# AN EXTERNAL SYNCHRONIZATION OF PHIL TO A HIGH POWER FEMTOSECOND LASER

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*Abstract*

The synchronization accuracy between laser systems and RF wave is a crucial ingredient for the successful operation of any particle accelerator based on photo-emission. In the case of ultra-short highly charged electron accelerator, the beam is highly sensitive to timing jitter. Thus, a high level of synchronization accuracy is needed. In this paper, we describe the current synchronization system of PHIL (electron accelerator at LAL) [1], and a new approach to synchronize PHIL externally with a high power femtosecond laser (LASERIX) [2]. The main goal of the experience is to design and study a compact way to obtain ultra-short electron bunches (few tens to few hundreds of femtoseconds) under high charge levels (hundred pC).

We continue with a description of different modifications made on PHIL timing master to adapt it to external synchronization.

## INTRODUCTION

PHIL is an electron beam accelerator at LAL dedicated to test and characterize electron photoguns and high frequency structures for future accelerator projects. It is also open to users to perform particle physic experiments and to calibrate detectors.

The accelerator is based on a low energy (E<5 MeV) and high current (1nC/bunch) photogun. It produces 10ps electron beam at a repetition frequency of 5Hz [3].
ESCULAP is a new collaborative project, in association with a high power laser facility"LASERIX". The project aims at obtaining, studying and controlling the features of high quality, highly charged, ultra-short electron beams, accelerated to quasi relativistic energies in order to implement a laser-plasma acceleration facility.

The main goal is to produce 150 fs long electron bunches, accelerated at quasi-relativistic energies (up to 10 MeV), with a maximal charge of 100 pC. To achieve such performances, it is possible to combine the photoemission process, induced on a cathode by an ultrashort laser pulse (30 fs RMS) with a high gradient photo injector (up to 90 MV/m).

The synchronization of the accelerator with the laser is a crucial step to ensure the stability of the beam. Thus, a general modification was brought to the master (PHIL low level RF generator) to allow two possible synchronizations of the machine: the first one is internal, based on a 75 MHz quartz, coupled to a PLL to generate either the 3 GHz RF wave and the timing signals (5 Hz), the second is external; the 75MHz frequency is provided in this case by LASERIX oscillator. A hardware security was added to the master to protect gun from eventual frequency drift.

The new configuration allows a double operation of the machine; internally mode to generate 10 ps duration electron bunches for experiences already installed at PHIL, and an external mode to obtain sub picosecond electron bunches to develop new applications.

## HARDWARE MODIFICATION OF PHIL MASTER

To operate PHIL with two different 75 MHz reference clock, a major change has been brought to the RF generation chain. The idea is to provide the master with two independent inputs clocks and common outputs that drive the machine. In addition, a security system was set up to protect the machine when the frequency of the external source is out of specifications.

### *Modification of the 3 RF Chain*

The following scheme (Fig. 1) shows the two most important parts of PHIL RF source. The blue part is the 75 MHz generation, the red part represents the low level RF system; it basically allows to generate, amplify and to pulse the RF signal to drive the amplification chain.

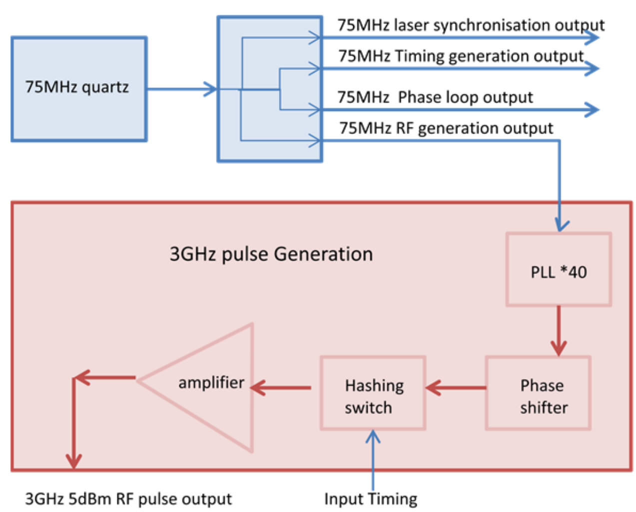


Figure 1: Old version of PHIL master.

In order to operate with external synchronization, the pilot must be deeply modified, taking into account that PHIL must maintain both modes; external with LASERIX and internal with local quartz. Moreover, switching between both modes should be easily adjustable and without impacting the rest of the machine.

To reach that goal, the 75MHz PCB (Fig. 1 blue part) which provides the 75 MHz signal to the timing system and to the RF generation part had been removed and replaced by a sequence of discrete elements that allows to use either internal 75 MHZ Quartz or external 75MHZ input (LaseriX oscillating cavity) (Fig. 2).

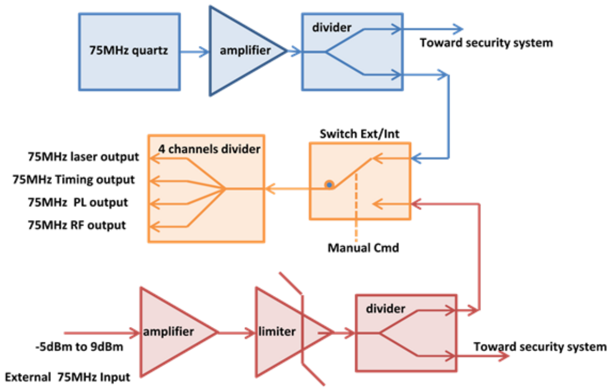


Figure 2: New version of PHIL master.

The system has been designed to have a 3 GHz generation completely independent from the 75 MHz source (external or internal). To switch between internal and external mode, a hardware switch has been installed at the back of the rack. To allow flexibility, an amplifier followed by a limiter (2 & 3 on Fig. 2) has been installed at the external input to give a -5 dBm to 9 dBm power dynamic.

## *Frequency Drift Security*

The $4.10^4$ quality coefficient of the RF gun cavity gives a 75 KHz bandwidth at 3 dB. To protect the High power RF generation systems (Klystron, circulator) from reflected power, we choose to keep the RF frequency in a 4 KHz bandwidth around the RF gun cavity central frequency [4]

In the internal RF generation mode, 75 MHz frequency thermally stabilized quartz is used (Reference Clock). The $10^{-8}$ quartz frequency stability allows a 40 Hz RF frequency stability that is far below RF Gun requirement.

Long time measurement (Fig. 3) of the LaseriX oscillating cavity frequency highlights that the laser frequency slowly shifts. The measured frequency drift is too big to be applied, without control, as an external 75 MHz source to the PHIL RF source according to the RF frequency bandwidth limitation.

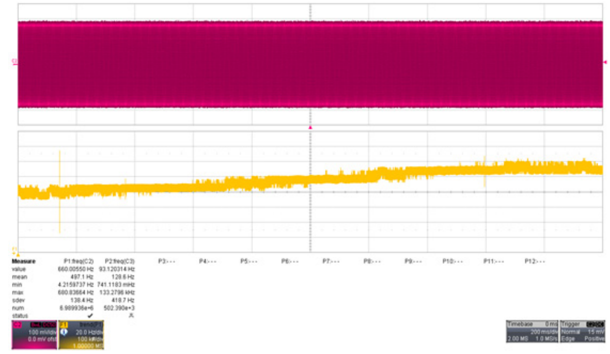

Figure 3: Frequency shifting of Laserix cavity oscillator versus time.

In the external mode, according to the 3 GHz bandwidth limitations, a security system checks the external signal frequency drift is kept in a 100 Hz range around 75 MHz. To achieve that point, the system compares the 75 MHz external signal to internal quartz (reference clock) using a frequency mixer (Fig. 4).

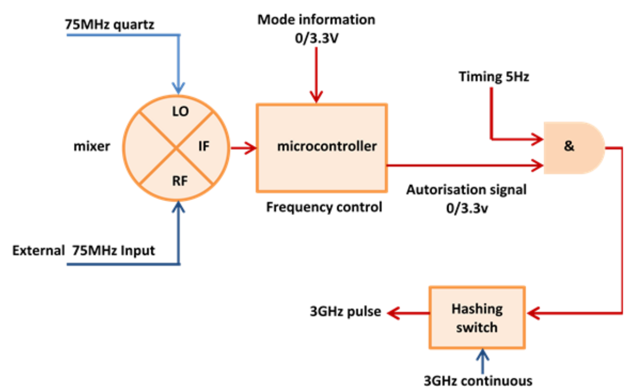


Figure 4: Frequency drift security system.

The figure above shows the architecture of the security mechanism installed on PHIL master. A microcontroller (NXP LPC 1768) manages the entire system. The mixer output signal frequency is measured by the microcontroller. An authorization signal is generated: logic “1” when the frequency of the external mode is within a bandwidth of ±100 Hz around the reference clock (74.963750 MHz); otherwise Logic “0”. combined with 5Hz timing using an “AND” logic gate. The result is sent to the RF hashing switch. A mode (external or internal) information signal is also sent to the microcontroller to disable security when the master is internally synchronized.




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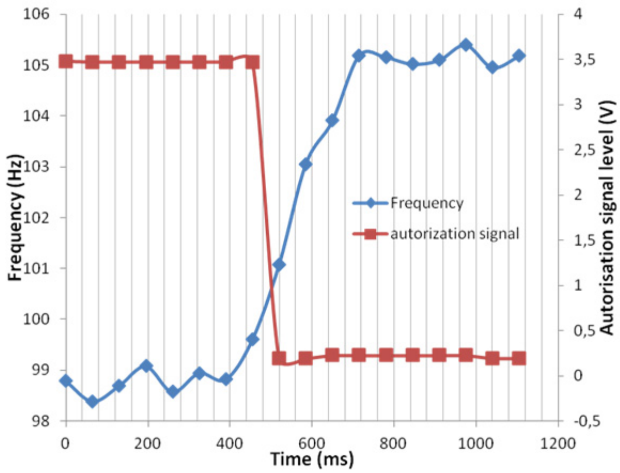


Figure 5: Response time of the frequency drift security.

The time response of the security system was measured to ensure the system efficiency. The figure above shows the authorization signal and the mixer output frequency versus time. We notice a reaction time of the security system lower than 80ms when the frequency exceeds 100 Hz. The system reaction time is well below the specification requirement (200 ms) corresponding to a 5 Hz repetition rate of the machine.

The next step for the timing modification will be to use, as we did for the External 75 MHz, an external 10 Hz signal from LaseriX to generate the RF Gun timing. This modification needs hardware changes, which will be done after a first complete test of very short bunch generation with PHIl and LaseriX.

## CONCLUSION

In this paper, we describe a new approach to synchronize an electron accelerator with either an internal or external source. The interest of this operation is to benefit from the advantages of each source on one machine. The internal source of PHIL allows generating a picoseconds beam with an adjustable charge level for particle accelerator and detector R&D. The external source is used to generate femtoseconds electron bunches in order to develop particle accelerator based on laser-plasma acceleration.

To improve the stability of the beam for both sources, a slow phase feedback was developed to correct the phase drift between the laser and the RF [5].

The integration of our system will have a positive impact on physic experiences performed at PHIL. it will also broaden the range of PHIL electron beam and touch more application.

## REFERENCES


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