IMPLEMENTATION OF COUPLER RF KICK & COUPLER WAKE FIELD EFFECTS IN LUCRETIA

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Abstract

It is well known that insertion of a coupler into a RF cavity breaks the rotational symmetry of the cavity, resulting in an asymmetric field. This asymmetric field results in a transverse RF Kick. This RF kick transversely offsets the bunch from the nominal axis & it depends on the longitudinal position of the particle in the bunch. Also, insertion of coupler generates short range transverse wake field which is independent from the transverse offset of the particle. These effects cause emittance dilution and it is thus important to study their behaviour & possible correction mechanisms. These coupler effects, i.e. coupler's RF kick & coupler's wake field are implemented in a beam dynamics program, Lucretia. Simulations are performed for Main Linac for International Linear Collider (ILC) like lattices. Results are compared with analytical results and a good agreement has been found.

INTRODUCTION

In a future linear collider, such as the International Linear Collider (ILC), trains of high current, low emittance bunches will be accelerated in a linac before colliding at the interaction point. Asymmetries in the accelerating cavities of the linac will generate fields that will kick the beam transversely & degrades the beam emittance, which will adversely affect the Luminosity at the interaction point (IP).

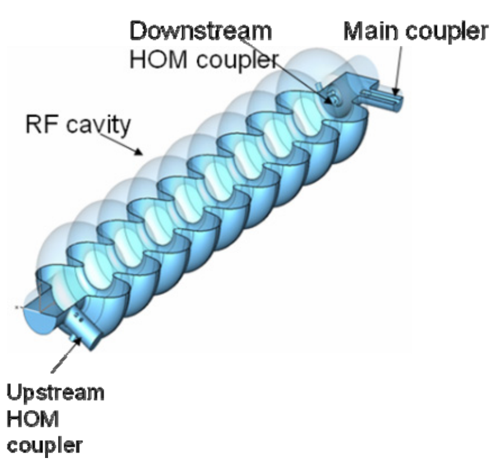

Figure 1: The ILC RF cavity with main & HOM couplers.

In the main linac of the proposed ILC accelerator, which is filled with TESLA-type superconducting cavities, fundamental (Input) coupler & higher order mode (HOM) coupler are the sources of asymmetric fields [1]. Transverse kicks are of two types: Coupler RF kick which is due to asymmetry in fundamental RF fields & coupler transverse short-range wake fields which are generated by the beam even if the beam is on-axis. In this paper we will discuss the implementation of coupler effects in Lucretia, which helps in further understanding of these effects & also provide means for exploring possible solutions. As emittance budget is limited in ILC like accelerator, so correction mechanisms help to redistribute the emittance budget for Main Linac. We calculate the emittance dilution in the Main Linac due to Coupler RF Kick & also study the influence of Coupler Wake Kick on the trajectory of the beam when it is propagated through the main linac.

IMPLEMENTATION OF COUPLER RF KICK

In Lucretia there is an element, TCAV, which works almost exactly like an RF accelerator cavity, except that voltage is applied in transverse plane to deflect the beam. Deflection of each ray is given by

$$dP_y = eV\sin(\varphi + ks)/c,$$

where V is applied voltage (Real component only), s is position of particle within bunch, ϕ is RF phase. It has been shown elsewhere [1,4] that RF kick can be implemented by an application of complex voltage instead of applying only real voltage. We have thus implemented RF Kick using same TCAV element, but now with an application of complex voltage [1] , i.e. $V = V_{real} + i\,V_{imag}$. Deflection of each ray under the effect of coupler RF Kick thus becomes

$$dP_y = e[V_{real}\cos(\varphi + ks) - V_{imag}\sin(\varphi + ks)]/c$$

We implement the coupler effect in Lucretia by using a single TCAV placed immediately after RF cavity. To include the effect of both upstream couplers & downstream couplers in single TCAV, a net complex voltage is fed to TCAV [1].

RF Kick Simulation Results

Simulations using Lucretia code were performed in order to estimate the emittance dilution caused by coupler RF kicks. Table 1 lists the important parameters used in simulation. Emittance is calculated for various cases in Main Linac. In Fig 2. only real part of complex kick voltage is applied to TCAV. Real kick doesn't depend on longitudinal position of the particle within bunch and hence corresponding kick remains same for the whole bunch. As seen from Fig.2, this emittace dilution can be corrected using one-to-one (1:1) correction mechanism. In contrast Imaginary kick depends on the longitudinal position of particle within bunch [1,3,4] so it will vary according to the position of particle within bunch and corresponding emittance dilution can not be compensated using one to one correction. In Fig 3, result of emittance dilution is shown when only imaginary voltage is applied to TCAV. Fig 4 shows the corresponding plot after 1:1 correction. In Fig 5 both real and imaginary parts of the voltages are applied to TCAV & effect is also studied after 1:1 correction. These results are consistent with analytical calculations [3]. Fig 6 shows the vertical trajectory of the beam when both real & imaginary part of coupler voltage is applied.

Table 1. Parameters Used for RF Kick Simulation

Parameters	Magnitude	Unit
Length of RF cavity	1.036	Meter
Length of TCAV	0,01	Meter
RF Phase	0	Degree
Tilt	90	Degree
Gradient	31.5	MV/Meter
Initial Emittance	20	nm rad
Kick Voltage (V)	7.3+ i 11.1	Volt
Length of Linac	~8.7	Km
Bunch Charge	3.2	nC

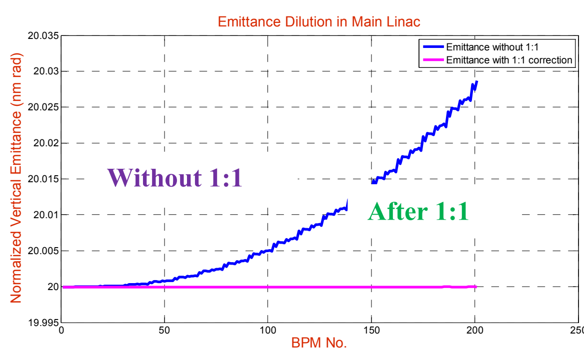

Figure 2: Emittance behaviour of the beam in the Main Linac when only real part of kick voltage is applied to TCAV (V: -7.3 + i0.0). Effect of 1:1 correction is also shown.

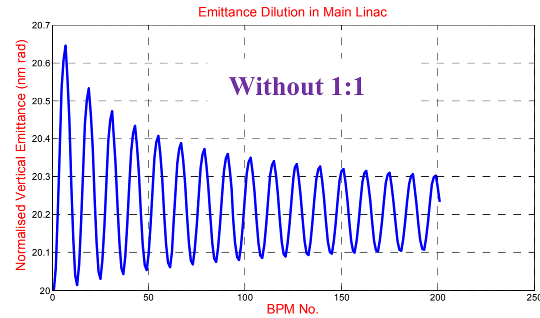

Figure 3: Emittance behaviour of the beam along the Main Linac when only imaginary part of kick voltage (V: 0.0+i 11.1) is applied to TCAV.

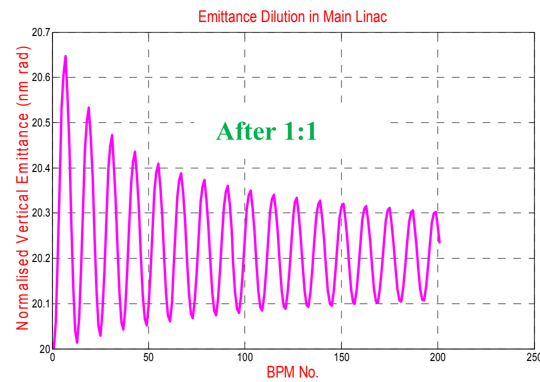

Figure 4: Emittance behaviour of the beam after 1:1 correction in Main Linac when only imaginary part of voltage (V: 0.0+i 11.1) is applied to TCAV.

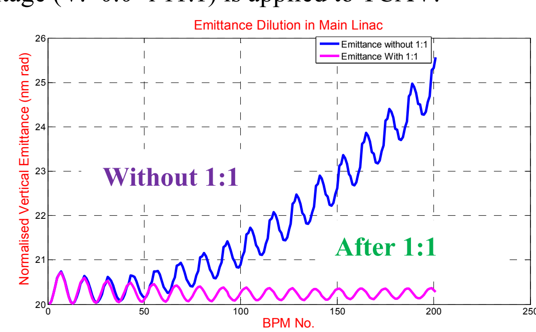

Figure 5: Emittance behaviour of the beam in Main Linac when both real & imaginary part of kick voltage (V: -7.3+ i 11.1) is applied to TCAV.

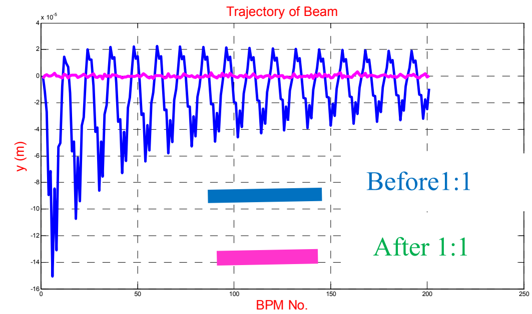

Figure 6: Vertical Trajectory of the beam in the main linac when both real & imaginary part of kick voltage (V:-7.3+ i 11.1) is applied to TCAV. Effect of 1:1 correction is also shown.

IMPLEMENTATION OF COUPLER WAKE FIELD

In Lucretia nominal wake kick for a cavity is defined by the deflection

$$dPy = e*W(z)*q*\Delta x*L/c,$$

Where z is relative position of trailing particle w.r.t head, W(z) is Wake data at that point ($V/C/m^2$), q is total charge of the bin, Δx is offset from the accelerating axis & L is length of cavity. To implement the coupler wake kick [2,3,4] it is important to understand the nature of this wake. To the first approximation, transverse kick neither depends on transverse coordinates of incident particle nor on the transverse coordinate of witness particle, so for fixed longitudinal charge distribution along bunch, transverse wake profile versus 's' is fixed, where 's' is position of particle within the bunch. So Coupler wake kick is defined by deflection given as:

$$dPy = e* W(s)*Q/c$$

Here Q is total charge of the bunch.

Transverse wake distribution W(s) is obtained by simple linear interpolation procedure of wake data file.

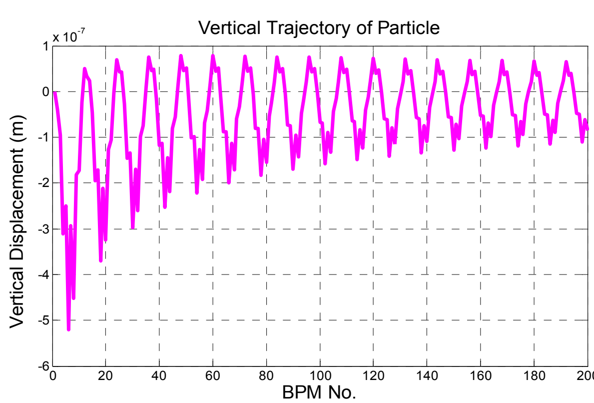

Figure 7: Trajectory of Particle under the influence of Coupler wake field.

Simulation is performed in order to estimate the effect of coupler wake kick on the vertical trajectory of the particle which is placed at the head of the bunch. Results can be seen in fig. 7.

CONCLUSIONS

We have implemented couplers' effects, both RF kicks and wake-fields, in beam dynamics program, Lucretia. Simulations are performed for ILC like Main Linac. RF kicks has been implemented by an application of complex voltage. It is found that 1:1 correction mechanism can be used to limit emittance growth for RF kicks induced by real component of applied voltage. However, emittance growth from the imaginary component of the applied voltage cannot be corrected. We have also implemented coupler wake field, and checked its corresponding effect on beam trajectory.

AKNOWLEDGEMENT

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