TECHNICAL NOTE

Successfully integrating PQS lasers

Summary: Due to their distinct physical nature, passively Q-switched (PQS) sub-nanosecond lasers offer a different set of controls than standard actively Q-switched systems. Understanding what are their actual capabilities - and the related limitations - is of major interest to choose the right laser for your application and successfully integrate it into its environment.

The various operation modes and live controls offered by Teem Photonics PQS microchip lasers are described in this note: they include gate function, output energy control at constant pulse-width and triggered or free-running modes. Other integration related inputs and outputs are also presented.

Highlights of passively Q-switched laser (PQS) operation

A typical architecture for passively Q-switched microchip laser is pictured in figure 1. It features:

- a continuous wave semiconductor pump diode
- a set of optics to couple the pump light into the microchip cavity
- the monolithic PQS microchip cavity = gain medium (Nd:YAG) + saturable absorber (Cr:YAG) + flat and parallel cavity mirrors.

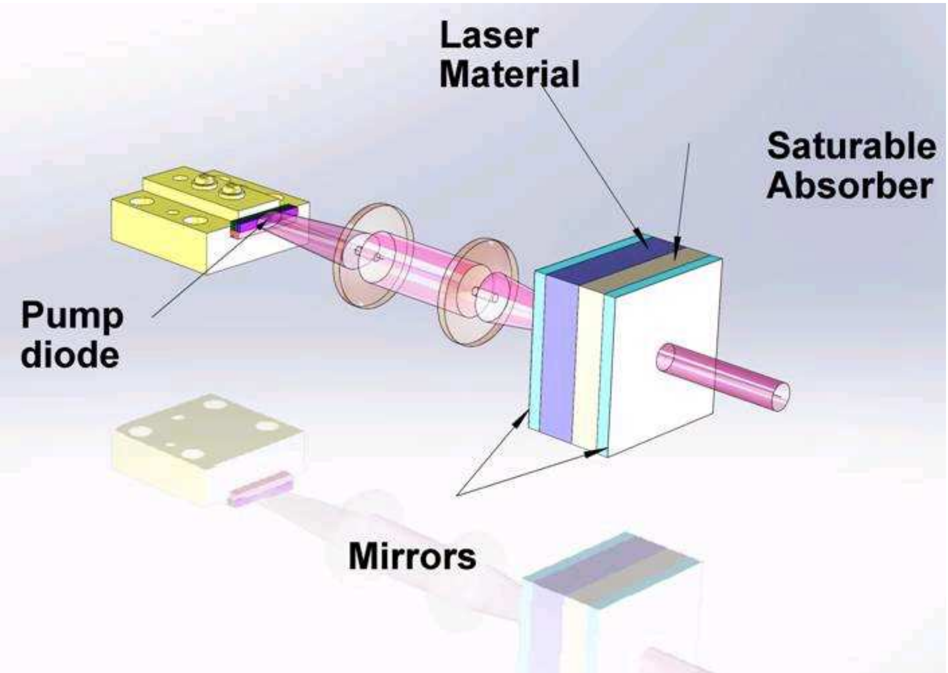

Figure 1: passively Q-switched microchip laser architecture

When pumped continuously by the telecom-grade pump diode, the PQS microchips 'naturally' emit a stream of typically sub-nanosecond optical pulses: this is the so-called free-running operation mode.

The pulse width and energy of the pulses are fixed by the cavity design. The repetition rate – so the output power as energy per pulse is constant- is given by the pump power coupled into the cavity. As a consequence, the pulse width and pulse energy are constant and independent from the output power.

Pulse-to-pulse stability or frequency stability (the frequency instability being often referred to as 'jitter') are mainly driven by longitudinal modes competition. This competition depends on the thermal equilibrium inside the cavity, whose main contributors are the thermal regulation and the pump power. Both stability parameters evolve depending on the temperature, in a correlated manner.

Regulating the cavity temperature is actually the way to set and maintain optimized emission conditions. There is a temperature range for which the emission spectrum is purely or close to single mode: here, you get both good energy stability and a low jitter. Outside this region, the competition gets fiercer and the laser emission less stable.

Different modes of operation

Free-running lasers

The PQS microchip is continuously pumped by the diode. It emits a constant stream of pulses, whose frequency is dependent on the pump power. These lasers can reach up to 130kHz repetition rate.

Triggered lasers

The pump diode current is modulated by the electronics. As the electronics receives the TTL trigger signal through the MOD-EXT input, the pump diode starts and the optical pulse is emitted a few tens of micro-second later, corresponding to the pulse creation delay (PCD). The pump diode is stopped right after the pulse emission thanks to an internal photo-detection loop (the sequence is described in figure 2). The repetition rate is thus driven by the pump modulation only, at a maximum value of 4kHz.

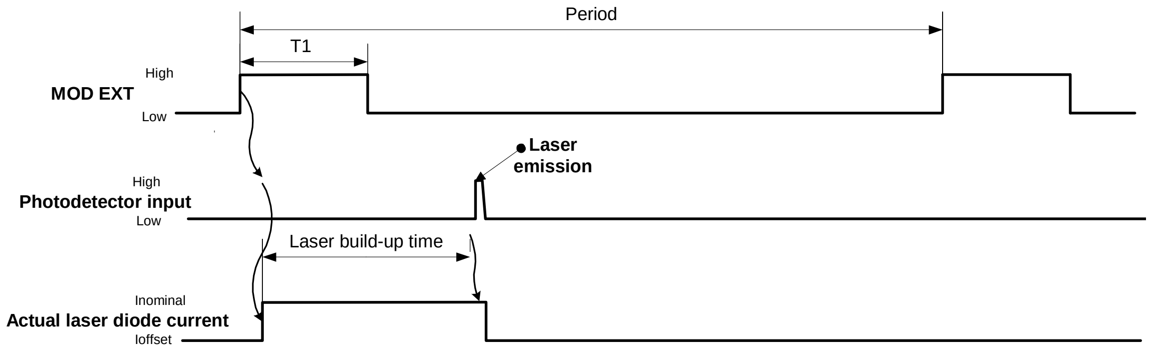

Figure 2 : triggered lasers pulse generation sequence

Internal trigger: the trigger signal is generated internally. For the user, this is similar to a free-running laser. It allows getting a minimum jitter at low repetition rate.

External trigger: the trigger signal is sent by the user, who can generate pulses on demand. One single optical pulse is generated for each trigger pulse received, with a minimum period corresponding to the maximum specified repetition rate for the laser.

The table 1 shows the different operation modes available depending on the product line.

Product line	Free-running	Triggered	Max repetition rate
Microchip	YES	YES	130kHz
Powerchip	NO	YES	1kHz
PicoFlash	YES	NO	130kHz
PicoSpark	YES	NO	50kHz

Table 1: available operation modes sorted by product line

Bare microchip controls

Bare microchips cover both the Microchip and the Powerchip product lines.

Repetition rate (output power) control

For free-running lasers, repetition rate can be adjusted by varying the pump diode output power. Using a specific type of controller (MR2), the user is able to continuously set the pump diode output power by mean of an analogical 0-5V input.

Depending on the range scanned, it is possible to end up outside of the optimally stabilized emission region described in the first paragraph.

Triggered lasers: for externally triggered lasers, repetition rate control is achieved by changing the trigger signal frequency. The lasers are continuously tuneable over 10Hz-2kHz with optimal stability conditions. Alternatively, they can be optimized at up to 3 user-defined repetition rate over 10Hz-4kHz.

Internally triggered laser run at fixed repetition rate only.

Computer on-off

This is basically a gate function. It is achieved by modulating the pump diode current between idle (=no pump emission) and nominal (=full power pump emission) levels.

The laser output reaches its final performances in a few 100µs (see figure 3).

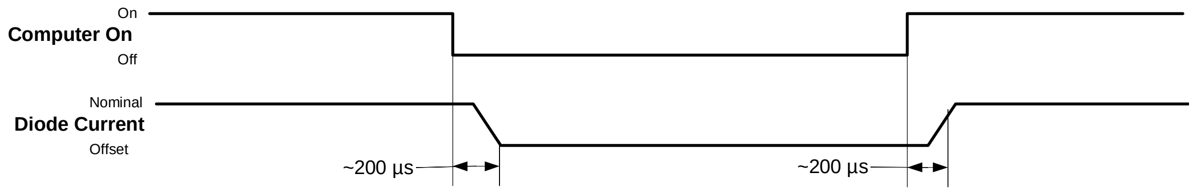

Figure 3 : Computer on-Off function diagram

Synchronisation output

It is always available on triggered products, and is offered as an option for free-running lasers.

This is basically a trigger output, provided by a photodiode inside the laser package. A typically 200-300ns electrical pulse is synchronously generated for each optical pulse. The delay between both pulses is in the ns range, and depends mainly on the cable length used to monitor the trigger output (see fig.4). This output can help monitoring the laser emission or synchronizing external downstream equipment.

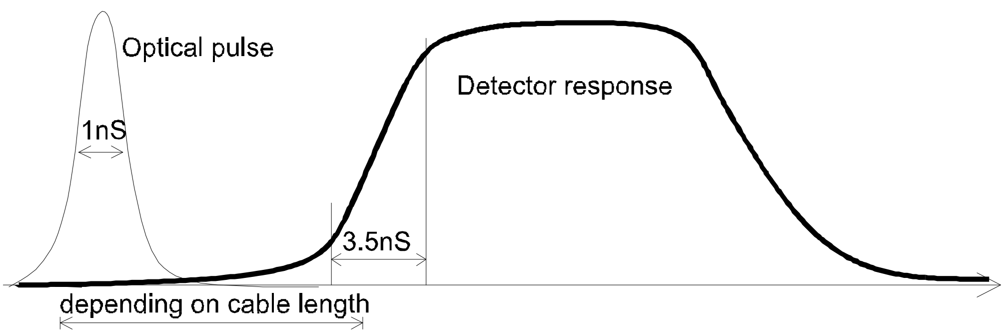

Figure 4: synchronization output and optical pulse

Amplified PQS microchip lasers controls

Amplified microchips cover both the PicoFlash and the PicoSpark product lines.

Teem Photonics amplified microchip systems feature a Master Oscillator Fiber Amplified (MOFA) architecture. In the essence, a seed microchip laser is coupled into a fiber amplifier, which increases the pulse energy while preserving all the other pulse parameters.

The seed microchip laser defines the repetition rate, pulse width, energy stability and jitter.

The fiber amplifier gain, depending on the amplifier pump power level, sets the output energy level.

Amplifier Gain Control

Amplified lasers offer the opportunity to adjust the output pulse energy while maintaining a constant pulse width and pulse shape. This is a very interesting feature for process optimization or automation.

It is achieved through a 0-5V analogical input that drives the amplifier pump diode current.

On the actual systems, the pump diode current is a linear function of the voltage command: as a consequence, the effective voltage range [V_{eff_min};V_{eff_max}] is dependent on the diode and amplifier characteristics (see fig.5).

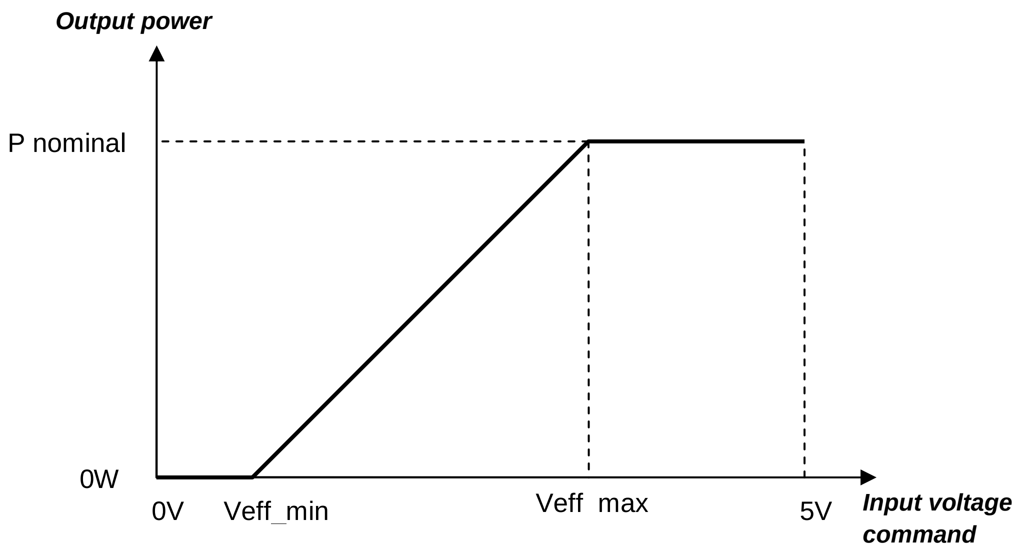

Figure 5: output power vs input voltage command typical characteristic

The typical response time of the laser output after a command change is in the order of a few 100µs, with a typical maximum value of 500µs (see fig.6). This response time is strictly fixed as it also depends on the gain step height (the higher the gain step requested, the longer the response time).

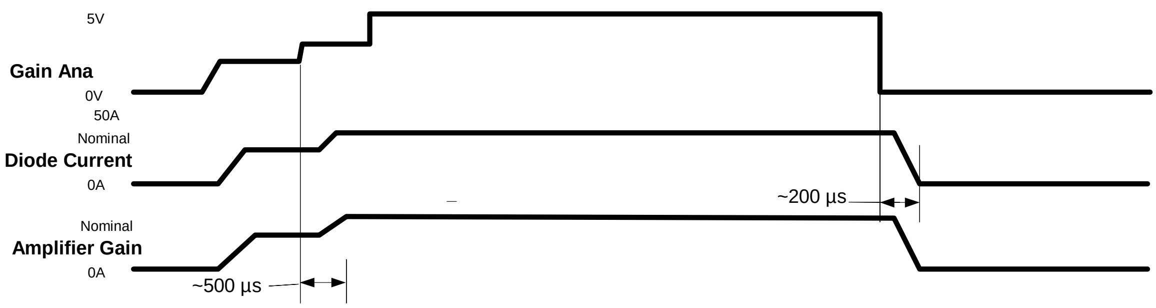

Figure 6: Fast On-Off diagram

Fast On-Off

This is a gate function controlling the amplifier pump current. The seed laser running steadily, the user can switch the amplifier pump level between idle (no pump output) and a nominal level by sending TTL command. The nominal level can be adjusted by using the Amplifier Gain Control function described in the preceding paragraph. The output power reaches its final state <500µs after the TTL command (see fig.7).

It is important to note that the seed laser is running all the time : when the amplifier is switched off, the laser may still outputs a few of milliwatts corresponding to the transmitted seed power.

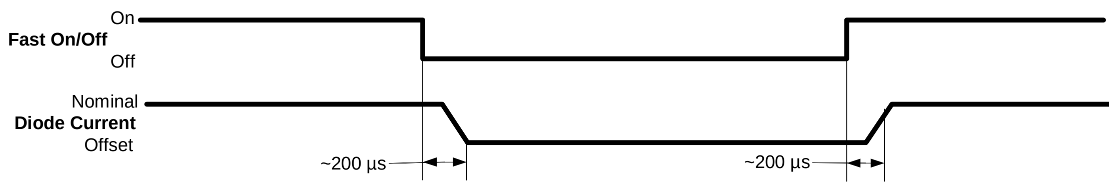

Figure 7: Fast On-Off gate function diagram

Repetition rate (output power) control

As the repetition rate is driven by the seed laser, repetition rate control is achieved in the same way as for free-running microchip lasers. The user has access to a 0-5V analogical input which drives the seed laser pump diode current (see fig.3)

Depending on the repetition rate range scanned, it is possible to end up outside of the optimally stabilized emission regions.

Synchronisation output

It is available on all amplified products, where it is also included in safety interruption management. This is the same trigger output, provided by the photodiode placed inside the seed laser package. A typically 200-300ns electrical pulse is synchronously generated for each optical pulse. The delay between both pulses is in the ns range, and depends mainly on the cable length used to monitor the trigger output (see fig.4). This output can help monitoring the laser emission or synchronizing external downstream equipment.

Other integration related inputs/outputs

These are available on all types of lasers.

Laser On-Off or STB-EXT

Laser On-Off (or STB-EXT depending on the product line) is a TTL input simulating a push on the start button. The time evolution is described on the figure 8 below.

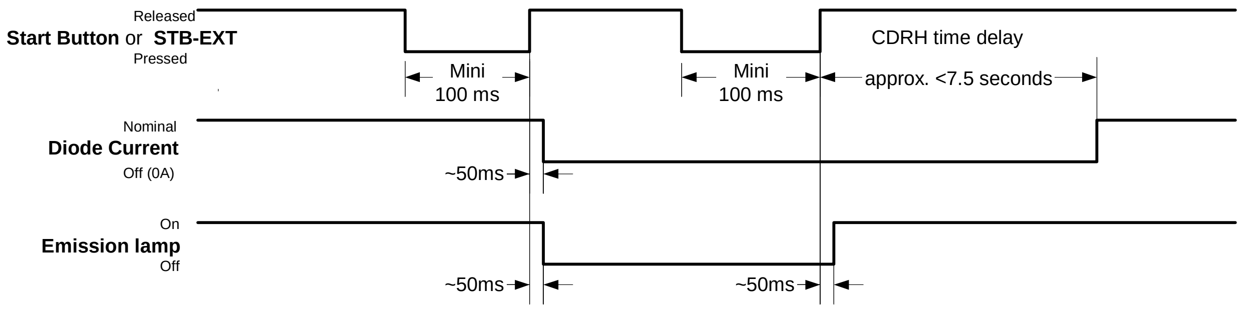

Figure 8: Laser On-Off function diagram (similar to STB-EXT)

Interlock

The interlock is an emergency stop function, typically used for laser safety management when the laser is integrated into more complex equipment. When it is activated (low level sent to the interlock input, corresponding to an open circuit), the diode current within 200µs (see fig.9). Then, the laser does not start again when the interlock input is inhibited. The laser needs to go though the whole start initialisation process, after trigger by a manual action on the start button or a STB-EXT/Laser On-Off command.

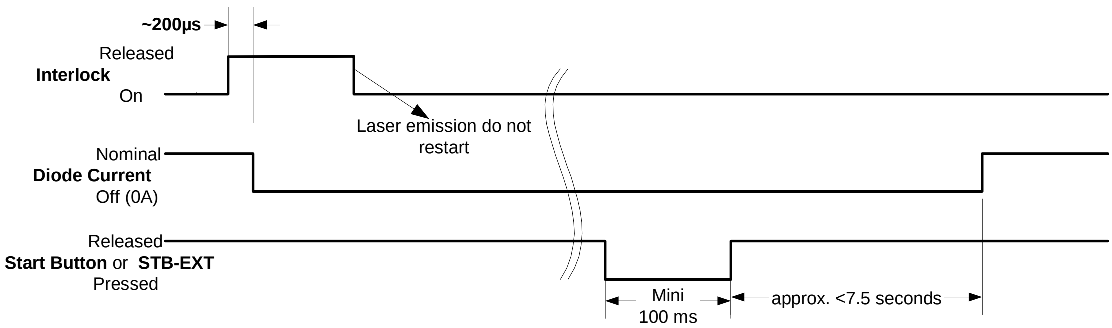

Figure 9: Interlock emergency stop function diagram