

5 **BLOCK-TERMINAL FIBER FOR LASER GENERATION
OF ULTRASONIC WAVES**

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of the filing date of U.S. provisional patent application serial no. 12/121,507, filed on May 15, 2008, the disclosure of which is incorporated herein by reference.

10 **BACKGROUND**

[0002] This disclosure relates to transmission systems for transmitting laser beams.

BRIEF DESCRIPTION OF THE DRAWINGS

15 [0003] FIG. 1 is a schematic illustration of an exemplary embodiment of a laser transmission system.

[0004] FIG. 2 is a schematic illustration of an exemplary embodiment of a laser ultrasound detection system that incorporates the laser transmission system of Fig. 1.

DETAILED DESCRIPTION

20 [0005] In the drawings and description that follows, like parts are marked throughout the specification and drawings with the same reference numerals, respectively. The drawings are not necessarily to scale. Certain features of the invention may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and
25 conciseness. The present invention is susceptible to embodiments of different forms. Specific embodiments are described in detail and are shown in the drawings, with the understanding that the present disclosure is to be considered an exemplification of the principles of the invention, and is not intended to limit the invention to that illustrated and described herein. It is to be fully recognized that the different
30 teachings of the embodiments discussed below may be employed separately or in any suitable combination to produce desired results. The various characteristics

5 mentioned above, as well as other features and characteristics described in more detail below, will be readily apparent to those skilled in the art upon reading the following detailed description of the embodiments, and by referring to the accompanying drawings.

10 **[0006]** Referring initially to Fig. 1, an exemplary embodiment of laser transmission system 100 includes a laser beam source 102 having an output that is operably coupled to the input of a lens assembly 104. The output of the lens assembly 104 is operably coupled to the input of an optically transmissive block 106. The output of the block 106 is coupled to an end of an optical fiber 108. The other end of the optical fiber 108 is coupled to input of an optically transmissive block 110. The
15 output of the block 110 is operably coupled to the input of a lens assembly 112.

[0007] In an exemplary embodiment, the laser beam source 102 may be a conventional laser beam source such as, for example, a laser beam capable of generating wavelengths within the middle of the infra red region such as, for example, in the 3 to 5 micron range. In an exemplary embodiment, the lens
20 assemblies, 104 and 112, may be conventional lens assemblies suitable for focusing a laser beam. In an exemplary embodiment, the blocks, 106 and 110, may be conventional optically transmissive blocks composed of a material having a refractive index similar to that of the optical fiber 108 and having minimal absorption for the wavelengths generated by the laser beam source 102. In an exemplary
25 embodiment, the ends of the blocks, 106 and 110, may be coupled to the corresponding ends of the optical fiber 108 by conventional methods such as, for example, bonding, casing, fusing, or any other techniques capable of providing minimal optical interference. In an exemplary embodiment, the diameter of the blocks, 106 and 110, are significantly greater than the diameter of the optical fiber
30 108. In an exemplary embodiment, the diameter of the blocks, 106 and 110, are larger than the diameter of the beam 102a at the ends of the blocks positioned in opposing relation to the lens assemblies, 104 and 112, respectively, taking into account the length of the blocks and the numerical aperture and diameter of the optical fiber 108. In an exemplary embodiment, the lengths of the blocks, 106 and
35 112, are significant relative to the focal lengths of the lens assemblies, 104 and 112,

5 such that the diameter of the laser beam 102a is significantly larger at the ends of the blocks versus at the ends of the optical fiber 108.

[0008] In an exemplary embodiment, during the operation of the system 100, the laser beam source 102 generates a laser beam 102a that is then focused by the lens assembly 104. The focused laser beam 102a then passes into the block 106 and
10 enters into and through the end of the fiber 108. At the other end of the end of the fiber 108, the laser beam 102a exits and passes into and through the block 110. As the laser beam 102a passes through and out of the block 110, the laser beam spreads and is then focused by the lens assembly 112.

[0009] Referring now to Fig. 2, in an exemplary embodiment, the system 100 is
15 incorporated into a laser ultrasound system 200 in which the block 110 and lens assembly 112 are operably coupled to a motion control system 202 for controllably moving the block and lens assembly relative to a work piece 204. A conventional optical detection system 206 is also provided proximate the work piece 204 that is operably coupled to a system controller 208. In an exemplary embodiment, the
20 motion control system 202 may include, for example, a robotic arm.

[0010] In an exemplary embodiment, during the operation of the laser ultrasound system 200, the system 100 is operated by the system controller 208 to focus the laser beam 102a onto the surface of the work piece 204. In an exemplary embodiment, during the operation of the system 200, the motion control system 202
25 may be operated to position and orient the block 110 and lens assembly 112 relative to one or more exterior surfaces of the work piece 204. Optical energy reflected by the exterior surfaces of the work piece 204 is then detected by the optical detection system 206 and processed by the system controller 208 in a well known manner to inspect the workpiece 204. The design and operation of using laser beam energy for
30 laser ultrasound inspection of a work piece is considered well known to persons having ordinary skill in the art.

[0011] In an exemplary embodiment, the diameters and lengths of the blocks, 106 and 110, are selected such that the diameter of the beam 102a at the open ends of the blocks that are positioned in opposing relation to the lens assemblies, 104 and
35 112, is about 5 to 100 times greater than the diameter of the optical fiber 108.

5 **[0012]** It is understood that variations may be made in the above without departing
from the scope of the invention. Further, spatial references are for the purpose of
illustration only and do not limit the specific orientation or location of the structure
described above. While specific embodiments have been shown and described,
modifications can be made by one skilled in the art without departing from the spirit
10 or teaching of this invention. The embodiments as described are exemplary only and
are not limiting. Many variations and modifications are possible and are within the
scope of the invention. Accordingly, the scope of protection is not limited to the
embodiments described, but is only limited by the claims that follow, the scope of
which shall include all equivalents of the subject matter of the claims.

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CLAIMS

1. A system for transmitting laser beams, comprising:
a source of laser beams;
a first lens assembly operably coupled to the source of laser beams;
a first optically transmissive block operably coupled to the first lens assembly;
10 an end of an optical fiber coupled to the first optically transmissive block;
a second optically transmissive block coupled to the other end of the optical
fiber; and
a second lens assembly operably coupled to the second optically transmissive
block.

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2. The system of claim 1, wherein the source of laser beams comprises a source
of laser beams having wavelengths in the range of 3 to 5 microns.

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3. The system of claim 1, wherein a refractive index of at least one of the first
and second optically transmissive blocks is about the same as a refractive index of
the optical fiber.

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4. The system of claim 1, wherein a diameter of at least one of the first and
second optically transmissive blocks range from about 5 to 100 times greater than a
diameter of the optical fiber.

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5. The system of claim 1, further comprising a motion control system operably
coupled to the second optically transmissive block and the second lens assembly for
controllably displacing the second optically transmissive block and the second lens
assembly with respect to a workpiece.

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6. A method of transmitting a laser beam from a laser beam source to a work
piece, comprising:
focusing the laser beam using a first lens assembly;
then transmitting the laser beam into and through a first optically transmissive
block;
then transmitting the laser beam into and through an end of an optical fiber;

- 5 then transmitting the laser beam out of an another end of the optical fiber;
 then transmitting the laser into and through a second optically transmissive
 block; and
 then focusing the laser beam using a second lens assembly.
- 10 7. The method of claim 6, wherein the laser beam source comprises a source of
laser beams having wavelengths in the range of 3 to 5 microns.
8. The method of claim 6, wherein a refractive index of at least one of the first
and second optically transmissive blocks is about the same as a refractive index of
15 the optical fiber.
9. The method of claim 6, wherein a diameter of at least one of the first and
second optically transmissive blocks range from about 5 to 100 times greater than a
diameter of the optical fiber.
- 20 10. The method of claim 6, further comprising controllably displacing the second
optically transmissive block and the second lens assembly with respect to a
workpiece.
- 25 11. A laser ultrasound system, comprising:
 a source of laser beams;
 a first lens assembly operably coupled to the source of laser beams;
 a first optically transmissive block operably coupled to the first lens assembly;
 an end of an optical fiber coupled to the first optically transmissive block;
30 a second optically transmissive block coupled to the other end of the optical
 fiber;
 a second lens assembly operably coupled to the second optically transmissive
 block;
 a motion control system operably coupled to the second optically transmissive
35 block and the second lens assembly for controllably positioning the
 second optically transmissive block and the second lens assembly with
 respect to a work piece;

5 an optical detection system positioned proximate the work piece for detecting
 optical energy reflected off of the work piece; and
 a controller operably coupled to the source of laser beams, the motion control
 system, and the optical detection system for controlling the operation of
10 the source of laser beams, the motion control system, and the optical
 detection system and for processing the optical energy reflected off of
 the work piece to determine one or more characteristics of the work
 piece.

12. The system of claim 11, wherein the source of laser beams comprises a
15 source of laser beams having wavelengths in the range of 3 to 5 microns.

13. The system of claim 11, wherein a refractive index of at least one of the first
and second optically transmissive blocks is about the same as a refractive index of
the optical fiber.

20 14. The system of claim 11, wherein a diameter of at least one of the first and
second optically transmissive blocks range from about 5 to 100 times greater than a
diameter of the optical fiber.

25 15. A method of determining one or more characteristics of a work piece,
comprising:
 generating a laser beam;
 focusing the laser beam using a first lens assembly;
 then transmitting the laser beam into and through a first optically transmissive
30 block;
 then transmitting the laser beam into and through an end of an optical fiber;
 then transmitting the laser beam out of an another end of the optical fiber;
 then transmitting the laser into and through a second optically transmissive
 block; and
35 then focusing the laser beam using a second lens assembly;
 controllably displacing the second optically transmissive block and the second
 lens assembly with respect to the work piece;
 impacting one or more surfaces of the work piece with the laser beam;

5 monitoring reflection of the laser beam off of one or more surfaces of the work
 piece; and
 processing the monitored reflections to determine one or more characteristics
 of the work piece.

10 16. The method of claim 15, wherein the laser beam source comprises a source
 of laser beams having wavelengths in the range of 3 to 5 microns.

 17. The method of claim 15, wherein a refractive index of at least one of the first
 and second optically transmissive blocks is about the same as a refractive index of
15 the optical fiber.

 18. The method of claim 15, wherein a diameter of at least one of the first and
 second optically transmissive blocks range from about 5 to 100 times greater than a
 diameter of the optical fiber.

20 19. The method of claim 15, further comprising controllably displacing the second
 optically transmissive block and the second lens assembly with respect to a
 workpiece.

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