LABORATORY FOR PARTICLE ACCELERATOR PHYSICS (LPAP)

Prof. Leonid Rivkin

Experience from a student for:
Laboratories (TP IV)
&
Master Thesis (PDM)

Matthieu George - Class 2010 – matthieu.george@gmail.com

Laboratories @ CERN (1)

FACTS :

- No initial knowledge about Particle Accelerators when beginning Master
- Due to the relationship between former experiences and the projects that have been suggested, choice to go to CERN, PSI, or stay at EPFL
- CERN: 1st term and then 2nd term on the same project. Publication at the end

Laboratories @ CERN (2)

PROJECT :

- Numerical part of a real project. A similar project had been successfully implemented before and has served as a basis
- Title: *Numerical studies for a new multi-turn injection*
- Idea: To create a new process for the injection of the protons in an accelerator (Proton Synchrotron) that are coming from another accelerator (Proton Synchrotron Booster)

ADVANTAGES :

- Learned a lot on the theoretical part (Non linear physics of particle accelerator) and provided numerous results and analysis from simulations

Abstract

Recently a new extraction scheme was proposed to eject the beam over a small number of turns after trapping particles in stable islands of the horizontal phase space. This multi-turn extraction has been successfully tested at the CERN Proton Synchrotron and is being commissioned for operational extraction of protons towards the Super Proton Synchrotron for fixed-target experiments.

Islands are generated by creating fixed points in the horizontal phase space by means of non-linear elements, such as sextupoles and octupoles, and by making the horizontal betatron tune cross the one-fourth resonance. Once created, the islands are moved apart and properly separated by changing the tune further away from the resonance, until the separation is enough not to intercept the magnetic septum used to eject the islands towards the extraction channel.

More recently it was proposed to use the same principle for a new multi-turn injection that generates hollow beams in the horizontal plane: this would be of great help in high-intensity low-energy rings, where the Coulomb repulsion among the particles, known as space charge, limit the beam intensity. The underlying idea is the reverse process of the beam splitting: stable islands are created by injecting turn by turn several beamlets from an upstream injector around the fixed points of the horizontal phase space, generated by non-linear magnets. At the end of the injection, the islands are merged down towards the centre by crossing adiabatically the resonance. It has been already observed, numerically, that eventually most of the beam remains confined into an annulus around the centre, hence generating a hollow horizontal profile. This in turn leads to less severe space charge effects compared to a Gaussian profile, the peak beam intensity being lower. The aim of the present study is to get a deeper understanding of this space charge effect on the final beam distribution.

The results of numerical multi-particle simulations of this process are presented and discussed in details. The dependence of the final beam profile on the initial beam and machine parameters, such as crossing speed, emittance and tune working point, is also established.

Some key words: Injection, adiabatic capture, phase space, non-linear fields, stable islands, space-charge effects.

Master thesis @ SLAC (Stanford) (1)

FACTS :

- SLAC is one of the world's leading research laboratories
- Circular world (CERN) to Linear world (SLAC) = Differences in term of science
- LCLS = The 1st 4th generation light source (1st operation of the machine 4 days after arrival -> Champagne !)

SPECIFICS :

- LCLS = Result oriented machine; need to deliver photon beam to user. More operational than CERN

Master thesis @ SLAC (Stanford) (2)

PROJECT :

- Create a new diagnostic for the machine
- Title: *A Preliminary Study for a Sub-Micron Electron Bunch Length Diagnostic*
- Idea: Measuring the length of packet of electrons that are used to produce X-Rays

ADVANTAGES :

- To work in a professional environment, not academic
- To learn how to lead a project by your own
- To interact on a daily basis with professionals of the field
- Possibility for publication

Abstract

In recent years, the operation of new 4^{th} generation, free-electron laser (FEL) light sources has become a reality, especially with the successful operation of the LCLS (Linac Coherent Light Source) at SLAC. This revolutionary new type of facility operates with high transverse photon coherence, femtosecond pulse durations, and extremely high photon brightness levels, which are already ten orders of magnitude above existing 3^{rd} generation sources.

Such a machine requires precise diagnostics, which become quite challenging, especially in the measurement of femtosecond pulse lengths. We propose a new laser-based scheme to obtain the length of the electron bunch, and therefore the approximate length of the photon pulse, within the femtosecond regime. As in the classical "zero-phasing" measurement method, the working principle of this device relies on a very fast external field variation to deflect the electrons differentially in time, similar to a standard streak camera approach. The main difference here is in the use of optical laser wavelengths (10 micron) rather than radio frequency (RF) wavelengths (10 cm).

As the phase of such a laser system is unknown and cannot be easily controlled, the development of a new approach is needed. The interaction of a CO_2 laser with the electrons propagating through a wiggler, as already demonstrated in the LCLS laser heater system, leads to an energy deviation, or a simple linear energy chirp over the electron bunch length. After the "modulation", the electron beam is bent by a dipole magnet dispersing it in the transverse direction onto an intercepting imaging screen. Both the beam's centroid position and its transverse size are read on each pulse, where each new measurement depends on the uniformly random phase of the laser, which is then reconstructed from this data. The physical parameters of the electron beam, i.e. the bunch length, its energy chirp, and the amplitude of the modulation, are contained in both the size and the centroid position of the beam.

The aim of the present study is both to establish an analytical model of this relationship between the data read on the screen and these physical variables and to develop a method allowing to exctract such variables. The results of numerical simulations of this diagnostic are presented and discussed in detail. The dependence of the errors of the measurement on both the device and bunch of electron parameters, such as its energy chirp and length, is also established.

Some key words: Diagnostic, sub-micron bunch length, energy chirp, zero-phasing, CO_2 laser.