FIRST MEASUREMENTS OF COHERENT SMITH-PURCELL RADIATION IN THE SOLEIL LINAC*

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Abstract

An experiment to measure the Coherent Smith-Purcell radiation has been installed in the SOLEIL Linac. Its aim is to produce a map of Smith-Purcell radiation emissions in several planes and compare it with theoretical predictions. Coherent Smith Purcell radiation is produced when a grating is brought close from a sufficiently short charged particles beam. The experiment consist of two detectors with 5 degrees of freedom. These two detectors can be moved around the emission point to measure the intensity of the radiation at different locations. Radiation maps are recorded parasitically by moving the detectors around during normal linac operations.

INTRODUCTION: SPESO

The Smith-Purcell Experiment at SOleil [1] (SPESO) aims at characterizing Coherent Smith-Purcell [2] radiation by accumulating a large statistical sample in a parasitic mode on a running accelerator. It is installed at the end of the SOLEIL [3] Linac.

SOLEIL's LINAC

The SOLEIL Linac, Helios [4], is made of a 50 kV thermioinc gun followed by a pre-bunched and two LIL cavities [5]. It accelerates the electrons up to an energy of 110 MeV.

The Linac can produce single bunches or trains. In users operation, several filling patterns in the ring can be delivered, requiring different modes of production in the linac. The Long Pulse Mode (LPM) enables to fill the ring with trains of bunches (maximum 104 bunches). The Short Pulse Mode (SPM) enables to produce single bunches.

In machine development mode, it is also possible to have a single shot mode with up to 0.5 nC/bunch, or a multibunch mode with trains of 104 bunches, with 1 to 7.5 nC/train, and bunches at 352 MHz. In user operation mode, a top-up system is used to maintain the beam current roughly constant in time. The frequency of Linac injection is:

- In hybride mode : every two minutes with the LPM (4 nC within 104 bunches) and every 6 min with the SPM (0.5 nC in the single bunch)
- In 8 bunches mode : every 90 seconds with the SPM (1 nC within 2 bunches)

SPESO

SPESO is installed at the end of the linac. It consists of a vacuum chamber with an insertion system that allows to insert a grating close to the beam axis. The vacuum chamber has a large crystalline quartz window (sealed with indium) to let the radiation exit toward the detectors. The distance of minimal approach of the grating to the beam has been calculated so that even when the grating is inserted, the beam is not affected and therefore the experiment can be run parasitically. The grating currently installed has a pitch of 10 mm and a blaze angle of 30°.

The experiment is mounted on an optical breadboard. The breadboard is mounted on 3 linear translators allowing rotation along 3 orthogonal axis X, S and Z (S being parallel to the linac direction and Z being the vertical axis). On the breadboard two sets of two rotary stages allow to control the direction of the detectors. A photo of the experimental apparatus can be seen on figure 1.

Two different detectors are used, one is sensitive to electromagnetic waves in the Q-band (33-50 GHz - 9.1 to 6 mm) and the other one is sensitive in the Ka-band (26.5-40 GHz - 11.3 to 5 mm). These detectors are based on zero-bias Schottky diodes to produce a signal proportional to the incoming radiation. The data coming from these detectors are acquired by an oscilloscope. A typical example of data is shown on figure 2

OPERATIONS

During normal beam operations the experiment is running autonomously: each time there is a linac trigger the data from the oscilloscope are recorded. Every 30 minutes the detectors are moved to a different location. In each 30 minutes cycle the grating is inserted for about 25 minutes and retracted for 5 minutes to allow measurement of the background (see figure 3). The data are then analysed by a script that runs every hours for data quality check (for security reasons this scripts has only access to detector signal level but not access to the machine data). On figure 4 one

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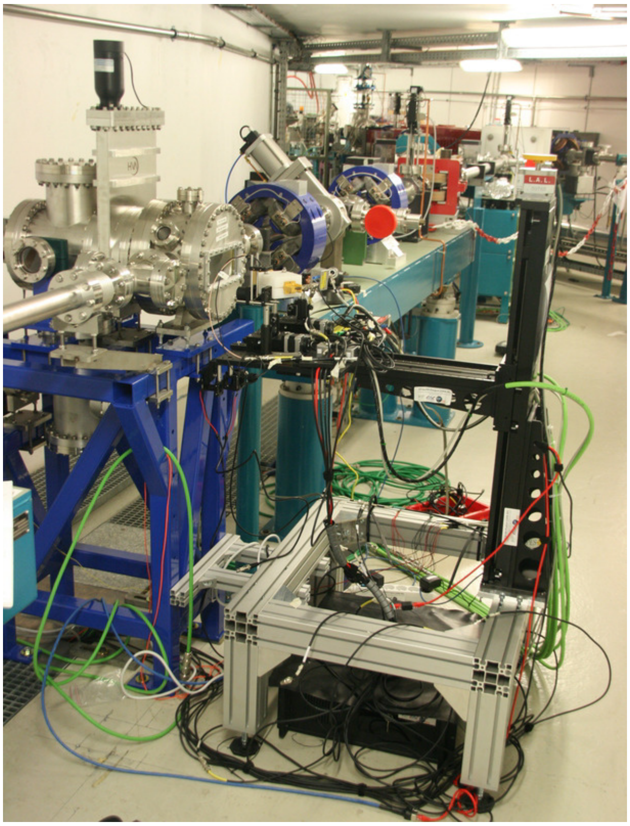

Figure 1: SPESO in the SOLEIL Linac

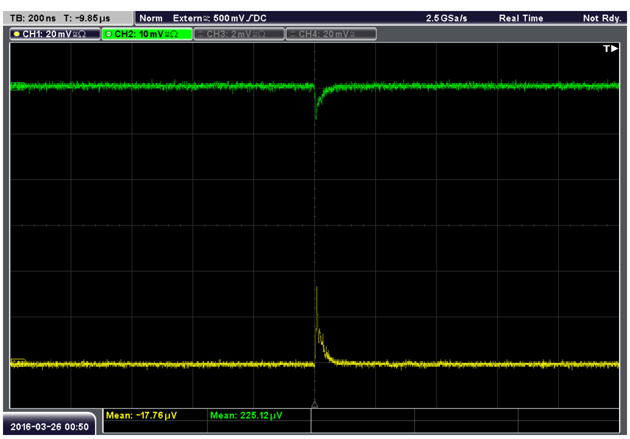

Figure 2: Example of data recorded with the two SPESO detectors (Green is the Q-band detector and yellow is the Ka-band detector).

can see the trend of data recorded over a day while the detectors where moving along the S-direction. A more advanced analysis is done off-line to extract physical information from the data, after merging the detector data with the machine data.

MEASUREMENTS

The data collected so far allow us to have a precise image of the signal in several directions: figure 4 shows the data taken over a day as the detectors are moving along the S-

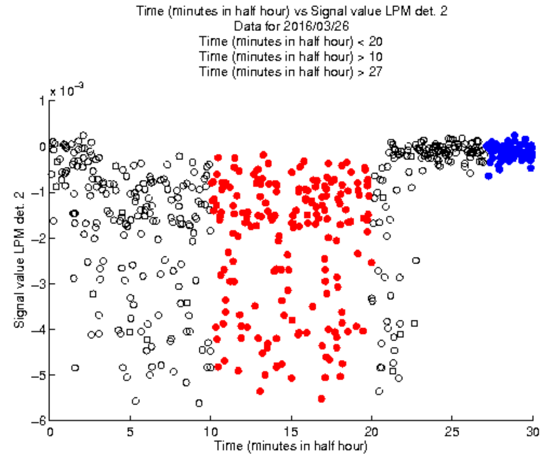

Figure 3: Contrast between the grating inserted and retracted for detector 2. The vertical axis is the signal axis (the lower value being the most intense) and the horizontal axis is the time in the 30 minutes period. The data are the black, blue and red dots. The data in blue and red are those that are used in the data quality analysis to check that the system is operating correctly (the red dots have to be lower than the blue dots). These data were integrated over one day. The different signal level in the 2-25 minutes range correspond to different positions of the detector.

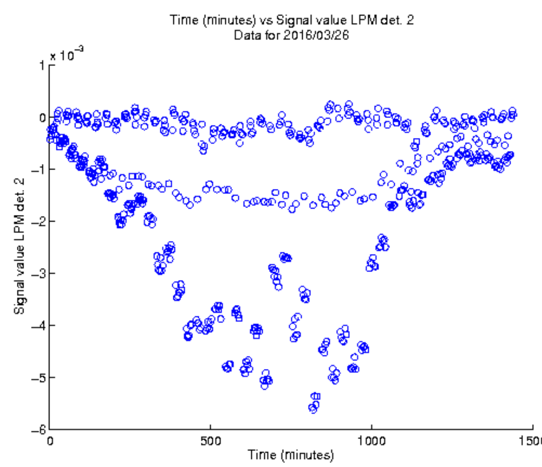

Figure 4: Example of data recorded during one day. During that day the detectors were moving along the linac axis. The 3 different lines correspond to 3 different regimes: grating retracted (upper line), SPM and LPM.

direction whereas figure 5 shows the data as the detector is moving vertically.

Using the data collected so far it is possible to reconstruct the radiation profile emitted in several angles. The power measured from the Schottky diodes has to be corrected to take into account the diode efficiency and to give the radiation intensity. The transmission efficiency of the window's crystalline quartz is also taken into account. The data distribution obtained after all these corrections is shown on figure 6. As the Schottky diodes sensitivity is certified by

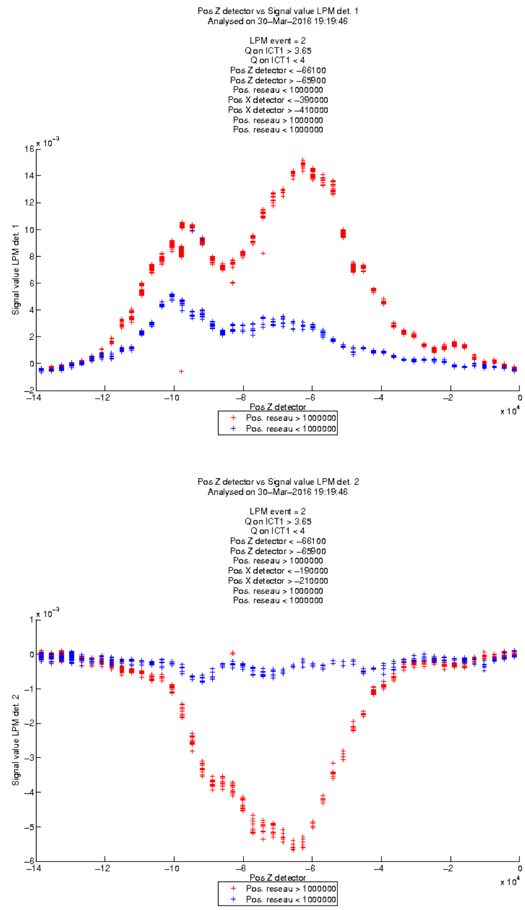

Figure 5: Example of raw signal collected with the the two detectors while the detectors were moving vertically. The red line corresponds to the grating in the inserted position and the blue line to the grating in the retracted position (background). The upper plot corresponds to the data recorded with the Ka-band detector and the lower plot to those recorded with the Q-band detector.

the supplier only on a narrow range (but our measurements clearly show that it is sensitive over a much wider range we separate the data for each detector in two sets. The figure also shows the expected signal for 4 different pulse lengths (corrected for near-field effect) using the model described in [2].

From these data it is possible to follow the method described in [6] to extract the form factor of the bunch and to recover its profile. The recovered profile is shown on figure 7. From this profile we get a measured bunch length of about 14.2 ps FWHM in high charge LPM mode.

OUTLOOK

The SPESO experiment at SOLEIL is now fully operational. It allows to study the distribution of Coherent Smith-Purcell Radiation in order to provide a better understanding of this phenomenon.

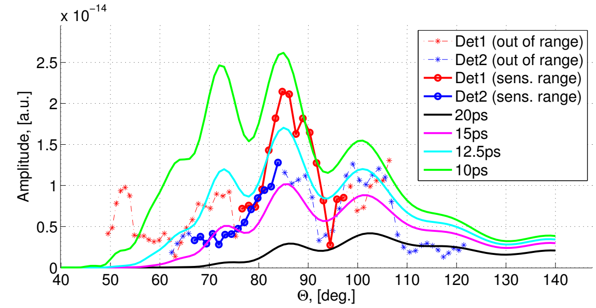

Figure 6: Distribution of the signal measured as function of the observation angle. The red dots correspond to the Ka band detector and the blue dots to the Q-band detector. The solid lines correspond to data points at frequencies within the sensitivity range of the detector and the dashed lines to data points at frequencies outside that range. These data are compared to simulations for 4 different bunch FWHM.

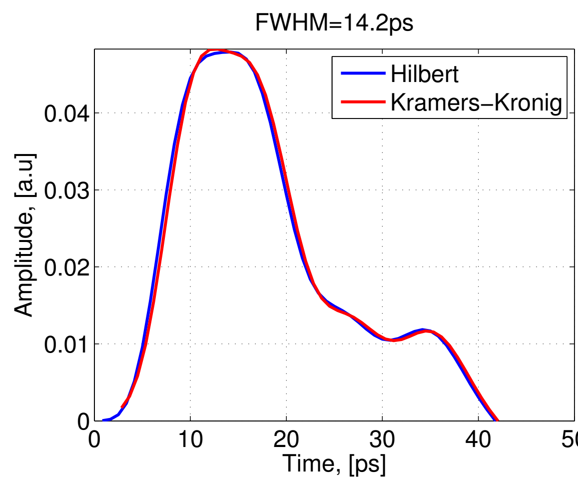

Figure 7: Bunch profile recovered from the data presented on figure 6 using the method described in [6].

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