CERN – EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CLIC – Note – 928

INTERACTION POINT FEEDBACK DESIGN AND INTEGRATED SIMULATIONS TO STABILIZE THE CLIC FINAL FOCUS

Balik, G (Annecy, LAPP) ; Brunetti, L (Annecy, LAPP ; Savoie U.) ;
Deleglise, G (Annecy, LAPP ; Savoie U.) ; Jeremie, A (Annecy, LAPP ; Savoie U.) ;
Pacquet, L (Annecy, LAPP ; Savoie U.) ; Badel, A (SYMME, Annecy-le-Vieux) ;
Caron, B (SYMME, Annecy-le-Vieux) ; Le Breton, R (SYMME, Annecy-le-Vieux) ;
Latina, A (CERN) ; Pfingstner, J (CERN) ; Schulte, D (CERN) ; Snuverink, J (CERN)

Abstract

The Compact Linear Collider (CLIC) accelerator has strong precision requirements on the offset position between the beams. Sensitive to ground motion (GM), the beam needs to be stabilized to unprecedented requirements. Different Beam Based Feedback (BBF) algorithms such as Orbit Feedback (OFB) and Interaction Point Feedback (IPFB) have been designed. This paper focuses on the IPFB control which could be added to the CLIC baseline. IPFB control has been tested for different GM models in presence of noises or disturbances and it uses digital linear control with an adaptive loop. The simulations demonstrate that it is possible to achieve the required performances and quantify the maximum allowed noise level. This amount of admitted noises and disturbances is given in terms of an equivalent disturbance on the position of the magnet that controls the beam offset. Due to the limited sampling frequency of the process, the control loop is in a very small bandwidth. The study shows that these disturbances have to be lowered by other means in the higher frequency range.

Presented at: 2nd International Particle Accelerator Conference, San Sebastian, Spain, 4 - 9 Sep 2011

Geneva, Switzerland
Date 28/02/2012

INTERACTION POINT FEEDBACK DESIGN AND INTEGRATED SIMULATIONS TO STABILIZE THE CLIC FINAL FOCUS

Balik, G (LAPP-Universite de Savoie-IN2P3/CNRS) *et al*

28 February 2012

The research leading to these results has received funding from the European Commission under the FP7 Research Infrastructures project EuCARD, grant agreement no. 227579.

This work is part of EuCARD Work Package **9: Technology for normal conducting higher energy linear accelerators**.

INTERACTION POINT FEEDBACK DESIGN AND INTEGRATED SIMULATIONS TO STABILIZE THE CLIC FINAL FOCUS*

G. Balik, L. Brunetti, G. Deleglise, A. Jeremie, L. Pacquet, IN2P3-LAPP, Annecy-le-Vieux, France
A. Badel, B. Caron, R. Le Breton, SYMME, Annecy-le-Vieux, France
A. Latina, J. Pfingstner, D. Schulte, J. Snuverink, CERN, Geneva, Switzerland

Abstract

The Compact Linear Collider (CLIC) accelerator has strong precision requirements on the offset position between the beams. Sensitive to ground motion (GM), the beam needs to be stabilized to unprecedented requirements. Different Beam Based Feedback (BBF) algorithms such as Orbit Feedback (OFB) and Interaction Point Feedback (IPFB) have been designed. This paper focuses on the IPFB control which could be added to the CLIC baseline. IPFB control has been tested for different GM models in presence of noises or disturbances and it uses digital linear control with an adaptive loop. The simulations demonstrate that it is possible to achieve the required performances and quantify the maximum allowed noise level. This amount of admitted noises and disturbances is given in terms of an equivalent disturbance on the position of the magnet that controls the beam offset. Due to the limited sampling frequency of the process, the control loop is in a very small bandwidth. The study shows that these disturbances have to be lowered by other means in the higher frequency range.

INTRODUCTION

One of the major challenges for CLIC [1] is to achieve the luminosity that the experiments require. Preserving the ultra-low emittance and position of the beam imposes effective GM mitigation techniques [2] such as mechanical stabilization and pulse to pulse feedback systems. While the OFB control [3] is designed to preserve the low emittance over the whole linac due to a pulse-to-pulse orbit feedback correction, the IPFB control deals with the beam position and minimizes the beam-beam offset at the IP. Figure 1 represents the layout of the Final Focus (FF) stabilization.

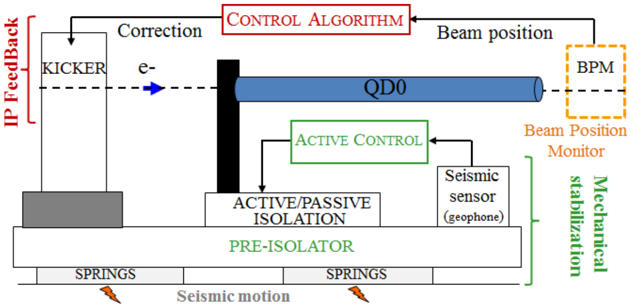

Figure 1: Overall layout of the FF stabilization.

Ground Motion

GM is considered the main cause of luminosity loss by dynamic imperfections because it is directly transmitted from the ground to the magnets via their support over the beam line and thus inevitable. Its influence has been studied extensively [4]. Two phenomena can be considered. On one hand, there is the Earth motion (fl<l1 Hz), due to swell, tectonic motion, atmospheric changes, which directly affects the beam position and emittance preservation, and on the other hand, there is cultural noise (f >1 Hz), mostly disturbing the beam position, because of human activities, which can drastically change from site to site. Regarding simulations, phenomenological models [5] of GM have been used (also described in [2]). On one hand, model B is based on measurements performed on the Fermilab site, and on the other hand, model B10, identical to model B in low frequencies, yet differentiated in high frequencies by additional peaks matching the technical noise level measured in the LAPP (Particle Physics Laboratory of Annecy-le-Vieux) [6] and in the CMS hall [7].

INTERACTION POINT FEEDBACK

The IPFB has been designed and optimized to minimize the beam-beam offset at the IP. It uses the deflection angles of the colliding beams obtained with a post collision Beam Position Monitor (BPM) to correct the beam position with a dipole kicker. This algorithm combines a feedback obtained after a parametric study and an adaptive control based on the generalized least-square method. The whole study is detailed in [8].

Considering the beam repetition rate of 50 Hz, the IPFB is efficient in a reduced bandwidth starting from very low frequencies to about 4-5 Hz. Thus, for higher frequencies, an additional mechanical stabilization is necessary. In this context, the Main Linac (ML) quadrupoles will be placed on an active stabilization system [9] and the last quadrupoles QD0 and QF1 will be put on a large spring-mass: the preisolator [10]. Regarding integrated simulations, a theoretical fit (see Figure 2) of the measured transfer functions of the current design has been used. Note that the last quadrupoles can be stabilized by adding an active stabilization (also represented in Figure 1) but the current simulation layout is limited to the stand-alone use of the preisolator.

---

* Work supported by the European commission under the fp7 research infrastructures project eucard, grant agreement no.227579.

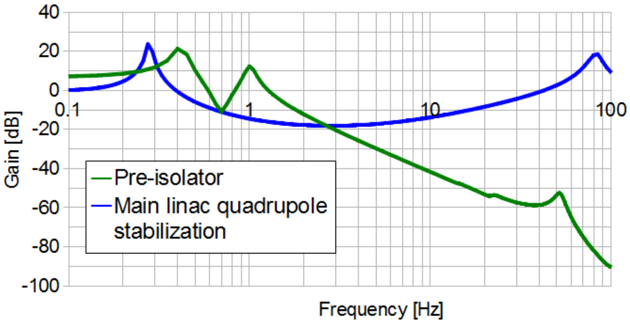

Figure 2: Transfer function of ML quadrupole stabilization and preisolator.

The peak around 0.2 Hz of the main linac quadrupole stabilization (MLQS) is detrimental because of its proximity to the micro seismic peak. This is also the case for the peak around 80 Hz which generates high frequency motion of the beam, where the IPFB is not able to correct the position. An upgraded design of the MLQS is currently under study and should limit these drawbacks. Note that the IPFB control has been tuned according to the MLQS and preisolator behavior to minimize the beam-beam offset. Thus, any change of the mechanical stabilization systems should lead to a re-optimization of the IPFB in order to increase overall performances.

Figure 3 represents a simplified model of the global control including MLQS, preisolator, and IPFB.

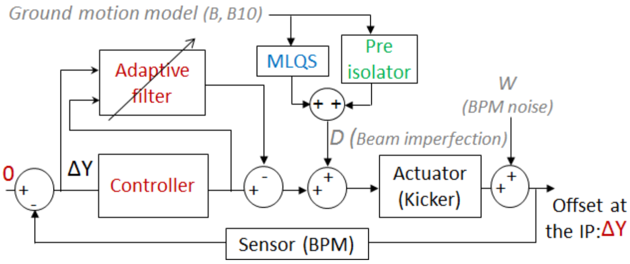

Figure 3: Control scheme including MLQS, preisolator and IPFB.

This representative model shows that the GM disturbance along the ML (damped by the MLQS) produces the same effect on the process as the final doublet stabilization (via the preisolator). This shows that ideally, the ML quadrupoles should be stabilized the same way the final doublet is.

SIMULATION SETUP

The next simulations have been performed using PLACET [11] and GUINEA-PIG [12]. The approach was to progressively add the different features of PLACET (i.e. without/with MLQS/IPFB) to understand better their effects and interactions. For each simulation, two different GM models (B and B10) are being used.

RESULTS

Figure 4 shows the PSD and the integrated RMS of the offset between the beams. For each GM, 3 different configurations have been tested;

- Beam Delivery System (BDS) only, preisolator, no IPFB

In this case, the incoming beam from the ML is considered to be perfect. It isn't influenced by any imperfection before the BDS. In the simulation layout, this is equivalent to put a perfect filter instead of the MLQS. Thus, the beam is only disturbed by the last quadrupoles which stand on the preisolator. No IPFB control is added.

- Full simulation, MLQS, preisolator, no IPFB

Here, the whole beam line is subject to GM. In comparison with the previous configuration, the MLQS effects on the whole beam-line stabilization is pointed out

- Full simulation, MLQS, preisolator, IPFB

This configuration adds the IPFB control to the previous simulation. This configuration is optimized to minimize the beam offset.

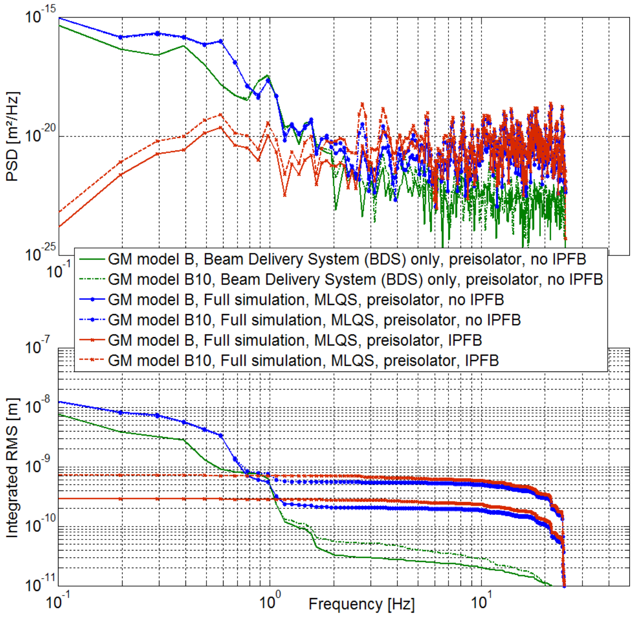

Figure 4: PSD and integrated RMS of the offset between the beams at the IP for different ground motion and configuration.

Results show that the ML amplifies the integrated RMS (around 10 Hz) by a factor 10. We assume that this component is due to the beam jitter and most probably to the incoming beam motion from ML. We believe that better results can be achieved with an upgraded design of the MLQS [2], [9]. Based on the results obtained with IPFB, it has been possible to reach very good beam offset attenuation for low frequencies. The integrated RMS (0.1Hz) is mainly due to the beam's motion at high frequencies (>10Hz), uncontrollable by the IPFB because of the beam repetition rate. Limitations in feedback control cause the IPFB to slightly amplify high frequency offset of the beam. However, in this case, the effect is insignificant compared to some other sources of amplification (MLQS amplification around 80 Hz, discrepancy between both stabilization transfer functions).

The final scope of this paper is to estimate the performances required for the BPM and mainly to evaluate which level of internal noise is acceptable without decreasing too much the efficiency of the IPFB control. The method consisted in observing the evolution of the integrated RMS of the beam's offset with additional noise on the measurement of the beam offset at the IP. We assumed that the noise of the BPM (*W*), see Fig. 3 is a white noise. Fig. 5 shows the results obtained for both tested GM with different level of integrated RMS of (*W*).

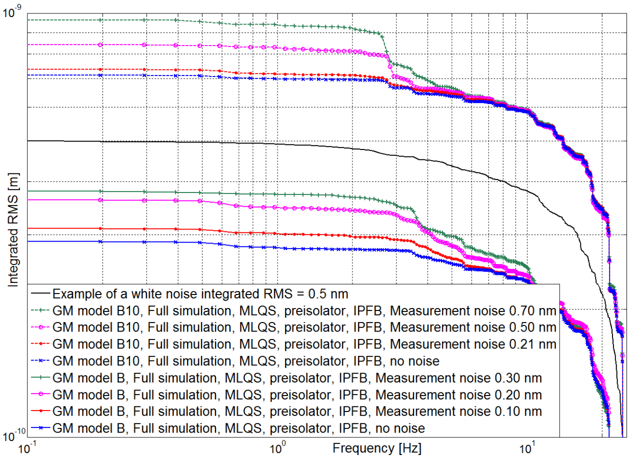

Figure 5: Evolution of the integrated RMS of the beam's offset with additional noise on the measurement.

As a fact, we can state that the measurement noise shouldn't exceed a third of the desired integrated RMS of the beam offset to avoid ≈ 5 % excess of the latter (see Table 1 which synthesizes the results). This statement is valid for both tested GM and simulation conditions specified above.

Table 1: Synthesis of the Integrated RMS of the Beam Offset According to the Measurement Noise.

Noise (integrated RMS)			**Beam offset integrated RMS**	
GM model B10	0.70 nm	(99 %)	0.96 nm	(135 %)
	0.50 nm	(70 %)	0.84 nm	(115 %)
	0.21 nm	(30 %)	0.74 nm	(104 %)
	None	(0 %)	0.71 nm	(100 %)
GM model B	0.30 nm	(103 %)	0.38 nm	(131 %)
	0.20 nm	(69 %)	0.36 nm	(125 %)
	0.10 nm	(34 %)	0.31 nm	(107 %)
	None	(0 %)	0.29 nm	(100 %)

CONCLUSIONS

CLIC requires unprecedented ground motion mitigation techniques for reaching the luminosity of 2.4e34 $cm^{-2}s^{-1}$. In this paper, integrated simulations, including ML and BDS, have been performed incorporating dynamic imperfections and IPFB control which is designed to minimize the offset between the two colliding beams. Simulations have shown the efficiency of the IPFB for low frequency whatever the GM model is. Furthermore, it shows the necessity to damp the GM vibrations by using a mechanical stabilization. The results in terms of integrated RMS of the beam's offset highly depend on the used GM, and on the measurement noise. The current MLQS amplifies the GM around 80 Hz. Therefore, the latter has to be as low as possible at high frequency, as is the model B, and the measurement noise has to be less than a third of the desired integrated RMS of the beam's offset.

REFERENCES

[1] H. Braun, et al., "CLIC 2008 parameters", CLIC-note-764, CERN document server.

[2] J. Snuverink et al., "Status of ground motion mitigation techniques for CLIC", TUPC023 IPAC 2011, San Sebastian (Spain).

[3] J. Pfingstner et al., "SVD-based filter design for the trajectory feedback of CLIC", MOPO014 IPAC 2011, San Sebastian (Spain).

[4] J. Adloff et al., "Vibration stabilization for the final focus magnet of a future linear collider", REM 2005.

[5] A. Sery and O. Napoly, "Influence of ground motion on the time evolution of beams in linear colliders", phys. Rev. E, 53:5323, 1996.

[6] B. Bolzon, "Etude des vibrations et de la stabilisation à l'échelle sous-nanométrique des doublets finaux d'un collisionneur linéaire", thesis, lapp-t-2007-05, Université de Savoie (France).

[7] Internal note, CERN document server, EDMS Nr: 1027459, 2009.

[8] B. Caron et al., "Vibration control of the beam of the future linear collider", Elsevier editorial system for Control Engineering Practice, 2011, submitted.

[9] K. Artoos et al., "Status of a study of stabilization and fine positioning of CLIC quadrupole to the nanometer level", MOPO027, IPAC 2011, San Sebastian (Spain).

[10] F. Ramos, "Dynamic analysis of the FF magnets pre-isolator and support system", Internal note, CERN document server, EDMS Nr: 1098581.

[11] D. Schulte, "Placet - a program to simulate drive beams", proceedings of EPAC 2000, Vienna.

[12] D. Schulte et al., "Beam-beam simulations with Guinea-pig", ICAP98, Monterey, Ca., USA, 1998.