A BEAM TEST OF CORRUGATED STRUCTURE FOR PASSIVE LINEARIZER

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Abstract

A dechirper which is a vacuum chamber of two corrugated, metallic plates with adjustable gap was successfully tested at Pohang, in August 2013. Another beam test was carried out to test the same structure to see if the flat geometry corrugated structure may work as a passive linearizer. The test result will be presented together with the simulation result.

PASSIVE LINEARIZER TO CORRECT QUADRATIC CHIRP

In August 2013, LBNL and SLAC experts were onsite at PAL-ITF to test a ***dechirper***, an interesting instrument consisting of a vacuum chamber of two corrugated, metallic plates with an adjustable gap. One-meter long proto-type of dechirper was tested successfully to accurately measure the longitudinal, dipole, and quadrupole wakes [1]. And the linear chirp is well corrected by the linear longitudinal wake of dechirper.

An idea to use the same structure came up to see if the flat geometry corrugated structure may work as a passive linearizer replacing an expensive X-band linearizer system which consists of an X-band linearizer cavity and an X-band RF system. The total cost of that system is over 3 MUSD, and if including one spare of klystron and others, it goes to 5 MUSD. However, the passive wake structure is very cheap, below 200 kUSD even though the gap control system of two plates is included.

Figure 1 shows the flat geometry corrugated structure. The dimensions of the structure used at the experiment in August 2013 at PAL-ITF are: the corrugation period (p) is 0.5 mm, the corrugation depth (h) is 0.6 mm, the wall distance (t) is 0.3 mm, and the width of plate (w) 50 mm. Figure 2 shows the longitudinal wake of flat geometry corrugated structure.

For the passive wake structure to act like an X-band linearizer, quadratic part of longitudinal wake needs to be involved in the beam-wake interaction to correct quadratic chirp. So, the longitudinal wakefield wavelength, $\lambda = 2\pi\sqrt{aht/p}$, needs to be comparable to bunch length. Dechirper has two independent motors: jaws are always parallel and move vertically. The gap is adjustable from 1 to 30 mm. As the gap of the two plates goes close, the wavelength is decreased. With the corrugated structure parameters (p=0.5 mm, h=0.6 mm, t=0.3 mm), the calculated wakefield wavelengths are 7.5 mm, 5.3 mm, 3.8 mm for the gaps of 8 mm, 4 mm, 2 mm, respectively. To have the electron beam interact with the quadratic part of longitudinal wake, the electron beam bunch needs to be longer than one fourth of the wake wavelength. But there is a limitation in the gap distance because the quadrupole wake of the flat geometry becomes very strong as the gap goes close.

Instead, we may increase the bunch length from 3 ps to 5 ps in rms in order to have the electron beam interact with the quadratic part of longitudinal wake. The simulation shows that the longitudinal wake at the gap of 6 mm can correct the quadratic chirp.

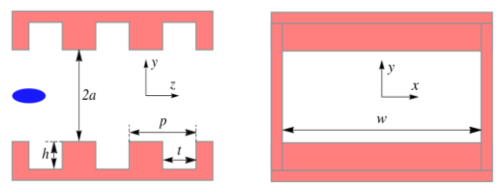

Figure 1: A flat geometry corrugated structure.

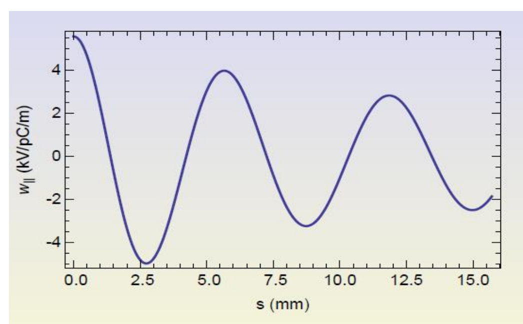

Figure 2: Longitudinal wake.

SIMULATION OF PASSIVE LINEARIZER AND BEAM TEST AT ITF

Figure 3 shows the layout of the PAL-ITF which consists of a PC RF-gun, two S-band Accelerating structures (L0a, L0b), a 1-m long S-band RF deflector, a 30-degree spectrometer, and three quads. A 1-m long corrugated chamber is located between L0b and the deflector. Six YAG screens are available, but Screen-6 is used for the analysis of the simulation and the experiment. In the simulation and measurement, all quads are turned OFF while the deflector is turned ON to allow the time-resolved measurement.

The beam energy is set at 80 MeV and the beam charge is 200 pC, and the pulse repetition rate is 10 Hz. Beam size and centroids measured on YAG screens, Spectrometer bend allows energy loss and energy spread measurements, and Dechirper offset is varied to guide the

ISBN 978-3-95450-133-5

beam at the center of the two plates to minimize the dipole wake of the flat geometry corrugated structure.

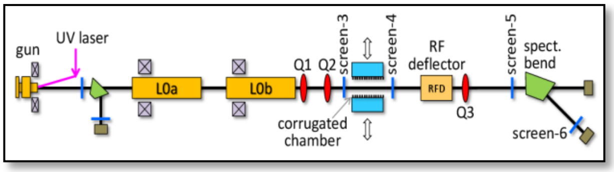

Figure 3: Layout of PAL-ITF.

Figure 4 shows the ELEGAT simulation result. Longitudinal phase space and x-y beam projection at Screen-6 are depicted for the gaps of (a) 30 mm, (b) 10 mm, and (c) 6 mm. The x-y beam projection at Screen-6 represents the energy-time phase space; x-axis represents the beam energy and y-axis represents the time streaked by the deflector. It is clearly seen that the quadratic energy chirp of Fig. 4(a) is well corrected by changing the gap to 6 mm in order to have a linear time-energy correlation as shown in Fig. 4(c).

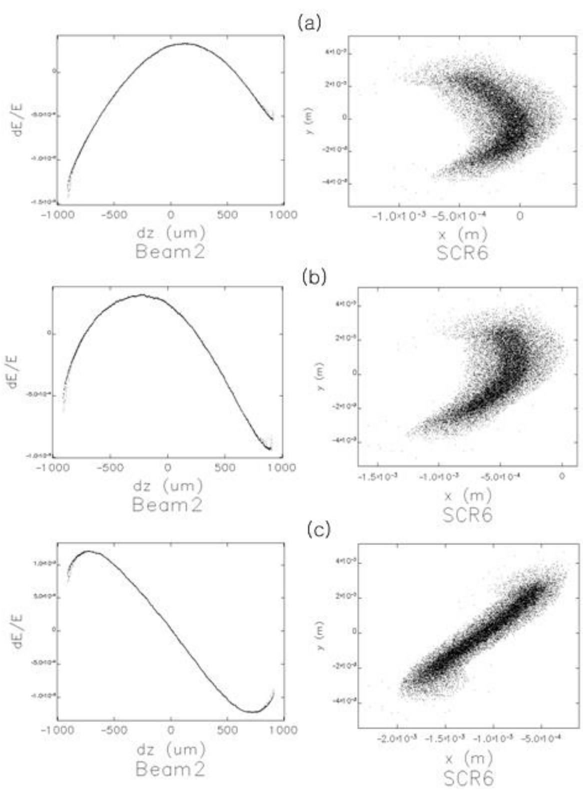

Figure 4: ELEGAT simulation result. Longitudinal phase space and x-y beam projection at Screen-6 for the gaps of (a) 30 mm, (b) 10 mm, and (c) 6 mm.

In the ELEGANT Simulation, the quadrupole wake of flat-geometry corrugation structure is not included because its effect is so strong that the linearization effect is not clearly seen. In the measurement, the beam shape at Screen-6 is altered due to a strong quadrupole wake (see Fig. 5(c). But the beam shape of Fig. 5(b) is quite similar to that of Fig. 4(b) at the same gap of 10 mm.

The quadrupole wake effect is more clearly observed than the measurement of August 2013 because the bunch length is changed to 5 ps, longer than 3 ps of the previous measurement. The quadrupole wake effect goes strong as the bunch length is increased.

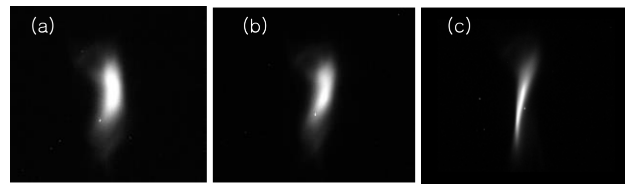

Figure 5: The measured beam images at Screen-6 for the gaps of (a) 15 mm, (b) 10 mm, and (c) 6 mm.

S2E SIMULATION OF PASSIVE LINEARIZER FOR PAL-XFEL

We carried out the S2E simulation of a passive linearizer for PAL-XFEL to look for a possibility of its use when the X-band linearizer happens to fail to work due to the system failure. The PAL-XFEL is a 0.1-nm hard X-ray XFEL facility (2011 ~ 2015) including a 10-GeV electron Linac (Normal Conducting S-band, 60 Hz) [2].

Figure 6 shows the layout of the PAL-XFEL. The X-band linearizer cavity, which is 0.6m long, is located between Linac-1 and BC1, where the beam energy is 330 MeV.

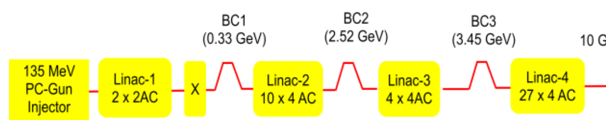

Figure 6: Layout of PAL-XFEL.

The corrugation parameters of passive linearizer used in this simulation are the same as ITF dechirper (p = 0.5 mm, h = 0.6 mm, t = 0.3 mm, w = 50 mm). But the structure length is increased to 2 m, and the gap is 3 mm. In the ELEGANT simulation, the quadrupole wake of flat-geometry corrugation structure is included. The simulation shows that the quadupole wake does not give a big impact on the beam emittance.

Figure 7 and 8 show the S2E ELEGAT simulation results without X-band linearizer and with a passive linearizer, respectively. The current profile and the longitudinal phase spaces become bad when the X-band linearizer does not work (see Fig. 7). By using a passive linearizer, the current profile and the longitudinal phase space are well recovered enough to perform SASE FEL interaction in undulators (see Fig. 8). To get similar property as the X-band linearizer, RF phase of Linac-2 is only changed from -15.8 degrees to -16.0 degrees with other parameters unchanged.

ISBN 978-3-95450-133-5

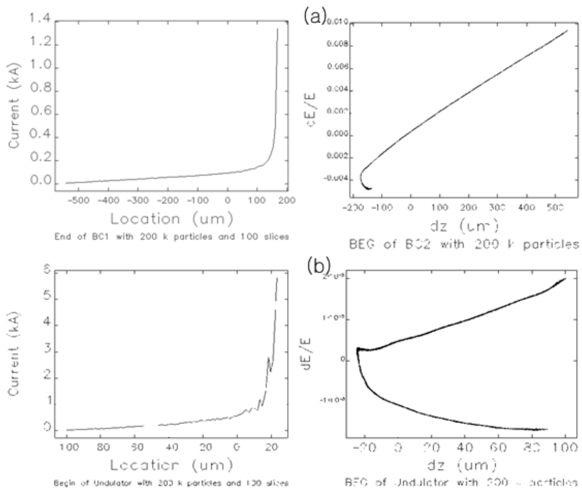

Figure 7: S2E ELEGAT simulation result without X-band linearizer. Current profile and longitudinal phase space (a) after BC1 and (b) at the entrance of undulators.

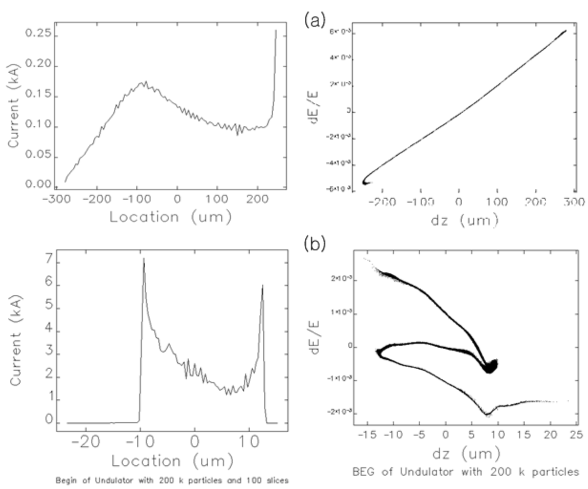

Figure 8: S2E ELEGAT simulation result with a passive linearizer. Current profile and longitudinal phase space (a) after BC1 and (b) at the entrance of undulators.

DISCUSSION

In the simulation, we found that it is impossible to get the exact same current profile and longitudinal phase space as an X-band linearizer system does. It is mostly because both the wake amplitude and the wake wavelength are dependent on the gap distance in the flat-geometry corrugated structure, so two parameters are correlated. Independent control of wake amplitude and wake wavelength is required for better linearization control.

The flat geometry structure is easy to change the gap, but it has a quadrupole wake effect. A round shape of wake structure is better in terms of quadrupole wake. But it lacks the controllability of wake amplitude and wake wavelength.

ACKNOLOWGEMENT

I would like to thank K. Bane, G. Stupakov, P. Emma (SLAC), Marco Venturini (LBNL) for the use of figures and data that they made.

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[1] Paul Emma et. al., PRL 112, 034801 (2014).
[2] Kang, H.S. et al. Current Status of PAL-XFEL Project. *Proc. IPAC Conf. 2013* paper WEODB103 (2013).

ISBN 978-3-95450-133-5