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REMARKS ON 'BEAM DYNAMICS CALCULATION FOR CTF'

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Remarks on 'Beam Dynamics Calculation for CTF'

In the above mentioned talk, given on Tuesday, May 30th in the CLIC Beam Dynamics Meeting, it has been shown, that for a Particle In Cell simulation of the RF gun, a relatively dense grid in combination with a increased number of particles has to be used in order to obtain the necessary calculation accuracy. In view of this, a number of participants expressed concern in the validity of the results. In order to clarify a few points, I would like to add the following comments.

The problematic results, shown in the talk, were emittance and energy spread calculation for a 10 psec (FWHM) bunch in the RF gun and the solenoid. The r.m.s. length of the bunch at the gun exit is $2\sigma_z = 2.4$ mm, exciting fields up to a frequency $f_c = c_0/\sigma_z = 250$ GHz with a wavelength $\lambda_c = 1.2$ mm. A very well known requirement of numerical field calculation is that the ratio of wave length to grid step be reasonably high. The computation of the RF gun using the 'coarse' discretisation employs a step width of 200μ, a value, which (allowing an error in the order of 20 mm mrad for the emittance, the most sensitive parameter) is sufficient for the calculation of the beam parameters at the gun exit.

Perhaps a not so well known property is the degradation of the numerical convergence of the numerical solution of Initial Value Problems with increasing simulation length. For PIC codes like TS2, Time Domain codes like ABCI/T2/T3 and tracking codes like PARMELA, this is given by the span of physical time and therefore the size of the structure which has to be simulated. The practical effects in a wake field calculation may be found in reference 1; the theory should be contained in any reasonable book on the numerical solution of Initial Value Problems. The effect is, simply described, that numerical errors sum up along the time integration, and are therefore a function of the size of the time interval simulated.

Returning to the simulation of the RF gun, we see that by adding the solenoid and the drift tube, the length and therefore the physical time span roughly doubles from 0.15 to 0.3 meter. In the talk it was shown, that we get in this case a decreased accuracy, as can be expected. This has to be corrected by a smaller mesh step $\Delta = 150\mu$.

The bunch in its overall dimensions extends roughly over a radius of 12 mm and a length of 4.8 mm ($\pm 2\sigma$). With the given grid step, this area spans approximately 2560 mesh cells. It is easy to see that it is not possible to approximate a more or less steady distribution on this grid using only 1000 macro particles. On the contrary, the fact that we need only 4000 macro particles to reach convergence tells quite a lot about the quality of the coupling between tracking algorithm and field calculation. (As a side remark, one has to say, that even with 8000 macro particles, the tracking algorithm uses only a few percent of the overall cpu time, so, this number is quite irrelevant.)

The conclusions, I personally would draw from this are the following. Inside the gun, where we have a low relativistic beam, being sensitive to the electromagnetic field, it is worthwile to do a Particle In Cell calculation to try to capture all effects in the range 0 to 300 GHz, even if the computational effort is high. Since we have a mix up of solenoidal fields with rf fields at the exit of the gun, the solenoid has to be included in the calculation. Consistently, the gun/solenoid combination should be seen as one modular element in the CTF beam line. Following elements as e.g. the High Charge Accelerating Section, which because of its rf coupling should be anyway analysed as a 3D structure, can be handled by tracking programs as Parmela or described in terms of values as e.g. R/Q, wakes, loss factors.

With these comments I hope to have given a few new arguments to the ongoing discussion on the CLIC design strategies. I would like to say thanks in advance for eventual comments and (counter)arguments.

References

1. M.Dehler, T.Weiland,
"Calculating Wake Potentials for Ultra Short Bunches,"
Proceedings of CAP 93, Computational Accelerator Physics, American Institute of Physics (1993).