% to 15% of the power of the partially attenuated signal while transmitting 85% to 99.9999% of the laser input signal through the second nano-textured beamsplitter. Finally, at least one optical characteristic of the attenuated measurement signal may be measured with at least one sensor system.

13. The method of claim 12 further comprising selectively inserting at least one attenuator/filter body between at least one of the first nano-textured beamsplitter, the second nano-textured beamsplitter, and the at least one sensor system.

[0010]

[0011] Other features and advantages of the nano-textured attenuator for use with laser beam profiling and laser beam characterization systems as described herein will become more apparent from a consideration of the following detailed description.

Brief Description of the Drawings

[0012] The novel aspects of the embodiments of a nano-textured attenuator for use with laser beam profiling laser beam characterization systems as disclosed herein will be more apparent by consideration of the following figures, wherein:

[0013] Figure 1 shows an elevated perspective view of an embodiment of a nano-textured attenuator for use with laser beam profiling and laser beam characterization systems;

[0014] Figure 2 shows alternate elevated perspective view of an embodiment of the nano-textured attenuator for use with laser beam profiling and laser beam characterization systems;

[0015] Figure 3 shows a planar side view of an embodiment of a nano-textured attenuator having a camera system coupled thereto for use with laser beam profiling and laser beam characterization systems;

[0016] Figure 4 shows an elevated perspective view of an embodiment of a nano-textured attenuator having a camera system coupled thereto for use with laser beam profiling and laser beam characterization systems;

[0017] Figure 5 shows a schematic diagram of the internal components of an embodiment of a nano-textured attenuator for use with laser beam profiling and laser beam characterization systems; and

[0018] Figure 6 shows a schematic diagram of the internal components of another embodiment of a nano-textured attenuator for use with laser beam profiling and laser beam characterization systems.

Detailed Description

[0019] The present application discloses various embodiments of a nano-textured attenuator for use with a variety of laser beam profiling systems, laser power measurement systems, and various other systems configured to measure or otherwise characterize laser output signals or beams. In one embodiment, the nano-textured attenuator disclosed herein is well-suited for use with laser outputs in excess of about 200 W to 5000 W (i.e. high power) or more, although those skilled in the art will appreciate that the various embodiments of the nano-textured attenuator disclosed herein may be used at any variety of laser powers. Further, those skilled in the art will appreciate that the physical dimensions and configuration of the embodiments of the nano-textured attenuator disclosed herein are intended to illustrate the operation of the nano-textured attenuator and are not intended to limit the components and characteristics of the nano-textured attenuator to those embodiments disclosed.

[0020] Figures 1-4 show various views of an embodiment of a nano-textured attenuator for use with laser beam profiling systems, laser measurements systems, and similar laser beam characterization systems. In the illustrated embodiment, the nano-textured attenuator 10 includes a body 12 having at least one input aperture 14 formed therein. In the illustrated embodiment, a single input aperture 14 is formed in the body 12, although those skilled in the art will appreciate that any number of input apertures 14 may be formed on the body 12. Further, the input aperture 14 may be formed on any surface of the body 12. Optionally, the input aperture 14 may be formed having any variety of transverse dimensions, shapes, or configurations. Further, the input aperture 14 may include one or more windows or protective elements enclosing the input aperture 14. Optionally, input aperture 14 not include one or more protective windows.

[0021] Referring again to Figures 1-4, at least one coupling fixture 16 may be formed on or couple to the body 12. In the illustrated embodiment, the coupling fixture 16 defines at least one profiling and/or measurement aperture or characterization aperture 18 (hereinafter

measurement aperture 18) therein. Like the input aperture 14, the measurement aperture 18 may or may not include at least one protective window. Optionally, any number of measurement apertures 18 may be formed on or positioned proximate to the coupling fixture 16. Further, the coupling fixture 16 may include at least one coupling member or feature 20 thereby permitting one or more cameras, sensors, characterization systems, or similar devices to be coupled to the body 12 of the nano-textured attenuator 10. In one embodiment, the coupling member 20 comprises one or more thread features permitting one or more cameras, sensors, characterization systems, or similar devices to be selectively coupled to and/or detached from the body 12 of the nano-textured attenuator 10 and threaded relation. Those skilled in the art will appreciate that any variety of coupling members 20 or similar coupling features may be used to selectively couple and/or detach one or more cameras, sensors, characterization systems, or similar devices to the body 12 of the nano-textured attenuator 10 disclosed herein. In another embodiment, the coupling member 20 may be configured to couple one or more fiber-optic devices or other systems to the body 12. Optionally, the coupling feature 16 may be configured to have one or more cameras, sensors, characterization systems, or similar devices non-detachably coupled to the body 12. For example, at least one camera, sensor, characterization system, or similar device may be integrally formed on or within the body 12 of the nano-textured attenuator 10. As such, the coupling fixture 16 need not include a coupling member 20.

[0022] As shown in Figures 1-4, the nano-textured attenuator 10 may include one or more attenuator or filter bodies configured to be selectively inserted into and withdrawn from at least one beam path formed within the body 12. As shown, the attenuator filter bodies may be positioned between the input aperture 14 and the measurement aperture 18. In the illustrated embodiment, a first attenuator/filter body 22 and a second attenuator/filter body 26 may be selectively inserted into withdrawn from the body 12. Those skilled in the art will appreciate the any number of attenuator/filter bodies may be used in the embodiments of the nano-textured attenuator 10 disclosed herein. As shown in Figure 1, the first attenuator/filter body 22 includes at least a first filter receiver 24 form thereon and configured to receive and retain at least a first filter or optical component therein. Similarly, as shown in Figure 2, at least a second filter

receiver 28 may be formed in or coupled to the second attenuator/filter body 26. Like the first filter receiver 24, the second filter receiver 28 may be configured to receive and retain at least one filter or optical component therein. For example, the first filter receiver 24 and/or the second filter receiver 20 may be configured to receive and retain at least one attenuator, optical component, filter, polarizer, wave plate, diffuser, or similar device therein. For example, in one embodiment at least one of the first filter 24 and the second filter 28 may comprise at least one thin film coated optical filter therein. During use, the first attenuator/filter body 22 and/or the second attenuator/filter body 26 may be selectively inserted into or withdrawn from at least one optical pathway formed within the body 12. As such, filters or optical components retained by the first attenuator/filter body 22 and/or the second attenuator/filter body 26 may be inserted into withdrawn from at least one optical pathway formed within the body 12. In the illustrated embodiment, the first attenuator/filter body 22 and the second attenuator/filter body 26 may be manually actuated. Optionally, at least one of the first attenuator/filter body 22 and the second attenuator/filter body 26 may include one or more mechanical actuators permitting autonomous insertion and withdrawal of at least one of the first attenuator/filter body 22 and the second attenuator/filter body 26 from the body 12.

[0023] As shown in Figures 2-4, one or more beam dump passages or apertures may be formed on the body 12. For example, as shown in Figures 2 and 4, a first beam dump aperture 30 may be formed on the body 12, while Figure 3b shows a second beam dump aperture 32 formed on the body 12. As such, in the embodiments shown in Figures 2-4, the nano-textured attenuator 10 includes a first beam dump aperture 30 and at least a second beam dump aperture 32 formed on the body 12. Those skilled in the art will appreciate that any number of beam dump apertures may be formed on the body 12 of the nano-textured attenuator 10. During use, the first beam dump aperture 30 and the second beam dump aperture 32 may be configured to permit at least one output beam to be transmitted or emitted therefrom. As such, the first beam dump aperture 30 may be configured to be positioned proximate to at least one beam dump (not shown). Similarly, the second beam dump aperture 32 may likewise be configured to be positioned proximate to at least a second beam dump (not shown). In another embodiment,

at least one of the first beam dump aperture 30 and the second beam dump aperture 32 may be configured to transmit or otherwise emit at least one output beam from the body 12.

[0024] As described above, the nano-textured attenuator 10 may be configured to be coupled to and/or be positioned proximate to at least one camera, sensor, characterization system, or similar device. Figures 3a, 3b, and 4 show various views of an embodiment of a nano-textured attenuator 10 having one or more cameras, sensors, characterization systems, or similar devices 40 coupled thereto. As shown, in one embodiment, the camera 40 includes a first camera body 42 and a second camera body 44. At least one camera coupling device or system 46 may be coupled to or formed on at least one of the first camera body 42 in the second camera body 44. During use, the camera coupling device 46 may be configured to selectively engage and be retained by the coupling member 20 formed on the coupling fixture 16 of the body 12 (see Figure 1). Optionally, the camera coupling device 46 may be configured to selectively engage in coupled to a portion of the body 12 such that at least a portion of the camera 40 is in communication with the measurement aperture 18 formed in the body 12. Optionally, the camera 40 need not be detachable from the body 12. In the illustrated embodiment, the camera 40 includes at least one output and/or data coupler 48, thereby permitting measurement or characterization data recorded by the camera 40 to be provided to at least one external processor (not shown). Those skilled in the art will appreciate that any variety of camera systems or devices may be used with a couple to the body 12 of the nano-textured attenuator 10. Exemplary camera systems or devices include, without limitation, 2-D matrix sensors, CCD devices, CMOS devices, InGaAs devices, polarization sensor or measuring devices, spectral or temporal measurement devices, power meters, and the like.

[0025] Figure 5 shows the internal components of an embodiment of a nano-textured attenuator. As shown in Figure 5, a first nano-textured beamsplitter or prism 50 and at least a second nano-textured beamsplitter 52 may be positioned within the body 12, although those skilled in the art will appreciate that any number of nano-textured beamsplitters, prisms, or alternate nano-textured optical elements may be positioned within the body 12. In one embodiment, at least one of the first nano-textured beamsplitter 50 and the second nano-textured beamsplitter 52 may be positioned on at least one selectively adjustable optical

mount. As such, the position and/or orientation of at least one of the first nano-textured beamsplitter 50 and/or the second nano-textured beamsplitter 52 may be selectively adjusted by a user. Optionally, at least one of the first nano-textured beamsplitter 50 and the second nano-textured beamsplitter 52 may be positioned on fixed optical mounts such that the position and/or orientation of the first nano-textured beamsplitter 50 and/or the second nano-textured beamsplitter 52 is fixed.

[0026] As shown in Figure 5, during use an input beam 70 may be directed into the body 12 of the nano-textured attenuator 10 via the input aperture 14. The input beam 70 may be incident on a portion of the first nano-textured beamsplitter 50 positioned within the body 12. As a result, a portion of the input beam 70 may be reflected or otherwise directed by the first nano-textured beamsplitter 50 to form a partially attenuated beam 74 which is directed within the body 12. In one embodiment, at least one of the first and second nano-textured beamsplitters 50, 52 are manufactured from Corning™ 7980 Grade 0F UV fused silica having undergone one or more nano-texturing processes, although those skilled in the art will appreciate that any variety of substrates may be used to form the of the first and second nano-textured beamsplitters 50, 52. Optionally, one or more thin film coatings may also be applied to at least one of the first and second nano-textured beamsplitters 50, 52. Exemplary thin film coatings include AR coatings and the like. Further, a portion of the input beam 70 is transmitted through the first nano-textured beamsplitter 50 to form a first output beam 72. In the illustrated embodiment, the first output beam 72 may be emitted from the body 12 via the first beam dump aperture 30. In one embodiment, the first nano-textured beamsplitter 50 is configured to transmit approximately 95% to about 99.9999% the power and/or fluence of the input beam 70 there through. As such, the first output beam 72 encompasses approximately 95% to about 99.9999% the power and/or fluence of the input beam 70, which may be directed to one or more external beam dumps (not shown). As such, the partially attenuated beam 74 traversing through the body 12 encompasses approximately 5% to about 0.1% or less of the power and/or fluence of the input beam 70.

[0027] Referring again to Figure 5, at least a portion of the partially attenuated beam 74 may be incident on a portion of the second nano-textured beamsplitter 52 positioned within the

body 12. Like the first nano-textured beamsplitter 50, the second nano-textured beamsplitter 52 is configured to transmit approximately 95% to about 99.9999% the power and/or fluence of an incident optical signal there through. As such, approximately 95% to about 99.9999% the power and/or fluence of the partially attenuated beam 74 incident on the second nano-textured beamsplitter 52 is transmitted there through to form a second output beam 76. In one embodiment, the second output beam 76 is directed through the second beam dump aperture 32 to one or more external beam dumps (not shown). Further, approximately 5% to about point one percent 0.1 or less of the power and/or fluence of the partially attenuated beam 74 may be directed by the second nano-textured beamsplitter 52 to form at least one attenuated measurement beam 78 directed to the camera/sensor 40 coupled to the body 12. In one embodiment, the attenuated measurement beam 78 encompasses approximately .25% to about 0.001 % or less of the power and/or fluence of the input beam 70. In another embodiment, the attenuated measurement beam 78 encompasses approximately .000001% or less of the power and/or fluence of the input beam 70. Those skilled in your will appreciate that the transmission characteristics of the first nano-textured beamsplitter 50 and second nano-textured beamsplitter 52 may range from about 85% to about 99.99999% transmission of an incident optical signal. As such, an optical signal reflected by at least one of the first nano-textured beamsplitter 50 and the second nano-textured beamsplitter 52 may contain about 15% to about .00001% or less of the power and/or fluence of an incident optical signal.

[0028] As shown in Figure 5, as stated above, the attenuated measurement beam 78 may be directed to the camera/sensor 40 coupled to the body 12. Optionally, the attenuated measurement beam 78 may traverse through at least one of the first attenuator/filter body 22 in/or the second attenuator/filter body 26 to further attenuate or otherwise filter the attenuated measurement beam 78.

[0029] Optionally, the nano-textured attenuator 10 may include a single nano-textured beamsplitter, prism, or optical element within the body 12. For example, Figure 6 shows an alternate embodiment of a nano-textured attenuator 10 having a single nano-textured beamsplitter 50 within the body 12. Like the previous embodiment, the first nano-textured beamsplitter 50 is configured to transmit approximately 95% to about 99.9999% the power

and/or fluence of the input beam 70 there through. As such, the first output beam 72 encompasses approximately 95% to about 99.9999% the power and/or fluence of the input beam 70, which may be directed to one or more external beam dumps (not shown). As such, the partially attenuated beam 74 traversing through the body 12 encompasses approximately 5% to about 0.1% or less of the power and/or fluence of the input beam 70.

[0030] Referring again to Figure 6, at least a portion of the partially attenuated beam 74 may be incident on a portion of at least one optical component 54 positioned within the body 12. In one embodiment, the optical component 54 comprises one or more lenses, beamsplitters, wave plates, polarizers, and the like. Further, the optical component 54 may include one or more optical coatings 56 applied thereto. Exemplary optical coatings 56 include, without limitation, anti-reflection (AR) coatings, thin-film coatings, and the like. Optionally, the optical component 54 may comprise a nano-textured substrate, a grating, or a similar optical component. The optical component 54 may be configured to transmit approximately 95% to about ninety-nine point nine percent 99.9999% the power and/or fluence of an incident optical signal there through. As such, approximately 95% to about 99.9999% the power and/or fluence of the partially attenuated beam 74 incident on the optical component 54 is transmitted there through to form a second output beam 76. In one embodiment, the second output beam 76 is directed through the second beam dump aperture 32 to one or more external beam dumps (not shown). Further, approximately 5% to about 0.1% or less of the power and/or fluence of the partially attenuated beam 74 may be directed by the optical component 54 to form an attenuated profiling/measurement beam 78 which may be directed to the camera/sensor 40 coupled to the body 12. In one embodiment, the attenuated measurement beam 78 encompasses approximately .25% to about 0.001 % or less of the power and/or fluence of the input beam 70. In another embodiment, the attenuated measurement beam 76 encompasses approximately .000001% or less of the power and/or fluence of the input beam 70. Those skilled in your will appreciate that the transmission characteristics of the first nano-textured beamsplitter 50 and the optical component 54 may range from about 85% to about 99.99999% transmission of an incident optical signal. As such, and optical signal reflected by at least one of

the first nano-textured beamsplitter 50 and the optical 54 may contain about 15% to about .00001% or less of the power and/or fluence of an incident optical signal.

[0031] It is appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and described hereinabove. Rather the scope of the present invention includes both combinations and subcombinations of various features described hereinabove as well as variations and modifications thereto which would occur to a person of skill in the art upon reading the above description and which are not in the prior art.

What is claimed:

1. A nano-textured attenuator for use in laser beam characterization systems, comprising:
 - a body defining at least one input aperture, at least one measurement aperture, and at least one beam dump aperture;
 - at least one coupling fixture positioned on the body, the coupling fixture positioned proximate to the at least one measurement aperture;
 - a first nano-textured beamsplitter positioned within the body, the first nano-textured beamsplitter configured to transmit 85% to 99.9999% of an input signal therethrough and reflect 15% to 0.0001% of the input signal to form at least one partially attenuated signal;
 - at least a second nano-textured beamsplitter positioned within the body, the second nano-textured beamsplitter configured to transmit 85% to 99.9999% of the partially attenuated signal therethrough and reflect 15% to 0.0001% of the partially attenuated signal to form at least one attenuated measurement signal; and
 - at least one camera system coupled to the body, the at least one camera system configured to receive the at least one attenuated measurement signal and measure at least one characteristics of the at least one attenuated measurement signal.
2. The nano-textured attenuator of claim 1 further comprising at least one attenuator/filter body configured to receive and retain at least one attenuator or optical filter therein, the at least one attenuator/filter body configured to be selectively positionable within the body between at least one input aperture and at least one measurement aperture.
3. The nano-textured attenuator of claim 2 further comprising:
 - a first attenuator/filter body having at least a first filter coupled thereto, the first attenuator/filter body selectively positionable within an optical beam path of the at least one attenuated measurement signal; and
 - a second attenuator/filter body having at least a second filter coupled thereto, the second attenuator/filter body selectively positionable within an optical beam path of the at least one attenuated measurement signal.

4. The nano-textured attenuator of claim 1 further comprising at least one selectively movable mount configured to adjustably support at least one of the first nano-textured beamsplitter and the second nano-textured beamsplitter.
5. The nano-textured attenuator of claim 1 wherein at least one of the at least one input aperture, at least one measurement aperture, and at least one beam dump aperture includes protective window.
6. A nano-textured attenuator for use in laser beam characterization systems, comprising:
 - a body defining at least one input aperture, at least one measurement aperture, and at least one beam dump aperture;
 - at least one coupling fixture positioned on the body, the coupling fixture positioned proximate to the at least one measurement aperture;
 - a nano-textured beamsplitter positioned within the body, the nano-textured beamsplitter configured to transmit 85% to 99.9999% of an input signal therethrough and reflect 15% to 0.0001% of the input signal to form at least one partially attenuated signal;
 - at least one nano-textured optical element positioned within the body, the at least one nano-textured optical element configured to transmit 85% to 99.9999% of the partially attenuated signal therethrough and reflect 15% to 0.0001% of the partially attenuated signal to form at least one attenuated measurement signal; and
 - at least one camera system coupled to the body, the at least one camera system configured to receive the at least one attenuated measurement signal and measure at least one characteristics of the at least one attenuated measurement signal.
7. The nano-textured attenuator of claim 6 further comprising at least one attenuator/filter body configured to receive and retain at least one attenuator or optical filter therein, the at least one attenuator/filter body configured to be selectively positionable within the body between at least one input aperture and at least one measurement aperture.
8. The nano-textured attenuator of claim 7 further comprising:
 - a first attenuator/filter body having at least a first filter coupled thereto, the first attenuator/filter body selectively positionable within an optical beam path of the at least one attenuated measurement signal; and

a second attenuator/filter body having at least a second filter coupled thereto, the second attenuator/filter body selectively positionable within an optical beam path of the at least one attenuated measurement signal.

9. The nano-textured attenuator of claim 6 further comprising at least one selectively movable mount configured to adjustably support at least one of the nano-textured beamsplitter and the at least one nano-textured optical element.

10. The nano-textured attenuator of claim 6 wherein at least one of the at least one input aperture, at least one measurement aperture, and at least one beam dump aperture includes protective window.

11. A nano-textured attenuator for use in laser beam characterization systems, comprising:
a body defining at least one input aperture, at least one measurement aperture, and at least one beam dump aperture;

at least one coupling fixture positioned on the body, the coupling fixture positioned proximate to the at least one measurement aperture;

a first nano-textured beamsplitter positioned within the body, the first nano-textured beamsplitter configured to transmit 85% to 99.9999% of an input signal therethrough and reflect 15% to 0.0001% of the input signal to form at least one partially attenuated signal;

at least a second nano-textured beamsplitter positioned within the body, the second nano-textured beamsplitter configured to transmit 85% to 99.9999% of the partially attenuated signal therethrough and reflect 15% to 0.0001% of the partially attenuated signal to form at least one attenuated measurement signal;

at least one camera system coupled to the body, the at least one camera system configured to receive the at least one attenuated measurement signal and measure at least one characteristics of the at least one attenuated measurement signal;

a first attenuator/filter body having at least a first filter coupled thereto, the first attenuator/filter body selectively positionable within an optical beam path of the at least one attenuated measurement signal; and

a second attenuator/filter body having at least a second filter coupled thereto, the second attenuator/filter body selectively positionable within an optical beam path of the at least one attenuated measurement signal.

12. A method of measuring high laser power optical signal comprising:

directing at least one input laser signal to a first nano-textured beamsplitter;

reflecting a portion of the input laser signal with the first nano-textured beamsplitter to form at least one partially attenuated signal, the at least one partially attenuated signal having 0.0001% to 15% of the power of the laser input signal while transmitting 85% to 99.9999% of the laser input signal through the first nano-textured beamsplitter;

reflecting a portion of the at least one partially attenuated signal from the first nano-textured beamsplitter with at least a second nano-textured beamsplitter to form at least one attenuated measurement signal, the at least one attenuated measurement signal having 0.0001% to 15% of the power of the at least one partially attenuated signal while transmitting 85% to 99.9999% of the laser input signal through the second nano-textured beamsplitter; and

measuring at least one optical characteristic of the at least one attenuated measurement signal with at least one sensor system.

13. The method of claim 12 further comprising selectively inserting at least one attenuator/filter body between at least one of the first nano-textured beamsplitter, the second nano-textured beamsplitter, and the at least one sensor system.

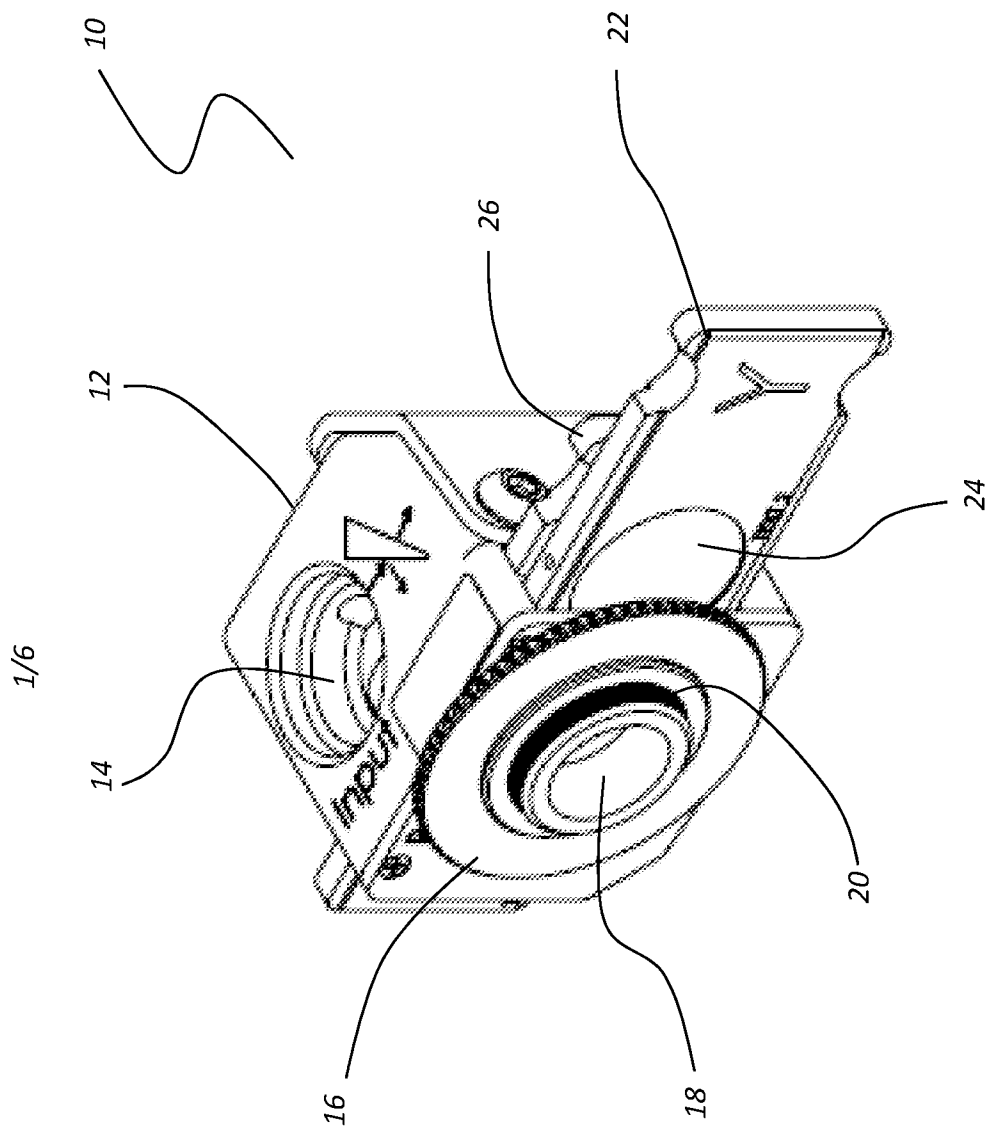


Fig. 1

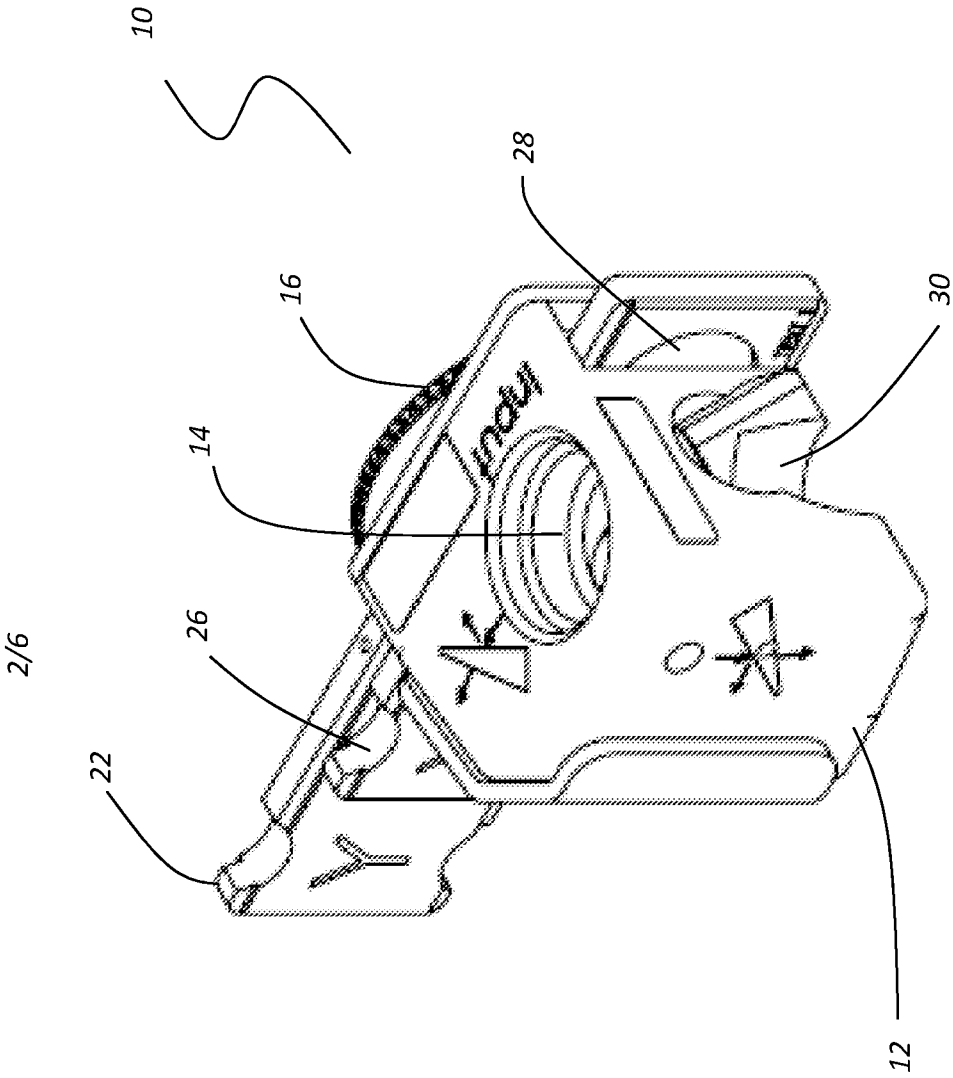
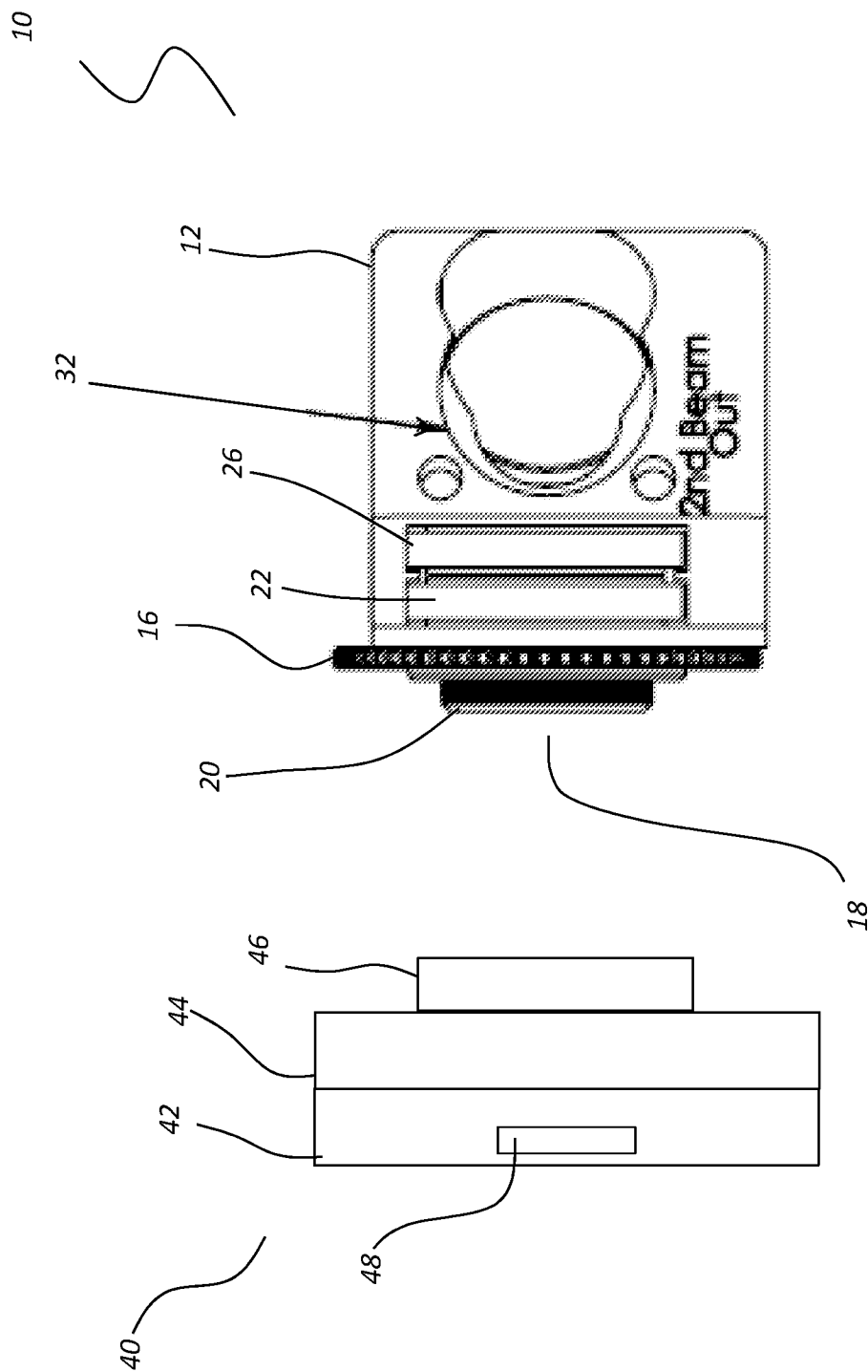


Fig. 2

3/6

Fig. 3



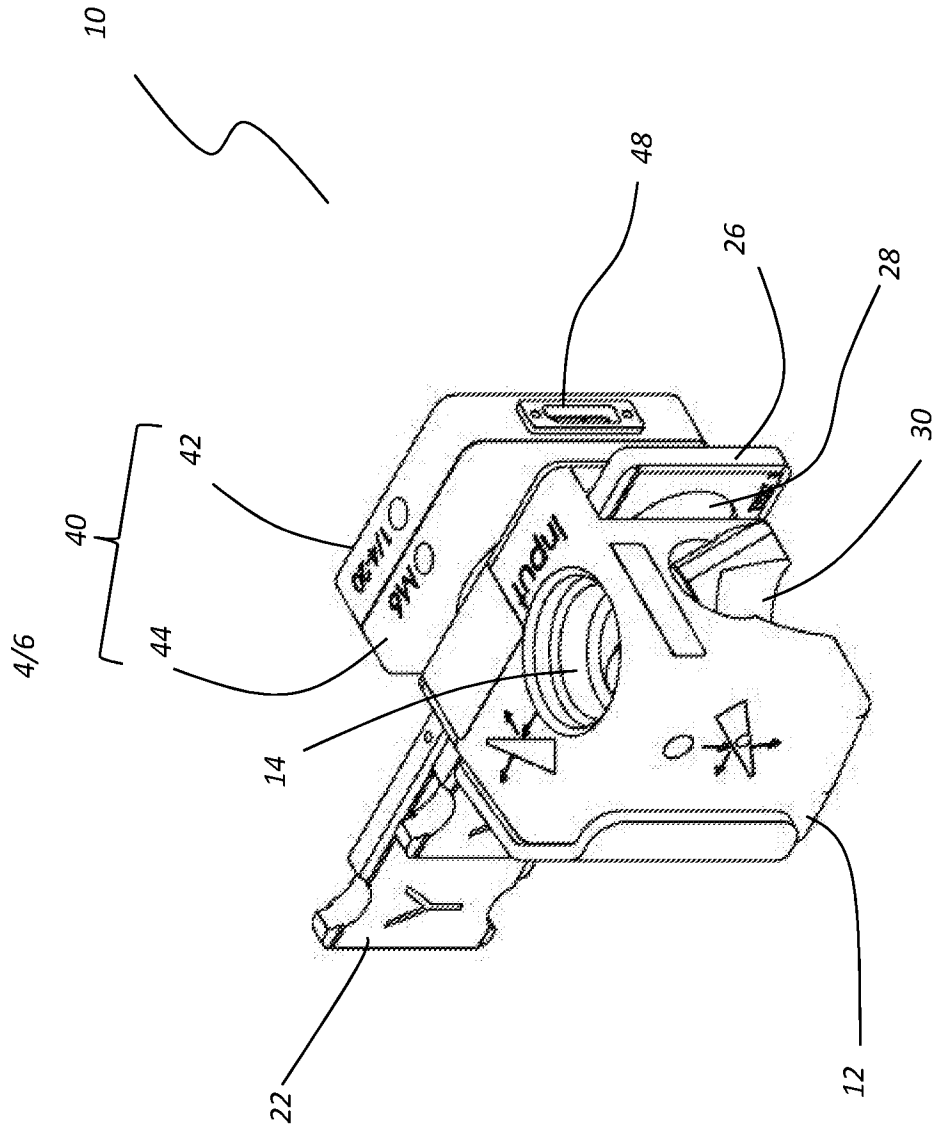
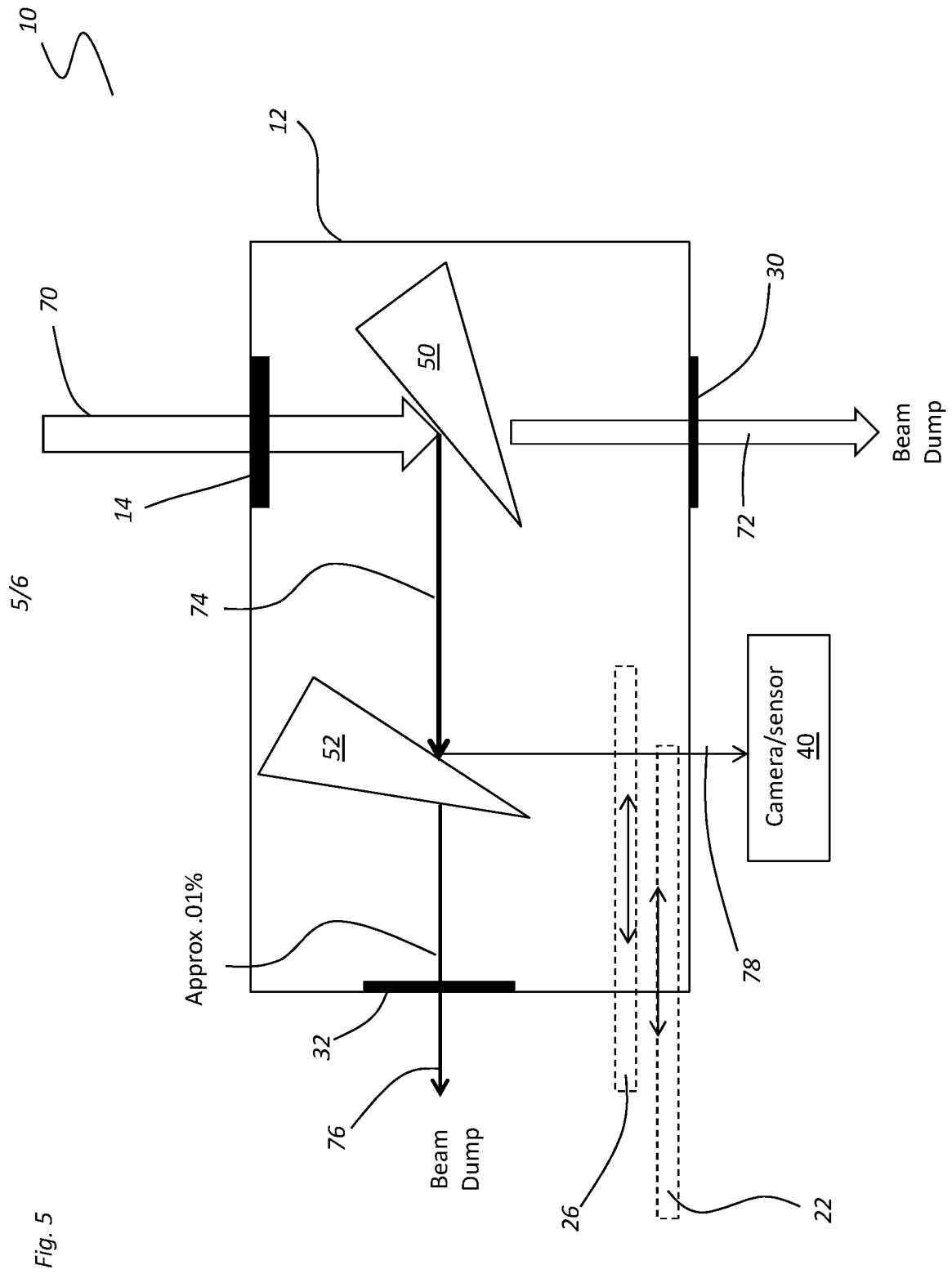
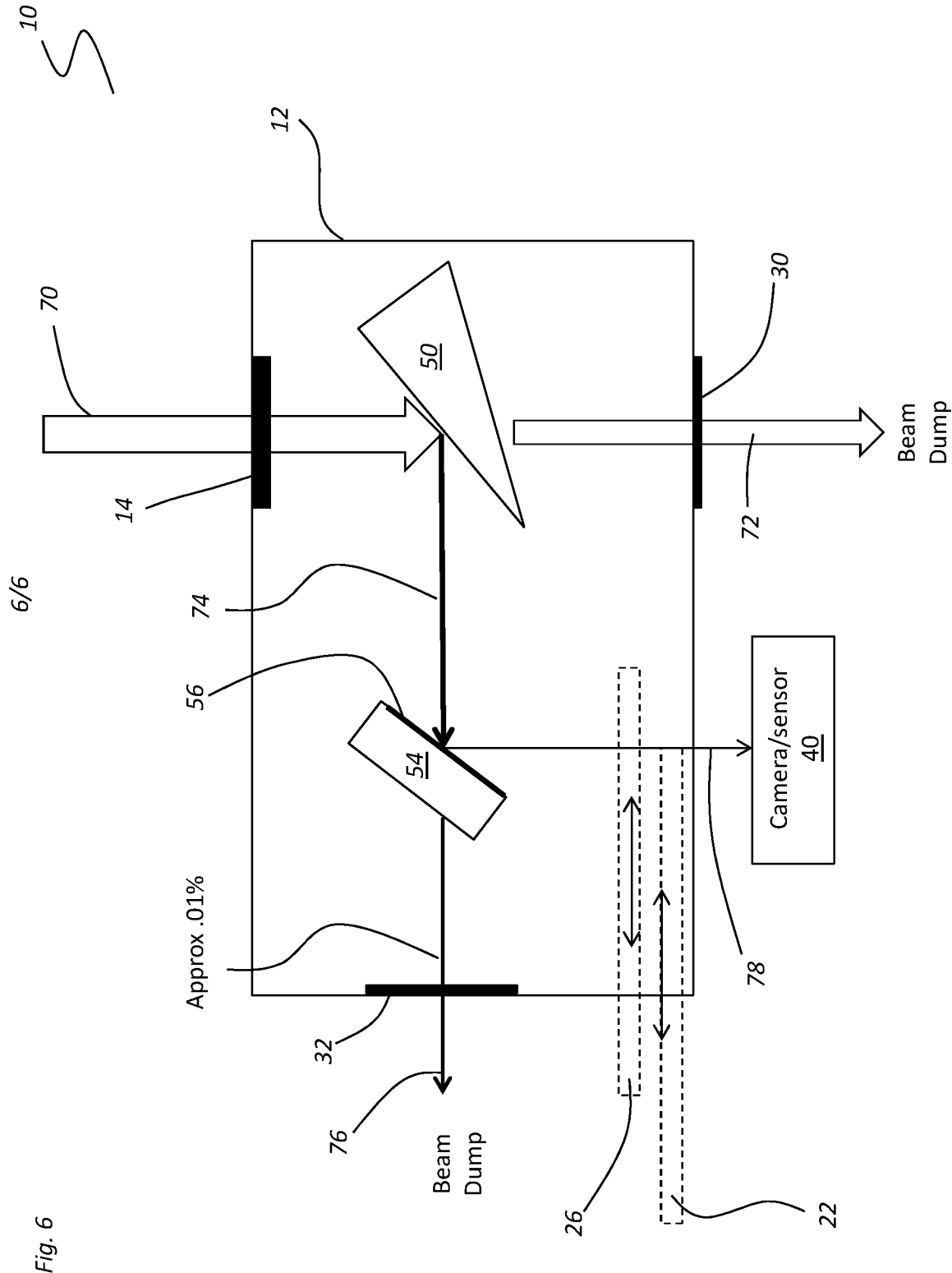


Fig. 4





A. CLASSIFICATION OF SUBJECT MATTER**G01J 1/42(2006.01)i, G01J 1/04(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01J 1/42; B23K 26/70; B41J 2/44; G02B 26/02; G02B 27/09; G02B 27/28; G02B 2700; G02B 504; G03B 15/02; G01J 1/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: attenuator, beamsplitter, housing, camera, aperture

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2019-0061063 A1 (DISCO CORPORATION) 28 February 2019 paragraphs [0026]–[0040] and figures 4, 5	12
Y		1–11, 13
Y	US 6497490 B1 (GREGORY D. MILLER et al.) 24 December 2002 column 4, lines 34–59 and figure 2	1–11
Y	US 5371655 A (NOLAN J. MURDOCK et al.) 06 December 1994 column 4, lines 43–46 and figure 5	2, 3, 7, 8, 11, 13
Y	CN 104238107 A (SHANGHAI INSTITUTE OF OPTICS AND FINE MECHANICS, CHINESE ACADEMY OF SCIENCES) 24 December 2014 claim 1 and figure 1	5, 10
A	JP 08-015638 A (TOSHIBA CORP.) 19 January 1996 paragraphs [0021]–[0028] and figure 5	1–13



Further documents are listed in the continuation of Box C.



See patent family annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

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Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-481-8578

Authorized officer

JUNG, Jong Han

Telephone No. +82-42-481-5642



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2020/038389

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