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PRELIMINARY DESIGN OF A BUNCHING SYSTEM FOR THE CLIC POLARIZED ELECTRON SOURCE

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Introduction

Major parameters of the CLIC and ILC electron sources are given in Table I. It is shown that the CLIC source needs to provide 312 15-ps-long 2-GHz microbunches. There are two approaches to achieve the time structure [2]: one is to develop a 2-GHz optical pulse train, and the other to develop a 156-ns-long CW optical pulse and use an RF bunching system to generate 312 2-GHz microbunches. The former scheme may ease the RF bunching system but still need it to bunch 100-ps of microbunch down to 15-ps level. Otherwise, a huge amount of energy spread is accumulated when the beam is accelerated through downstream 2-GHz accelerator. In addition, in the former scheme, the space charge is high and surface charge is not yet proven in the parameter regime and 2-GHz mode locked laser is challenging. The latter scheme needs a high-efficiency bunching system to generate 312 15-ps microbunches with 2-GHz repetition rate but it has some notable advantages: a 156-ns CW laser technique is matured, and the charge limit behavior in the scheme is better characterized than that in the former case, as listed in the table. This note presents a design and modeling of the bunching system for the latter scheme to convert a 156-ns CW pulse to 312 15-ps long 2-GHz microbunches.

Table I: Major parameters of the ILC and CLIC electron sources

E-source parameters	ILC	CLIC (original) [1]	CLIC (SLAC proposed)
Number of microbunches @cathode	2625	312	1 DC beam
Electrons/(micro)bunch @cathode	5 nC	0.96 nC	300 nC
Number of microbunches @injector	2625	312	312
Width of (micro)bunch @cathode	1.3 ns	~100 ps	156 ns DC
Width of microbunch @injector	20 ps	-	14 ps
Micropulse repetition rate @cathode	3 MHz	2-GHz	-
Microbunch repetition rate @injector	3 MHz	2-GHz	2-GHz
Width of Macropulse	1 ms	156 ns	156 ns
Macropulse repetition rate	5 Hz	50 Hz	50 Hz
Charge per macropulse	13125 nC	300 nC	300 nC
Average current from gun	66 μA	15 μA	15 μA
Peak current @cathode	4.0 A	9.6 A	1.9 A
Current intensity @1cm radius	1.25 A/cm^2	3.0 A/cm^2	0.64 A/cm^2
Polarization	>80%	>80%	>80%

Bunching system

A bunching system comprising two 2-GHz prebunchers, one 5-cell tapered-β buncher, and 2-GHz accelerator is proposed, as shown in Figure 1. While two prebunchers are used to modulate macrobunch, a 5-cell tapered-β travelling wave 2-GHz structures are used as a buncher to compress the microbunches down to 14-ps FWHM. Then 2-GHz accelerator downstream of the buncher accelerates the beam to 19-MeV. Higher energy can be easily achieved by adding more RF structures but the bunching performance will not be changed. Distance from the gun to the first prebuncher and from the first to the second prebuncher is 56.5-cm and 54-cm, respectively. 14-kV and 36-kV of voltages are applied into the first and second prebunchers respectively to modulate the 156-ns pulse. The beam transported from the gun to the first pre-buncher is focused by two magnetic lenses so that they can be used to adjust the radius and convergence of the beam at the entrance to the solenoid that confines the beam in the following second pre-buncher and buncher. While primary bunching is achieved in a 5-cell 2-GHz traveling wave tapered-β from 0.75 to 0.93 RF structure running at the gradient of ~8.6 MV/m, a final, small increment of bunching takes place in the first several cells in the 2-GHz accelerator, which immediately follows the buncher. 14 MV/m of the accelerating gradient in the structure is used in the simulations. The first several cells of the 2-GHz buncher and accelerator are immersed in a 1700-G solenoid field to focus the beam, and then the field is tapered down to zero as the beam gains energy. The field map along the beamline from the gun to the accelerator is shown in Figure 2. The generation of 2-GHz microbunches and its beam dynamics are modeled with PARMELA. In principle, the generation of 312 2-GHz microbunches from 156-ns DC beam (i.e., 312 2-GHz RF periods) transporting through the bunching system can be simulated. To simplify the simulations, initial pulse duration of four 2-GHz RF periods is modeled as an example to generate four microbunches with the bunching system. The initial pulse duration and final pulse structure at injector exit are shown in Figs. 3a and 3b, respectively. The final microbunch and its energy spectrum at 19-MeV are shown in Figs. 4a and 4b, respectively. 88% of electrons from the gun are captured within a window of $\Delta t \times \Delta E$ = 30ps×0.45MeV at 19-MeV. The simulation results are summarized in Table II.

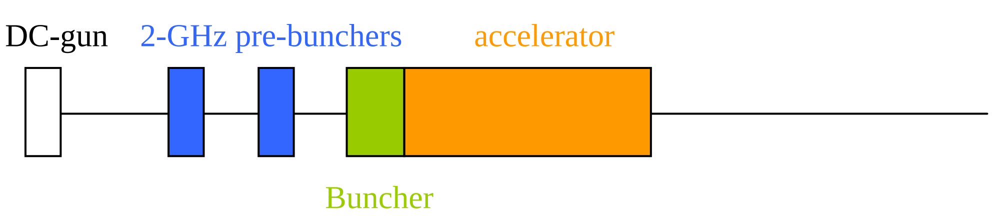


Figure 1: The schematic layout of bunching system for CLIC electron source.

Conclusion and outlook

A bunching system to generate a train of microbunches with 2-GHz repetition rate from a macropulse for the CLIC injector is preliminarily designed and modeled. The tracking shows that 88% of electrons from the DC-gun are captured within a window of 30ps×0.45MeV at 19-MeV. Looking toward the technical design, more detailed work is needed including: (1) adding more RF structures to get energy at about 80 MeV; (2) bunching system optimizations to meet the engineering design; (3) detail definitions of system components.

References

[1] L. Rinolfi, CLIC workshop, 2007.

[2] J. Sheppard, A. Brachmann, and F. Zhou, Proposal to demonstrate a polarized electron source for CLIC, unpublished, 2009.

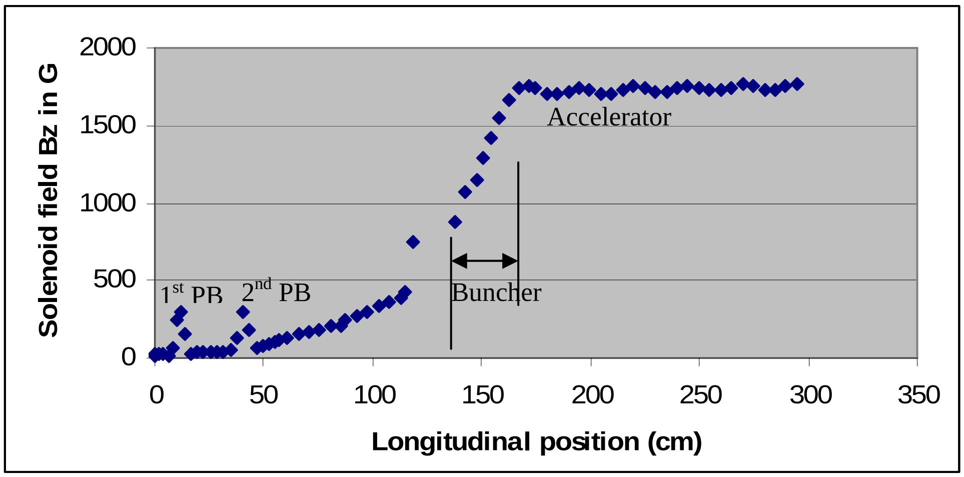
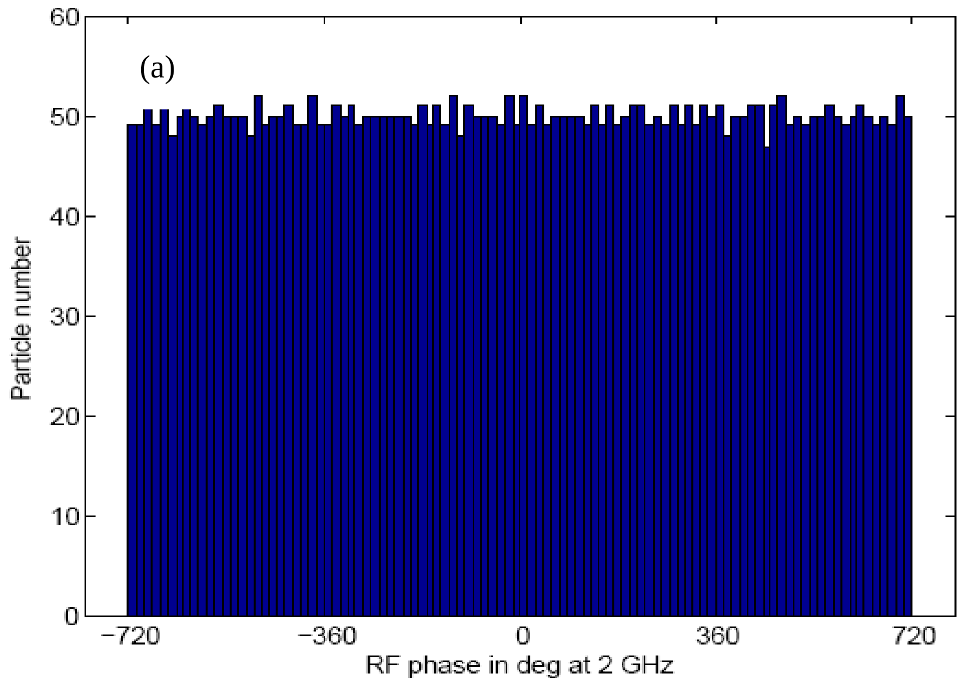


Figure 2: Field map along the beamline. PB is prebuncher.

Table II: Summary of modeling results

Gun voltage Injector energy	140 kV 19 MeV
Charge required/microbunch @inj Efficiency from gun to injector exit Achieved charge/microbunch within a window ($\Delta t \times \Delta E$ = 30ps×0.45MeV)	~1 nC 88% 1.3 nC
Initial DC pulse length on cathode Final phase extension FWHM (FW) # of generated microbunches @ inj	156 ns 14 ps (30 ps) 312
Final energy spread FWHM (FW)	100 keV (1 MeV)
Norm. rms emittance at injector exit	22 μm



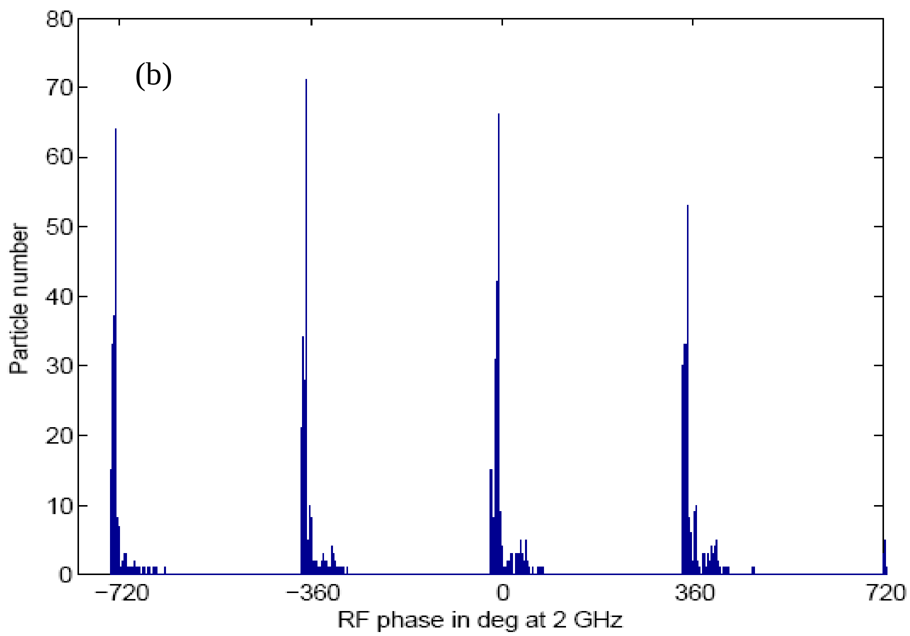


Figure 3: Initial pulse duration (a) on the cathode, and final bunched pulse structure (b) at 19 MeV

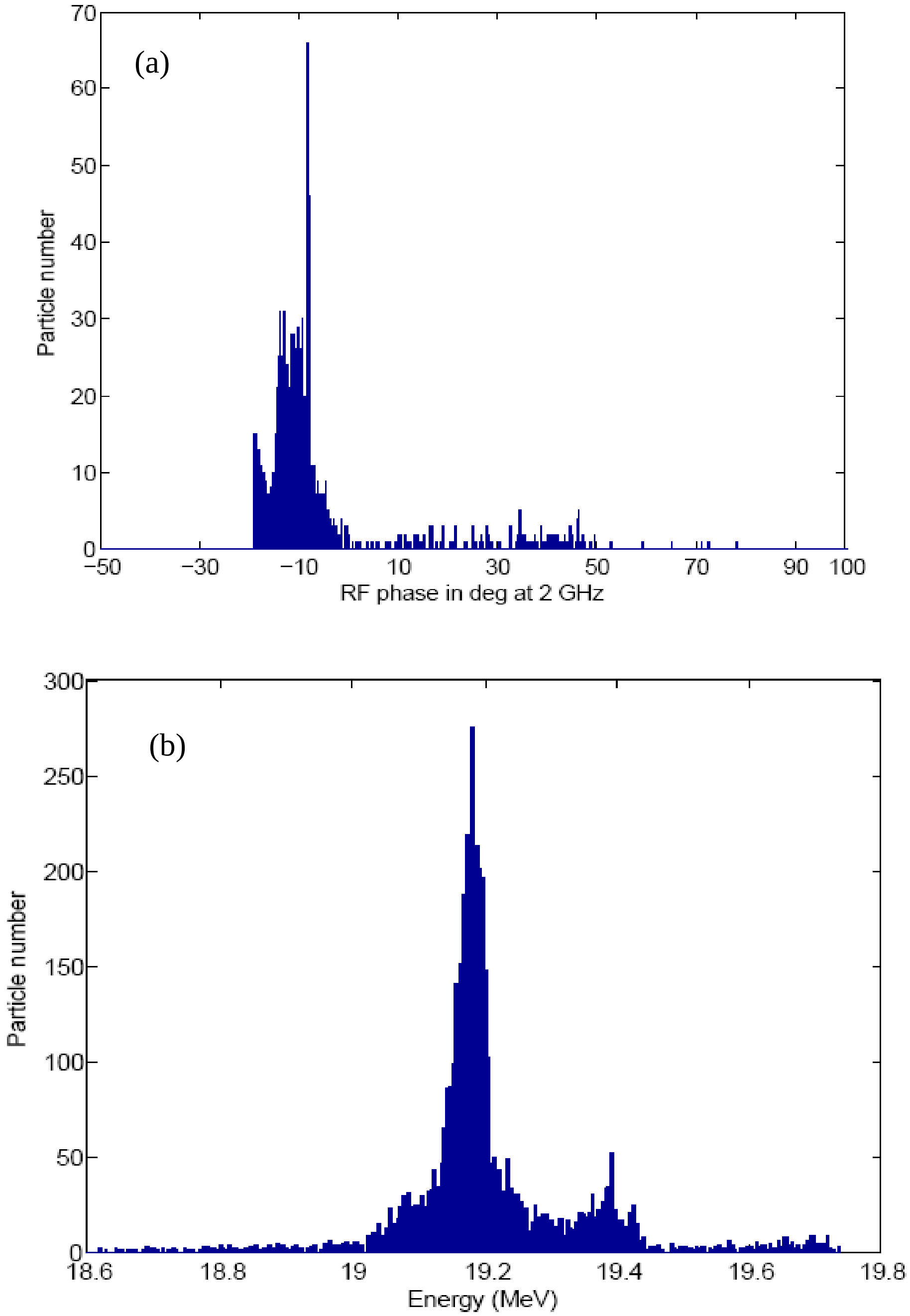


Figure 4: Microbunch (a) and energy spectrum (b) at 19 MeV