3+L (TIME RESOLVED e^+ LIGHT)

A. Bocci (Art.23), M. Cestelli Guidi (Art.23), A. Clozza, A. Drago (Resp. Naz.),
A. Grilli (Tec.), A. Marcelli, R. Sorchetti (Tech.), A. Raco (Tec.), G. Zangari (Ass.)

1 Introduction

At LNF, 3+L (Time Resolved e^+ Light), a beam diagnostics experiment funded for the years 2007-2009 by the National Scientific Committee V of the INFN, has been set-up on one of the bending magnet of the DAΦNE positron ring. The 3+L experiment has been designed to monitor in real time the e^+ bunch shape and to study the bunch dynamics in the DAΦNE Φ-Factory performing bunch-by-bunch and turn-by-turn longitudinal and transverse beam diagnostics by using compact uncooled IR detectors. 3+L operated during 2009 in the DAΦNE hall where a compact optical system has been installed and aligned. It collects the IR synchrotron radiation emission and focus the radiation on a small spot where a fast detector can be aligned to perform real-time bunch diagnostics. Several measurements have been carried out using different IR photodiodes. Moreover, efforts have been dedicated to test and characterize a prototype of an IR array detector that can be used to monitor the bunch-by-bunch transverse profile of the e^+ beam.

2 Experimental set-up

The 3+L experiment collects the IR light emitted by particles circulating in the DAΦNE positron ring and extracted from the first bending magnet after the Interaction Region 2. It consists of a compact front-end with an HV chamber that hosts a gold-coated silicon plane mirror. The mirror collects and deflects the light emission through a ZnSe window that transmits radiation in the range 0.6 to 12 μm (800-17000 cm^{-1}). Inside the storage ring hall, after the ZnSe window, five mirrors working in air focus the radiation in a spot of about 0.1 mm^2. This compact optical layout demagnifies the source of a factor ~ 5 and allows also the imaging of the source. Detectors placed behind the 4^{th} mirror are mounted on a xyz micrometer stage to align them to the light spot. The installation is completed by a computer to remotely control the experiment. A PCI-COM bridge RS-232 board controls motors and the xyz stage and two webcams and a camera monitor the detector and the mirrors positions. A power supply connected to the PC by a USB-GPIB interface is used to supply amplifiers and detectors. Dedicated software packages have been developed under the LabVIEW platform for data acquisition, to control the power supplies and the xyz stage. An oscilloscope model Tektronics TDS 820 with 6 GHz of bandwidth connected to the PC by the same USB-GPIB interface is used for data acquisition.

3 Activity

During 2009 different measurements have been carried out with the 3+L optical system both to characterize the emitted light in the IR region and the detectors. In particular, measurements were carried out using fast PVMI 3-stages detectors from VIGO System S.A. These detectors are based on HgCdTe multilayer hetero-structures grown by the MOCVD technology on oriented GaAs (211) and (111) substrates. They have been optimized to work in the mid-IR at 10.6 μm and their best response time may reach 100 ps or lower when cooled at 205 K with the 3-stage Peltier cooler. Photodiodes were inverse polarized varying bias voltages in order to optimize performances, i.e., response times and the highest S/N ratio. The output of the device was connected to a broadband preamplifier to enhance the signal of the photodiode. The amplifier was characterized by ≈ 46 dB gain and 0.01- 2500 MHz of bandwidth. Detectors are very sensitive and during measurements we detected also noise associated to the two radio cavities of the DAΦNE rings. In order to shield the RF signal of the klystrons installed in the DAΦNE hall, the circuit used to polarize the photodetector, the photodiode and the amplifier were closed inside a metal box. Coaxial cables and SMA connectors were used to connect the output of the amplifier to two channels scope for data collection. For all IR devices, the measurements were carried out at room temperature.

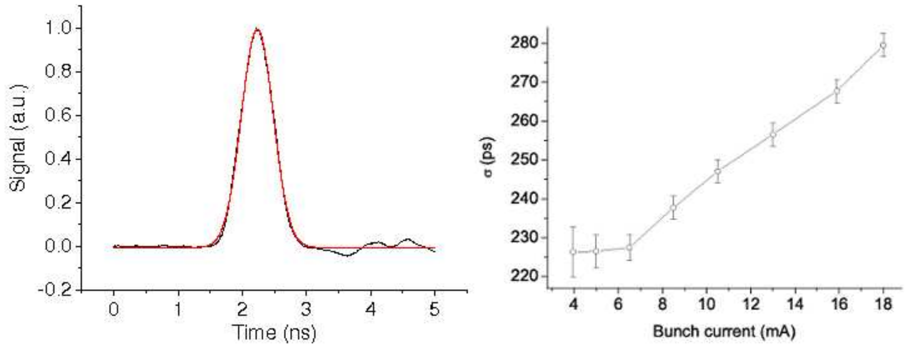

Figure 1: (color online). The shape of a typical positron bunch (black) measured at IR wavelengths and its Gaussian fit (red) (left panel). The behaviour of the rms bunch length vs. the bunch current measured with the IR uncooled photodiode (right panel).

Data in the left panel of Fig.1 show that with a bunch current of ≈ 5 mA the bunch profile is Gaussian with a length of $\sigma \approx 240$ ps while both the rise and fall time measured by this detector are ≈ 400 ps. Data have been collected vs. the positron current in order to characterize the bunch length behavior. In the right panel of Fig. 1 we show the rms bunch length of the Gaussian distribution used to fit data as a function of the bunch current. The σ of the Gaussian distribution increases as function of the bunch current, exhibiting a linear behavior for currents higher than $\approx$ 7 mA, while, at lower currents, the σ has a constant value of ≈ 225 ps. The observed behavior is probably due to the limited response time of the photodiode working at room temperature. In order to reduce the RF noise a new, better shielded device with a dedicated electronics was also used to amplify the photodiode. A photograph of the detector with its compact electronics, mounted at the focus of the 3+L experiment is showed in Fig. 2. The electronics allows to bias the device at a fixed voltage and cool down it at 205 K to optimize performances.

With the original set-up above described, because the RF power of klytrons increases with the beams currents we measured an increasing noise level as function of the e^- and of the e^+ currents. With the new experimental set-up we measured a peak-to-peak voltage associated to the RF noise at high beam currents in the range 10 to 30 mV that allows obtaining a S/N ratio ≥ 100, a factor 10 times better. The signal of the e^+ bunch pattern with a separation of 2.7 ns as measured by the PVI-3TE-10.6, SN 5986 device is showed in the right panel of Fig. 2. In these runs, in order to optimize the response time of the detector, we cut the power associated

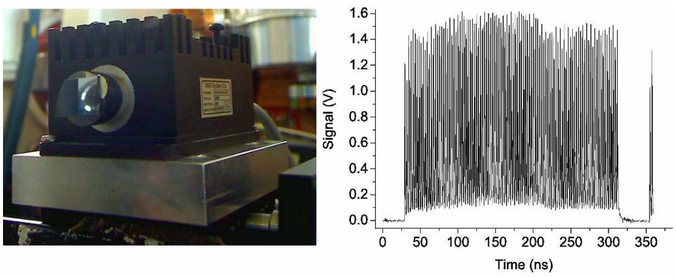

Figure 2: The amplifier, the IR photodiode with its mid-IR filter installed at the focus of the 3+L optical system inside the experimental hall (left panel). The typical bunch pattern with the 105 e^+ bunches and the gap measured with the shielded electronics of the cooled PVMI 3-stages VIGO detector (right panel).

to wavelengths lower than 10.6 μm for which the photodiode was optimized, using a mid-IR filter with a cut-off at 5 μm was in front of the device (Fig. 2). The electronics system was made by a transimpedance amplifier with a (high) bandwidth in the range 0.0001-1000 MHz and with a gain of 3900 V/A ($\approx$ 37 dB). Although an optimization of the voltage value was not possible, with the new electronics set-up, a reverse bias voltage was applied to the photodiode to obtain similar response times as those achieved with the previous electronics set-up. Actually the response time of this second device, that, in principle, may reach response time lower than 100 ps was $\approx$ 500 ps, a factor $\approx$ 2 slower than the best device previously measured. Nevertheless, the electronics set-up exhibited a much better shielding of the RF signal and a much lower noise level. In the future, this electronics should allow to achieve response times down to $\approx$ 100 ps really improving the longitudinal diagnostics of the 3+L experiment.

Finally during 2009 we carried out different tests of an infrared array prototype made by 32 x 2 pixels. For the preliminary measurements an interface board has been built and the pixels of the array have been connected by gold bonding wires to the board and finally to the input of an analog electronics board (see left panel in Fig. 3).

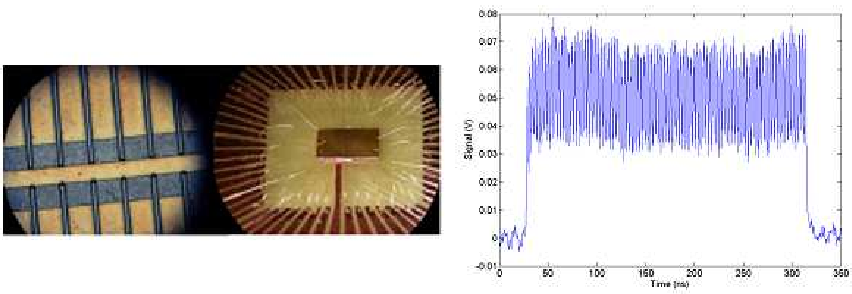

Figure 3: Magnified view of the IR array showing a few pixels of the photoconductive detector and the interface board of the device showing the connection between pixels and the gold bonding wires at the interface board (left panel). In the right panel the IR signals of the 105 e^- bunches collected by one of the pixels of the IR array.

The dedicated electronics of the array is composed by 64 channels with a bandwidth of 1 GHz for channel designed to amplify signals of the array with a gain of $\sim$ 40-50 dB depending by the power supply voltage. A four channels oscilloscope has been used to characterize each pixel of the device, to collect and analyze the signals. A dedicated digital electronics, based on powerful FPGA (Field Programmable Gate Array) chip, is under development to collect and store the signals from all the 64 channels. Up to now, during the preliminary measurements, only four pixels of the array have been connected to the data acquisition system. To perform tests we used the IR emission of the electron beam at the SINBAD beamline. The array has been placed at the focus spot of the optical system after the last toroidal mirror of the SINBAD optical system. It demagnifies the source image by a factor 2.3 with an estimated spot of about 2.0x1.5 mm at mid-IR wavelengths. The array has been placed in the vertical position in front to the IR spot. With a pixel size of 50x50 μm a large fraction of the spot can be monitored by the array with only 4 pixels connected to the electronics system. Measurements obtained from a single pixel of the array are shown in the right panel in Fig. 3 where the individual IR emission of the 105 bunches of the e^- beam and the gap are clearly resolved. Signals of four pixels have been also collected at the same time by an oscilloscope using four input channels and a bandwidth of 1 GHz with 4 Gsample/s. The analysis of the large amount of data collected by the array is still in progress but the first results are interesting. In Fig. 4 data acquired from the bunch pattern stored in the electron ring are shown in a 3D plot. Four pixels (of 64) are analyzed: they show clearly a change of intensity along the bunch train versus different transverse positions (correlated to pixel numbers).

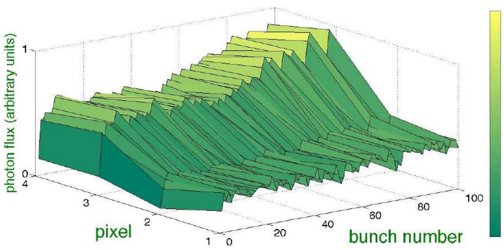

Figure 4: The image shows the multibunch pattern of the DAΦNE electron ring as reconstructed from the signals of the four pixels of the linear array. It is evident a change of the intensity along the bunch train.

4 2010 Activities

The activities foreseen in the year 2010, being finished both the beamline construction and the experimental program funded by the V$^{\text{th}}$ National Scientific Committee, shall consist mainly of the analysis of the large amount of data recorded in 2009 both by single-pixel and multi-pixels detectors. After the end of DAΦNE shutdown due to the installation of the KLOE detector, the 3+L vacuum chamber would be reinstalled on the exit port of the positron main ring. If this will happen, new and faster infrared detectors should be tested during next year. Moreover, data could be collected at the 3+L and/or at the SINBAD beam line using the new portable FPGA-based digital acquisition system.

5 Publications

1. A. Bocci et al., *Beam Diagnostics for positron beam at DAΦNE by 3+L experiment*, Proceedings PAC09, Vancouver, BC, Canada, MO4RAI01.

2. A. Bocci et al., *Beam Diagnostics at IR Wavelengths at NSRL*, Proceedings PAC09, Vancouver, BC, Canada, TH5RFP056

3. A. Bocci et al., Proceedings DIPAC09, Basel, Switzerland, May 25-27, 2009, 194.

4. A. Bocci et al., Frascati Report LNF - 09/15(R).