[0004] Moving the beam in different near field scanning patterns or "wobble" patterns along a workpiece may provide a favorable distribution of laser energy, particularly in welding applications. The different patterns result in different laser energy distributions on the workpiece depending on various process parameters and beam movement parameters. Existing systems, however, do not provide a way for the user to visualize (e.g., prior to a laser processing operation) the various laser energy distributions likely to result from these parameters and thus do not allow the user to make an informed decision on the pattern and/or parameters most suitable for a particular application.

SUMMARY OF INVENTION

[0004A] According to a first aspect of the present disclosure, there is provided a method for visualizing a laser energy distribution in a laser processing operation performed by a laser processing system including a laser energy source and a scanning laser processing head that provides laser movement, the method comprising:

receiving laser processing parameters associated with the laser energy source and laser movement parameters associated with the laser movement provided by the scanning laser processing head,

wherein the laser processing parameters and the laser movement parameters are used in a laser processing operation performed by the laser processing system including the laser energy source and the scanning laser processing head;

determining laser energy distributions at a plurality of locations within the laser movement based at least in part on the received laser processing parameters and the laser movement parameters; and

displaying a visual representation of the laser energy distributions at the plurality of locations within the laser movement,

wherein the visual representation of the laser energy distributions is used to troubleshoot the laser processing operation and/or to predict actual laser energy distributions in the laser processing operation.

[0004B] According to a second aspect of the present disclosure, there is provided a method for visualizing a laser energy distribution in a laser processing operation performed by a laser processing system including a laser energy source and a scanning laser processing head that provides at least one laser movement, the method comprising:

performing a laser processing operation on a workpiece using the laser processing system, wherein the laser processing operation is performed using laser processing parameters associated with the laser energy source and laser movement parameters associated with the at least one laser movement provided by the scanning laser processing head;

inputting the laser processing parameters and the laser movement parameters into a visualization system;

determining laser energy distributions at a plurality of locations within the at least one laser movement based at least in part on the laser processing parameters and the laser movement parameters input into the visualization system; and

displaying a visual representation of the laser energy distributions at the plurality of locations within the laser movement, wherein the visual representation of the laser energy distributions are used to troubleshoot the laser processing operation.

[0004C] According to a third aspect of the present disclosure, there is provided a method for visualizing a laser energy distribution in a laser processing operation performed by a laser processing system including a laser energy source and a scanning laser processing head that provides at least one laser movement, the method comprising:

inputting, into a visualization system, laser processing parameters associated with the laser energy source and laser movement parameters associated with the at least one laser movement provided by the scanning laser processing head;

determining laser energy distributions at a plurality of locations within the at least one laser movement based at least in part on the laser processing parameters and the laser movement parameters input into the visualization system;

displaying a visual representation of the laser energy distributions at the plurality of locations within the laser movement; and

performing a laser processing operation on a workpiece using the laser processing system, wherein the laser processing operation is performed using the laser processing parameters and the laser movement parameters that produced the visual representation of the laser energy distributions.

[0004D] According to a fourth aspect of the present disclosure, there is provided a non-transitory computer readable storage medium comprising computer readable instructions which when executed by a processor, cause the processor to perform the following operations comprising:

receiving laser processing parameters associated with a laser energy source and laser movement parameters associated with at least one laser movement to be generated by a scanning laser processing head, wherein the laser processing parameters and the laser movement parameters are used in a laser processing operation performed by a laser processing system including the laser energy source and the scanning laser processing head;

determining laser energy distributions at a plurality of locations within the laser movement based at least in part on the received laser processing parameters and the laser movement parameters; and

displaying a visual representation of the laser energy distributions at the plurality of locations within the laser movement,

wherein the visual representation of the laser energy distributions is used to troubleshoot the laser processing operation and/or to predict actual laser energy distributions in the laser processing operation.

[0004E] According to a fifth aspect of the present disclosure, there is provided a laser welding system comprising:

a fiber laser including an output fiber;

a welding head coupled to the output fiber of the fiber laser, the welding head comprising:

a collimator configured to be coupled to the output fiber of the fiber laser;

at least one movable mirror configured to receive a collimated laser beam from the collimator and to move the beam in at least one axis; and

a focus lens configured to focus the laser beam;

a control system for controlling at least the fiber laser and positions of the at least one mirror; and

a laser energy distribution visualization system programmed

to receive laser processing parameters associated with the fiber laser and laser movement parameters associated with at least one laser movement by the at least one mirror in the welding head,

to determine laser energy distributions at a plurality of locations within the laser movement based at least in part on the received laser processing parameters and the laser movement parameters, and

to display a visual representation of the laser energy distributions at the plurality of locations within the laser movement.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] These and other features and advantages will be better understood by reading the following detailed description, taken together with the drawings wherein:

[0006] FIG. 1 is a schematic block diagram of a laser welding system capable of being used with a system and method for visualizing laser energy distributions provided by different near field scanning patterns, consistent with an embodiment of the present disclosure.

[0007] FIG. 2 is a schematic diagram of a focused laser beam with a relatively small range of movement provided by dual mirrors for purposes of wobbling, consistent with an embodiment of the present disclosure.

[0008] FIGS. 3A-3D are schematic diagrams illustrating different wobble patterns together with micrographs of sample welds formed by those wobble patterns, consistent with an embodiment of the present disclosure.

[0009] FIGS. 4 and 5 are perspective views of a laser welding head with a collimator module, wobbler module, and core block module assembled together and emitting a focused beam, consistent with an embodiment of the present disclosure.

[0010] FIG. 6 is a flow chart illustrating a method for visualizing laser energy distributions provided by different near field scanning patterns, consistent with embodiments of the present disclosure.

[0011] FIG. 6A is a diagram illustrating one example of calculating laser energy distributions, consistent with embodiments of the present disclosure.

[0012] FIG. 7 is an illustration of an embodiment of a user interface for visualizing laser energy distributions provided by different near field scanning patterns.

CLAIMS

What is claimed is:

1. A method for visualizing a laser energy distribution in a laser processing operation performed by a laser processing system including a laser energy source and a scanning laser processing head that provides laser movement, the method comprising:

receiving laser processing parameters associated with the laser energy source and laser movement parameters associated with the laser movement provided by the scanning laser processing head,

wherein the laser processing parameters and the laser movement parameters are used in a laser processing operation performed by the laser processing system including the laser energy source and the scanning laser processing head;

determining laser energy distributions at a plurality of locations within the laser movement based at least in part on the received laser processing parameters and the laser movement parameters; and

displaying a visual representation of the laser energy distributions at the plurality of locations within the laser movement,

wherein the visual representation of the laser energy distributions is used to troubleshoot the laser processing operation and/or to predict actual laser energy distributions in the laser processing operation.

2. The method of claim 1 further comprising:

performing a laser processing operation on a workpiece using the laser processing system, wherein the laser processing operation is performed using the laser processing parameters and the laser movement parameters that were used to display the visual representation of the laser energy distribution.

3. The method of claim 2,

wherein the laser processing operation is performed before using the laser processing parameters and the laser movement parameters to display the visual representation of the laser energy distribution, and wherein the visual representation of the laser energy distributions is used to troubleshoot the laser processing operation.

4. The method of claim 2,

wherein the laser processing operation is performed after using the laser processing parameters and the laser movement parameters to display the visual representation of the laser energy distribution, and wherein the visual representation of the laser energy distributions is used to predict laser energy distributions in the laser processing operation.

5. The method of claim 1,

wherein the laser movement is within a field of view less than 30 x 30 mm.

6. The method of claim 1,

wherein the laser movement parameters are selected from the group consisting of laser movement pattern, laser movement orientation, laser movement frequency, and laser movement amplitude.

7. The method of claim 1,

wherein the laser movement parameters include at least a laser movement pattern.

8. The method of claim 7,

wherein the laser movement pattern is selected from the group consisting of a circular pattern, a figure 8 pattern, an infinity pattern, and a line pattern.

9. The method of claim 7,

wherein the laser movement pattern is user defined.

10. The method of claim 7,

wherein the laser movement parameters further include laser movement frequency and laser movement amplitude.

11. The method of claim 1,

wherein the laser processing parameters are selected from the group consisting of beam profile, beam diameter, velocity and laser power.

12. The method of claim 1,

wherein determining the laser energy distributions includes calculating a beam exposure time for each of the plurality of locations based on the laser processing parameters and the laser movement parameters and calculating an energy density for each of the plurality of locations based on the beam exposure time.

13. The method of claim 12,

wherein displaying the visual representation includes transforming the energy density for each of the plurality of locations into a color and displaying the color in the respective locations on a screen.

14. The method of claim 1,

wherein displaying the visual representation includes displaying colors associated with the laser energy distributions in the respective locations on a screen.

15. The method of claim 1,

wherein the laser energy distributions are determined for a plurality of laser movement patterns, and wherein the visual representation is displayed for each of the laser movement patterns.

16. A method for visualizing a laser energy distribution in a laser processing operation performed by a laser processing system including a laser energy source and a scanning laser processing head that provides at least one laser movement, the method comprising:

performing a laser processing operation on a workpiece using the laser processing system, wherein the laser processing operation is performed using laser processing parameters associated with the laser energy source and laser movement parameters associated with the at least one laser movement provided by the scanning laser processing head;

inputting the laser processing parameters and the laser movement parameters into a visualization system;

determining laser energy distributions at a plurality of locations within the at least one laser movement based at least in part on the laser processing parameters and the laser movement parameters input into the visualization system; and

displaying a visual representation of the laser energy distributions at the plurality of locations within the laser movement, wherein the visual representation of the laser energy distributions are used to troubleshoot the laser processing operation.

17. A method for visualizing a laser energy distribution in a laser processing operation performed by a laser processing system including a laser energy source and a scanning laser processing head that provides at least one laser movement, the method comprising:

inputting, into a visualization system, laser processing parameters associated with the laser energy source and laser movement parameters associated with the at least one laser movement provided by the scanning laser processing head;

determining laser energy distributions at a plurality of locations within the at least one laser movement based at least in part on the laser processing parameters and the laser movement parameters input into the visualization system;

displaying a visual representation of the laser energy distributions at the plurality of locations within the laser movement; and

performing a laser processing operation on a workpiece using the laser processing system, wherein the laser processing operation is performed using the laser processing parameters and the laser movement parameters that produced the visual representation of the laser energy distributions.

18. A non-transitory computer readable storage medium comprising computer readable instructions which when executed by a processor, cause the processor to perform the following operations comprising:

receiving laser processing parameters associated with a laser energy source and laser movement parameters associated with at least one laser movement to be generated by a scanning laser processing head, wherein the laser processing parameters and the laser movement parameters are used in a laser processing operation performed by a laser processing system including the laser energy source and the scanning laser processing head;

determining laser energy distributions at a plurality of locations within the laser movement based at least in part on the received laser processing parameters and the laser movement parameters; and

displaying a visual representation of the laser energy distributions at the plurality of locations within the laser movement,

wherein the visual representation of the laser energy distributions is used to troubleshoot the laser processing operation and/or to predict actual laser energy distributions in the laser processing operation.

19. The non-transitory computer readable storage medium of claim 18~~1~~,

wherein receiving the laser processing parameters and the laser movement parameters includes communicating with a laser processing system to receive the laser processing parameters and the laser movement parameters input into the laser processing system.

20. A laser welding system comprising:

a fiber laser including an output fiber;

a welding head coupled to the output fiber of the fiber laser, the welding head comprising:

a collimator configured to be coupled to the~~an~~ output fiber of the~~a~~ fiber laser;

at least one movable mirror configured to receive a collimated laser beam from the collimator and to move the beam in at least one axis; and

a focus lens configured to focus the laser beam;

a control system for controlling at least the fiber laser and positions of the at least one mirror; and

a laser energy distribution visualization system programmed

to receive laser processing parameters associated with the fiber laser and laser movement parameters associated with at least one laser movement by the at least one mirror in the welding head,

to determine laser energy distributions at a plurality of locations within the laser movement based at least in part on the received laser processing parameters and the laser movement parameters, and

to display a visual representation of the laser energy distributions at the plurality of locations within the laser movement.

21. The laser welding system of claim 20~~18~~,

wherein the fiber laser includes an Ytterbium fiber laser.

22. The laser welding system of claim 20~~18~~,

wherein the control system is configured to control the at least one mirror to provide a wobble pattern.

23. The laser welding system of claim 2018,

wherein the control system is configured to control the fiber laser to adjust laser power in response to movement and/or a position of the beam.

24. The laser welding system of claim 2018,

wherein the at least one movable mirror is configured to move the beam within only a limited field of view defined by a scan angle of about 1-2º.