The TimBeL Synchronization Board for Time Resolved Experiments at SOLEIL

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Introduction

In photography, when a subject is moving fast, it will appear fuzzy on the picture (figure 1-a).
To make it appears clear, we have to decrease the exposure time or the flash time (figure 1-b).

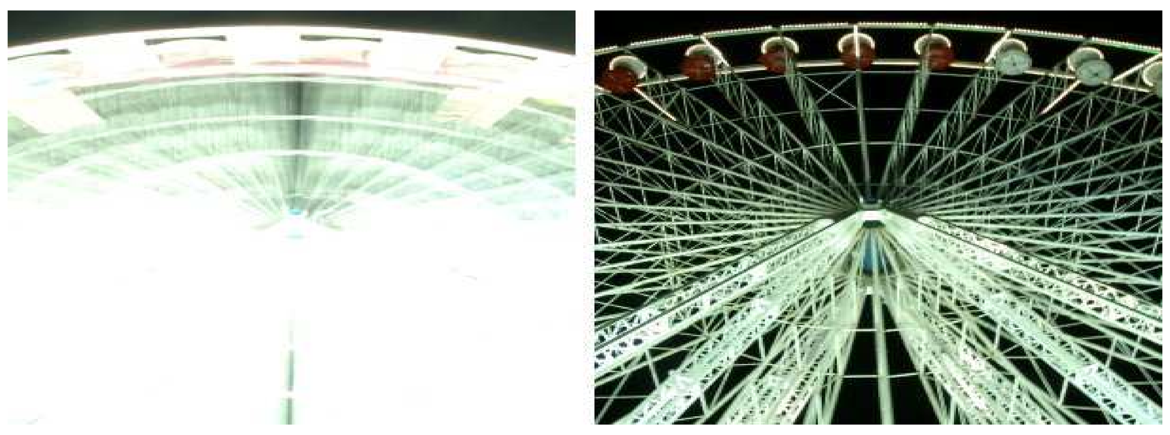


Figure 1 : fuzzy picture due to long exposure time

By using the stroboscopic effect of successive shots, it become possible to see how the subject evolves over time (figure 2).

Figure 2 : Movement broken down with successive pictures

Scientists use the same photography principle for studying sample and for pump-probe experiments. Synchrotrons are very effective instruments for that purpose.

“Temporal” modes at SOLEIL

In synchrotrons, bunches of electrons fly in a circular storage ring. They produce a regular flash of light each time they pass in front of a beamline. Special “temporal” filling modes are dedicated to time resolved experiences.
At Synchrotron SOLEIL, three filling modes are dedicated to time resolved experiments (figure 3): single bunch, 8 bunch and hybrid mode. These flashes are very short (20ps – 40ps RMS) and very bright.

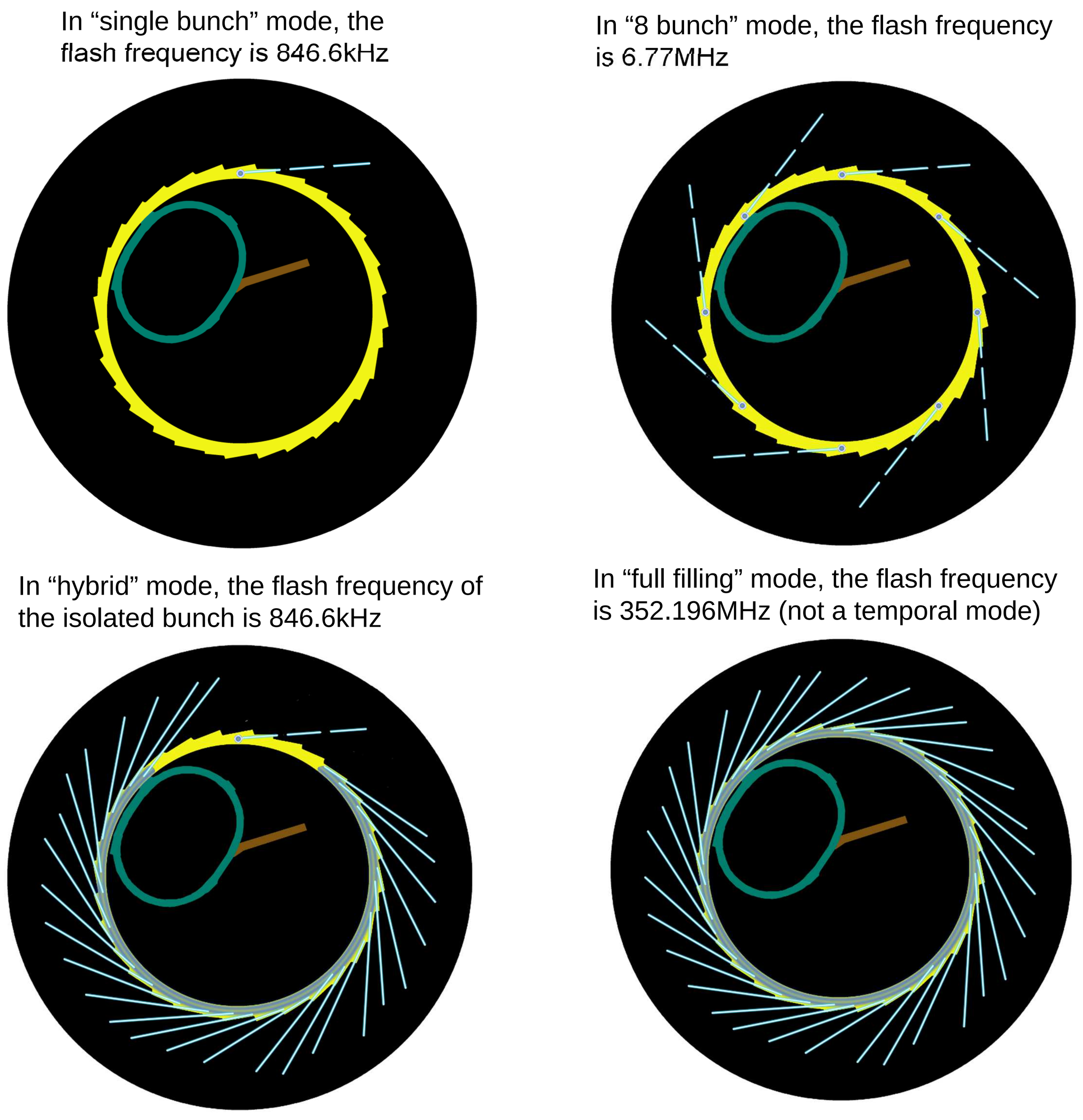


Figure 3 : Synchrotron SOLEIL filling modes

Requirements

Beamlines need a signal to trigger their acquisitions synchronously with electrons bunches inside the storage ring.
The acquisition frequency depends on the equipment’s frequency and Soleil’s filling mode (8 bunch, hybrid, etc.).
The synchronization signal’s jitter must be under 20ps RMS to avoid missing flashes.
Cables offsets and the equipment’s latency must be compensated.

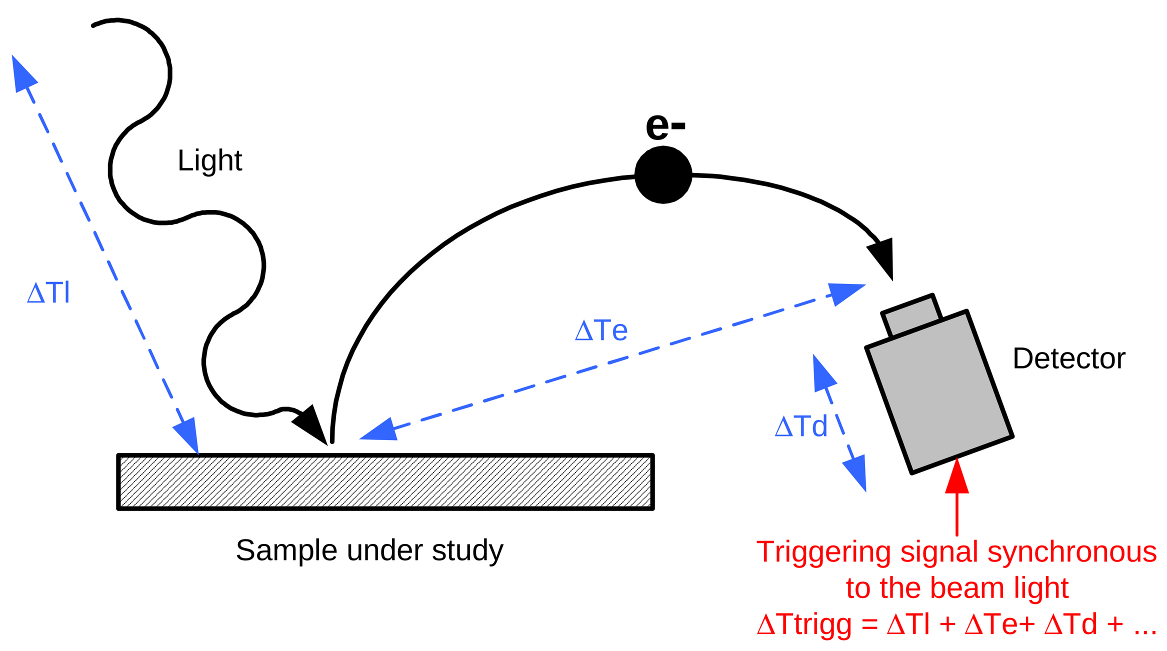


Figure 4 : Beamlines requirements

A typical application where tight synchronization is required is pump-probe measurements. A laser (pump) is used to excite a sample and the synchrotron light (probe) allows to measure how this excitation evolves over time.
The laser and the detector must be synchronized with the electrons bunches inside the storage ring and the time offset between the two devices must be perfectly adjusted.

TimBeL board

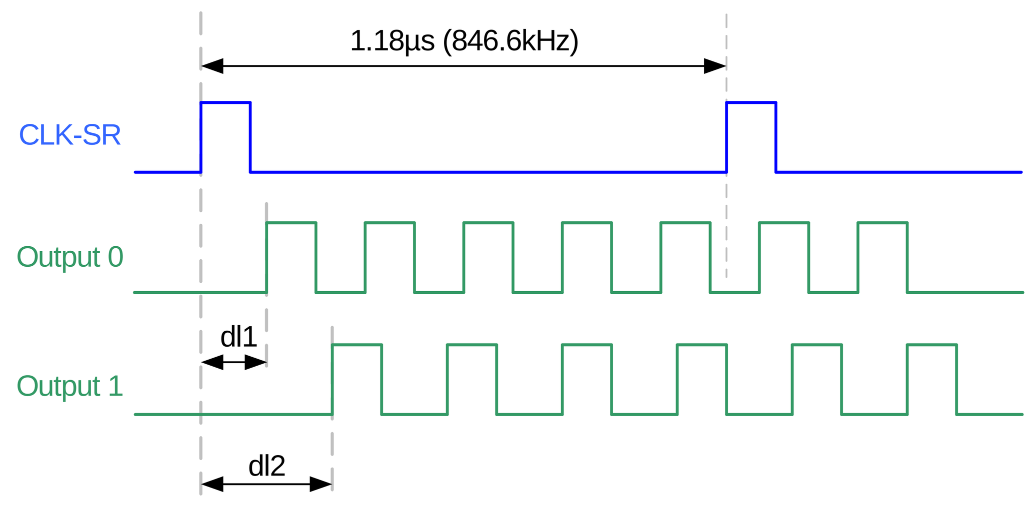
To fulfill the beamlines requirements, SOLEIL has developed a low cost compact PCI synchronization board called TimBeL (TIMing BEamLines).
Each beamline has different requirements. To fulfill all needs, the board is highly configurable by users.
The TimBeL board uses the RF and the storage ring clocks to provide low jitter, bunch synchronous triggering signals.

TimBeL functionalities

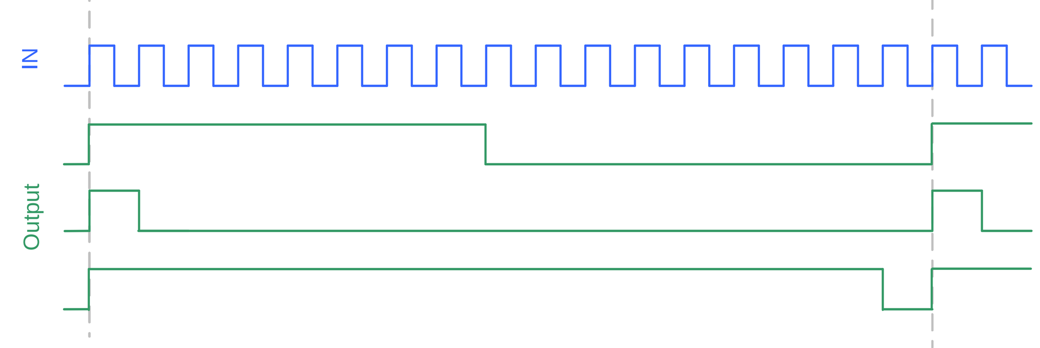
2 independents frequency dividers (RF / n) outputs.
Each output can be configured independently to provide a clock between 88MHz (RF / 4) and 0.76Hz. Thus they can be used for the 8 bunch (6.77MHz) and the hybrid mode (846.6kHz).

Each clock output can be delayed between 0 and 1.44µs through a coarse and a fine delay generator.

- For frequencies between 88MHz and 5.5MHz, the coarse delay’s step is 5.76ns (RF x 2) and the fine delay’s step is #10ps.
- For frequencies between 5.5MHz and 0.76Hz, the corse delay’s step is 11.36ns (RF x4) and the fine delay’s step is #10ps.



The two clocks high and low levels ratio can be adjusted by the user.
This allows odd frequency division. For example for a RF / 17 division, the user can configure the output for 8 high levels and 9 low levels (8 + 9 = 17). Of course, he can also configure 1 high level and 16 low levels, or 16 high levels and 1 low level.

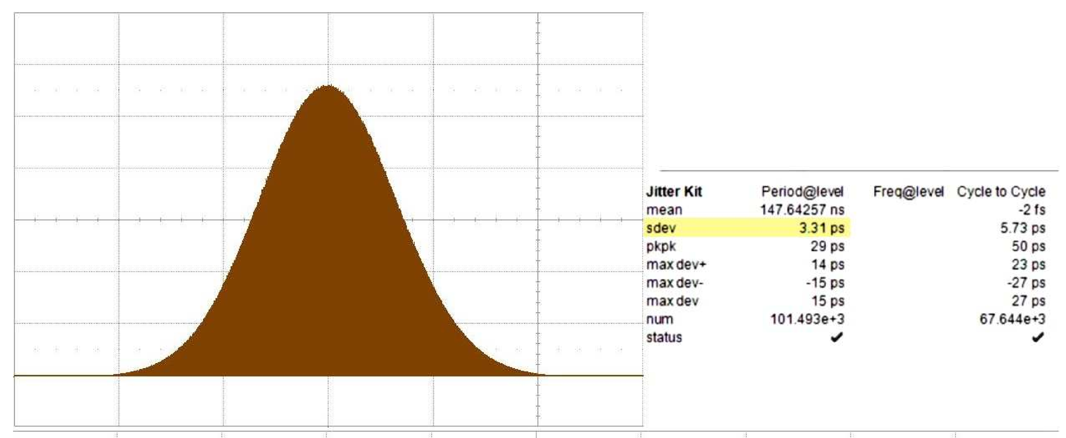


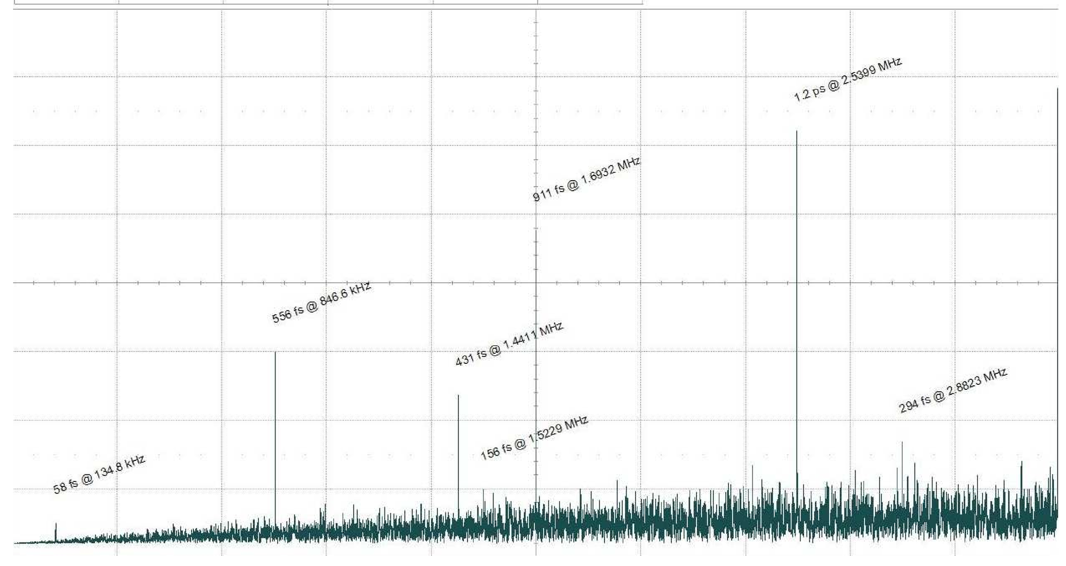
Clock outputs are automatically synchronized to the storage ring clock. Thus the offsets from the electron bunches are always the same.

Beamlines can configure and use the board through a TANGO device developed by the ICA group. This device uses C++ libraries developed by the ECA group.

The jitter measured in LVPECL differential mode is 3.31ps RMS @ 6.77MHz (8 bunches frequency).
In LVPECL single ended mode (OUT0 P), it is 3.85ps RMS @ 6.77MHz (8 bunches frequency).

The jitter has been measured with a Lecroy’s 820 Zi-A oscilloscope (20GHz ; 4x40Gs/s). The source jitter is #7ps RMS.





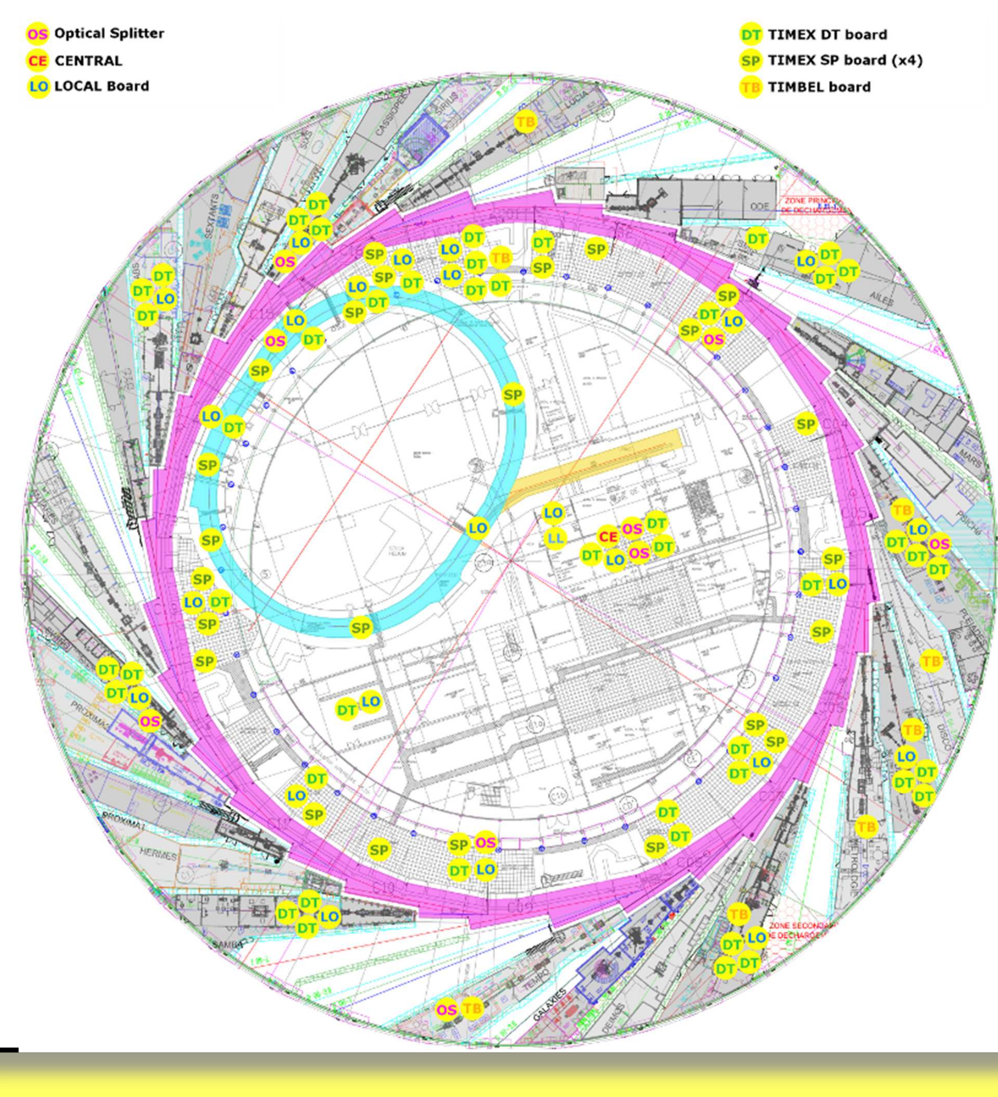
Results (and why D.I.Y. hardware is good for you)

Each year, two to four runs are dedicated to temporal mode at SOLEIL. This year (2011), SOLEIL has already supplied to its users 8 temporal runs (4 hybrid, 2 single bunch and 2 eight bunch), and for the commissioning of the pump-probe lasers on TEMPO and CRISTAL beamlines the hybrid mode will be delivered until the end of the year.
Since 2009, 6 beamlines are using the TimBeL board either with their own devices or with the devices of their users. To date, all users have been satisfied by this board and its functionalities. No major complaints or problems have been reported.

The TimBeL board has been entirely designed by SOLEIL. This has helped us to modify and adapt it to experiments requests several times. Five firmware upgrades have been made since the board has been installed on beamlines.
More important, because we are perfectly familiar with the board, it was possible to adapt it very quickly, in just a few days, to meet new requirements within a tight deadline. Beamlines and their users always have new and changing requirements. With commercial or subcontractors products, it would be more difficult to modify and adjust the hardware to quickly fulfill beamline requirements.

For beamline synchronization, D.I.Y. (Do It Yourself) hardware was the best solution considering the cost, the functionalities, the performance and the future enhancements and redesign of the system.

Distribution of the synchronization at SOLEIL



The **CENTRAL** system generates frames containing the booster clock, the storage ring clock and events. Events are used to trigger devices : event 2 for LINAC and BOOSTER devices ; event 3 for STORAGE RING devices, etc.

A fiber optic network broadcast the CENTRAL system’s frames all over SOLEIL. These frames are duplicated by 1 to 16 **optical splitters**.

LOCAL boards receive the optical frames. Each output of a LOCAL board is configured to trigger on a specific event. After a user defined delay, a TTL pulse is generated.

TIMEX DT boards duplicate the LOCAL’s outputs. These signals trigger the devices of the LINAC, of the BOOSTER and of the STORAGE RING (injection, extraction, diagnostics, etc.).

99 **TIMEX SP** boards duplicate and convert the TTL synchronization pulse to LVPECL for the Beam Position Monitors (BPM).

TIMBEL boards have been developed specially for beamline synchronization. To date, 7 beamlines have been equipped with these boards. 6 beamlines have used them regularly with Synchrotron SOLEIL’s temporal mode .