Electron beam transfer line design for plasma driven Free Electron Laser

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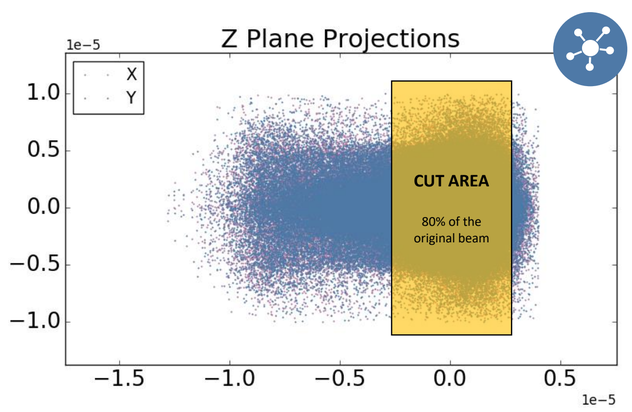
Introduction

A good beam matching is needed In order to optimize the performances of an FEL amplifier.
We studied the possibility of application of a Genetic Algorithm to the matching problem of a machine like the Eupraxia@SPARCLAB Free Electron Laser. We used GIOTTO, a Genetic Code for beam-dynamics optimizations, and ASTRA, a tracking algorithm to perform a wide domain search the correct parameters of the transfer line.
We used a laser driven plasma beam pre-accelerated in the Adiabatic Bunching regime.

The beam

We chose to select the portion of the beam with the highest peak current and lowest emittance. These particles where cut and used as the beam to transport in the transfer line



σ_x	σ_y	$\varepsilon_{n,x}$	$\varepsilon_{n,y}$	En	Esp	Charge
2.4 µm	2.4 µm	0.42 mm mRad	0.43 mm mRad	1 GeV	3.29e-03	32 pC

Undulator matching

The undulator matching is performed imposing the periodicity of the average Twiss functions (α and β) all over the periodic module of the lattice **Figure X**. Once this condition is granted, the exact values of the average Twiss functions of the bunch at the entrance of the first undulator module are known. The transfer line then must be set up to obtain this values.
For the beam I used for the tracking (parameters in table **Table 1**) the the values required at the entrance are:

σ_x	σ_y	α_x	α_y
31.41µm	10.75µm	2.927	-0.442

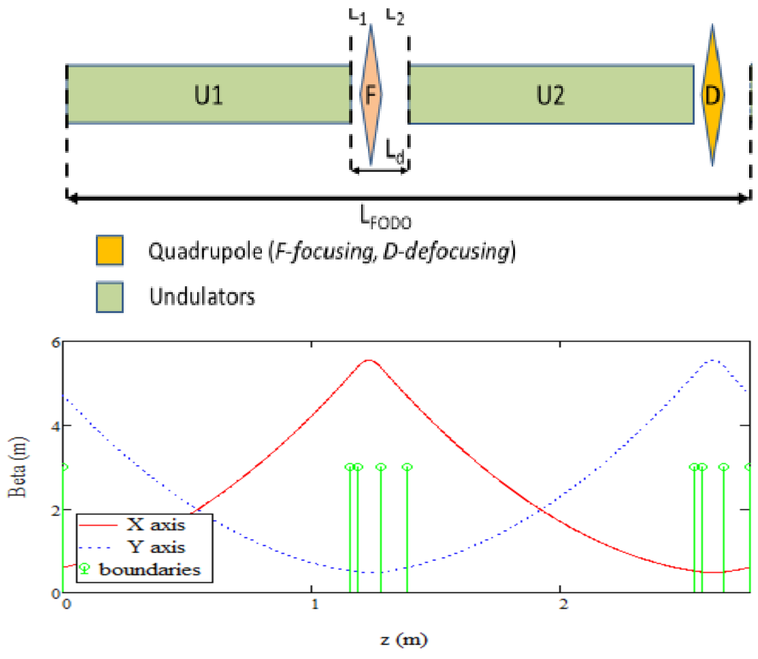


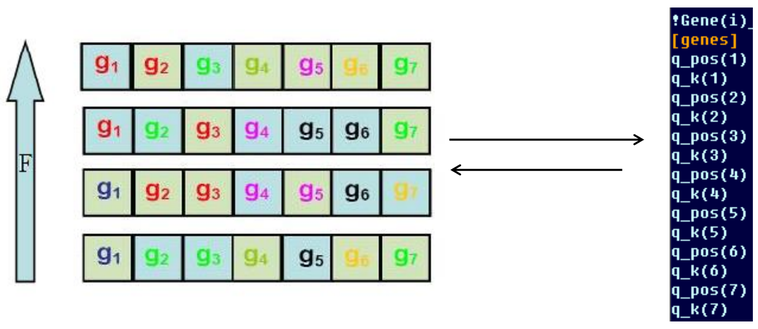
Figure 2: **Up**. The periodic block of the undulator of Eupraxia@SPARCLAB. The quadrupoles are in FODO configuration.
Down. The values of the β functions in the periodic block. These values grant the periodicity of the solution all over the undulator.

Building a transfer line with a genetic algorithm

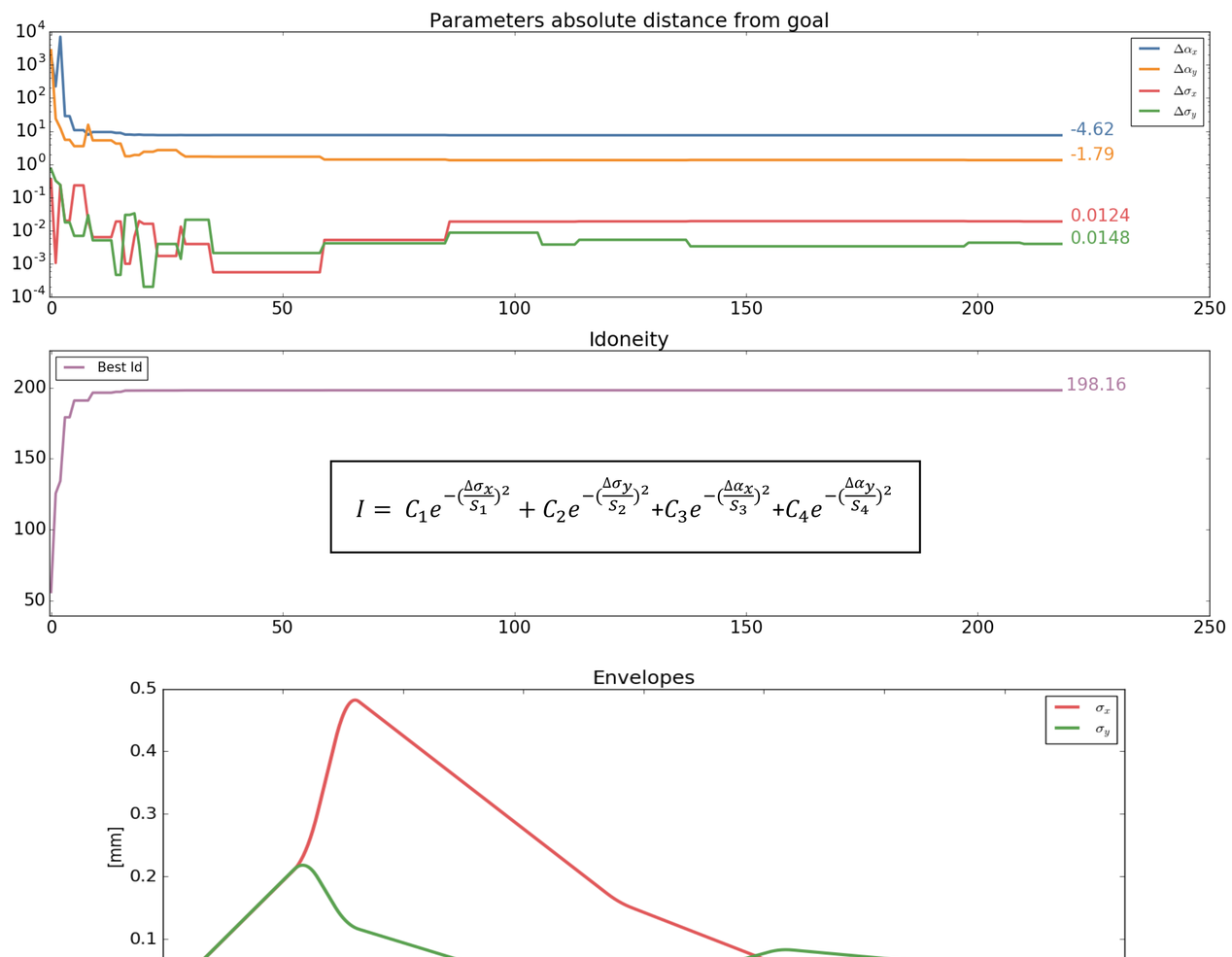
Genetic Algorithms

Genetic Algorithms are a family of stochastic optimization methods, their structure is inspired by the evolutionary theory of Darwin.

Gene	**Machine parameter**
Chromosome	**Parameters set**
Population	**Proposed solutions**
Idoneity function	**Tracking with Astra**



Performances



Tweaks and Tricks

Some new features of the genetic optimization have been introduced in GIOTTO in order to deal this specific new kind of problem.

- **smarter chromosome structure.**
- **silent genes:** turned on by rare lucky mutations or stay silent without perturbing the solution.
- **expanded mutation range**: for better exploration outside local minima

We also chose to increase the optimization velocity, by **under-sampling** the bunch and **turning off the space charge** forces

References

[1] M. Quattromini et al. PRSTAB 15, 080704 (2012)
[2] K. Floettmann, “ASTRA, A Space-charge TRacking Algorithm”,
[3] A. Bacci et al. Conference proceedings IPAC’16, paper WEPOY03