FIRST MEASUREMENTS WITH A KICKED OFF AXIS BUNCH FOR PSEUDO SINGLE BUNCH MODE STUDIES AT SOLEIL

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Abstract

At SOLEIL, the time resolved community benefits from a single bunch operation few weeks a year. Meanwhile most of the multi-bunch filling pattern based experiments are not possible due to the low photon flux. Following the pioneer work performed at ALS [1], a new operation mode is under study at SOLEIL where the storage ring is filled up with a special hybrid mode: ¾ multi-bunch filling pattern and a single bunch with higher current in the last ¼. The so-called pseudo single bunch-filling pattern is obtained if the closed orbit of the single bunch is not the same as the one of the other bunches. Preliminary results are presented where the existing fast kicker magnet time impulse response has been significantly reduced while its frequency was increased from 3 Hz up to 1 kHz. This magnet is used as an additional corrector magnet to change only the single bunch closed orbit. First experimental results observed at one interested beam-line are also discussed.

INTRODUCTION

Synchrotron SOLEIL is a 2.75 GeV third generation synchrotron light source delivering beam to user since January 2007. Its intermediate energy has been chosen to satisfy a very broad range of photon energies from a few electron volts with long period insertion devices to a few tens of kilo-electron volts with in-vacuum undulators and wigglers [2]. It deserves several user communities asking for either high flux/brilliance based experiments or time resolved experiments. To answer the later demand, SOLEIL operates every year with different filling patterns: 8 bunches spaced by 146 ns with a full current of 100 mA and single bunch operation with 11 mA. The increasing user demands for a few bunch operation motivated us to look for new operation modes that could benefit at the same time to all user communities.

A first answer is the so-called hybrid mode: 392 mA in ¾ of the storage ring and an 5 mA isolated bunch in the last ¼. The spontaneous CSR threshold, source of noise on the data acquisition of the two infrared beamlines, dictates the maximum current of the single bunch.

A total of six beamlines are strongly asked for single bunch operation. Facing increasing demands we decided to evaluate an innovative and novel operation mode first developed at ALS: the so-called pseudo single bunch (PSB) mode [1,3-5].

PSEUDO SINGLE BUNCH MODE

The principle of pseudo single bunch mode consists in a special hybrid mode in which the isolated bunch is orbiting on a different closed orbit. This latter is created by one or several additional correctors that are seen only by the isolated bunch. There are then two different closed orbits in the storage ring, one for the multi-bunch electrons and a second for the single bunch. The challenges of this nice solution on the paper are the design of a few nanosecond time response pulsed magnets used for the new closed orbit, the operation of a machine with two closed orbits while maintaining the highest performances, and reducing drawbacks such as background radiation [3-5] on the user side.

At SOLEIL six beamlines have already expressed their strong interest for the PSB mode either in the horizontal or in the vertical plane. The needs in term of orbit displacement and repetition rate are not the same depending on users. CRISTAL beamline would like to operate as in femto-slicing mode with a 2.8 mm horizontal separation of the single bunch with respect to the normal bunches. Moreover to reduce irradiation on their samples, a low repetition rate of 0.1 to 10 kHz is asked. TEMPO beamline is equipped with a femtosecond laser operating from 5 to 250 kHz. PLEAIDES and DESIRS beamlines could benefit of the PSB mode at a frequency up the revolution frequency (847 kHz) of the storage ring.

Mainly questions are still opened concerning the use of PSB mode at SOLEIL. How many fast kickers to use to satisfy one or several beamlines? What repetition rate? What are the drawbacks of PSB if operating at different frequencies? What is the closed orbit bump achievable and compatible with maintaining high orbit stability and beam performances?

To answer these questions, we decided to start simulations and beam experiments using the available fast kicker magnet used for frequency map analysis [6]. In the following sections, first simulations are described. Then we discuss the modification of the machine study dedicated kicker magnets and timing system to carry out a first experiment with the TEMPO beamline.

ORBIT SIMULATION

TEMPO requirement for PSB mode is to separate the radiation from the normal beam orbiting on the almost zero closed orbit and that of the single bunch. The first mirror is located 10 m downstream of the source point (an APPLE2 type undulator). The maximum separation is 1 mm FWHM (four times the normal radiation emission cone from normal beam). The typical closed orbit followed by the isolated bunch is displayed on Fig. 1 for a horizontal orbit shift of 2.8 mm at CRISTAL beamline for the present location of the horizontal kicker. Our degrees

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of freedom are limited to the kicker amplitude and the choice of the working tunes. In addition since the kickers are running at a frequency much lower than revolution frequency, the single bunch will cross the beamline at different position and diverge over the turn number. The beam will get slowly damped to the zero amplitude. This gives another degree of freedom for selecting the radiation of the single bunch.

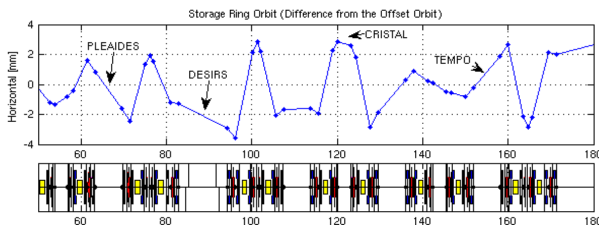

Figure 1: Closed orbit followed by the single bunch with four source-points for an orbit deviation of 2.8 mm in the undulator of CRISTAL beamline.

FAST KICKER MAGNET

Presently two fast kicker magnets [6] are installed in the injection straight section for kicking the electron in both transverse planes and analyzing transverse beam dynamics using beam turn by turn data.

In order to start our exploratory studies, the kicker pulsers have been modified. The requirements were to increase the trigger frequency from 3 Hz to 1 kHz and to shorten their time response duration down to 800 ns while keeping the maximum deviation strength compatible with TEMPO and CRISTAL experiments. A new pulse forming line whose length is reduced to 15 m, has been installed to replace the existing one used to operate the kicker for standard turn-by-turn measurements. Figure 2 gives the waveform obtained for the horizontal kicker; the reached performances are summed up in the Table 1 with respected to the original design kicker performances.

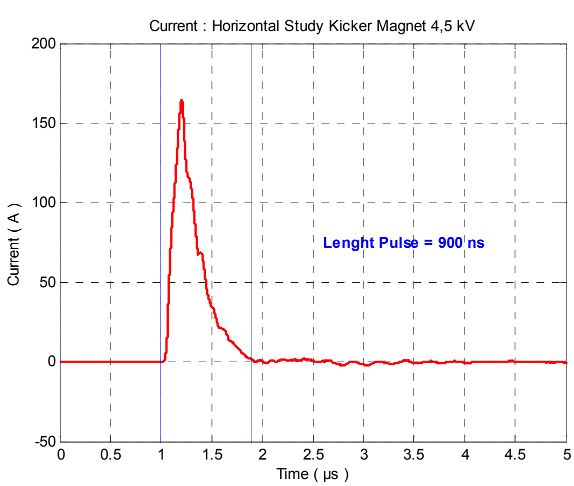

Figure 2: Horizontal time response of the horizontal fast kicker for suiting PSB requirements.

Table 1: Fast horizontal (H) and vertical (V) kicker performances for PSB mode versus design values.

Parameter	Design Value (H/V)	Value for PSB experiment (H/V)
Rising time	380/400 ns	280/400 ns
Flat top time	420/480 ns	<40 ns
Falling time	450/380 ns	580/400 ns
Max. frequency	3 Hz	1 kHz
Max. deviation	2.8/1.1 mrad	270/100 µrad

TIMING SYSTEM

The beamline timing system was modified in order to accommodate high trigger frequency for the kicker. The TIMBEL timing board was in-house developed [7] for providing users with timing signals. It allows us to synchronize the acquisition devices to electron bunch inside the storage ring. This board divides the RF clock and enables to tune the frequency in the 88-2.7 kHz range and to compensate the delay offsets. To meet the PSB specification sheet it was successfully upgraded in order to reach frequencies as low as 334 Hz for triggering the fast kickers.

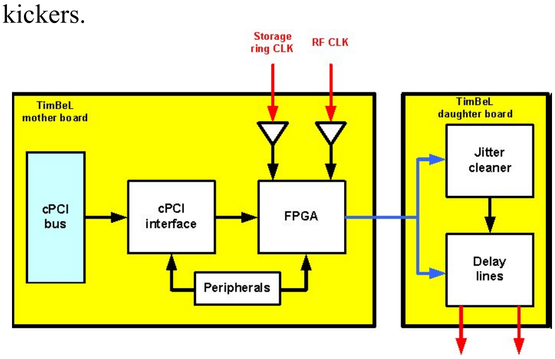

Figure 3: TIMBEL board's architecture.

PRELIMINARY RESULTS

Kicker Commissioning

Beam-based experiments have been carried out during the year 2010 to first validate the performances of the kicker and timing system.

The new modified kickers were successfully commissioned. Their response versus current is quite linear as soon as deviation angle is large enough with characteristics close to the expectations. In the horizontal plane the deviation range is from 70 to 270 µrad. The Figure 4 gives an example of comparison between the simulated orbit and the one built from the turn-by-turn data. The reproducibility is good but a factor two discrepancy between measurement and model needs to be further investigated. Operation at 827 Hz meets the baseline for a first experiment with users.

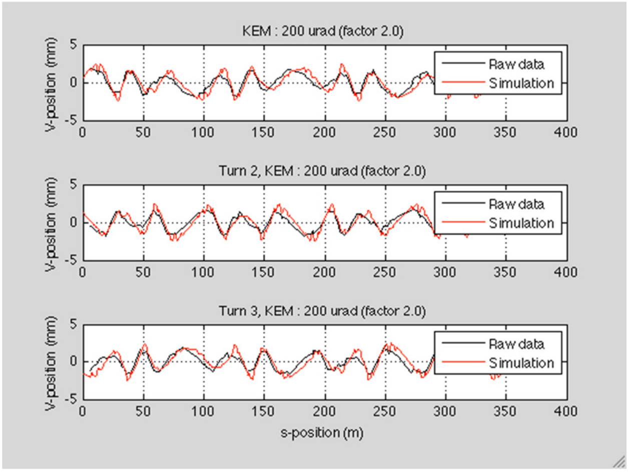

Figure 4: Comparison with the model of the closed turn-by-turn data of 3 subsequent turns.

First Results on TEMPO beamline

A first experiment was performed with the TEMPO beamline and the experimental station dedicated to time resolved photoelectron spectroscopy experiments [8]. The purpose was to synchronize to the data acquisition with the kicker excitation and to verify the pseudo single bunch operation at the experimental station level. During this experience the storage ring was injected with a 20 mA current in a hybrid filling pattern consisting of ¼ in multi-bunch and 1 single bunch in the rest of the machine. In the inset of Fig. 5 we present the time resolved photoemission intensity measured at the TEMPO experimental station on the time interval of the SOLEIL orbit. If the data acquisition is synchronized with the kick excitation frequency, the intensities associated to the ¼ multi-bunch and to the single bunch indicated with the red and blue regions respectively can be used to monitor the kicker operation and the effects on the hybrid intensity for each turn of the electrons in the storage ring. The integrated intensities are presented in Fig.5. The hybrid photoemission intensity (red curve) is not affected by the kicker operation, while the oscillations of the single bunch described in Fig. 5, are seen at the experimental station as damped periodic oscillations in the photon beam intensity.

PERSPECTIVE

After first encouraging experimental results another set of experiments is foreseen with the TEMPO beam-line before the end of the year. The aim is to validate the principle of PSB mode with a final user. If the results are positive enough a dedicated strip-line will be designed with a flat top of few tens of nanoseconds and higher repetition rate.

ACKNOWLEGMENT

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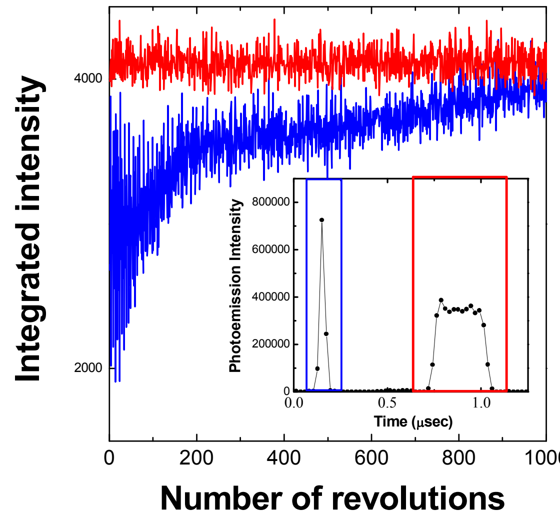

Figure 5: Integrated photon intensity recorded on the TEMPO photoelectron spectroscope for isolated bunch (blue) and multi-bunch (red).

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