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Development of the C-Band BPM System for ATF2*

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Abstract

The ATF2 international collaboration is intending to demonstrate nanometre beam sizes required for the future Linear Colliders. An essential part of the beam diagnostics needed to achieve that goal is the high resolution cavity beam position monitors (BPMs). In this paper we report on the C-band system consisting of 32 BPMs spread over the whole length of the new ATF2 extraction beamline. We discuss the design of the BPMs and electronics, main features of the DAQ system, and the first operational experience with these BPMs.

INTRODUCTION

The ATF2 (Accelerator Test Facility) is a major upgrade to the extraction line of the original ATF machine, and is intended as a proof of principle of the local chromaticity correction scheme planned for use in future linear colliders. The goals of this collaboration are to demonstrate the ability of this optics to achieve a spot size of 37 nm, and to maintain this over a long period of time.

To this end, it is vital that sufficient high quality beam diagnostics are available for use by the various, proposed, tuning algorithms (for example [1], [2], and [3]). In this paper we report on the C-band Beam Position Monitors (BPMs), which comprise of 32 rf BPMs spread over the entire length of the new ATF2 extraction and final focus line, including a description of the design of the cavities and electronics, the data acquisition (DAQ) system, and the first operational experience with these devices.

BPM CAVITY

The C-band cavities used in the ATF2 extraction line and final focus are based on the previous ATF design, but with some alterations to more closely match the needs of ATF2.

The cavities have a 4-coupler, symmetric, structure, with two couplers for each transverse plane, and have a resonant dipole mode frequency of 6426 MHz. Figure 1 shows the

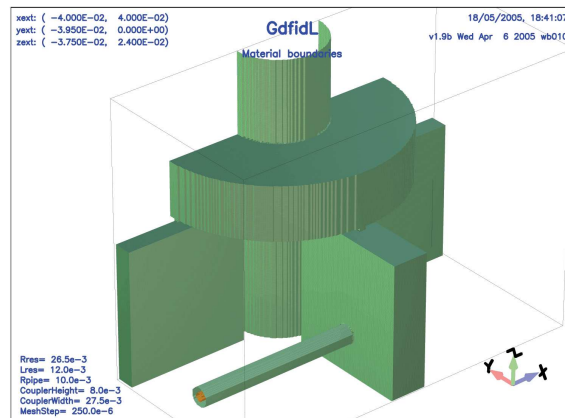


Figure 1: Design of the ATF2 C-Band cavity shown in the format used for the GdfidL simulations.

design of such a cavity in the format used for the GdfidL calculations.

The aperture of these cavities was increased to 20 mm in order to satisfy the ATF2 optics requirements, and the coupling has been increased to $Q_{ext} = 13000$ to gain higher sensitivity. Simulations of the leakage of the monopole mode suggest that this is less than the computational error.

ELECTRONICS AND DATA ACQUISITION

The electronics installed on each channel of each output are designed to mix the signal down from the cavity output frequency of ~ 6.4 GHz to a frequency of ~ 20 MHz, before inputting to SIS digitisers running at 103 MS/s.

The signals from the two output ports per plane are combined with a hybrid to increase the signal amplitude on the input to the electronics.

The self-contained electronics boards first pass this signal through a 6.7 GHz low pass filter, couplers for calibration tones, and power limiters to protect downstream components from excessive signal amplitude. After this, the signals are then amplified and fed into an I/Q mixer, whose output is combined in a 90° combiner in order to double the single sideband amplitude. The LO power is fed in at

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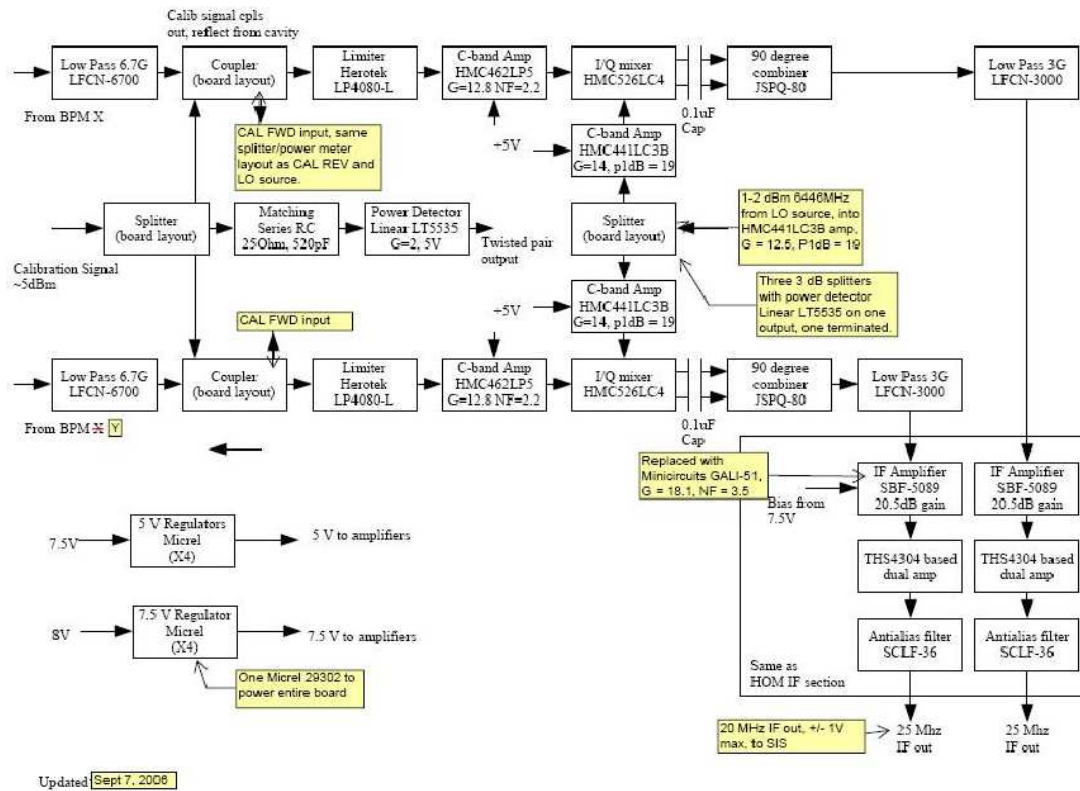


Figure 2: Schematic of the BPM downmix electronics.

6446 MHz; 20 MHz above the expected cavity frequency.

Finally, the signals are low-pass filtered, before being passed to a final amplifier chain, and an anti-alias filter.

The digitisers have been incorporated into an EPICS IOC, to allow remote control, and to ease the acquisition and processing of the raw data.

CALIBRATION AND ANALYSIS

The analysis and calibration utilise a method known as Digital Down Conversion (DDC), a description of which is given in [4].

This method consists of multiplying the digitised waveform by a complex oscillator, whose frequency is identical to that of the downmixed cavity output, and then filtering this product to remove the high frequency component. The result of this process is a complex signal whose amplitude varies with the envelope of the cavity waveform, and whose phase is the phase of the cavity waveform with respect to that of the DDC oscillator.

Software written in C has been included with the EPICS system described in section in order to perform the DDC, and includes a front panel for control of the DDC parameters (see figure 3). This software reads in the raw waveforms, multiplies by a complex oscillator whose frequency is set on the front panel (in units where 1.0 is the sampling frequency of the digitiser), and filters to remove the high side-band. After this, the real and imaginary components

of the signal are determined from the amplitude and phase at a particular point in the waveform (which is also controllable from the front panel).

Each of these calculated parameters – the amplitude, phase, and the real (I) and imaginary (Q) amplitudes – are then inserted into the EPICS database where they can be extracted by the main calibration routine.

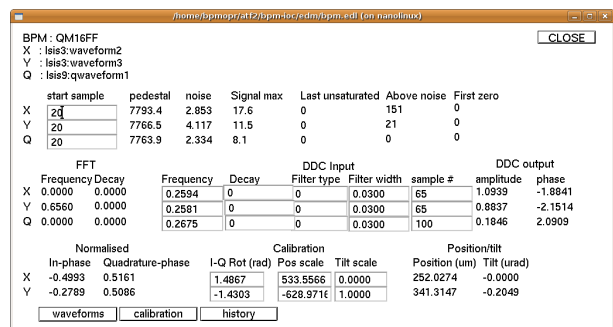


Figure 3: Screen shot of the EPICS control panel for the BPM analysis.

Calibration

To calibrate these devices, the position of the beam inside the cavity is moved, in both x and y , by either physically moving the cavity using motorised, remotely controllable, movers, or by steering the beam with upstream

correctors. The I and Q amplitude (as calculated by the EPICS C code) is recorded for a number of pulses at each of five or more beam positions, and fit to a straight line.

Using the inverse tangent of the gradient of this fit as the rotation angle, the data was then rotated into a new coordinate frame, where the output change due to the movement of the beam within the cavity only appears along the horizontal axis (referred to as I_{rot}). When this rotation is performed correctly, there will be no correlation between the beam position and the vertical axis of this rotated frame of reference (referred to as Q_{rot}).

Finally, a straight line fit is performed on the I_{rot} vs beam position data, where the gradient of this fit is the constant of proportionality between I_{rot} and the beam position. Each of these steps is illustrated in figure 4.

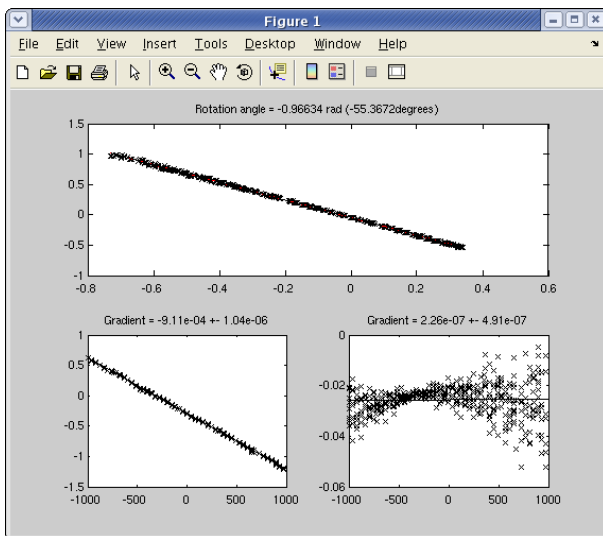


Figure 4: Calibration data. a) Is the data in I/Q space, showing the straight line fit, and the calculated rotation angle. b) I_{rot} vs beam position. c) Q_{rot} vs beam position.

The measured rotation angle and constant of proportionality are then uploaded to the EPICS server, where they are used to convert the calculated I and Q for each pulse into a position output.

INITIAL EXPERIENCE

With the recent turn-on of the ATF2[5], the collaboration has had some initial experience with calibrating and using the cavity BPMs. This experience has, in general, been good, with some promising initial results that demonstrate the robust performance of the cavity, downmix electronics, and digitising system.

Also of note is the stability demonstrated by the combination of the EPICS database server, and the C analysis software. This system has been shown to run stably for several weeks, with no user intervention, serving the processed data to the EPICS database.

However, some lessons have been learnt. One is the importance of ensuring that the analysis code is written in

such a way that it can be guaranteed that all values in the database are for the same machine pulse. Dealing correctly with machine triggers and preventing the overloading of the server CPU are of critical importance for ensuring this.

Additionally, it is important there be a stable relationship between the digitiser trigger and clock. Although a slow timing drift between these may be thought to be unimportant (since this drift will be the same for all digitiser channels), the situation where the trigger edge coincides, within its jitter, with that of a clock cycle, causes uncertainty as to which clock cycle will receive the trigger. This introduces a stability in both the amplitude and phase, and makes the channels in this digitiser card unusable for the duration of the instability. It is, therefore, important to ensure a stable time relationship between these signals, and to make sure the clock and digitiser edges are separated enough to prevent the instability arising.

In conclusion, the system has been observed to be a robust, stable, deployment of BPMs. First experience with this system indicates that the cavities and electronics are behaving as designed, and that the EPICS database and C analysis combination is an extremely stable system. The first problems that have been encountered are far from insurmountable, and it may be said that this system, when taken as a whole, could be viewed as a model for future, large-scale, BPM deployments.

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