BENCHMARKING THE PERFORMANCE OF THE PRESENT BUNCH ARRIVAL TIME MONITORS AT FLASH

M.K. Bock*, M. Bousonville, M. Felber, P. Gessler, T. Lamb, S. Ruzin, H. Schlarb, B. Schmidt, S. Schulz, DESY, Hamburg, Germany

Abstract

Presently, at the Free Electron Laser in Hamburg (FLASH) four bunch arrival time monitors (BAMs) are installed and in permanent operation. Moreover, they are incorporated in a longitudinal intra-bunch train feedback. In this paper, we present a review of the performance and the limitations of the current BAM design, based on the most recent machine studies. The detection principle of the monitor implements the electro-optical modulation of synchronised laser pulses. The RF and electro-optical front-ends are designed to be operated in a frequency band from DC up to 10 GHz. This allows for measuring the arrival time of each individual electron bunch at femtosecond resolution. The current design of the BAMs has been tested under the influence of disturbances on the arrival time measurement, such as variation of the bunch charge as well as deviation from the reference transverse bunch position. Those results will be incorporated in an upcoming design revision to upgrade the application and robustness of the BAMs.

INTRODUCTION

At FLASH four bunch arrival time monitors of different opto-mechanical design versions have been installed during the last few years. The progressive design revisions improved the stability and reliability of the arrival time measurement to a large extent. [1]

The BAMs are an integral part of the pulsed optical synchronisation system [2, 3]. They utilise a commercial electro-optical modulator (EOM) in order to measure the electron bunch arrival times relative to the optical timing reference [1, 4]. The button type RF-pickup as well as the EOMs are rated for RF signals bandwidths of up to 10 GHz. It was shown, that the intrinsic resolution of the BAMs is be better than 10 fs [4].

MEASUREMENTS

Recently, we have performed measurements during scheduled FEL study periods at FLASH in order to benchmark the reliability and operability of the currently installed BAMs. The goal was to investigate the dependency of the bunch arrival time on different machine parameters and to determine the dependence of the arrival time measurement on variations of the transverse orbit and of the bunch charge. The latter issue has a large impact on the future design of the next generation BAM, not only regarding the RF pickup [5], but also the optical front-end. With the extension to FLASH II and for the European XFEL, an operation mode with low bunch charge for short FEL pulses is demanded increasingly, requiring special diagnostics applicable at both, low and high bunch charge modes. In the following, we present some of the recent results, evaluating the current BAM design.

* corresponding author, e-mail: marie.kristin.bock@desy.de

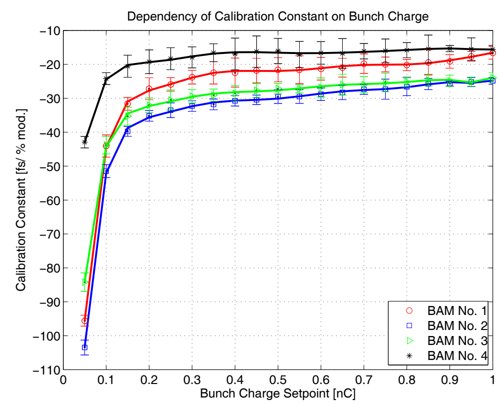

Figure 1: Charge dependent calibration constants of all BAMs.

Charge Dependence of Calibration

The calibration is done by measuring the laser pulse amplitude modulation while sweeping the relative timing between the reference laser pulses and the RF pickup signal at the EOM within the linear BAM signal regime [6]. The calibration constant is then given in units of [fs] timing change per [%] modulation.

As shown in Figure 1, the calibration and hence the resolution depends only weakly on the bunch charge above 200 pC, whereas below 150 pC the resolution of the BAMs strongly decreases with decreasing bunch charge. This linear drop exhibits the limitation in signal bandwidth of the current RF-frontend design of the BAMs.

Orbit Dependence of Arrival Time Measurement

We measured the bunch arrival times while varying the electron beam position by use of horizontal and vertical steerer magnets in front of each BAM. From earlier simulations and measurements, we expected a slight quadradic dependence of the arrival time measurement, symmetrically around the nominal beam position. This behaviour remains although the RF-pickup and cabling design is already intended to minimise the orbit dependency, by combining the outputs of two opposing RF pick-up buttons.

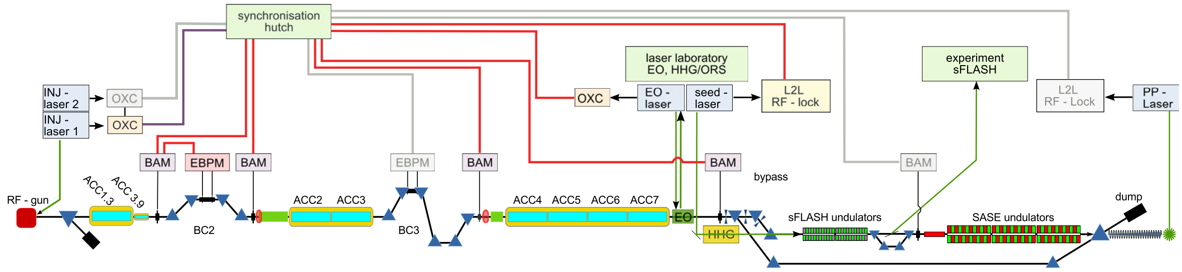

Figure 2: Schematic of the laser-based synchronisation system at the upgraded FLASH accelerator facility.

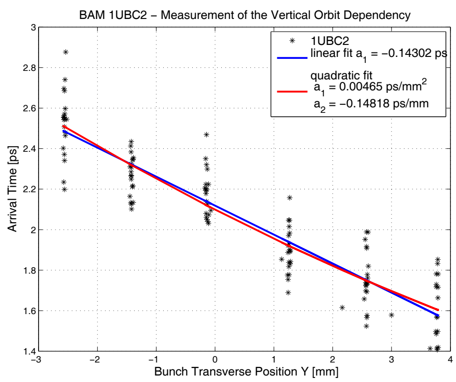

Figure 3: Arrival time vs. beam position in the vertical plane for BAM No.1, located in front of BC2. The arrival time does not depend on the horizontal position for this BAM.

Figure 3 to 5 show the orbit dependencies for BAM No.1,3 and 4, being numbered after their longitudinal position along the FLASH accelerator facility (see Fig. 2). Measured arrival times at BAM No. 2 (not shown here) have a similiar behaviour as at BAM No.4. Any deviation from the expected orbit dependence, could be due to an asymmetry in either the RF pick-up itself or in the RF cabling between pickup and RF power-combiner. The transverse offset of about 3 mm in case of BAM No.4 (Fig. 5, lower plot) is probably due to a misaligned pickup.

Longterm Arrival Time Measurement

Recently, during several FEL study and user shifts, the longitudinal beam-based feedback (BBF) [7] has been established on request, especially for low charge operation, i.e. below 0.4 nC. The gained information will be used to further improve the feedback algorithms. Figure 6 and 7 show exemplarily 13 hours of arrival time data, which were taken from a 48 hours BBF shift. The feedback has been switched on after the first 3 hours and used two independent feedback loops to stabilise the arrival time at BAM No. 2 and 3. The steps in the data of BAM 1 in Fig. 7 are due to hourly automatic calibrations. Arrival times at BAM 3 and 4 are strongly correlated, if not counting for the slow drift in arrival time offset between those two BAMs, which is most probably due to temperature induced polarisation rotation in the fibre links and due to temperature induced timing drifts in the unstabilised fibre parts in the BAM chassis [3, 1]. During this measurement no active polarisation adaption has been switched on in any of the timing stabilised fibre links which connect to the BAMs. This might be a large contribution to the arrival time drifts in BAM 1, which in contrast to BAM 3 and 4 has a temperature stabilisation in the BAM chassis avoiding laser pulse timing drifts.

SUMMARY AND OUTLOOK

Several measurements had been performed to benchmark the current BAM design. This information will be used in an upcoming design revision to further improve the

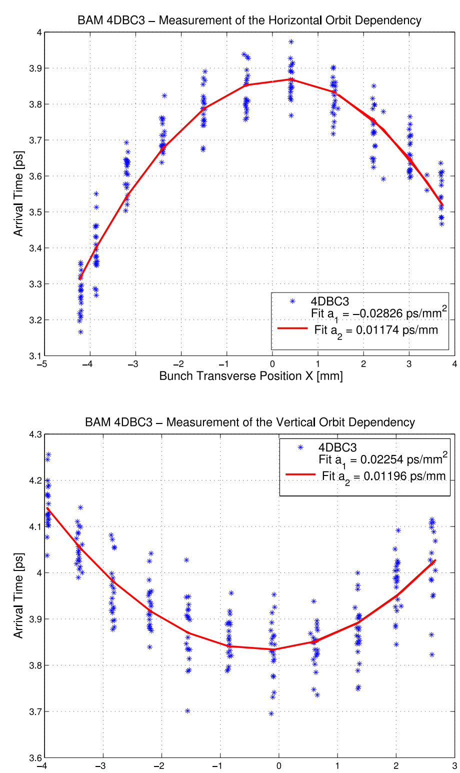

Figure 4: Arrival time vs. beam position in the horizontal (upper plot) and in the vertical plane (lower plot) for BAM No.3, located at the exit of BC3.

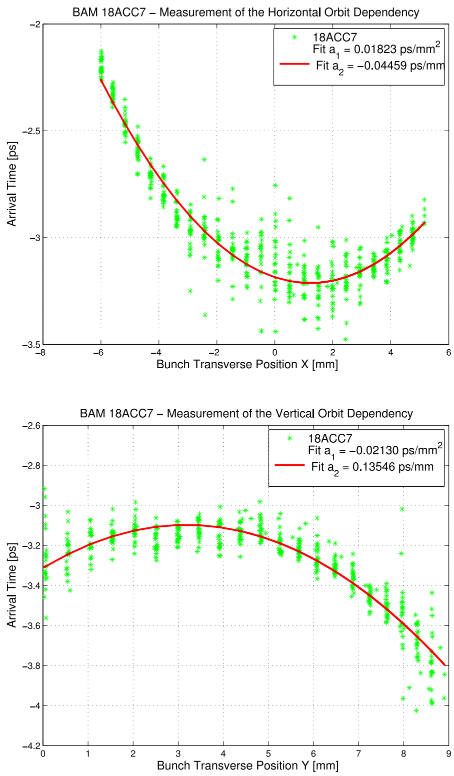

Figure 5: Arrival time vs. beam position in the horizontal (upper plot) and in the vertical plane (lower plot) for BAM No.4, located downstream of the last accelerator module, ACC7

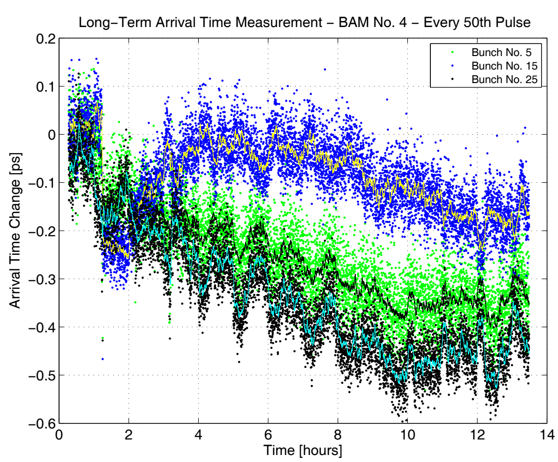

Figure 6: Long-term arrival time measurement with BAM 4. Shown is data from bunches No. 5, 15 and 25 of bunch trains with 25 bunches. Only the last one was used to generate FEL pulses. Those short-term timing oscillations are due to not optimal BBF settings in the first accelerator module ACC1 and are then transported thoughout the whole machine.

reliability of the BAMs and to expand their application to low bunch charge operations. This includes a redesign of the RF-pickup and RF cabling. [5, 8].

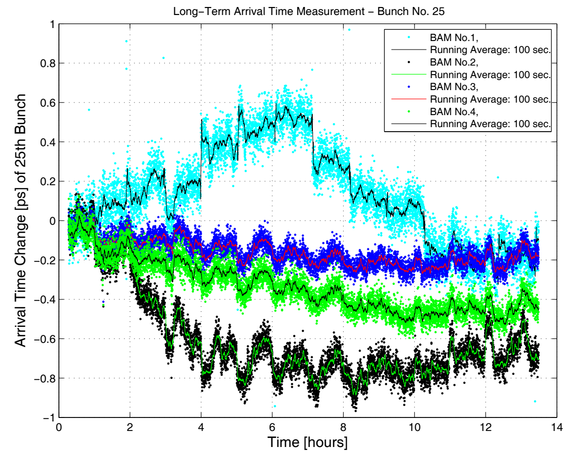

Figure 7: Long-term measurement with all BAMs. Arrival time is stabilised at BAM 2 and 3, while BAM 4 is used as an out-of loop monitor. The arrival time feedback loop on the injector is not yet commissioned.

ACKNOWLEDGEMENT

This work is partly supported by IRUVX-PP, an EU co-funded project under FP 7(Grant Agreement 211285).

REFERENCES

[1] M.K. Bock, et al., IPAC 2010, WEOCMH02, Kyoto, Japan, 23–28 May.

[2] S. Schulz, et al., FEL 2009, WEPC72, Liverpool, England, 23–28 August.

[3] S. Schulz, et. al., DIPAC 2011, TUPD36, Hamburg, Germany, 16–18 May.

[4] F. Loehl, et. al., Phys. Rev. Lett., Volume 104, Issue 14, 144801 (2010)

[5] A. Angelovski, et al., DIPAC 2011, MOPD33, Hamburg, Germany, 16–18 May.

[6] M.K. Bock, et al., FEL 2009, WEPC66, Liverpool, England, 23–28 August.

[7] W. Koprek, et al., FEL2010, THOAI2, Malmö, Sweden, Aug.

[8] A. Kuhl, et al., DIPAC 2011, MOPD34, Hamburg, Germany, 16–18 May.