Claims

1. A system for transmitting laser beams, comprising:

a laser beam source;

a first lens assembly operably coupled to the source, the first lens assembly causing the laser beam to converge from a larger diameter at an outlet of the first lens assembly to a smaller diameter;

a first hollow core waveguide operably coupled to the first lens assembly and have flat inlet and outlet ends for receiving the laser beam, the first hollow core waveguide causing the laser beam to continue converging to a smaller diameter at an outlet of the first hollow core waveguide;

an inlet end of an optical fiber physically abutting and coupled to the outlet end of the first hollow core waveguide;

a second hollow core waveguide having flat inlet and outlet ends, the inlet end of the second hollow core waveguide being in physical abutment with and coupled to the an outlet end of the optical fiber, the second hollow core waveguide causing the laser beam to diverge from a smaller diameter at the inlet end of the second hollow core waveguide to a larger diameter at the outlet end of the second hollow core waveguide;

wherein a diameter of the first hollow core waveguide and a diameter of the second hollow core waveguide are each significantly larger than a diameter of the first optical fiber; and

a second lens assembly operably coupled to the outlet end of second hollow core waveguide, the second lens assembly directing the laser beam from to a target;

wherein the lengths of the hollow core waveguides are significant relative to the focal lengths of the lens assemblies, such that the diameter of the laser beam is significantly larger at the ends of the first and second hollow core waveguides versus at the ends of the optical fiber.

2. The system of claim 1, wherein the second lens assembly collimates the laser beam to a constant diameter.

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

4. The system of claim 1, wherein the diameters of the first and second hollow core waveguides range from about 5 to 100 times greater than the diameter of the optical fiber.

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

6. A method of transmitting a laser beam from a laser beam source to a work piece, comprising:

providing first and second hollow core waveguides, each block having a flat inlet end and a flat outlet end;

abutting and joining an inlet end of an optical fiber to the outlet end of the first hollow core waveguide and an outlet end of the optical fiber to the inlet end of the second hollow core waveguide, each of the hollow core waveguides being larger in diameter than the optical fiber, wherein the lengths of the hollow core waveguides are significant relative to the focal lengths of the lens assemblies, such that the diameter of the laser beam is significantly larger at the ends of the first and second hollow core waveguides versus at the ends of the optical fiber;

focusing the laser beam using a first lens assembly such that the laser beam converges from a larger diameter at an outlet of the first lens assembly to a smaller diameter at the inlet end of the first hollow core waveguide;

then transmitting the laser beam into and through the first hollow core waveguide, causing the laser beam to continue to converge within the first hollow core waveguide;

then transmitting the laser beam from the outlet end of the first hollow core waveguide into and through the optical fiber;

then transmitting the laser beam out of the outlet end of the optical fiber into and through the second hollow core waveguide, the laser beam diverging from a smaller diameter at the inlet end to a larger diameter at the outlet end of the second hollow core waveguide; and

causing the laser beam to continue to diverge from the outlet end of the second hollow core waveguide to an inlet of a second lens assembly, then collimating the laser beam to a constant diameter using the second lens assembly.

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 hollow core waveguides is about the same as a refractive index of the optical fiber.

9. The method of claim 6, wherein the diameters of the first and second hollow core waveguides range from about 5 to 100 times greater than the diameter of the optical fiber.

10. The method of claim 6, further comprising controllably displacing the second hollow core waveguide and the second lens assembly with respect to a workpiece.

11. The system according to claim 1, wherein the first hollow core waveguide has a length selected such that the laser beam passing through converges to a diameter at the outlet end of the first hollow core waveguide that is no greater than a diameter of the optical fiber.

12. The system according to claim 1, wherein the second hollow core waveguide has a length selected such that the laser beam passing through diverges to a diameter at the outlet end of the second hollow core waveguide that is no greater than a diameter of the second hollow core waveguide.

13. The system according to claim 1, wherein the constant diameter of the laser beam at an outlet of the second lens assembly is greater than a diameter of the optical fiber.

14. The method according to claim 6, wherein the first hollow core waveguide has a length selected such that the laser beam passing through converges to a diameter at the outlet end of the first hollow core waveguide that is no greater than a diameter of the optical fiber.

15. The method according to claim 6, wherein the second hollow core waveguide has a length selected such that the laser beam passing through diverges to a diameter at the outlet end of the second hollow core waveguide that is no greater than the diameter of the second hollow core waveguide.

16. The method according to claim 6, wherein the constant diameter of the laser beam at an outlet of the second lens assembly is greater than a diameter of the optical fiber.

17. A system for transmitting laser beams, comprising:

a laser beam source;

a first lens assembly operably coupled to the laser beam source, the first lens assembly receiving a single laser beam from the source and causing the laser beam to conically converge;

a first hollow core waveguide having a flat inlet end optically coupled to the first lens assembly for receiving the laser beam, the laser beam having a smaller diameter at the inlet end of the first hollow core waveguide than at an outlet of the first lens assembly, the first hollow core waveguide having a diameter greater than the diameter of the laser beam at the inlet end of the first hollow core waveguide, the first hollow core waveguide causing the laser beam to continue converging at a same rate of convergence to a smaller diameter at an outlet end of the first hollow core waveguide, the outlet end of the first hollow core waveguide being flat;

an inlet end of an optical fiber abutting and coupled to the outlet end of the first hollow core waveguide, the optical fiber having a diameter smaller than a diameter of the laser beam between the source and the first lens assembly;

a second hollow core waveguide having a flat inlet end in abutting and coupled to an outlet end of the optical fiber, the second hollow core waveguide causing the laser beam to diverge from a smaller diameter at the inlet end to a larger diameter at the outlet end of the second hollow core waveguide the outlet end of the second hollow core waveguide being flat;

wherein a diameter of the first hollow core waveguide and a diameter of the second hollow core waveguide are each larger than the diameter of the first optical fiber; and

a second lens assembly optically coupled to the outlet end of the second hollow core waveguide, the laser beam having a larger diameter at an inlet of the second lens assembly than at the outlet end of the second hollow core waveguide, the second lens assembly collimating the laser beam from divergence to a constant diameter that is larger than a diameter of the fiber;

wherein the lengths of the hollow core waveguides are significant relative to the focal lengths of the lens assemblies, such that the diameter of the laser beam is significantly larger at the ends of the first and second hollow core waveguides versus at the ends of the optical fiber.

Claims

1. A system for transmitting laser beams, comprising:

a laser beam source;

a first lens assembly operably coupled to the source, the first lens assembly causing the laser beam to converge from a larger diameter at an outlet of the first lens assembly to a smaller diameter;

a first optically transmissive block operably coupled to the first lens assembly and have flat inlet and outlet ends for receiving the laser beam, the first optically transmissive block causing the laser beam to continue converging to a smaller diameter at an outlet of the first optically transmissive block;

an inlet end of an optical fiber physically abutting and coupled to the outlet end of the first optically transmissive block;

a second optically transmissive block having flat inlet and outlet ends, the inlet end of the second optically transmissive block being in physical abutment with and coupled to the an outlet end of the optical fiber, the second optically transmissive block causing the laser beam to diverge from a smaller diameter at the inlet end of the second optically transmissive block to a larger diameter at the outlet end of the second optically transmissive block;

wherein a diameter of the first optically transmissive block and a diameter of the second optically transmissive block are each larger than a diameter of the optical fiber; and

a second lens assembly operably coupled to the outlet end of second optically transmissive block, the second lens assembly directing the laser beam from to a target;

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wherein the lengths of the optically transmissive blocks are greater than the focal lengths of the lens assemblies, such that the diameter of the laser beam is larger at the ends of the first and second optically transmissive blocks versus at the ends of the optical fiber.

2. The system of claim 1, wherein the second lens assembly collimates the laser beam to a constant diameter.

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.

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

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.

6. A method of transmitting a laser beam from a laser beam source to a work piece, comprising:

providing first and second optically transmissive blocks, each block having a flat inlet end and a flat outlet end;

abutting and joining an inlet end of an optical fiber to the outlet end of the first optically transmissive block and an outlet end of the optical fiber to the inlet end of the second optically transmissive block, each of the optically transmissive blocks being larger in diameter than the optical fiber, wherein the lengths of the optically transmissive blocks are greater than the focal lengths of the lens assemblies, such that the diameter of the laser

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beam is larger at the ends of the first and second optically transmissive blocks versus at the ends of the optical fiber;

focusing the laser beam using a first lens assembly such that the laser beam converges from a larger diameter at an outlet of the first lens assembly to a smaller diameter at the inlet end of the first optically transmissive block;

then transmitting the laser beam into and through the first optically transmissive block, causing the laser beam to continue to converge within the first optically transmissive block;

then transmitting the laser beam from the outlet end of the first optically transmissive block into and through the optical fiber;

then transmitting the laser beam out of the outlet end of the optical fiber into and through the second optically transmissive block, the laser beam diverging from a smaller diameter at the inlet end to a larger diameter at the outlet end of the second optically transmissive block; and

causing the laser beam to continue to diverge from the outlet end of the second optically transmissive block to an inlet of a second lens assembly, then collimating the laser beam to a constant diameter using the second lens assembly.

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 the optical fiber.

9. The method of claim 6, wherein the diameters of the first and second optically transmissive blocks range from about 5 to 100 times greater than the diameter of the optical fiber.

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.

11. The system according to claim 1, wherein the first optically transmissive block has a length selected such that the laser beam passing through converges to a diameter at the outlet end of the first optically transmissive block that is no greater than a diameter of the optical fiber.

12. The system according to claim 1, wherein the second optically transmissive block has a length selected such that the laser beam passing through diverges to a diameter at the outlet end of the second optically transmissive block that is no greater than a diameter of the second optically transmissive block.

13. The system according to claim 1, wherein the constant diameter of the laser beam at an outlet of the second lens assembly is greater than a diameter of the optical fiber.

14. The method according to claim 6, wherein the first optically transmissive block has a length selected such that the laser beam passing through converges to a diameter at the outlet end of the first optically transmissive block that is no greater than a diameter of the optical fiber.

15. The method according to claim 6, wherein the second optically transmissive block has a length selected such that the laser beam passing through diverges to a diameter at the outlet end of the second optically transmissive block that is no greater than the diameter of the second optically transmissive block.

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16. The method according to claim 6, wherein the constant diameter of the laser beam at an outlet of the second lens assembly is greater than a diameter of the optical fiber.

17. A system for transmitting laser beams, comprising:

a laser beam source;

a first lens assembly operably coupled to the laser beam source, the first lens assembly receiving a single laser beam from the source and causing the laser beam to conically converge;

a first optically transmissive block having a flat inlet end optically coupled to the first lens assembly for receiving the laser beam, the laser beam having a smaller diameter at the inlet end of the first optically transmissive block than at an outlet of the first lens assembly, the first optically transmissive block having a diameter greater than the diameter of the laser beam at the inlet end of the first optically transmissive block, the first optically transmissive block causing the laser beam to continue converging at a same rate of convergence to a smaller diameter at an outlet end of the first optically transmissive block, the outlet end of the first optically transmissive block being flat;

an inlet end of an optical fiber abutting and coupled to the outlet end of the first optically transmissive block, the optical fiber having a diameter smaller than a diameter of the laser beam between the source and the first lens assembly;

a second optically transmissive block having a flat inlet end in abutting and coupled to an outlet end of the optical fiber, the second optically transmissive block causing the laser beam to diverge from a smaller diameter at the inlet end to a larger diameter at the outlet end of the second optically transmissive block the outlet end of the second optically transmissive block being flat;

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wherein a diameter of the first optically transmissive block and a diameter of the second optically transmissive block are each larger than the diameter of the first optical fiber; and

a second lens assembly optically coupled to the outlet end of the second optically transmissive block, the laser beam having a larger diameter at an inlet of the second lens assembly than at the outlet end of the second optically transmissive block, the second lens assembly collimating the laser beam from divergence to a constant diameter that is larger than a diameter of the fiber;

wherein the lengths of the optically transmissive blocks are greater than the focal lengths of the lens assemblies, such that the diameter of the laser beam is larger at the ends of the first and second optically transmissive blocks versus at the ends of the optical fiber.

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