Beam stabilization system
“Compact”

Appendix to user manual for the

Additional sample & hold circuit
to fix the laser beam position during laser-off times

1. General description

In some applications with the laser beam stabilization the laser beam might be switched on and off during the operation. In laser off times there is no intensity on the detectors and hence no control signal for the closed-loop controller. In such situations, the *Compact* beam stabilization without additional measures will drive the Piezo-driven steering mirrors into a defined position, the so-called zero position (please refer to the *Compact* system's user manual for more information).

Once the laser is switched on again the stabilization will start its operation from this position. The zero position should have been used for the first adjustment of the optical set-up. That is why this is usually a good starting point for the stabilization. However, in case of large drifts of the laser beam in the overall set-up, the zero position can – at least in the long term – strongly deviate from the required steering position. Switching on the laser after a time interval without laser beam and the resuming of the stabilization can therefore lead to an undesired spike of the beam position.

With the additional sample & hold circuit in the *Compact* beam stabilization system the positions of the steering mirrors can be freezed for an arbitrarily long time interval without control signal or laser intensity on the detectors, respectively. In that way it is possible to start the control-loop after the switching on of the laser not from the zero position but from that latest stabilized position.

The additional sample & hold (S&H) circuit is of special advantage for the following applications:

- In all systems where the laser must be switched on and off several times during the laser process, e.g. in material processing machines. Even if the system has been drifted away from its basic adjustment, the beam position will start from the last stabilized position after resuming of the control loop. In this way an oscillation of the beam from the “zero position” to the desired position is eliminated and a potential faulty processing of the work piece is prohibited.

- In systems with a very large distance between the steering mirrors and the detectors. These set-ups bear the risk that a drift changes the adjustment in that way, that the laser beam will no longer hit the detector in uncontrolled intervals. Thus, it can happen, that the beam stabilization can not catch the beam on the detectors after a resuming of the stabilization when the laser was switched off for some time.

- In systems with very low repetition rates or lasers with irregular intervals of laser pulses (or pulse packages). If the S&H circuit of the beam stabilization is triggered for each laser pulse the beam position will get closer to the desired position with each pulse.

2. Modes of operation

2.1 Automatic control of sample & hold elements

The beam stabilization with additional S&H circuit includes an automatic recognition of laser on and off states. This is done by sampling the intensity on the position detectors. The automatic operation controls the S&H elements in order to store the signals in laser on times and fix the position of the steering mirrors during intervals with no intensity.

For this automatic control the laser on intervals or the respective duration of pulse packages must be longer than 100 ms.

There is no need for the user to provide any trigger signals for this mode of operation.

2.2 External triggering of the sample & hold elements

For single laser pulses or lasers with very low repetition rate, modulated cw lasers or pulse trains < 100 ms the automatic control can not release the stored beam position in due time. In such cases it is necessary to control the S&H elements by means of external triggering. The requirements for the trigger signals are described in section 3.2.

3. Configuration and start of operation

3.1 Cabling

The cabling of the beam stabilization system with additional S&H circuit can be carried out in the same way as described in the *Compact* system's user manual.

In the operation mode of automatic control there is no need for additional cabling.

If the external triggering is used, the trigger signals have to be fed into the controller box via the respective Lemo connectors marked with “Trig” (see figure 1). The right connector controls the S&H function for stage 1 / steering mirror 1. The left connector controls it for stage 2 / steering mirror 2.

Figure 1: Right panel of controller box

3.2 External triggering

The external triggering enables an accurate timely assignment when the system shall store the position of the steering mirrors and when the position shall be fixed. This assignment is especially important in case of single laser pulses. For an optimal function of the S&H circuit there are time restrictions for the trigger signal which should be met. Figure 2 illustrates the respective tolerances of the trigger signal.

- Duration of trigger signal: $t_{min} \geq 10$ µs
- Start time of trigger in relation to start of laser on interval: -10 µs $\geq \tau_1 \leq$ 50 µs
- End time of trigger signal after end of laser on interval: $\tau_2 \leq$ 1 ms

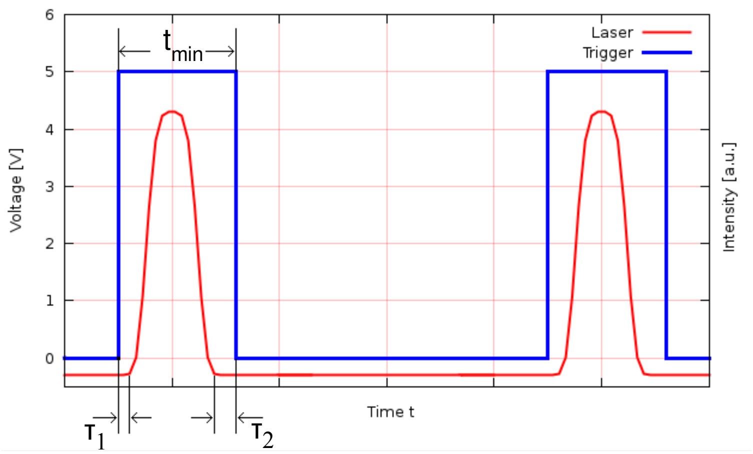

Figure 2: Timing of trigger signal

The electronic requirements for the trigger signals are:

- TTL levels
- Level “high“ when there is laser intensity on the detectors, level “low” when there is no intensity

3.3 Start of operation

The installation and adjustment of the beam stabilization with the additional S&H circuit can be carried out in the same way as described in the *Compact* system's user manual.

Whenever the stabilization is de-activated (i.e. the *Start/Stop* button is in off-state) the stored position of the steering mirrors is reset. In this state the steering mirrors are in their zero position. In this way it is guaranteed that the system can be adjusted as described in the user manual.

Please note that the last position of the steering mirrors is lost whenever the stabilization system is de-activated. As soon as the system is started again it starts from the “zero position” of the steering mirrors. In case of large distances between steering mirrors and detectors there is a risk that the beam will not hit the detector without a prior re-adjustment.

4. Performance

The performance of the additional S&H circuit shall be explained in the following sections with the help of some examples. In figure 3 a sequence of pulse trains with a repetition rate of 1 kHz and a duration of about 300 ms was applied. The pulse trains are displayed with green colour. The violet curve shows the position signal of the laser on the detector.

During the first pulse train the stabilization was de-activated. You can see that the pulse does not hit the detector in the centre. During the second pulse train the stabilization was started. You can see an initial spike of the position (enlarged view is shown in figure 4) and then a stable position signal which is also stable during the third and fourth pulse train. Without the S&H circuit the spiking of the steering mirror would occur again and again in the second and all following pulse trains.

At the time the beam stabilization is started the steering mirrors are in their zero position. Since this position usually differs from the desired position the system recognizes a strong control amplitude immediately after its activation. This leads to the described spike. In normal use cases where the laser provides a continuous control signal this is not a problem since the controller always gets a signal. However, in case of the applications mentioned in section 1 there are time intervals without a control signal. In these cases the additional S&H circuit becomes effective: After time intervals without laser intensity the stabilized operation is re-activated for the next pulse train without a larger spike. This will be demonstrated in sections 4.1 and 4.2.. Without the S&H circuit it would have started from the upper position and would have produced a spike.

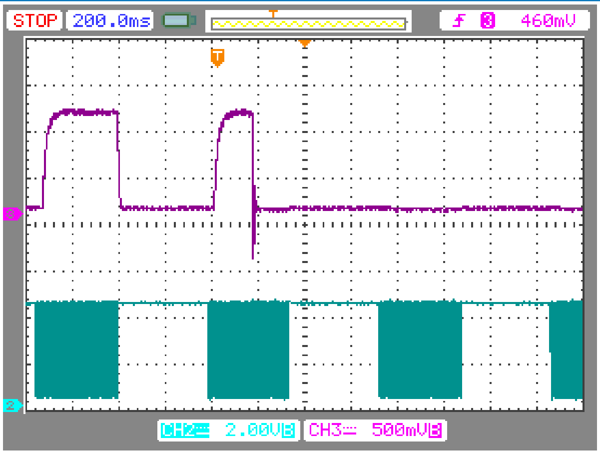

Figure 3: Activation of control-loop (without Hold value)

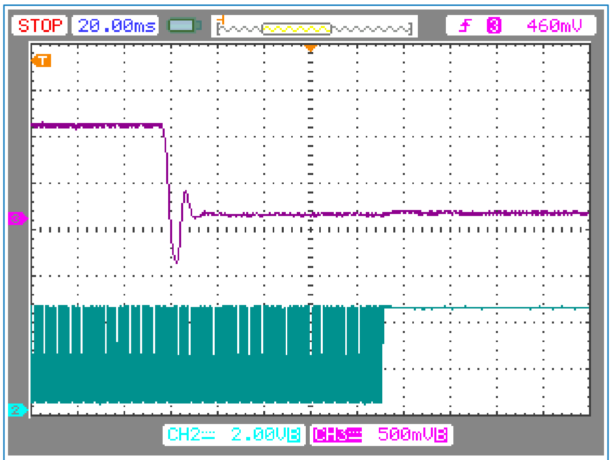

Figure 4: Enlarged view of figure 3

Only for the first pulse train the S&H circuit has no influence since at this time there are no valid position data for the desired position in the S&H elements. After that the control signals for the steering mirrors are stored continuously and for arbitrarily long time intervals where there is no intensity (or no trigger "low" signal). This is true as long as the stabilization system is switched on and activated.

4.1 Automatic control

The operation mode of automatic control is especially suited for long switching periods of the laser light or long trains of single laser pulses.

In figures 5 and 6 an example with pulse trains of a laser with a repetition rate of 1 kHz is illustrated. Again, the green curve shows the laser signal and the violet curve shows the position signals. In figure 5 the laser is running without stabilization. In figure 6 it is running with the automatic control. In the latter case the position of the steering mirrors is freezed during the laser off times whereby it is refreshed by each signal on the detectors.

During the operation, the laser intensity should not be modulated by means of a laser shutter or another blocking component. Due to their functional principle the detectors would determine a wrong position for the short times of a partly blocked beam. Therefore the position signal would be distorted.

The laser intensity should not be modulated by means of covering the laser beam. This can lead to wrong signals for the position of the steering mirrors.

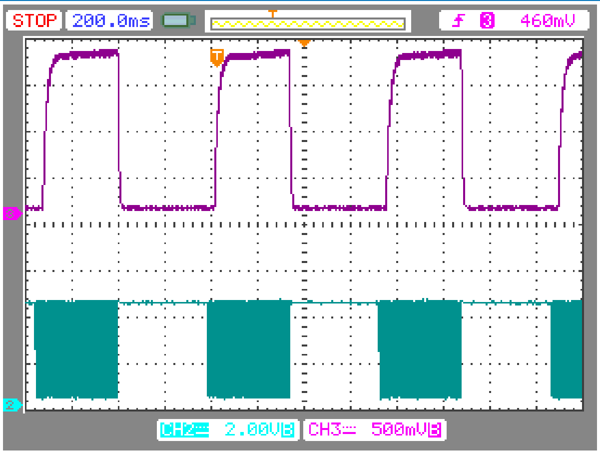

Figure 5: Pulse trains without stabilization

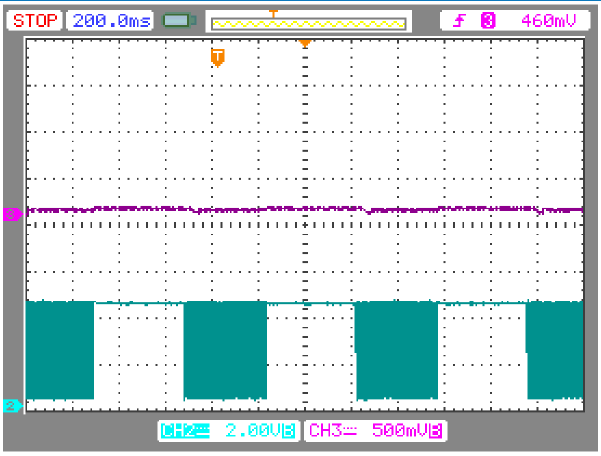

Figure 6: Pulse trains with automatic control

For technical reasons, in the operation mode with automatic control the timing for the position freeze and the re-start of the stabilization is slightly delayed to the on and off times of the laser intensity. This can lead to slight deviations of the stored positions.

4.2 Operation with external triggering

In case a trigger signal for the laser on and off times is available, we recommend to choose the operation mode with external triggering. The improved timely correlation with the laser intensity usually leads to a better performance.

Figure 7 shows the example of section 4.1, now with external triggering. In addition to the curves described above you can see now the trigger signal as a blue curve.

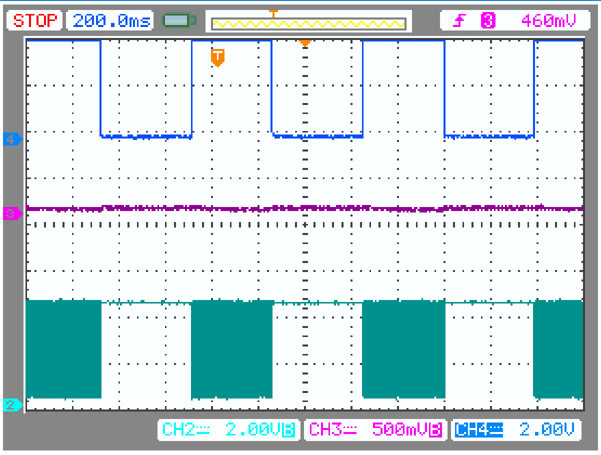

Figure 7: Pulse train stabilized with external trigger

As shown in this example, in case of pulse trains there is an advantage not to trigger on each single pulse but on the start and the end of the pulse train. This is recommended for pulse repetition rates of about 300 Hz and higher.

4.3 Operation with single laser pulses and external trigger

The use of an external trigger signal also enables the stabilization of single or irregularly occurring laser pulses or lasers with very low repetition rates.

The performance in such cases is illustrated with an example in figure 8. Here, the position signal of a laser pulsed at 10 Hz is shown as a violet curve. The green curve shows the trigger signal for single laser pulses. At the beginning, the laser beam is at an arbitrary position. The beam stabilization was started at the time of the fourth laser pulse (counted from the left). In the following course you can see very well that the beam gets closer to the desired position with each pulse until it finally stays in the desired position in a stable manner.

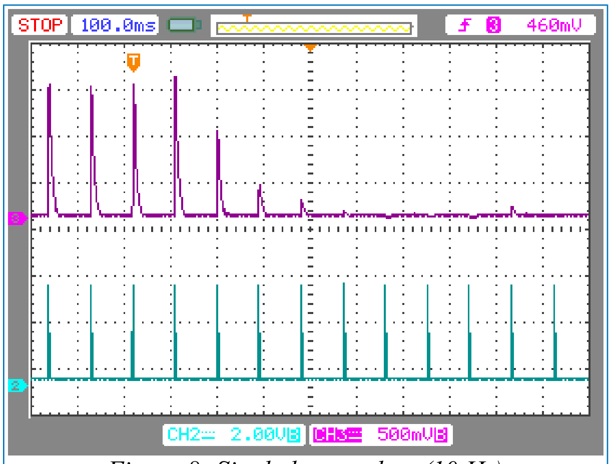

Figure 8: Single laser pulses (10 Hz)

In this example only four additional pulses are required to reach the stable position. Depending on the set-up of the optical system, the pulse duration and the duration of the external trigger signal the number of required pulses can be different.

⚠ **The time interval for the stabilization is very short in case of short trigger intervals. Since the Active LED on the front panel of the beam stabilization system is directly connected to this time interval, it can happen that you will not recognize the shining of the LED due to the short time.**

5. Specification

Technical specification:

Sample & Hold circuit	
Storage principle	Digital storage of position data
Sampling rate	25 kHz
Freezing interval	unlimited
Requirement for automatic triggering	Minimal laser on time: > 100 ms

Trigger	
Signal levels	TTL, “high“ for laser on, “low“ for laser off
Connection	2x LEMO, separate connectors for stage 1 and stage 2
Minimal length of trigger signal “high“	$t_{min} \geq 10$ µs

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