ACOUSTO-OPTIC Q-SWITCH
&
ELECTRONIC CONTROL

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ACOUSTO-OPTIC Q-SWITCH & ELECTRONIC CONTROL

I.0 ACOUSTO-OPTIC Q-SWITCH:

The U. S. Laser high power acousto-optic Q-Switch is an optical device utilizing Bragg diffraction to spoil the gain of the laser cavity, allowing loss modulation, or, "Q-Switching". Operating in the shear wave mode, it is unaffected by laser polarization, making it especially useful with randomly polarized as well as polarized lasers. The Q-Switch is driven by modulated 24 MHz R.F. power from the R.F. driver assembly. In TEM_{00} mode or lower power multimode lasers, the R.F. power used is generally 35 to 55 Watts to the Q-Switch. In these applications, the Q-Switch should never be driven with over 60 Watts. In high power multimode applications, 50 to 65 watts of R.F. drive is typical. Due to the high R.F. powers applied to these Q-Switches, they are water cooled, and a safety interlock provides overheat protection. As utilized in the laser system, the Q-Switch is mounted on a 2-axis kinematic mount, which facilitates optical alignment and Bragg angle adjustment (see alignment section of manual).

The acousto-optic Q-Switch is made up of the following elements:

A. An Inductive Impedance Matching Network which properly couples the 24 MHz R.F. driver output to the Q-Switch.

B. A Lithium Niobate, or similar, Piezoelectric Transducer which converts the incident R.F. energy to an ultrasonic wave which is transmitted to the quartz optical block.

C. An A.R. Coated Schleiren Grade Fused Silica Optical Transmission Block which transmits the laser beam, and is excited by the R.F. power which is applied to the transducer. The R.F. power is converted to acoustic energy which, in turn, creates an optical phase grating in the material as the ultrasonic wave travels through it. A portion of the light is diffracted by this optical grading, thus inducing a substantial intracavity loss which is sufficient to spoil the cavity gain, or "Q". To attain the optimum angle (the Bragg angle) at which this diffraction occurs, the Q-Switch is mounted on a kinematically adjustable mount.

D. A water Cooling System which is connected into the main laser cooling system to dissipate generated heat buildup.

E. An Overtemp Interlock which turns off the R.F. power in the event of a cooling system, or Q-Switch malfunction.

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I.I CLEANING PROCEDURE:

I.I.I MATERIALS REQUIRED:

a) Acetone
b) Methanol
c) Cotton Swabs
d) Low Lint Lens Tissue
e) Finger Cots or Surgical Gloves
f) 10x Magnification Microscope or Magnifying Loop (recommended but not necessary)

NOTE: Items a) thru e) are included in U. S. Laser Corporation's Optics Cleaning Kit Model #007.

I.I.2 PROCEDURE:

a) Always wear protective finger cots or surgical gloves while cleaning the acousto-optic (AO) device.
b) Remove cover (if applicable) on the AO device.

CAUTION!!!

DO NOT TOUCH THE OPTICAL CRYSTAL SURFACES. DO NOT ALTER THE R.F. TUNING NETWORK. DO NOT UPSET THE LEAD BONDING TO THE TRANSDUCER.

c) Inspect the condition of the optical entrance and exit faces of the optical crystal with the microscope or magnifying loop.
d) Fold a piece of lens tissue to a convenient width so it can wipe the optical face in one pass.
e) Always use a clean tissue with each wipe to prevent streaks.
f) Soak the tissue with acetone and begin wiping from the middle of the optical face to the outside edge. Use the microscope or magnifying loop while performing this step.
g) Repeat step f) with a clean tissue, but wipe in the opposite direction or rotate crystal 180°.
h) Soak another lens tissue with methanol and repeat steps f) and g).
i) Inspect the optical face carefully with the microscope or magnifying lens and repeat the cleaning procedure, if necessary, this time with damp, not soaked, tissues.

j) If the optical face still appears contaminated after two or three cleanings, there may be permanent damage done to the surface. If this has occurred, the AO device will have to be operated with the laser beam in a different position on the optical face. This may not be possible on some AO devices. Contact U. S. Laser's Customer Service Department for more information.

k) Use the cotton swabs if some minor touch up is necessary to remove solvent stains. Use a figure 8 motion or straight strokes.

l) Repeat the cleaning procedure on the opposite face of the crystal.

m) Install cover (if applicable) on the AO device.

1.2 CAUTIONS:

a) Do not use anything but low lint lens tissue or cotton swabs to clean the optical face.

b) Do not blow directly on the optical face with any type of compressed gas.

c) Do not clean the optical face starting from the beveled edges of the optic.

d) Do not use any other solvents except for those listed.

NOTE: If there are any questions or concerns contact U. S. Laser's Customer Service Department.

2.0 Q-SWITCH CONTROL:

The Q-Switch function allows the laser to operate in a pulse train mode. Each pulse is a compression of the continuous wave power over the period of the repetition rate (assuming operation above 1 KHz). The peak power of a pulse may easily be several thousand times the average power of the non-Q-Switched laser. These intense pulses are capable of instantaneously vaporizing the target when finely focused, and therefore are desirable for cutting and trimming applications.

2.1 THE BRAGG CELL:

The optical element for creating the Q-Switch function is the Bragg cell. Under acoustic vibration, this crystal device diffracts the laser cavity light so that the laser is "held off". During the hold-off period, the laser rod is allowed to populate to a highly excited state. When the acoustic wave is rapidly removed, the diffraction ceases and lasing occurs again. Since the laser rod is highly pumped, the cavity gain is high and lasing is strong. Inversion is rapid and complete, producing a pulse of several hundred nanoseconds, after which lasing ceases. Before the rod can populate enough to begin continuous wave lasing, the Bragg cell is re-energized to again hold off the cavity gain. The process is repeated in accord with the desired repetition rate.

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2.1.1 HIGH POWER CONSIDERATION:

In high power lasers (above ≈ 80 watts average power), single element Bragg cell hold-off is not practical. Therefore, two Bragg cells are placed in the laser cavity and driven in tandem.

2.2 THE ACOUSTIC WAVE:

To create the acoustic wave in the Bragg cell, R.F. power stimulates a transducer which is fused to one face of the crystal.

2.2.1 R.F. DRIVER:

Approximately 50 watts of R.F. power are required to drive the transducer on the Bragg cell. In some applications, higher or lower R.F. powers are mandated. For example, high power multi-mode lasers (>100 watts) may require 60 watts of R.F. drive to each of two Q-Switches. TEM_{00} mode lasers, on the other hand, typically are operated below 45 watts of R.F. drive to minimize acoustic decay time, maximize pulse-to-pulse stability, and minimize pulse width. U. S. Laser systems typically incorporate a 24 MHz or 27MHz oscillator and keyable R.F. power amplifier. The Bragg Cell Q-switch must be frequency compatible with the R.F. driver frequency. Note , also, that the Bragg cell is water cooled to dissipate the R.F. power. If in doubt, consult U. S. Laser's Service Department before altering or realigning the R.F. power level.

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2.3 Q-CONTROL:

The Q-Switch control panel is mounted in the Power Supply/Cooler console. The Q-Switch rate is selectable via the control knob to the right of the frequency display meter. For ease of alignment two ranges are available: 0 to 10KHz (range switch down) and 0 to 50 KHz (range switch up). Although the controller will switch the Bragg cell at very high repetition rates, laser performance above 30 KHz is rarely meaningful. The Q-Control modes are as follows:

a) INTERNAL Q:
In this mode, the controller will directly Q-Switch the laser at the rate set on the digital panel meter.

b) GATED Q:
In this mode, the controller will hold off the cavity (inhibit lasing) until a gate command is given. The gate command may be initiated via an external input, or manually from the blue GATE push-button on the Q-Control panel.

Q-Gate input command is a logic low signal applied to either J1-10 (with ground on pin 25), or applied to the front panel BNC GATE jack.

c) TRIG Q:
In this mode, activating either the manual or computer gate command will generate a single laser pulse.

d) GATED CW:
In this mode, the gate command merely allows the laser to come on as a CW laser (no Q-Switching).

2.4 REMOTE FREQUENCY CONTROL:

Two methods of remote frequency control are provided.

2.4.1 POTENTIOMETER CONTROL:

To manually vary the frequency at a remote location, connect a 1K ohm potentiometer across pins J1-23 and J1-3 with the wiper connected to J1-4.. Set the Remote/Local switch to Remote. Adjusting the Remote pot will change the frequency which will be displayed on the panel meter.

2.4.2 V.C.O. CONTROL:

The frequency may also be controlled remotely via accessing the voltage controlled oscillator. For this operation mode, connect a voltage source to pin 4 of the J1 connector. Use pin 3 for the ground. Set the Local/Remote switch to remote. The frequency may now be controlled by varying the applied voltage. 10 x Vapplied=frequency in KHz. Voltages above 10 volts should not be applied.

3.0 PULSE-TO-PULSE STABILITY:

The pulse-to-pulse stability of the Q-Switched pulse train is a function of two principal parameters: 1) laser rod pump level, and 2) cavity gain. For applications which require good pulse-to-pulse stability proper alignment of the system components is paramount.

3.1 POWER SUPPLY:

The degree of power supply ripple can be a significant factor in the Q-Switched pulse amplitude variation. Therefore, for lasers equipped with SCR controlled power supplies, it is essential to perform the phase angle balancing alignment as described in the Power Supply section of this laser manual. For lasers equipped with switching power supplies, no alignment is necessary.

3.2 BRAGG CELL ALIGNMENT:

Initially, the Q-Switch, or Bragg Cell, is mounted in the laser cavity such that the laser beam will pass without obstruction through the vertical center of the aperture. In high power applications, some performance enhancement can be achieved by locating the beam as close to the Bragg cell transducer as is practical.

Then, the Q-Switch is autcollimated to the laser rod end. Next, operate the laser at maximum current; apply R.F. power to the Q-Switch (or Q-Switches) by setting the controller to Gated Q; and tune the Bragg angle for full hold off.

To maximize the pulse-to-pulse stability, it may be necessary to make minor alignment adjustments of the cavity mirrors while observing the Q-Switched pulses with a photodiode and oscilloscope.

On dual Q-Switched lasers, autocollimate the cavity mirrors and Q-Switches. Operate the laser and tune the Bragg angle for maximum hold-off. Operate the laser in the C.W. mode and tune the mirrors for maximum power. Recheck the hold-off and make minor Bragg adjustments if needed. View the Q-Switched laser pulses at 1 KHz with a photodiode and oscilloscope, and tune the Q-Switches for best pulse-to-pulse stability.

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4.0 FIRST PULSE SUPPRESSION: (OPTIONAL)

Since the intensity of the Q-Switched laser pulse is a function of how long the laser rod has been pumped, the first pulse in any pulse train greater than approximately 1 KHz repetition rate will be greater than the rest of the pulses in the train. In some processing applications, this first giant pulse is detrimental and must be suppressed. U. S. Laser Corporation offers two methods of first pulse suppression to accommodate different processing requirements.

4.1 CAVITY LEAKAGE SUPPRESSION:

One method to prevent the first pulse from being too large is to allow the laser cavity to "leak"; that is, a controlled small amount of CW laser action is permitted to partially deplete the excited states of the laser rod. This function is accomplished by reducing (but not extinguishing) the R.F. drive to the Bragg cell for a controlled time period.

4.1.1 INTERVAL:

The leakage time may be different for each Q-Switch rate and/or laser power level. Therefore, the R.F. power drop interval is controllable on the Q-Switch control panel. The range of this interval is from about ten to several hundred milliseconds, and does effect a delay to the Q-Gate. In some processing, this delay may have to be accounted for in the programming. However, when the Interval adjustment is properly set, the first pulse can be virtually identical in amplitude to the following pulses in the train

4.1.2 ON/OFF:

The leakage suppression pulse killer function may be turned off for those instances when either the first giant pulse is desirable for the process or the time delay is not tolerable.

4.2 CAVITY GAIN SUPPRESSION:

For applications which cannot tolerate the delay of the pulse train that is inherent to the Cavity Leakage Suppression scheme, the Cavity Gain Suppression method is available for immediate first pulse suppression. In this mode of operation, the laser cavity gain is controlled by controlling the R.F. power during the Q-Switch time period. By limiting the cavity gain, the pulse amplitude can be controlled.

Note, however, that in order to reach stable Q-Switch operation, there is excess energy to be purged from the laser rod. In order to accomplish this depletion, the first, or first several pulses of a train are larger in amplitude than the subsequent pulses.

4.2.1 GAIN CONTROL (Optional):

The circuitry to provide Gain Control is extensive and not supplied in standard systems. When supplied, the initial setting to produce attenuated first pulses can be done at the front panel of the Q-Switch Controller or via external input. The setting will vary depending upon the laser parameters; current, Q-Switch frequency, cavity mirrors, laser rod, etc. To align the gain setting, operate the laser at the desired current level, enable the pulse suppression circuitry, and send Q-Switched bursts (separated by more than one millisecond). View the laser output via a suitable photodiode and oscilloscope and adjust the Gain control or the external gain signal voltage to produce the desired attenuation. Note that when operating with external gain signal voltage, the front panel gain control must be set to zero.

4.2.2 ON/OFF:

The Cavity Gain Suppression pulse killer function may be turned off via the switch on the front panel of the Q-Controller for such processes when the first pulse is desirable.

4.2.3 RANGE:

As supplied from the factory, the Cavity Gain Suppression circuitry is aligned for use over a Q-Switch frequency range up to 15 KHz. For useful operation above 15 KHz , internal adjustments are necessary. Consult U. S. Laser Corporation's technical staff for operation above 15 KHz.

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