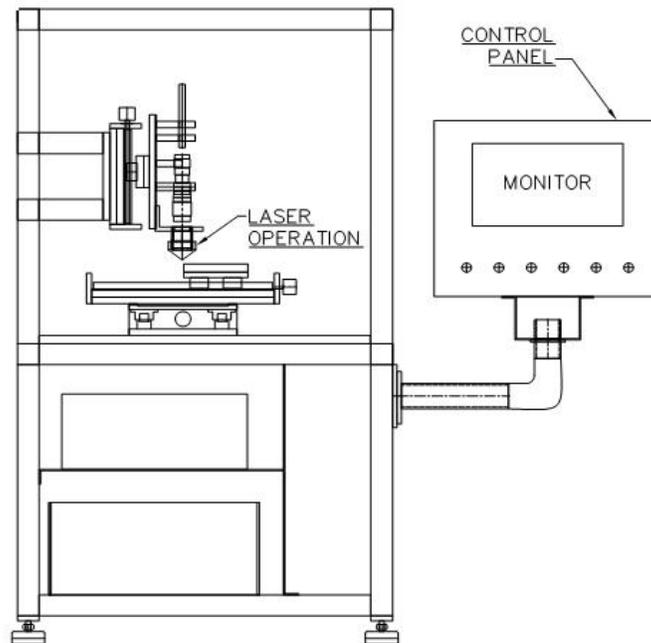


Safe operating procedure (v 1.2)

1070 nm laser doping tool



System owner

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Department of Energy Science & Engineering

Operating procedure prepared by

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Department of Energy Science & Engineering
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NCPRE Characterization Lab
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1. Information regarding the vendor/manufacturer

Laser make	SPI laser
Vendor/ Indian representative	Laser Science Services (I) Pvt. Ltd.
Address	A-454, TTC Industrial Estate, MIDC Mahape, Navi Mumbai-400701
Telephone	022-2778-1673 022-4155-3232
URL	http://www.laserscience.in/
Contact person	Mr. Anant Deshpande anant@laserscience.in 9324299246
System designer and manufacturer	Scantech Laser Pvt. Ltd.

NOTE: Under any circumstances related to laser, please contact Mr. Anant Deshpande or Laser Science

2. System features and capabilities

Laser	Type	Fiber
	Wavelength	1070 ± 10 nm
	Beam mode	TEM ₀₀
	Pulse mode	CW and modulated
	Power output	2.5 W – 25 W
	Pulse modulation (1/Tp)	1 kHz – 100 kHz
	Minimum pulse width (tp)	<10 μs
	Pulse on/off ratio (tp/Tp)	10% - 100%
	Primary beam-width	5 mm
	Additional feature	Red pointing and alignment laser
Optics	Beam expander	2x – 8x
	Lens	Dual lens focus
	Spot size ¹	20 μm – 50 μm
Linear translation stage	Movement (translation) along	X, Y and Z
	Raster scanning along	X and Y
	Minimum line to line resolution	< 5 μm
	Maximum translation	X – 200 mm, Y – 200 mm, Z – 60 mm
	Maximum tested scan speed	X – 100 mm/s, Y – 100 mm/s
	Gas jet	N ₂ /CDA

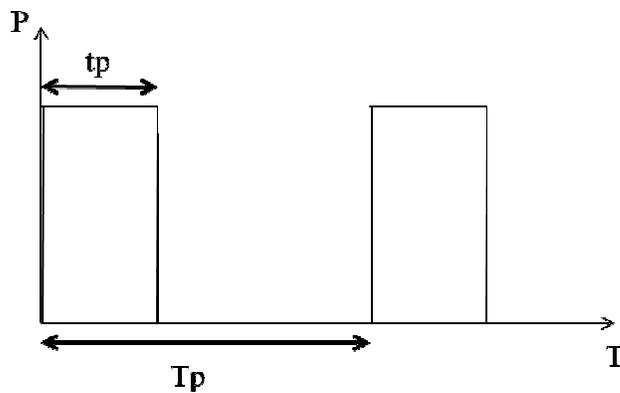


Fig 1: pulse train

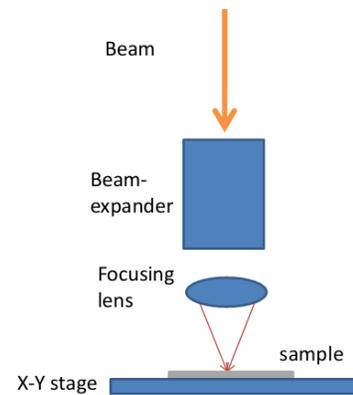


Fig 2: optics of the system

¹ As specified in quotation. Spot size variation was not tested till this SOP was prepared.

3. Operating procedure

1. Turn on the main power line and the gas line valve.
2. Turn on the system by rotating the 'Emergency' switch.
3. Turn on the computer.
4. Run 'LaserControl.exe' from start menu. A shortcut is also provided on the desktop. The original file is located at D:\Control software.
5. Once the alarm rings, enable the 'Axis Enable' key at the control panel.
6. At the software interface, go to 'Mode' → 'Jog' menu. This will open a new window as shown in figure 3. This interface is used to move the stage for positioning.

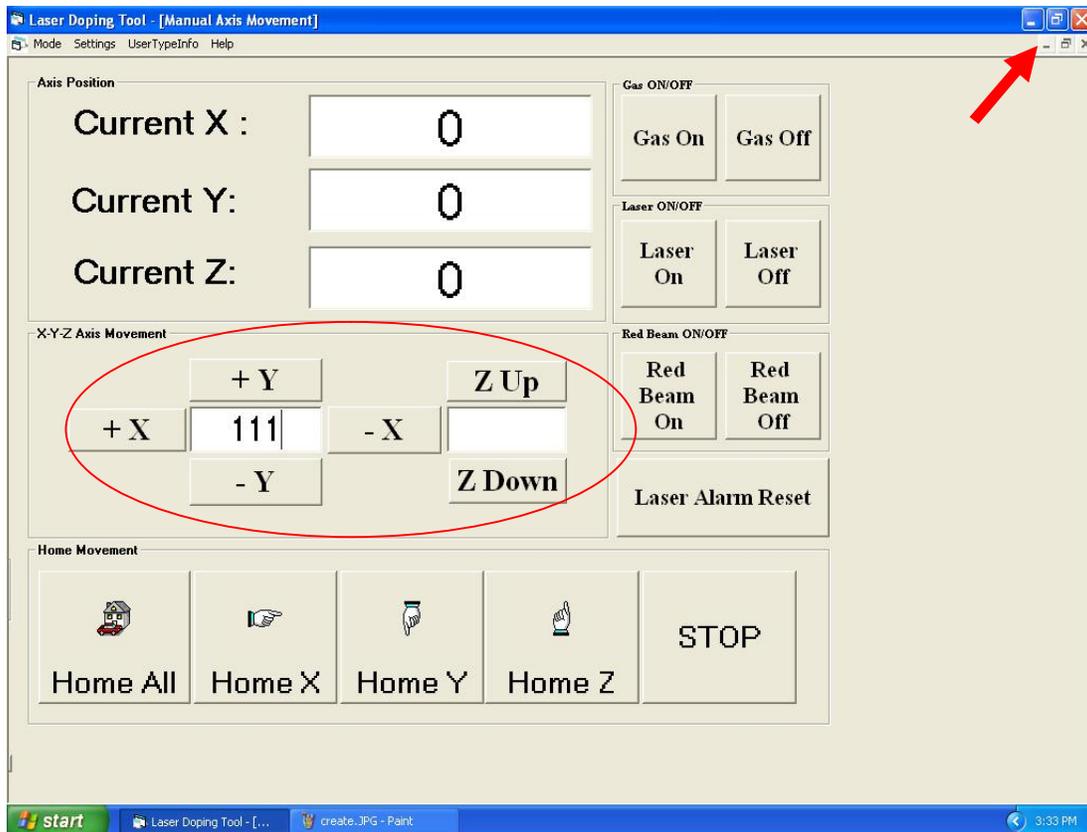


Fig 3: X-Y-Z movement interface

7. The first step is *Homing* all the axes. First click 'Home Z'. This will move the Z-axis of the stage to home/origin of the axis. Next do 'Home X' and then 'Home Y'. **Do not click 'Home All'**. Do them as the sequence specified.

8. Use the +X, -X buttons after entering some values in the box to move the stage along X direction. Similarly use +Y, -Y buttons to move the stage in Y direction. The position of the stage will be shown as 'Current X' and 'Current Y'. Assume them to be coordinates.
9. Similarly z-axis can be moved up and down in same way by using 'Z up' and 'Z down'. The z coordinate will be shown as 'Current Z' value.
10. Now to focus the beam at 250 – 300 μm thick silicon surface, the z-coordinate (Current Z) should be in the **range of 59.2-59.5 mm**.

NOTE: The z-coordinate should never be higher than 60 mm. The lens assembly's nozzle should never touch the sample or stage surface. The z-axis should be moved only after X and Y movements are done (opposite to *Homing* sequence). Maximum X and maximum Y are both 200 mm.

11. Now click the 'Red Beam On' button. The button should become green and a red point should be visible on the sample/stage surface.
12. There is a 50 mm X 50 mm square marked on the sample stage. If the (X, Y) coordinates are (111, 107) and z coordinate is like 59, the red beam should point the center of the square. This could be used as the reference point. Turn off the Red laser after this alignment.
13. Now enable the laser by turning on the 'Laser Enable' key at the control panel. There is also another such key at the body of laser source too. That should have to be on too. Set the laser power, frequency and duty at the control panel (explained in next section). Turn on the gas by clicking 'Gas On'. Slide down the front shutter of the system. Now the laser can be turned on/off by clicking 'Laser On'/ 'Laser Off' button at the 'Jog' interface. When main laser is enabled, red laser won't get on. Turn off the gas jet after the laser is turned off.
14. Now minimize the 'Jog' window only (click minimization button as shown by the arrow in figure 3). Go to 'Mode' \rightarrow 'Scanning' menu. This will open a new window as shown in figure 4. This interface is used to raster scan the laser over a specified rectangular/square area.

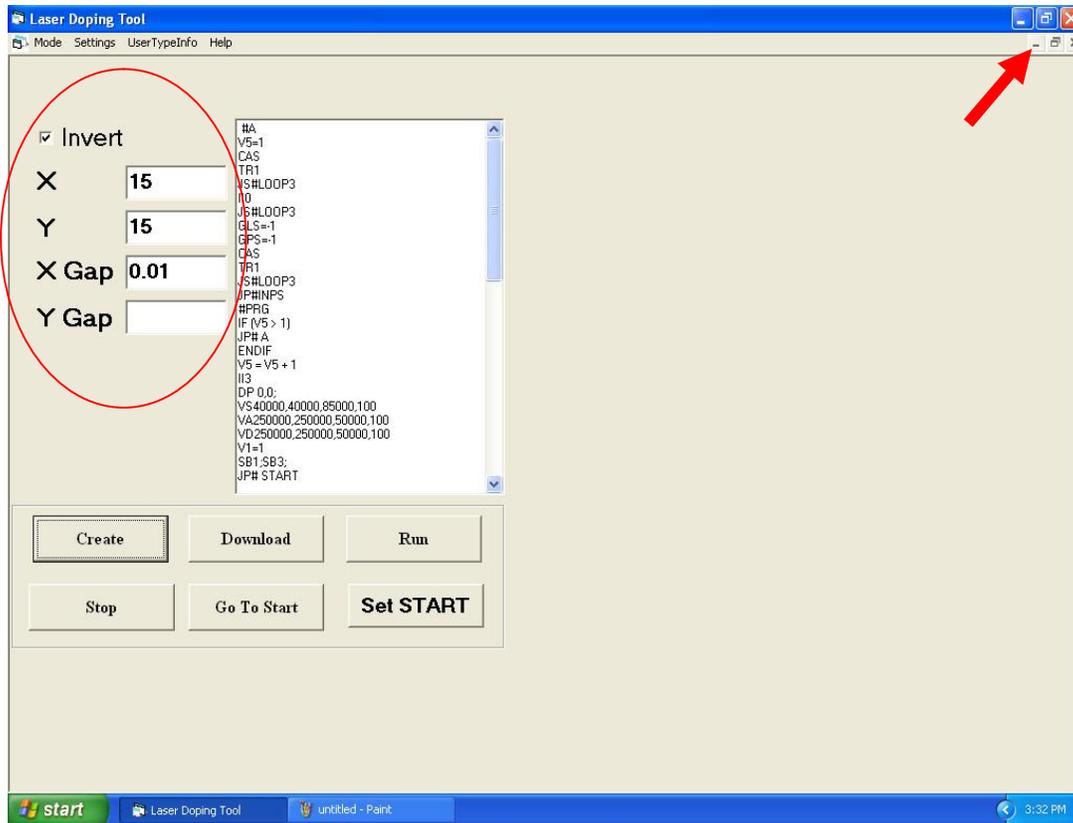


Fig 4: Raster scan interface

15. Set the laser power, frequency and duty at the control panel (explained in next section). Set X, Y and 'X Gap' values (all in mm). Click 'Create' → 'Download' → 'Run'. Check if laser is enabled. Slide down the front shutter of the system. Now push the green 'Start Cycle' button at the control panel. This will start the raster scan of lines parallel to Y axis and the increment along X axis as specified by 'X Gap' value.
16. If you tick off the option 'Invert', 'X Gap' will be disabled and 'Y Gap' will get enabled. If the same procedure, as mentioned above, is followed, raster scan will start along X-axis and with increment along Y-axis. During the scans, gas jet will work automatically.
17. At any point of time if you want to stop the scan, push the red 'Stop Cycle' button at the control panel or click the 'Stop' button at the 'Create file' interface. Once you stop the scan, click 'Go To Start'. Then to start a new or same scan, follow all steps as mentioned above.

NOTE: Always click 'Go To Start' after you stop a scan. Otherwise, the coordinate values of the reference point will be disturbed and you have to again do *Homing* of X and Y. The 'X Gap' and 'Y Gap' values should not be set less than 0.005 mm (5 μm).

18. To change the position of the start of the scan, minimize the 'CreateFile' window (click minimization button as shown by the arrow in figure 3) and maximize the 'Jog' (Manual Movement) window and follow procedures explained earlier.
19. To change the speed, acceleration and deceleration of scanning, go to 'Settings' → 'Cutting SPACDC'. To change the speed, acceleration and deceleration of manual movement, go to 'Settings' → 'Movement SPACDC'. All the values are in $\mu\text{m/s}$ or $\mu\text{m/s}^2$.
20. At any point of time, if you exit the software or restart the computer, do *Homing* for all three axes in the sequence specified earlier.
21. During shutting down system, first do *Homing* for all three axes in the sequence specified earlier. Exit the software. Turn off the computer. Switch off the 'Axis Enable' and 'Laser Enable' keys on the control panel. Push the 'Emergency' button to shut down the system. Close the gas line valve and turn off the main power line.

4. Laser power, frequency and duty² control

1. These three parameters are controlled by the three regulation knobs on the control panel. The values of these knobs varies from 1.00 – 10.00 except for ‘Frequency Control’ for which the upper limit is 9.70.

NOTE: All the three knobs have a lock on top of the knob. While changing the value, unlock it, change it and again lock it. Do not hurry, vary them slowly and smoothly.

2. For these knobs, 1.00 is equivalent to 10% and 10.00 is equivalent to 100%. The scale is linear.
3. These three parameters may be varied between 10% - 100% of their maximum values.
4. The maximum values for Laser Power, Frequency and Duty are 25 W, 100 kHz and 100% respectively. Hence Laser Power, Frequency and Duty can be varied between 2.5 – 25 W, 10 kHz – 97 kHz and 10% - 100% respectively.
5. However for safety, ‘Laser Power’ and ‘Duty Control’ should not be set below 15% (1.50).
6. For bare Si, the value of ‘Laser Power’ = 3.00 ‘Frequency’=6.50 and ‘Duty Control’=2.50 would melt the substrate due to very high fluence. Enhancing the laser power and duty or reducing the frequency will lead to ablation.
7. If the laser is focused on silicon surface, under the above condition, bright yellow spot should be visible while laser is operational. This may be considered to identify the focus of the lens assembly.

² Duty = Pulse on/off ratio (tp/Tp)

5. Precautions

1. Never set the laser power, duty and frequency below 1.50 (15%). Also avoid the highest values for them.
2. Check if the knobs are locked or not before varying them.
3. While system start and shut down, do *Homing* in the sequence: Home Z → Home X and Y.
4. Do not use 'Home All'.
5. While manually moving the stage, follow the sequence: Move X and Y → Move Z.
6. Z coordinate value should never be higher than 60 mm. X and Y should not be higher than 200 mm.
7. Do not set the 'X Gap' or 'Y Gap' values below 0.005 mm (5 μm).
8. Do not touch the optical components or the beam delivering fiber optic cable. They are finely positioned on optical axis.
9. Slide down the shutter while the main laser is operational.
10. Gas jet should be on while main laser is operational.
11. The body of the system is powder coated. Do not use acetone or huge quantity of alcohol to clean.
12. The power density at focus is extremely high $\sim 10^9 - 10^{10}$ W/m². So be careful.

6. Cleaning

Wear hand-gloves first. To clean the system, use small amount of IPA in lint-free cloth and clean the chuck/sample stage first. Then clean other area within the chamber. The optical components are aligned along the optical axis. So do not try to clean the optical components and the beam delivery cable if you are not aware of the sensitivity of alignment. After cleaning the inside chamber, pull down the shutter and clean the outer body of the system and the control panel. Take proper care for fumes of IPA.

NOTE – Be careful while cleaning. Your hand/body should not collide with the lens.