Study on ILC bunch compressor*

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Abstract In this paper, we have found a new set of parameters for the short two-stage ILC bunch compressors. The RF sections are both in the accelerating phase rather than the decelerating phase to improve the accelerating efficiency. We have also studied the CSR related issues. The results show that the microbunch instability exists extensively in the second bunch compressor, but the emittance dilution is small due to the relatively long bunch.

Key words bunch compressor, CSR, microbunch instability

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1 Introduction

The ILC[1] damping rings produce beams with very low transverse emittances but very large longitudinal emittances. The ILC main damping ring (MDR) designs produce typical normalized emittances of 8 μm×20 nm (x and y plane), but rms bunch lengths of 6 or 9 mm and rms energy spread of 0.15%. It is not practical to reduce the bunch length in the MDR, since this would make the ring more sensitive to a lot of collective effects. On the other hand, in order to get luminosity at the IP, it is essential that the rms bunch length be not bigger than the smaller one of the beta functions at IP so that the entire bunch is in focus at the collision point. Since the luminosity requires a vertical beta function of 0.4 mm, the specified rms bunch length is 0.3 mm in the baseline design, and for some parameter sets one may want to get down to as little as 0.15 mm rms. So the beam should be compressed after it exits out of the damping ring and before it enters the main linac through the bunch compressor section.

There are several design choices for the ILC bunch compressors, and the bunch compressors are of the wiggler types or C/S types. Dr. E. S. Kim proposed a short two stages of bunch compressors (with C type). In this paper, we propose new parameters for the short two-stage bunch compressors based on Kim's work and study the CSR related issues in the second bunch compressor.

2 New parameters for the short two-stage bunch compressor

In the layout of ILC, the ILC ring to the main linac (RTML) is responsible for transporting and matching the beam from the damping ring to the entrance of the main linac. One of the RTML functions is the compression of the long damping ring bunch length by a factor of 30—45 to provide the short bunches required by the main linac and the IP. In order to achieve the required bunch compression factor of 30—45, a two-stage system is adopted in the ILC RDR[1]. The one stage compression system is unstable with the phase error. In addition to stability in the phase errors, the two-stage bunch compressor allows some flexibility to balance the longitudinal and transverse tolerances by adjustment of the magnet strengths, RF voltages, and RF phases. P. Tenenbaum proposes the long wiggler type bunch compressor for ILC RTML, while E. S. Kim proposes the short single chicane bunch compressor. In this paper, we continue the work on short single chicane bunch compressor. We find new parameters for the short two-stage bunch compressors. Fig. 1 shows

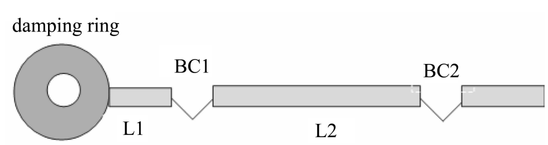

Fig. 1. Layout of bunch compressor linac section.

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Table 1. Main parameters of BC linac section (6 mm case).

	$E_{\rm in}$/GeV	$E_{\rm out}$/GeV	$\sigma_{z\text{-in}}$/mm	$\sigma_{z\text{-out}}$/mm	$\sigma_{\delta\text{-in}}$(%)	$\sigma_{\delta\text{-out}}$(%)	$\Phi_{\rm rf}$/(°)	R_{56}/mm
L1	5	5.17	6	6	0.13	0.94	−60	–
BC1	5.17	5.17	6	1.68	0.94	0.94	–	−500
L2	5.17	13.44	1.68	1.68	0.94	2.9	−45	–
BC2	13.44	13.44	1.68	0.142	2.9	2.9	–	−60

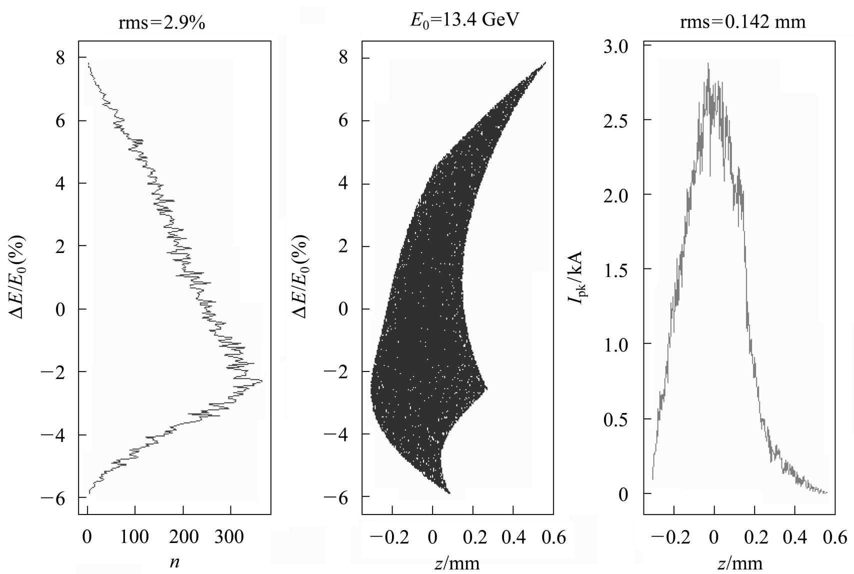

Fig. 2. The output longitudinal phase space.

the layout of the bunch compressor linac section which is made of two RF linac parts (L1, L2) and two bunch compressors (BC1, BC2). The RF linac parts use the standard cryomodule similar to the main linac, the bunch compressors are four-dipole chicanes. In this new parameters, the two-stage RF sections for BC are all in the accelerating phase rather than the decelerating phase to improve the accelerating efficiency. In Kim's work, the RF section for the first BC is in the decelerating phase. The linac parameters are summarized in the following Table 1, we use ELEGANT[2] to simulate the linac.

Table 2. BC1 parameters.

parameter	value
energy/GeV	5.17
energy spread(rms)(%)	0.94
compressing ratio(rms)	3.6
R_{56}/mm	~500
total length/m	34.2
project distance between the first and second bend magnet/m	2.5
project distance between the second and third bend magnet/m	2
bend length/m	6.8
deflection angle/(°)	10.4
emittance dilution(%)	1

The main parameters for the two bunch compressors are summarized in the Table 2 and Table 3.

With the initial bunch length of 6 mm, the output parameter for the linac is the energy of 13.44 GeV, the horizontal normalized emittance of 8.58 mm·mrad, the vertical normalized emittance of 0.02 mm·mrad, and the energy spread of 2.9%. Fig. 2 is the output longitudinal phase space, the rms output bunch length is 0.142 mm, Fig. 3 is the twiss function along with the bunch compressor linac section.

Table 3. BC2 parameter.

parameter	value
energy/GeV	13.44
energy spread(rms)(%)	2.9
compressing ratio(rms)	11.8
R_{56}/mm	~60
total length/m	34.2
project distance between the first and second bend magnet/m	2.5
project distance between the second and third bend magnet/m	2
bend length/m	6.8
deflection angle/(°)	3.6
emittance dilution(%)	2.8

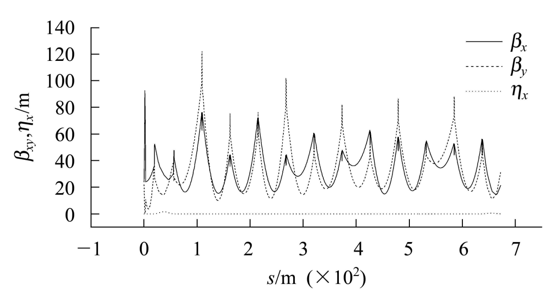

Fig. 3. The twiss function.

Our parameters also apply to the case with the initial bunch length of 9 mm. In this case the output bunch length is 0.3 mm. Table 4 summarizes the main parameters of BC linac section.

Table 4. Main parameters of BC Linac section (9 mm case).

	E_{in}/GeV	E_{out}/GeV	$\sigma_{z\text{-in}}$/mm	$\sigma_{z\text{-out}}$/mm	$\sigma_{\delta\text{-in}}$(%)	$\sigma_{\delta\text{-out}}$(%)	Φ_{rf}/(°)	R_{56}/mm
L1	5	5.16	9	9	0.13	1.4	−60	–
BC1	5.17	5.17	9	2.49	1.4	1.4	–	−500
L2	5.17	13.44	2.49	2.49	1.4	4.0	−45	–
BC2	13.45	13.45	2.49	0.31	4.0	4.0	–	−60

3 Microbunch instability in second bunch compressor

The mechanism for microbunch instabilty is similar to that in a klystron. A high brightness electron beam with a small amount of density modulation can create longitudinal self-fields that lead to beam energy modulation. Since bunch compressor introduces path length dependence on energy, the induced energy modulation is then converted to additional density modulation that can be much larger than the initial density modulation . This amplification process is accompanied by a growth of energy modulation and growth of emittance. The less the bunch length, the more serious the microbunch instability. The bunch length in the first bunch compressor is relatively long, so we just study the microbunch instability in the second bunch compressor. We have developed a program[4] to simulate the microbunch instability. The RMS bunch length at the entrance of the second bunch compressor is 1.68 mm. We find that the microbunch instability exists extensively in the second bunch compressor, and that the most dangerous perturbation wavelength is about 300 μm. Fig. 4 gives the relation between the density amplifying factor and the perturbation wavelength.

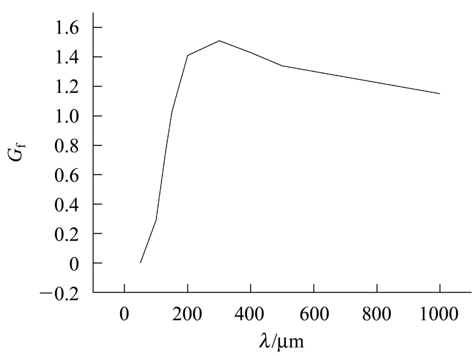

Fig. 4. The density amplifying factor vs the perturbation wavelength.

4 CSR induced emittance dilution

When a short bunch goes through the bent trajectories, CSR (coherent synchrotron radiation) occurs to deteriorate the emittance. There are several simulation codes to simulate this effect. The shorter the bunch, the more serious the CSR effect. So the CSR effect is not important in the BC1. We just use TraFiC[3] to calculate the emittance dilution on BC2. The initial parameters for bunch and lattice are from the ELEGANT simulation result. The TraFiC[4] simulation result is shown in Fig. 5, which agrees well with the ELEGANT result. The emittance dilution caused by ISR (incoherent synchrotron radiation) can be omitted[5].

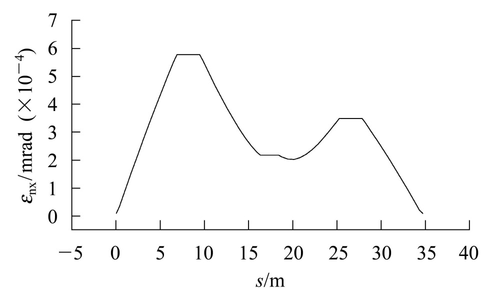

Fig. 5. The emittance dilution on BC2.

5 Conclusion

In this paper, we have found a new set of parameters for the short two stages ILC bunch compressors. The RF sections are both in the accelerating phase rather than the decelerating phase to improve the accelerating efficiency. We have also studied the CSR related issues. The results show that the microbunch instability exists extensively in the second bunch compressor, but the emittance dilution is small due to the longer bunch.

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