MiniGL

FIRMWARE REQUIREMENT SPECIFICATION

May 29, 2003

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1 PURPOSE

The purpose of this document is to define the requirements of the firmware for the Mini-GL and LE laser systems. The firmware for these lasers will be designed to deliver and calibrate the selected fluence settings, control system functions, and provide user interface functions. The firmware will be used to control internal parameters, monitor and maintain operation variables.

The intended audience for this document includes the following:

- Marketing
- Engineering
- Regulatory Affairs
- Clinical Research
- Quality Assurance
- Field Service
- Manufacturing

2 DEFINITIONS

The following are definitions of terms and acronyms used in this document:

A/D:	Analog-to-Digital Converter
CDRH:	Center for Devices and Radiological Health
CP:	Cal Port Energy
CPU:	Central Processing Unit (Microprocessor)
D/A:	Digital-to-Analog Converter
DCD:	Dynamic Cooling Device
DI:	De-Ionized Water
EOC:	End of Charge
HD:	Head Energy
HVPS:	High Voltage Power Supply
HP:	Handpiece
I/O:	Input/Output
LCD:	Liquid-Crystal Display
LVM:	Laser Variable Mode (User access to Service Information)
MM:	Maintenance Mode (Service Tech access to in-depth System Control)
RAM:	Random Access Memory
ROM:	Read Only Memory
TSDP:	Touch Screen Display Panel (LCD display with touch panel overlay)
UI:	User Interface
xHD:	Expected Head Energy

3 REFERENCES

The following reference documents were used in the development of this requirement:

- 8502-30-0010 CANDELA Firmware Standard Operating Procedure (FSOP)
- 9914-90-0880 Mini-GL Engineering Design Specification
- 9914-92-0880 Mini-GL System Requirement Specification
- 9914-84-0880 Mini-GL Functional Block Diagram

4 PRODUCT DESCRIPTION

4.1 PRODUCT CONCEPT

4.1.1 MINI-GL

The MiniGL laser is a pulsed, flash lamp excited medical laser, controlled by an embedded microprocessor (or CPU), to be used for the removal of vascular lesions that absorb strongly at the 755nm wavelength. The Mini-GL laser delivers the energy using one of six delivery systems: 1) A DCD enabled HP with a 6mm/8mm/10mm slider, 2) A non-DCD version with the same slider, 3) A DCD enabled HP with a 12mm/15mm/18mm slider, and 4) A non-DCD version with this same slider, 5) A DCD enabled HP with a 12mm slider, and 6) A non-DCD version with this same slider.

4.1.2 MINI-GL (LE)

The MiniGL (LE) uses exactly the same firmware. The differences from the Mini-GL are slight. The LE only supports two delivery systems: 1) A DCD enabled HP with a 12mm slider, and 2) A non-DCD version with this same slider. The HVPS is modified to only allow repetition rates of 1Hz, The laser-type selection is accomplished by entering a different model number in MM.

4.1.3 BOTH SYSTEMS

The system is comprised of a HVPS, flash lamp, laser head, and associated optics to direct the laser beam into a fiber delivery system for accurate control of the laser beam spot size. An embedded 68HC12 micro-controller is used to control the laser components, display and touch screen, and control electronics to deliver proper treatment energy.

The system's User Interface is achieved through the use of an LCD display, and a resistive touch screen overlay integrated into the display. Graphical buttons are displayed on the LCD display to allow for flexible control. The UI allows the operator to select treatment energies, set optional parameters, and control operational states of the system.
An optional Dynamic Cooling Device (DCD) is available with the Mini-GL system to provide cooling to the epidermis prior to each laser pulse. The firmware regulates the cryogen pressure, maintains a remaining spray count, and delivers cryogen.

The laser has the ability to calibrate the output energy of the delivery system to the fluence level selected by the operator. Once the energy has been calibrated, the laser can deliver a single pulse or deliver continuous pulses at a rate of 1.5Hz (MGL) or 1.0Hz (MGL-LE), while the trigger switch is engaged.

Lasing is accomplished by discharging the charged Pulse Forming Network (PFN) into the flash lamp thereby exciting the lasing material. Through a calibration process, the firmware calculates the charge voltage necessary to establish a relationship between the applied PFN voltage and the delivered energy. During treatment pulses, the system monitors the HV charging process, and measures the energy of each pulse.

4.2 CONTROL SYSTEM FIRMWARE

The system firmware will be designed to accomplish the following tasks:

- Initialization of all hardware into a known safe state at power-on. (see section 5.1.1)
- Verification of memory: ROM & Battery Backed RAM (see section 5.1.1).
- Verification of hardware diagnostic (see section 5.1.1).
- Control all system states & processes (*Italic*) (see section 5.1):
  - STANDBY
    - *WARMUP*
  - READY
    - *CALIBRATE*
    - *ACTIVATE*
  - FAULT
- Maintain a User Interface (UI) via a control panel located on the laser façade. The UI will allow the operator to select the user adjustable parameters of the system. The interface will also be used to convey faults, warnings, and system status to the user (see section 5.2).
- Control DCD pressure and DI temperature critical to system operation (see sections 5.3, 5.4).
- Calibrate and monitor laser energy when the system is pulsing
- Monitor and control capacitor charge and charging state.
- Control and monitor system safety interlock components when in a READY state (see section 5.5)
- Provide a Laser Variable Mode display screen. This screen provides read-only information as to system status.
- Provide Service Mode (formerly Maintenance Mode) display screens. Service Mode will allows users (service personnel and in-house personnel) to monitor, control, and change values normally maintained by system software (see section 5.6).
- Handle all controllable conditions where the system is not operating within "specified" parameters (see section 6).

4.3 CONSTRAINTS

The following constraints shall be imposed on the firmware design:

4.3.1 HARDWARE

- The system µP will operate at 8-MHz.
- The firmware program will be programmed at CANDELA onto a 512K EPROM or FLASH memory device. Note that the board only supports the upper 256 Kbytes of program memory (ROM).
- The maximum amount of external memory (RAM) available shall be 32 Kbytes (non-volatile). This external memory will be partitioned to hold non-volatile variables, temporary variables, and stack information in separated regions of memory.

- Battery backed system parameters and calibration data used by the firmware shall be stored in the non-volatile sector of RAM and will be checked at each power-up.
- A hardware interlock prevents laser operation if the remote CDRH interlock is not inserted.

4.3.2 PROGRAMMING LANGUAGE

- The firmware program shall be written in the C language, using assembly language only where absolutely necessary, to allow for easier firmware maintenance.
- The firmware program will be compiled, assembled, and linked using Cosmic Software's C Cross Compiler for Motorola MC68HC12.

4.3.3 SAFETY

- The system shall always power-up in a system-safe state and revert to a system-safe state when the laser faults.
- The firmware prevents laser output while the trigger switch is not being depressed.
- Non-volatile system parameters that are out of range at start-up will default to safe parameters when initialized by software.

4.4 ASSUMPTIONS AND DEPENDENCIES

The following assumptions shall be used in designing the firmware:

- The embedded system is stable and data integrity is preserved while system is powered. Periodic data checks are only required for system-critical parameters.
- All hardware is calibrated to provide the micro-controller with correct input voltages where applicable.
- The operator will use the system in a manner consistent with intended use and comply with direction displayed by the UI and the instruction manual.
- Depressing the trigger switch will be the only method for software to trigger the laser.

5 DETAILED REQUIREMENTS

5.1 SYSTEM STATES

The laser system shall have 3 States: STANDBY, READY, & FAULT. A detailed state chart describing the interaction of the three states and state sub-processes is provided in Figure 1.

1) After the system is powered on and initialized the laser will enter STANDBY state.
2) The laser must be placed in the ready state in order to pulse the laser.
3) Any exceptions to normal system operation parameters will put the laser in the FAULT state.
4) Program execution will always flow through the main loop regardless of state. Background functions and main loop modules will periodically monitor and control system operation.

Mini-GL State Diagram

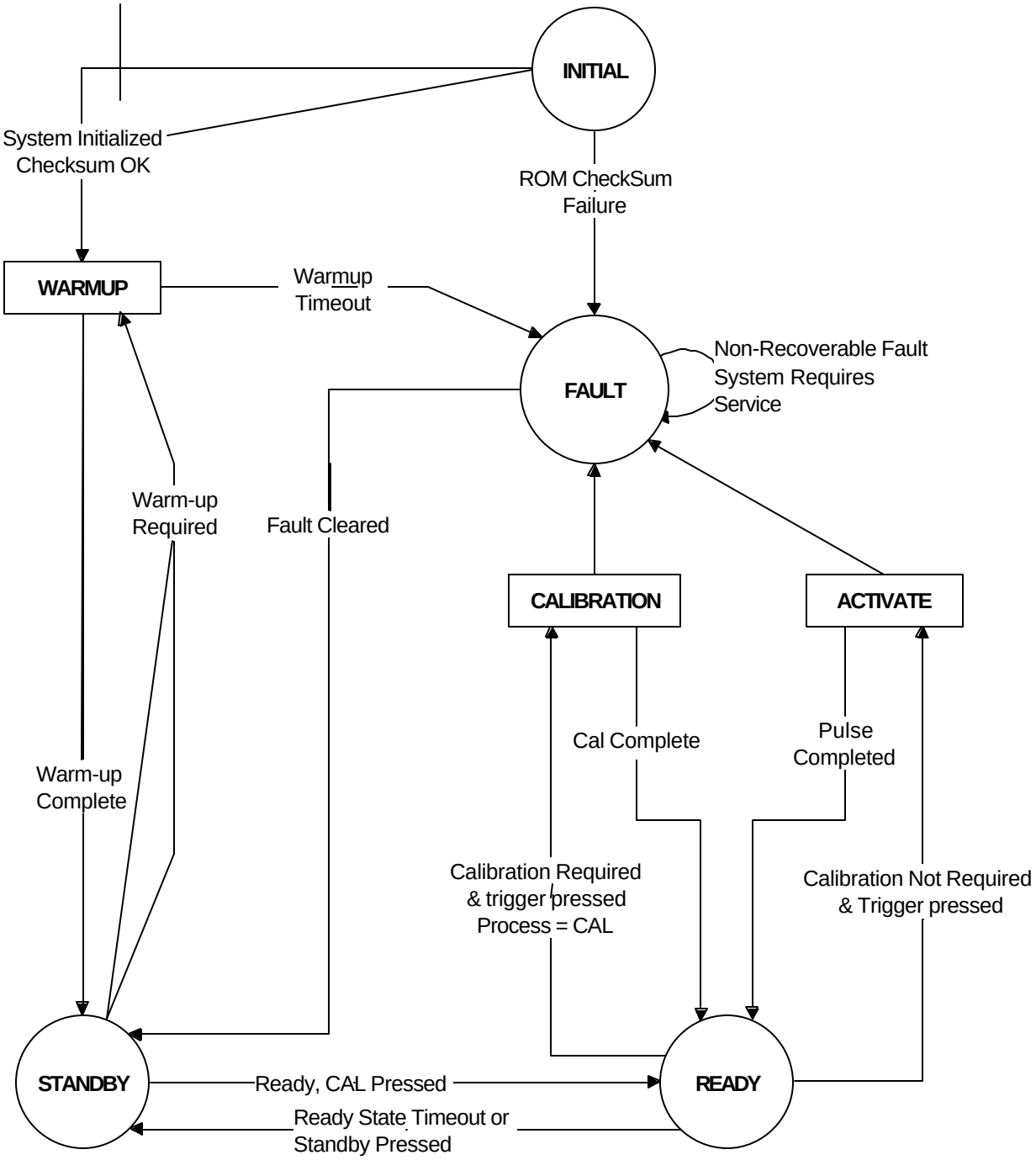


Figure 1 – Mini-GL State Diagram

5.1.1 INITIALIZATION STATE

When the system is powered on, the firmware shall execute the following:

1) System Power On Initialization
   - All system hardware will be reset to a known non-lasing state via the firmware.
2) Firmware/Data Diagnostics:
   - Checksum verification of Read Only Memory is performed. If the calculated value does not equal the stored value, a fault will be indicated.
   - RAM Validity Tests:
3) Check that the software version has not changed from previously stored value. Used as an indication that memory was corrupted or the ROM has been changed. All non-volatile data except Pulse counts and the canister weight are set to a default value if ROM has changed.
4) Check that critical variables are within bounds. If not, then set to default values.
5) Perform a diagnostic of hardware
   - System will determine if external DCD unit is attached.
   - System will verify the DI fluid pump and pressure sensor are operational.
   - System will determine the delivery system connected to the system at all times.
6) Set initial system state to STANDBY.
7) Set Calibration Required – Clear CAL table (forces a Full CAL).
8) Keep UI parameters (Fluence, DCD…) same as previous power-up. If outside range, set to nominal parameters. – No messages are displayed that these changed.
9) Display the Candela Logo along with the firmware P/N and revision.

5.1.2 STANDBY STATE

The firmware shall perform as follows when entering the STANDBY state:

1) Set the laser to the STANDBY state.
2) Indicate the system state as "STANDBY" via the UI.
3) Ensure laser is disabled, and lasing is off.
4) Ensure the laser is in a non-charging state.
5) Ensure the Aiming Beam is off.

5.1.2.1 Standby Sub-process

The firmware shall perform the following while the STANDBY process is executing:

1) Set the Calibration Required if the calibration timer has expired (30minutes), or delivery system is disconnected, or the HP slider position has been changed.
2) Verify Laser Shutter is closed.
3) Verify HV reference is set to a zero value.
4) Allow entry into LVM or MM.

5.1.2.2 Warm-up Sub-process

The firmware shall perform the following while the WARMUP process is executing:

1) DI water temperature and (if connected) cryogen pressure will be monitored periodically.
2) A Warm-up status percentage bar is set according to the following:
   - Calculate %Complete of DI temperature from nominal ambient temperature to operating temperature.
   - Calculate %Complete of DCD Pressure (if connected) from nominal ambient pressure to operating pressure.
   - Display %Complete of the lowest percentage on the UI.
3) Warm-up will complete when both DI temperature and DCD Pressure have come within the proper range.
4) Allow entry into LVM or MM.
5) Upon completion of WARMUP the unit reverts to the STANDBY process.

5.1.3 READY STATE

The firmware shall perform as follows when entering the READY state:

1) Set the laser to the READY state.
2) Indicate the system state as "READY" via the UI.

3) Set aiming beam ON. The user can set the aiming beam intensity to 3 different settings. The beam must always be visible while in Ready to meet "remote Ready Indicator" safety condition.
4) Prevent entry if the trigger switch is pressed, and display a warning message until trigger switch is released.
5) Do a Bubble Circuit test on HP and Canister sensors (DCD enabled). If there are no bubbles during test – then fault.
6) As a safety precaution, delay 2 seconds after Ready Lamp and Aiming Beam (remote Ready indicator) ON, before enabling the HVPS.
    - HVPS only enabled if calibration is not required and valid charge voltage is set.

5.1.3.1 Ready Sub-processes

The firmware shall perform the following while in the READY sub-process:
1) Initiate HV charge sequence prior to each laser pulse.
2) Monitor pulse timer to deliver pulses at a rate of up to 1.5 Hz when the trigger switch is continuously depressed.
3) Determine when conditions have been met to pulse.
    - Rep Rate Timer has expired
    - HV Charged
    - Trigger is pressed
4) Shutter is open while in Ready to allow Aiming Beam to be seen.
5) As a safety precaution, if the laser is in the READY and laser output has not been generated within the last 2 minutes, the system will automatically return to the STANDBY State. (READY state timeout).
6) When a valid trigger source is detected the ACTIVATE process or CALIBRATION process will be executed based on the cal required flag status.
7) MAIN screen is the only screen available while pulsing. This is so that Fluence, and other parameters are present while pulsing.
8) When using a long PreSpray and Delay time, the laser can start spraying prior to the HV charge attains the EOC to allow the laser to run at it's fastest rep rate.

5.1.3.2 Calibrate Sub-processes

The firmware shall perform the following while the CALIBRATION process is executing:
1) Display a spot size confirm message on entry into CAL. This should not be shown on the LE model.
2) Prompt the user to place the handpiece in the CAL PORT and depress the trigger switch.
3) Initialize calibration variables.
4) Calculate initial HVPS voltage from the selected fluence and fluence vs. Voltage curve.
5) With the trigger switch depressed, pulse laser into CAL PORT and adjust voltage to achieve desired fluence.
6) On completion of a CAL, when the user removes the handpiece from the Cal Port, the system will automatically revert back to Standby to allow the user to install a distance gauge. The handpiece MUST be removed at the end of the calibration to clear the CAL required status. If the Standby button is pressed at the end of the CAL, the CAL required status would not be cleared. This is done to ensure the cal port switch is tested for a state change. Note that the footswitch and fingerswitch will both meet these criteria.
7) Force the system to Standby if a required user action has not been performed in a short time period (15 seconds – 1 minute).

5.1.3.3 Activate Sub-processes

The firmware shall perform the following while executing the ACTIVATE process when the trigger is activated:
1) Start the DCD/Lasing sequence.
2) Measure laser energy output and verify system operation is within limits.
3) Update system and treatment pulse counters as necessary.
4) Display a Lasing icon.

5.1.4 FAULT STATE

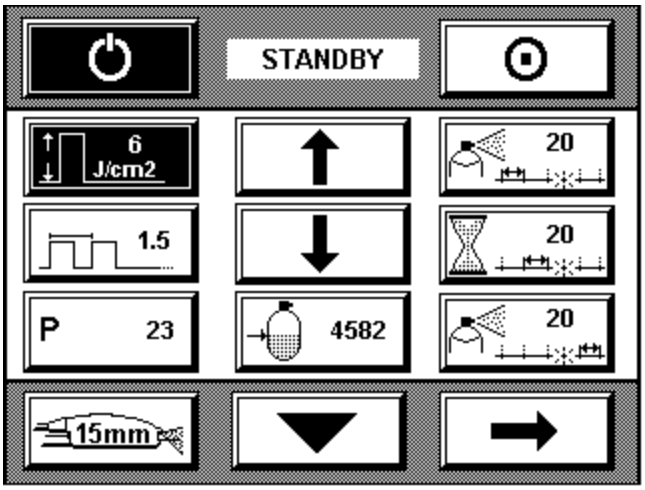
The firmware shall perform as follows when in the FAULT state:
1) Set the laser to the fault state.
2) Inform the user of fault condition via UI.
3) Return the laser to a non-lasing state to prevent personal injury or damage to the laser.
4) System disallows further emission until the user corrects the problem (if possible) and clears the fault via the UI.
5) Set required flags (CAL or Warmup required) required by a fault when system cleared from the fault state. See individual fault list.

6) When a fault condition is cleared the system will enter the STANDBY state.
7) If the system is in maintenance mode, faults will be not be serviced, and the system will continue running.

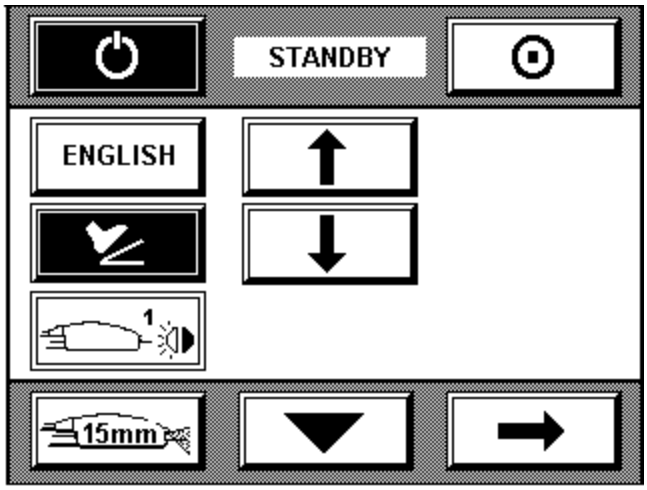
5.2 USER INTERFACE

5.2.1 OPERATOR CONTROLS

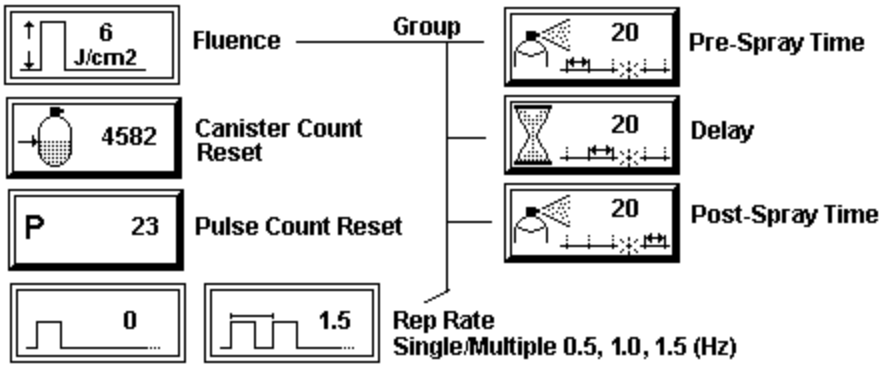
The firmware shall acquire operator input by monitoring the control panel touch screen.



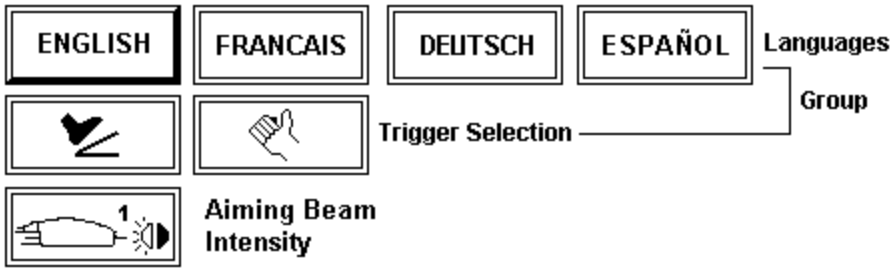
Main



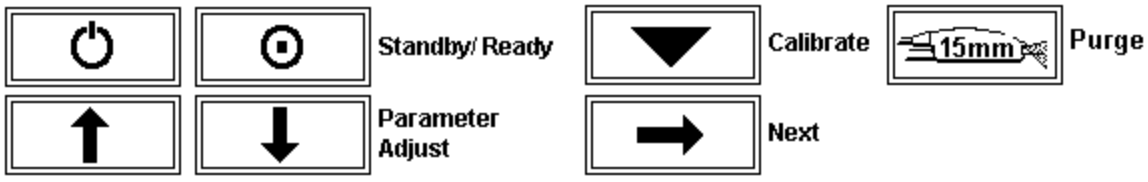
Options



Main Screen Buttons



Options Screen Buttons



System Control Buttons

5.2.1.1 Control Buttons

The following display buttons are in the "Control" section (upper and lower portion) of the UI.

1) Standby - Places the system in STANDBY state.
2) Ready - Places the system in READY state.
3) Calibrate - Causes the system to begin energy calibration.
4) Purge - Purges the DCD cryogen lines of air/gas. Also displays the currently selected spot size. If the DCD is not enabled, a "handpiece" icon will be displayed in the lower Control section (instead of the purge button.) This displays the active spot-size. If the spot size is unknown, it will display "---". When the slider position is changed, and the Fluence is outside the range for this new spot-size, it is set to the lowest.
5) Next - Selects the next screen (Main or Options screen).

5.2.1.2 Main Screen Parameter Buttons

The following display buttons are in the 'Parameter" section (mid section) of the Main screen.

1) Fluence Select - Selects the fluence parameter. The Up/Down Adjust buttons are used to adjust the fluence in 1, 2 or 5J increments based on the spot size and displayed fluence. (Spot size is limited to 12mm only for the LE version.)
2) Rep Rate Select - Selects the Laser pulse repetition rate. The Up/Down Adjust buttons can select Single (0Hz), 0.5Hz, 1.0Hz, or 1.5Hz. (Rep Rate maximum is 1.0Hz for the LE version.)
3) DCD Pre-Spray Select - Selects the cryogen spray timing (if DCD connected) prior to lasing. The Up/Down Adjust buttons are used to adjust the time to 0, and 20-100 in 10 ms increments. If the spot size is changed to 15mm or 18mm, the pre-spray will default to 30ms or 40ms, respectively, if below these values. This default will occur at power-up as well.
4) DCD Delay Select - Selects the delay between first cryogen spray and lasing pulse. The Up/Down Adjust buttons are used to adjust the time to 3, 5, and 10-150 in 10ms increments.
5) DCD Post-Spray Select - Selects the cryogen spray timing (if DCD connected) after lasing completed. The Up/Down Adjust buttons are used to adjust the time to 0, and 10-100 in 10ms increments.
6) Up/Down Adjust - Adjusts the selected parameter. If an Adjust button is held down, the selected parameter is incremented to its limit. The increment speed also increases if held down.
7) Pulse Count Reset - Displays Patient Pulses counted. Pressing the button for 2 seconds resets the counter.
8) Canister Pulses Reset - Displays the remaining DCD cryogen pulses. Pressing the button for 2 seconds resets the canister pulses to indicate a full canister for the current spray selections.

5.2.1.3 Option Screen Parameter Buttons

The following display buttons are in the 'Parameter" section (mid section) of the Options screen.

1) Language Select - Selects the Language parameter. The Up/Down Adjust buttons are used to select the language used to display all messages.
2) Trigger Switch Select - Selects the Trigger switch. The Up/Down Adjust buttons are used to select Footswitch or Fingerswitch.
3) Aiming Beam - Selects the Aiming Beam Intensity. The Up/Down Adjust buttons are used to select three different intensities.

5.2.2 DISPLAYED CONTROL VARIABLES

The following information will be provided via the control panel:

1) Laser Status (READY or STANDBY).
2) Fluence setting.
3) Repetition Rate setting.
4) DCD Pre-Spray timing.
5) DCD Delay timing.
6) DCD Post-Spray timing.
7) DCD pulses remaining.
8) Patient Pulses (Reset by user).

5.3 DCD CONTROL (OPTIONAL)

The DCD spray sequence is defined as a PreSpray time (from TSDP), a Delay Time (from TSDP), a fixed spray time, the 1st fixed delay, and then the laser pulses. After the laser pulse, the DCD spray sequence continues with a 2nd fixed delay, and the PostSpray time (from TSDP).

- Pre-Spray time [TSDP PreSpray time in ms] – 5ms (accommodates the Fixed Spray Time)
- Delay time [TSDP Delay time in ms]
- Fixed Spray time [5ms]
- 1st Fixed Delay time [9ms]
- Laser Pulse
- 2nd Fixed Delay time [6ms]
- Post-Spray time [TSDP PostSpray time in ms]

The following tolerance requirements are for the above time segments:

Time segment < 50ms +-2ms
Time segment >= 50ms +-5%

The DCD or cryogen system is installed as an option. There are four different scenarios of cooling:

5.3.1 NO DCD CONNECTED (NO TREATMENT AREA COOLING)

1) DCD related Buttons (Purge, Pre-Spray, Delay, Post-Spray, Canister Volume) are not displayed.
2) A spot-size selected icon is displayed in place of the Purge button
3) Firmware keeps DCD Canister Heater signal Off (safe condition)
4) DCD Pressure sensor is ignored
5) DCD Bubble detects both ignored
6) Firmware pulses laser w/o any DCD time delays
7) Allow use of either DCD (no spray of course) or non-DCD delivery systems.

5.3.2 INTERNAL DCD (CANDELA 1000G CANISTER) CONNECTED

1) HP and Canister Bubble detectors are tested for proper operation on entry into Ready.
2) DCD unit is detected when changed by a dedicated control signal.
3) DCD related Buttons (Purge, Pre-Spray, Delay, Post-Spray, Canister Volume) are displayed and active.
4) Control a canister heater to maintain pressure as specified in Engineering Design Spec #9914-90-0880. A PI algorithm is used to determine the heater duty cycle.
5) Determine if a DCD enabled delivery system is connected to the system. If not connected, don't display buttons.
6) Monitor bubble sensors located in the handpiece and at the base of the canister. The sensors will be used to perform the following tasks:
   - Ensure bubbles are not in the cryogen line when DCD is being sprayed, and fault when bubbles present.
   - Determine when the cryogen canister needs to be replaced.
7) Dispense cryogen during pulse or purge operations (for length of Pre-spray + Post-spray settings) by controlling an electronic valve in the cryogen delivery system.
8) Allow the user to purge the cryogen delivery system.

5.3.3 EXTERNAL DCD (EXTERNAL LARGE CYLINDER) CONNECTED

1) Only HP Bubble detector is tested for proper operation on entry into Ready.
2) DCD unit is detected when changed by a second dedicated control signal.
3) DCD related Buttons (Purge, Pre-Spray, Delay, Post-Spray), except Canister Volume, are displayed and active.
4) Firmware keeps DCD Canister Heater signal Off (safe condition)
5) Determine if a DCD enabled delivery system is connected to the system. If not connected, don't display buttons.
6) Monitor bubble sensor located only in the handpiece. The sensor will be used to perform the following tasks:
7) Ensure bubbles are not in cryogen line when DCD is being sprayed, and fault when bubbles present.
8) Dispense cryogen during pulse or purge operations (for length of Pre-spray + Post-spray settings) by controlling an electronic valve in the cryogen delivery system.
9) Allow the user to purge the cryogen delivery system.

5.3.4 THIRD PARTY VENDOR COOLING

This option allows other cooling devices to be used. There is no synchronization provided. The Laser firmware operates as if there is no DCD connected.

5.4 DI TEMPERATURE CONTROL

To control the DI temperature, the firmware will:

1) Maintain DI temperature to +-2degC.
2) Utilize 'bang-bang' control to heat DI reservoir temperature when below the set point.
3) Utilize PI control of a pulse-width modulated DC fan to maintain DI temperature when above set point.
4) Run a diagnostic at power up to ensure water pump and pressure switch operate correctly.
5) Monitor water pressure during system operation.
6) Turn DI fans on for 3 seconds every 3 minutes in Standby if they haven't been on.

5.5 SYSTEM SAFETY MONITOR COMPONENTS

To ensure operator and patient safety, the firmware will:

1) Monitor Cal Port switch to insure hand piece is in Cal Port when necessary.
2) Monitor Delivery System detection circuitry.
3) Differentiate between hand piece spot sizes and DCD and Non-DCD enabled hand pieces and enable DCD control based on the HP.
4) Monitor removal of the delivery system fiber when in READY state.

5.6 SYSTEM MAINTENANCE INTERFACE

5.6.1 LASER VARIABLE MODE (LVM)

The firmware will allow viewing of critical system parameters in LVM. The purpose of LVM is to simplify system diagnostics over the phone with service personnel. It provides the following:

1) Access to the LVM is accomplished by pressing the Next button for 2 seconds.
2) Display calculated Head energy at 60J parameter.
3) Provide a Touch Screen calibration button.
4) Display firmware P/N and revision.
5) Display Model and Serial # to allow customer easy access to info when talking with Tech Support.
6) Display Total Treatment Pulses (non-CAL Pulses).
7) Display pulse data consisting of: pulse #, HV, HD, CP, TX (to 2 decimal places).
8) Provide Standard Deviation, and mean of HD and CP energies. A button is provided to reset counts.

5.6.2 MAINTENANCE MODE (MM OR MAINT MODE)

The firmware will provide service with a Maintenance Mode that performs the following:

1) This mode is accessed by first, pressing an internal switch, and then entering a 4 digit access code.
2) All control of the laser is through the lasers' UI.
3) An external PC laptop connected via an RS-232 serial port (baud rate of 9600 bps) provides the ability to output pulse data.
4) The user cannot access this mode without opening the laser.
5) The Model # and Serial # can be entered in MM. The Mini-GL uses 0880 and 0890, and the LE uses 0910 and 930. This will allow the firmware to detect the difference between the two lasers. The model # will be checked at each power-up to ensure it is these values. The default value will be 9914-0880-0001.
6) Total Treatment Pulses (PP) can be modified.

6 FAULTS AND WARNINGS

The Mini-GL constantly monitors its sub-systems. The following are conditions that may interfere with 'normal' system operation and will display a warning or fault message. Note the "C" and "W" indicates a CAL or Warmup is required.

-1. Mini-GL Fault Type	FAULT	DESCRIPTION	
1 - BUBBLE DETECT CIRCUIT FAULT	1.1	HP Bubble Circuit Test didn't detect a change in the signal (with DCD-enabled HP). (Internal [Candela] or External Cylinder DCD system must be installed)	
	1.2	Canister Bubble Circuit Test didn't detect a change in the signal (with DCD-enabled HP). (Internal [Candela] DCD system must be installed)	
2 - ROM CHECKSUM	2	Calculation of checksum at power-up does not match checksum value in memory.	
3 - SHUTTER FAULT	3	Shutter isn't in correct state when checked. Does not respond to actuation to correct state.	
5 - HV TOLERANCE FAULT	5.1	HV sample does not settle to within +-8 volt at End of Charge (EOC) within 1.5 seconds.	C
	5.2	HV sample is not within +-3% of HV reference when HVPS is at EOC.	C
	5.3	HV sample is not within +-3% of HV reference after DCD pre-spray already occurred.	C
6 - CALIBRATION FAULT	6.1	CAL Low slope point not in range of 500V to 1800V.	C
	6.2	Expected Head Energy (xHD) is calculated > Max HD Energy of 75 J.	C
	6.3	Laser failed to CAL to desired Fluence within 25 pulses.	C
	6.4	CAL required a HV > 2000V for desired Fluence.	C
7 - DI SYSTEM FAULT	7.1	DI temp < 60degC when not in warm-up.	CW
	7.2	DI temp > 70degC while in Ready state.	CW
	7.3	DI pressure switch does not change when power turned on. OR DI pump is not ON or DI pressure switch not actuated.	CW
	7.4	DI temp < Thermistor Open Temperature (5) OR DI temp > Thermistor Shorted Temp (98) while in Ready state	C
8 - DCD PRESSURE FAULT	8.1	DCD pressure < 105 psi while in READY & INT_DCD & HP w/DCD & spray setting is non-zero.	W
	8.2	DCD Pressure > 135 psi & INT_DCD	W
9 - WARM-UP TIMEOUT	9.1	DI temperature < 62degC after 60 minute warm-up	W
	9.2	DCD pressure < 105psi after 60 minute warm-up (Only when DCD enabled)	W
10 - DELIVERY SYSTEM FAULT	10.1	HP type changed or unrecognized while in Ready (15 consecutive reads at 50 ms interval)	C
	10.4	Fiber not detected while in Ready (15 consecutive reads at 50 ms interval)	C
	10.5	Slider button pressed while in Ready State. Cannot change spot-size while in Ready.	C
12 - ENERGY OUT OF RANGE FAULT	12.1	On last treatment pulse, the head energy (HD) was 14% lower than expected head energy (xHD).	C
	12.2	On last treatment pulse, the head energy (HD) was 14% higher than expected head energy (xHD).	C
	12.3	The head energy (HD) of the last pulse > Max Treatment HD Energy of 75 J.	C
13 - TRIGGER SWITCH FAULT	13	The redundant trigger switches were in two different states for > 1 second while in ready.	
15 - TRANSMISSION FAULT	15.1	Transmission (Tx) is < 70%. (HD or CP energy > 5.0 J)	C
	15.2	Transmission (Tx) is > 100%. (HD or CP energy > 5.0 J)	C

WARNING	DESCRIPTION
(16) REPLACE CANISTER	Displays once when DCD Canister Pulse count = 0 Displays if canister bubble is detected in Ready and DCD is enabled.
(17) PURGE REQUIRED	Bubble percentage is outside of tolerable range (~15% bubbles).
EXIT TO CLEAN WINDOW?	Transmission is < 75% - Delivery system degrading - Clean Window