## Revisions

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I. Introduction

MirSense provides POEM (PowerMir Original Equipment Manufacturer) or PTKS (PowerMir TurnKey System) systems as agile pulsed and continuous wave QCL current driver coupled to a HHL laser package. They are compact, powerful and controlled either by a user-friendly graphical interface or directly over a serial line.

The aim of this application note is to give more details on how MirSense manages to operate its lasers with these systems.

Don’t hesitate to contact MirSense or your authorized MirSense distributor should you have additional technical or application questions. We provide web-based as well as direct e-mail and telephone support.

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### II. Nomenclature

#### A. Nomenclature

<table>
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<th>Abbreviation</th>
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<tr>
<td>QCL</td>
<td>Quantum Cascade Laser</td>
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<tr>
<td>QCW</td>
<td>Quasi Continuous-Wave</td>
</tr>
<tr>
<td>PTKS</td>
<td>PowerMir TurnKey System</td>
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<td>POEM</td>
<td>PowerMir Original Equipment Manufacturer</td>
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#### B. List of Abbreviations

<table>
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<td>Driver</td>
<td>This abbreviation designates either the POEM or the PTKS.</td>
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III. The QCW regime

Quasi Continuous-Wave (QCW) regime of QCL can be obtained by applying rectangular shaped current pulses to the laser as shown in Figure 1. Laser light emission will occur as soon as the current flowing through the laser is above the laser current threshold.

The QCW regime is characterized by short current pulses periodically repeated at a high repetition rate. The duration $PW$ of the pulses is usually in the hundreds of ns, while the repetition period $PI$ can vary from the hundreds of ns to several µs. In MirSense products, $PW$ can be set as low as 10 ns.

![Figure 1 - Current waveform used for the standard characterization of a laser in QCW mode.](image)

The QCW repetition rate is obtained as follows:

$$F_{QCW} = \frac{1}{PI}$$

The duty cycle of the QCW can be easily computed using the following formula:

$$DC = \frac{PW}{PI}$$

True CW operation is obtained if $PI = PW$ is set. Lasers manufactured by mirSense are designed and optimized to be used in QCW operation and not true CW operation because it allows to reach better performances without any functional counterparts.

The reached current amplitude, denoted $I$ in Figure 1, is constant and can be changed by changing the voltage across the QCL. The typical resulting characterization curve is shown in Figure 2.
Figure 2 - Typical characteristic of a PowerMir QCL laser obtained at a temperature of $T_L = 25^\circ C$, with a pulse width $PW = 1.5 \mu s$ and a pulse interval of $PI = 2.8 \mu s$.

For this particular laser displayed in Figure 2, the QCW repetition rate is $F_{QCW} = \frac{1}{2.8 \times 10^{-6}} = 357 \ kHz$. This laser displays a duty cycle of $DC = \frac{1.5}{2.8} = 53.6\%$. This means that the laser will be tuned on 53.6\% of the time and turned off 46.4\% of the time. This also means that the laser will always be limited to $P = 450 \ mW$ output power, when the peak current amplitude is constant and equals $I_{max} = 2.1 \ A$.

It is important to note that this laser’s limitation of $P = 450 \ mW$ depends on its operating temperature $T_L$. If a lower operating temperature is imposed, the available maximum power would be higher.

The choice of the pulse width and the pulse modulation, often referred to as “carrying modulation”, is factory set and you can’t modify it. Those values can however be tailored for the user specific needs if required. That means the QCL is delivered to you with a fixed pulse width and duty cycle, controlled by the Driver. This is key to ensure the laser safety, since not all QCL can be operated in any duty cycle without risking complete destruction. Also, the average output power and beam shape strongly depends on those two parameters and cannot be guaranteed for any set of QCW parameters.

On top of this QCW mode of operation, it is possible to modulate the average optical power over time using frequency modulation. Please refer to section IV for more details.
IV. Power modulation

Power modulation can be achieved by selecting only some of the peak currents of the QCW regime. This technique is also be called frequency modulation.

This frequency modulation can be used for example to modulate the average output power of the laser. If $M$ denotes the normalized mean of the selection waveform, the average output power will be $P = P_m \times M$, with $P_m$ the maximum available power.

The selection can be done by using two different mechanism within MirSense Drivers.

A. External modulation

An electrical external trigger input can be used to indicate when to enable the laser current pulses. The sampling of the external trigger is performed at 100MHz, allowing to have very sharp edges on the laser rise and fall time.

![Figure 3 - Example of a frequency modulation using the external trigger mechanism.](image)

A new current pulse is applied on each rising edge of the external trigger by default. This behavior has however one security limit. The Driver will not authorize to send two current pulses whose time separation would be shorter than the fixed pulse interval $PI$. If the external trigger given by the user has a falling edge and a rising edge that are very close and would imply to emit two current pulses closer than one $PI$, then the pulse that would be emitted on the rising edge is discarded. Instead, the current pulse is sent as soon as possible, provided that the $PI$ is fulfilled.

Because of the latter security, it is important to note that the QCW pattern is not always synchronized with the modulation pattern incoming on the external modulation input.
Indeed, the average output power can show some unwanted modulation if the OFF intervals in the external trigger modulation are comparable in duration with the time period $P_I$.

This unwanted modulation is a consequence of the superposition of two frequencies (the QCW frequency and the frequency modulation). It is common and sometimes called a “Moiré pattern” and can be illustrated in the geometrical model with two sets of lines with slightly different periodicity.

### B. Internal modulation

MirSense Drivers are able to generate waveforms internally to accomplish the frequency modulation. Due to the finite Driver internal memory, the waveform is supposed periodic and the user only has to declare one period.

Two parameters have to be declared:
- The period of the modulation, denoted $T_{E_1}$.
- The envelop values, supposed to be evenly spaced over a period of time. We can denote by $N$ the number of values, which is usually equal to 252 in MirSense products.

The time resolution of the envelop is hence set by the modulation period: $\Delta t = T_{E_1}/N$.

The pulses are not correlated with the envelop with this internal modulation, so a new pulse is not starting on the rising edges of the envelop on the contrary to the external modulation mechanism described in section IV.A. The pulses will be locked to the envelop only if the modulation period $T_{E_1}$ is an exact multiple of the pulse interval $P_I$.

To help the user visualize the envelop periodicity outside of the MirSense Driver, an output trigger is generated at the beginning of each period. A square electrical signal is internally generated with a width of $T_W$, usually set to 100ns.

We show in Figure 4 an example of the internal modulation. The $N$ envelop values are represented as green dots, and we can also see that a new pulse does not obviously starts on the rising edges of the envelop.
Figure 4 - Example of a frequency modulation using the internal modulation mechanism.