There is also disclosed a cleaning nozzle to be used with a laser processing head configured to deliver laser radiation emitted from a laser source onto a surface to be cleaned is provided. In one example, the cleaning nozzle comprising an opening configured to allow the laser radiation and a gas to be delivered to the surface.

In one example, the cleaning nozzle has a nozzle tip configured with one of: a one-point configuration, a two-point configuration, or a groove. In another example, the nozzle tip is configured to be coupled onto a tubular body portion of the cleaning nozzle. In another example, the tubular body portion is configured to be coupled to the laser processing head. In another example, the tubular body portion is coupled to the laser processing head with an attachment mechanism. In one example, the laser radiation that is delivered to the surface forms a scan line. In one example, the laser processing head is configured to wobble a laser beam of the laser radiation that is delivered to the surface, the opening configured to accommodate a wobble amplitude of the laser beam.

There is also disclosed a system for passivating a surface using laser radiation is provided. In one example, the system includes a laser source configured to generate laser radiation, the laser source configured to emit laser radiation in a modulated continuous wave (CW) mode having a duty cycle less than 100%, a pulse-repetition frequency in a range of 30-55 kilohertz (kHz) inclusive, and a FWHM pulse duration of nanosecond order or longer, a housing configured as a handheld apparatus that directs the laser radiation to the surface, and an optical fiber coupling the handheld apparatus to the laser source.

In one example, the modulated CW mode has a maximum power of 1500 watts (W) inclusive.

In one example, the duty cycle is in a range of 10 – 95% inclusive.

In one example, the FWHM pulse duration is up to millisecond order inclusive.

In one example, the system further includes at least one movable mirror positioned within the housing, the at least one movable mirror configured to wobble a laser beam of the laser radiation such that the laser beam has a wobble amplitude greater than 5 mm.

In one example, the system further includes a cleaning nozzle configured to attach to the housing and to deliver laser radiation emitted in the passivation mode onto a surface to be passivated.

In one example, the cleaning nozzle is configured with an opening that permits the passage of the laser radiation and delivers gas to the surface.

In one example, the laser radiation forms a scan line on the surface.

In one example, the opening is further configured such that a laser beam of the laser radiation has a wobble amplitude of 15 mm.

There is also disclosed a method for passivating a surface with a laser. In one example, the method includes providing a laser source, the laser source configured to emit laser radiation in a modulated continuous wave (CW) mode having a duty cycle less than 100%, a pulse-repetition frequency in a range of 30-55 kilohertz (kHz) inclusive, and a FWHM pulse duration of nanosecond order or longer, generating laser radiation from the laser source in the modulated CW mode, and directing the laser radiation emitted from the laser source onto a surface to be passivated.

In one example, the modulated CW mode has a maximum power of 1500 watts (W) inclusive.

In one example, the duty cycle is in a range of 10 – 95% inclusive.

In one example, the FWHM pulse duration is up to millisecond order inclusive.

In one example, the method further includes wobbling a laser beam of the emitted laser radiation such that the laser beam has a wobble length greater than 5 mm.

In one example, the method further includes providing a handheld device that emits the laser radiation. In a further example, the method further includes providing a cleaning nozzle configured to attach to the handheld device and to deliver laser radiation emitted in the modulated CW mode onto the surface to be passivated.

In one example, the surface comprises a weld seam, and the laser radiation is directed to the weld seam.

In one example, the surface is a metal material comprising one of: nickel, nickel alloys, Inconel, titanium, titanium alloys, and stainless steel.

There is also disclosed a system for passivating a surface using laser radiation. In one example, the system includes a laser source configured to generate laser radiation, the laser source configured to emit laser radiation in a continuous wave (CW) mode having a maximum power of 1500 watts (W) inclusive, a housing configured as a handheld apparatus that directs the laser radiation to the surface, and an optical fiber coupling the handheld apparatus to the laser source.

In one example, the system further includes at least one movable mirror positioned within the housing, the at least one movable mirror configured to wobble a laser beam of the laser radiation such that the laser beam has a wobble amplitude greater than 5 mm.

In one example, the system further includes a cleaning nozzle configured to attach to the housing and to deliver laser radiation emitted in the CW mode onto a surface to be passivated. In another example, the cleaning nozzle is configured with an opening that permits the passage of the laser radiation and to deliver gas to the surface. In one example, the laser radiation forms a scan line on the surface. In one example, the opening is further configured such that a laser beam of the laser radiation has a wobble amplitude of 15 mm.

There is also disclosed a method for passivating a surface with a laser is provided. In one example, the method includes providing a laser source, the laser source configured to emit laser radiation in a continuous wave (CW) mode having a maximum power of 1500 watts (W) inclusive, generating laser radiation from the laser source in the CW mode, and directing the laser radiation emitted from the laser source onto a surface to be passivated.

In one example, the method further includes wobbling a laser beam of the emitted laser radiation such that the laser beam has a wobble length greater than 5 mm.

In one example, the method further includes providing a handheld device that emits the laser radiation.

In one example, the method further includes providing a cleaning nozzle configured to attach to the handheld device and to deliver laser radiation emitted in the CW mode onto the surface to be passivated.

In one example, the surface comprises a weld seam, and the laser radiation is directed to the weld seam.

In one example, the surface is a metal material comprising one of: nickel, nickel alloys, Inconel, titanium, titanium alloys, and stainless steel.

Still other aspects, embodiments, and advantages of these example aspects and embodiments, are discussed in detail below. Moreover, it is to be understood that both the foregoing information and the following detailed description are merely illustrative examples of various aspects and embodiments, and are intended to provide an overview or framework for understanding the nature and character of the claimed aspects and embodiments. Embodiments disclosed herein may be combined with other embodiments, and references to "an embodiment," "an example," "some embodiments," "some examples," "an alternate embodiment," "various embodiments," "one embodiment," "at least one embodiment," "this and other embodiments," "certain embodiments," or the like are not necessarily mutually exclusive and are intended to indicate that a particular feature, structure, or characteristic

CLAIMS

1. A system for cleaning a surface using laser radiation, the system comprising:

a laser source configured to generate laser radiation, the laser source configured to emit laser radiation in a cleaning mode, the cleaning mode characterized as a modulated continuous wave (CW) mode having a duty cycle less than 100%, a pulse-repetition frequency of at least 10 kilohertz (kHz), and a FWHM pulse duration in a range of 1 microsecond (μs) to 10 milliseconds (ms) inclusive;

a housing configured as a handheld apparatus that directs the laser radiation to the surface; and

an optical fiber coupling the handheld apparatus to the laser source.

2. The system of claim 1, wherein the pulse-repetition frequency is in a range of 10 - 55 kHz inclusive.

3. The system of claim 1, wherein the cleaning mode has a maximum power of 1500 watts (W) inclusive.

4. The system of claim 1, wherein the duty cycle is in a range of 10 – 95% inclusive.

5. The system of claim 1, further comprising a controller configured to control the laser source.

6. The system of claim 1, further comprising at least one movable mirror positioned within the housing, the at least one movable mirror configured to wobble a laser beam of the laser radiation such that the laser beam has a wobble amplitude greater than 5 mm.

7. The system of claim 1, further comprising a cleaning nozzle configured to attach to the housing and to deliver laser radiation emitted in the cleaning mode onto a surface to be cleaned.

8. The system of claim 7, wherein the cleaning nozzle is configured with an opening that permits the passage of the laser radiation.

9. The system of claim 8, wherein the laser radiation forms a scan line on the surface.

10. The system of claim 8, wherein the opening is further configured to deliver gas to the surface.

11. The system of claim 8, wherein the opening is further configured such that a laser beam of the laser radiation has a wobble amplitude of 15 mm.

12. The system of claim 8, wherein the cleaning nozzle has a nozzle tip configured with one of:

a one-point configuration,

a two-point configuration, or

a groove,

wherein the nozzle tip is configured to be press fitted onto a tubular body portion of the cleaning nozzle.

13. A method for cleaning a surface with a laser, comprising:

providing a laser source, the laser source configured to emit laser radiation in a cleaning mode, the cleaning mode characterized as a modulated continuous wave (CW) mode having a duty cycle less than 100%, a pulse-repetition frequency of at least 10 kilohertz (kHz), and a FWHM pulse duration in a range of 1 microsecond (μs) to 10 milliseconds (ms) inclusive;

generating laser radiation from the laser source in the cleaning mode; and

directing the laser radiation emitted from the laser source onto a surface to be cleaned.