HIGH CURRENT MULTIBUNCH OPERATION AT DAΦNE

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Abstract

At present the Frascati Φ-factory DAΦNE is operating in multibunch regime with stored currents in the range of 0.5-1 A in both e+ and e- rings. A longitudinal bunch-by-bunch feedback system has been operating in each DAΦNE main ring since the beginning of the machine commissioning. The transverse bunch-by-bunch feedback system working in the vertical plane has been implemented last year in both rings. This paper describes the performance of the feedback systems and reports the instability observations and the rise-time measurements. The present current limitations and the plans aimed at further current increase are also discussed.

1 INTRODUCTION

DAΦNE is a Φ-factory in operation at the Laboratori Nazionali di Frascati of I.N.F.N. Two detectors, Kloe and Dear are currently taking data and a synchrotron light facility is under development. At present the Frascati Φ-factory DAΦNE is operating in multibunch regime with stored currents in the range of 0.5-1 A in both e+ and e- rings. The achieved peak luminosity is $2.79 \cdot 10^{31}$ cm^{-2} sec^{-1} in the IP1 (Kloe detector) while the reached integrated luminosity is 1.4 $pbarn^{-1}$ per day [1].

A longitudinal bunch-by-bunch feedback system, developed in collaboration with SLAC and LBL, has been operating in each DAΦNE main ring since the beginning of the machine commissioning.

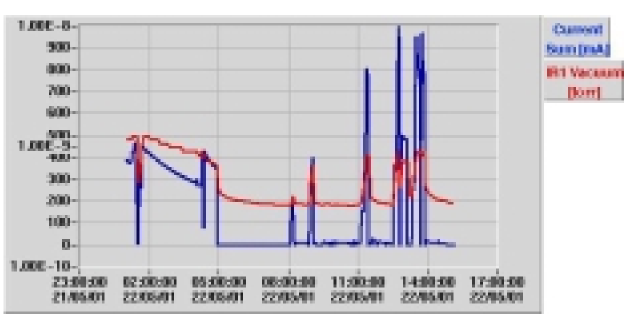

Figure 1: E- machine development shift plot.

Last year transverse bunch-by-bunch feedback systems in the vertical plane were implemented. These new systems have become necessary to increase the electron and positron current, the number of colliding bunches and to pass from a filling pattern of one bunch every three buckets, to one every two. This has allowed typical collisions with 800mA of electrons against 700 mA of positrons.

In single beam more than 1 Ampere has been stored in each ring. In Fig. 1 a machine development run with 1015 mA of a stable electron beam is shown.

2 LONGITUDINAL DYNAMICS

The longitudinal dynamics in DAΦNE has to cope with three kinds of effects limiting the maximum stored currents and the luminosity: synchrotron (dipole) oscillations, quadrupole longitudinal oscillations and mode-0 oscillations. Different actions have to be taken to damp or stop these undesired instabilities.

The synchrotron oscillations are rigid movements of every bunch backwards and forwards. In the DAΦNE main rings are damped by a bunch-by-bunch longitudinal feedback described in the next subsection.

The quadrupole internal bunch motion is a kind of oscillation appearing at the double of synchrotron frequency and changing the charge distribution, i.e. the longitudinal bunch shape. It can not be damped by the longitudinal feedback. In DAΦNE this instability is stronger in the electron ring. The ways we cure the instability are following: increasing the momentum compaction, RF voltage variation and appropriate orbit correction (since the impedance depends on the bunch orbit).

The mode-0 oscillations can appear at frequency equal to the synchrotron one or at lower frequencies. The mode frequency decreases for higher currents. The beam gets unstable when the frequency reaches zero. We damp these oscillations by a zero mode feedback that corrects the common mode signal through the main RF cavity.

2.1 Bunch by bunch longitudinal feedback

A longitudinal bunch-by-bunch feedback system has been operating in each DAΦNE main ring since the beginning of the machine commissioning. A large collaboration between laboratories has allowed to test the system first on the Advanced Light Source main ring and then to install it on many other storage rings without modifications [2]. In DAΦNE the very high synchrotron frequency requires the use of one Digital Signal Processor every two bunches. The power stage has been upgraded and now three 250 W amplifiers are installed for each system. High pass filters at 1.5MHz on the input signal have allowed avoiding crosstalk effects with the mode-0 oscillations.

Usually FIR (Finite Impulse Response) filters are running in the DSP's but also IIR (Infinite Impulse Response) filters [3] have been tested successfully.

The IIR filters show a better rejection to the mode-0 signal and a flatter phase response in the frequency range selected.

2.2 Characteristics and performances

Up to the achieved currents the longitudinal feedback damps the instabilities very well. Turning off for a while the correction signals makes possible to measure the growing and the damping time. The electron beam with a ~500mA current shows the presence of mode 21 with a growing time of 800 µsec, while the feedback gives a damping time of 90 µsec. In the positron ring the same mode 21 shows a growing time of 600 µsec at 214mA, while the feedback shows a damping time of 220 µsec. A correct comparison should be done at the same total currents. Both measurements have been done storing a bunch every two buckets.

3 TRANSVERSE DYNAMICS

One year ago transverse bunch-by-bunch feedback systems working in the vertical plane have been implemented in each ring.

At the beginning of commissioning this systems was considered not strictly necessary. Moving toward more populated filling patterns and increasing the stored currents, the need of a vertical system became clear. In the present situation during collisions a horizontal feedback is not mandatory, but the installation is foreseen in the next future.

3.1 Vertical bunch-by-bunch feedback

The vertical feedback is designed completely at Frascati, but similar systems are well known, see as an example the PEP-II transverse feedback [4].

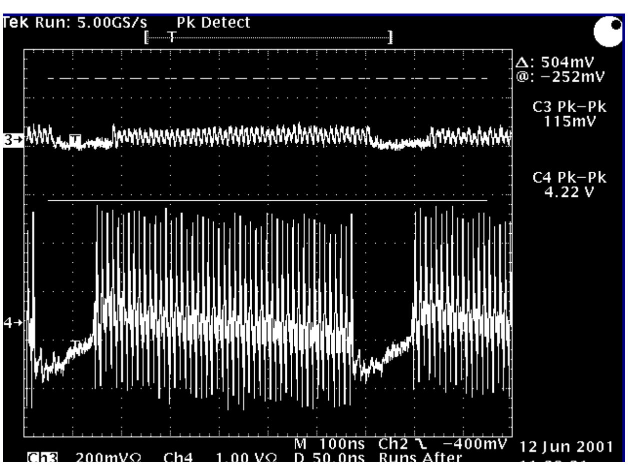

Figure 2: E- correction signal and stripline output at 750mA.

The DAΦNE vertical feedback system allows to select offline a suitable beam position monitor in order to assure the 90 degrees phase advance between monitor and kicker. An operative comparison between a baseband front end receiver and another working at 4*RF has made to prefer the first system for a smaller crosstalk between adjacent bunches. An 8 bits analog-to-digital converter samples at the radiofrequency (368MHz) the input received signal without discarding any samples. The digital signal can be inverted or put at zero. The beam position offset gives a spurious input signal that has to be minimized by a local bump in the orbit. An improvement in the offset management is on the way, by adding to the feedback system a digital bunch by bunch offset corrector. A digital-to-analog converter produces a bunch by bunch correction signal that is sent to the power stage. The sampler timing is done digitally phasing the RF clock, while in the back end a programmable delay line for analog signals is used. The power stage is composed by two 250W amplifiers for each ring. In Fig.2 it is plotted the correction signal and the stripline output for an electron beam of 750mA with 49 over 60 bunches.

4 EXPERIMENTAL MEASUREMENTS

The fabrication of one cavity prototype and two final devices all made of Aluminium has been decided. The prototype, whose picture is shown in Fig. 2, has been delivered to the LNF at the end of last year, while the fabrication of the two final cavities is almost completed and their delivery is scheduled by the end of June 2001.

3.2 Characteristics and performances

The analysis of the correction signal of the vertical instability has shown that the oscillation is stronger toward the end of the bunch train as shown in Fig. 3. This is true for both beams.

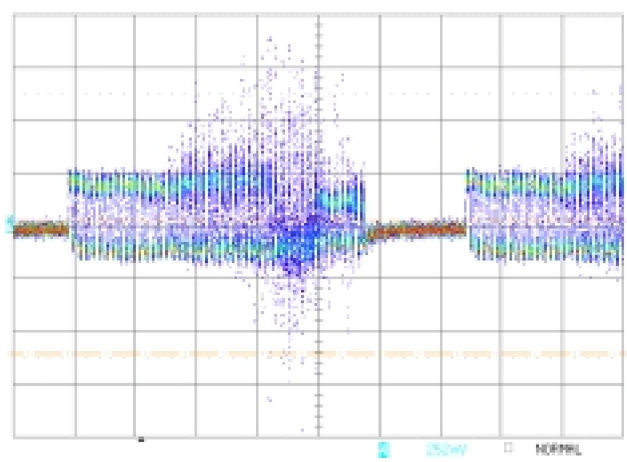

Figure 3: E+ correction signal with 45/60 bunches (~400mA)

The analysis shows also a frequency spread of 20KHz in the betatron oscillation on both beams, while the electron beam requires a feedback gain at least 3dB higher than positron. In both rings the instability threshold is proportional to the distance between contiguous bunches (lower threshold for closer bunch pattern).

For example with 45/60 bunches and feedback off the vertical instability in the e- ring starts at ~100mA, while in the case with 32/40 bunches it starts at ~300mA.

In both rings the unstable mode is 100 or 101 which seems related with the longitudinal mode 21 considering that the harmonic number is 120. The growing time of the modes is around 125 msec at 500mA for the positron beam with 45/60 bunches. The damping time measured of the feedback was 83 msec with the old reduced power of 200 W. A preliminary measurement with the new 500 W power amplifiers evaluates the damping time <40 msec.

In Fig. 4 it is shown the vertical oscillation in the electron ring with the vertical feedback off, and in the Fig. 5 the same situation after the feedback turning on. The beam current is ~400mA with 45/60 bunches.

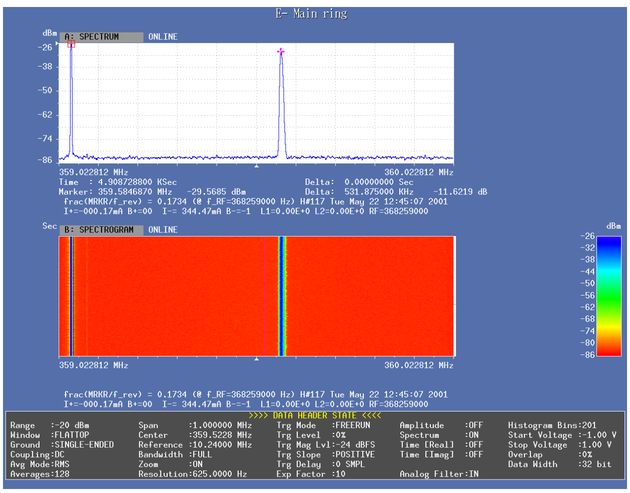

Figure 4: E- beam: vertical oscillation (feedback off)

4 CONCLUSIONS

DAΦNE collider requires powerful feedback systems to achieve the high stored currents needed to reach the high luminosity. At present the longitudinal and the vertical feedback systems are adequate to store more than 1 Ampere in each ring.

In the next future we are considering to double the power amplifiers for the longitudinal feedback systems, feeding all the six ports of the "cavity" kicker [5] (now only three ports are fed).

For horizontal transverse instabilities we are preparing a system identical to the vertical feedback: pickups, kickers [6] and cables are already installed and the electronics is ready. Two 100 Watts amplifiers for each ring are installed. We have to tune the betatron phase advance between monitor and kicker, some optics modifications could be necessary to make the system operative. For the vertical feedback we have planned to improve the management of the beam position offset, upgrading the feedback system with a digital bunch by bunch offset corrector now in fabrication at the Frascati laboratory.

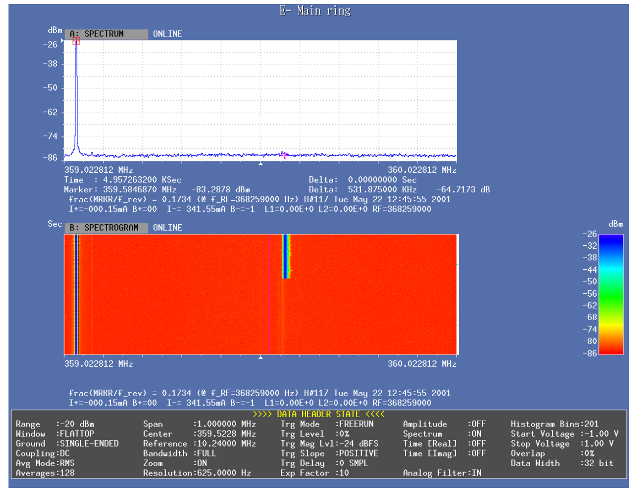

Figure 5: E- beam: no vertical oscillation (feedback on)

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6 REFERENCES

[1] S. Guiducci et al., "Status Report on DAΦNE", these proceedings.

[2] J.D. Fox et al., "Programmable DSP Based Multibunch Feedback: Operational Experience from Six Installations", SLAC-PUB-8410, May 2000. BIW 2000, Cambridge, Mass., May 2000.

[3] D. Teytelman et al., "Design and Implementation of IIR Algorithms for Control of Longitudinal Coupled Bunch Instabilities", SLAC-PUB-8411, May 2000. BIW 2000, Cambridge, Mass., May 2000.

[4] W.Barry et al., "Status of the PEP-II Transverse Feedback Systems", PAC'97, Vancouver, Canada, May 1997.

[5] R. Boni et al., "A Waveguide Overloaded Cavity as Longitudinal Kicker for the DA_NE Bunch-by-Bunch Feedback System", Particle Accelerator, Vol. 52 N.2, pp 95-115, 1996.

[6] A. Gallo et al., "The Transverse Feedback Kicker", DAΦNE Technical Note CD-5, December 14, 1995.