NLC Rote 6
SLAC
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Bunch-to-bunch phase variation in the NLC DR

Equilibrium bunch-to-bunch phase variation in the DR may be translated to the bunch spacing and energy variation in the linac and ought to be under control. The tolerable variation of the bunch spacing is ±20 ps (T. Raubenheimer). Here is an attempt to make a crude estimate of the effect.

The main reason for the phase variation is the beam loading in the RF cavities, which may depends on the location of a bunch in a train due to transients in the cavities-induced by the gaps between trains. To estimate the effect, let us scale parameters of the HER ring of the B-factory. The nominal parameters of the HER are close to the DR: the average current $I = 1.1$ A and the cavity voltage $V = 0.9$ MeV. A cavity has the shunt impedance $R_s = 3.5$ MOhms and $Q_0 = 3.10^4$ at $f_{RF} = 476$ MHz. Hence, the NLC DR may have two cavities of this type and, if R_s scales as $\omega^{-1/2}$, each would have $R_s = 2.86$ MOhms and the same R_s/Q_0 as that of B-factory cavity.

(The broad-band loss factor for the B-factory cavity has been estimated as 0.5 V/pC for the beam pipe radius $b = 5$ cm and bunch length $\sigma = 1$ cm. If it scales as k_l cc $\frac{1}{b}\sqrt{g/\sigma} \propto \sqrt{\sigma/b}$, it is 8% larger for the DR ($b = 1.4$ cm and $\sigma = 3.3$ mm).

The loss to the radiation in the DR is 0.32 MV/turn in the dipoles. Wigglers increase it to $U = 0.65$ MV/turn. Hence, the beam phase $\cos\theta_b = U/V_c^{tot} = 0.43$ for $V_c^{tot} = 1.5$ MV. That gives the coupling

$$\beta = 1 + \frac{2R_c}{V_c} I_{dc} \cos\theta_b$$

equal to $\beta = 4.63$. The loaded $Q_L = 6472$ and the detuning angle

$$\tan \& \frac{\beta - 1}{\beta + 1} \tan\theta_b$$

)

is $4\tan\phi_z$ = 1.35. Hence, the detuning for the optimum matching

$$\frac{\text{Aw}}{\omega_{RF}} = \frac{\tan\phi_z}{2Q_L} = 1.04\,10^{-4}$$

or $\Delta f = f_{RF} - f_c =$ 0.067 MHz-small compared to the revolution $f_0 =$ 1.36 MHz.

Phase of the k-th bunch

$$eV_c^{tot}\cos\theta_k = eU + \sum_{j=k}^{\infty} e^2 N_b W^\delta[s_b(j-k)]$$

gives the phase variation

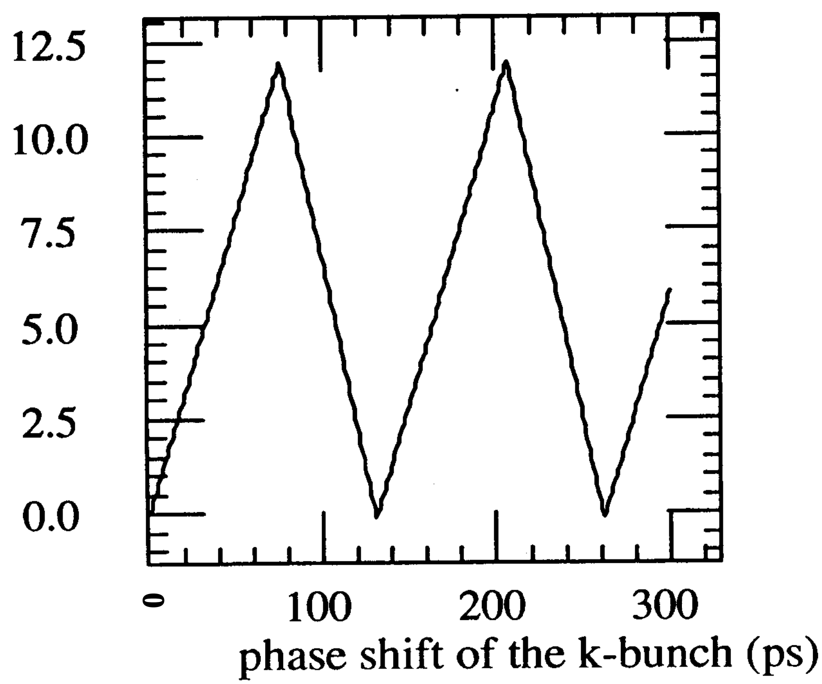
$$\Delta\theta_b(k) = \frac{eN_b}{V_c^{tot}\sin\theta_b}\sum_{j=k}^{\infty}\kappa(j)W^\delta[s_b(j-k)]$$

where $\kappa = 1$ only within the gaps and

$$W^\delta(s) = \frac{\omega_{rf}R_c^{tot}}{Q_0}\cos(\omega_c s/c)e^{-\omega_c s/2Q_L c}.$$

The phase variation is shown in the Fig. 1. The phase variation is calculated assuming 4 trains of 75 bunches with N_B = 1.5 10^{10} particles per bunch in the ring assuming 2 RF cavity with R_s = $2.8 M\Omega$, Q_0 = 3 10^4 each, and the accelerating voltage $V^{tot} =$ 1.5 MV. The calculation was carried out for all buckets in the ring. The result of Fig. 1 shows monotonic change of the phase within the tram of bunches. The phase drops down for empty buckets between trains.

The bunch spacing variation is related to the phase: $\Delta\tau_b(k)$ = $\Delta_b(k)/\omega_{rf}$ = *223&,(k)* [ps]. The maximum variation is f6.7 ps, what is quite acceptable.


12.5
10.0
7.5
5.0
2.5
0.0
0
100
200
300
phase shift of the k-bunch (ps)