

Exercise:

Design Extraction Line from ATF Damping Ring

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Abstract

The goal of this exercise is to design an extraction line (EXT) for the 1.3 GeV electron damping ring (DR). Taking into consideration the machine constraints and hardware limitations. The extraction line should preserve the emittance delivered by the DR. To this end an emittance measurement section should be present in the extraction line.

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I. INTRODUCTION

The accelerator and particle physics communities are considering a lepton linear collider as the most appropriate machine to carry out high precision particle physics research in the high energy regime. There exist two proposals for the next generation of e^+e^- linear collider (LC), the International Linear Collider (ILC) [1], [2] and [3] and the Compact Linear Collider (CLIC) [4], [5] and [6]. In order to reach the required luminosity (\mathcal{L}) for the experiments, the vertical spot size at the IP (σ_y^*) is of the order of a few nanometers. The final focus systems (FFS) of both LC projects reduce the $\beta_{x,y}$ functions $\leq 100\mu m$. Although this strong focusing is quite challenging, it is equally important to inject a beam with extremely small vertical emittance $\epsilon_y \approx pm$. To this end, the Accelerator Test Facility (ATF), was designed to experimentally verify the generation of such a small emittance.

II. DESCRIPTION OF ATF

The ATF damping ring receives a 1.3 GeV electron beam from the ATF linac. There is a common point in the ring for injection and extraction of the beam. The extraction beam line extends over about 52 m and delivers the beam to the final focus system (ATF2

TABLE I. Comparison between relevant parameters of different final focus systems.

Project	Status	Beam Energy [GeV]	$\gamma\epsilon_y$ [nm]	σ_y^* [nm]	β_y^* [mm]	L^* [m]	ξ_y [μ]
FFTB	Designed	46.6	2000	52	0.1	0.4	4000
FFTB	Measured	46.6	2000	70	-	0.4	-
ATF2 Nominal	Designed	1.3	30	37	0.1	1.0	10000
ATF2 Nominal	Measured	1.3	30	65 ^a	0.1	1.0	10000
ATF2 Ultra-low β^*	Proposed	1.3	30	23	0.025	1.0	40000
CLIC $L^*=3.5$ m	Designed	1500	20	1	0.069	3.5	50000
ILC	Designed	250	35	5.9	0.48	3.5	7500

^a This value is considered as an upper limit of the actual beam size due to relative phase jitter between the laser fringe pattern and the e^- beam, see more details in [?].

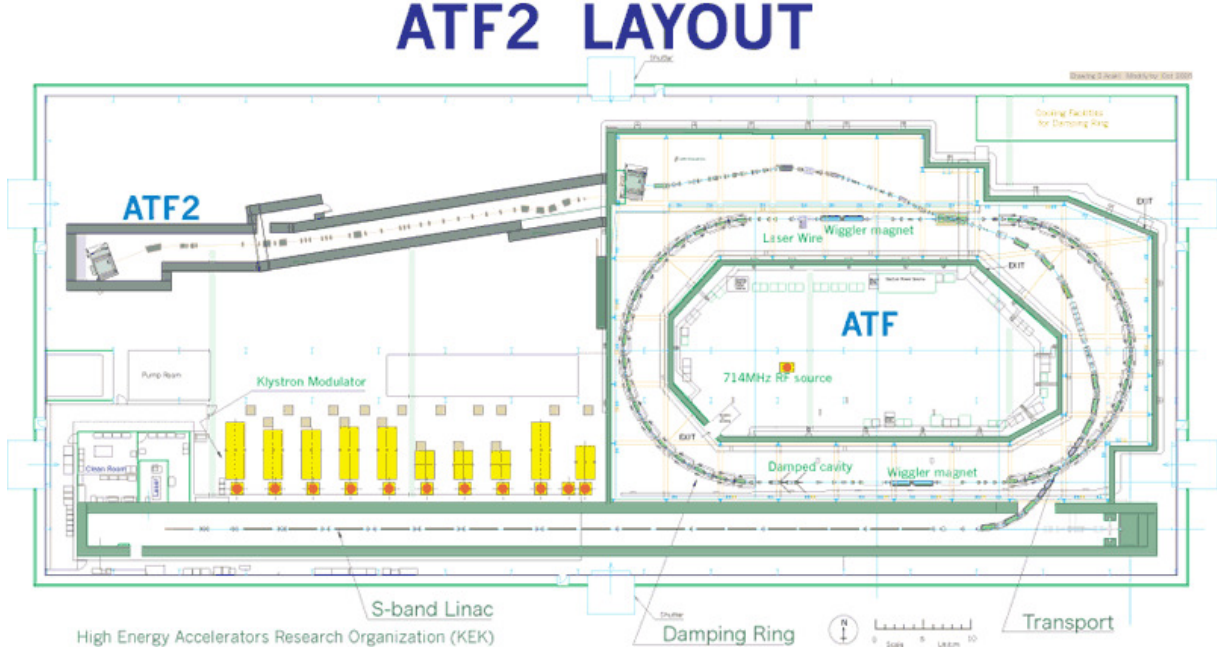


FIG. 1. Scheme of the ATF facility.

beamline). Figure 1 shows a layout of the ATF and ATF2 facility.

Figure 2 shows a layout of the ATF2 (Extraction and Final Focus System) beam line.

The ATF2 beam line is divided into two sections, the extraction beam line (EXT) and the final focus system. The EXT extends over 52 m, it comprises an extraction and diagnostic sections. The diagnostic section is used for measuring the emittance and the Twiss parameters and for correcting the dispersion and transverse coupling of the electron beam. The ATF2 FFS beam line extends over 40 m, it is responsible for transporting and vertically focusing the beam at the IP to tens of nanometres.

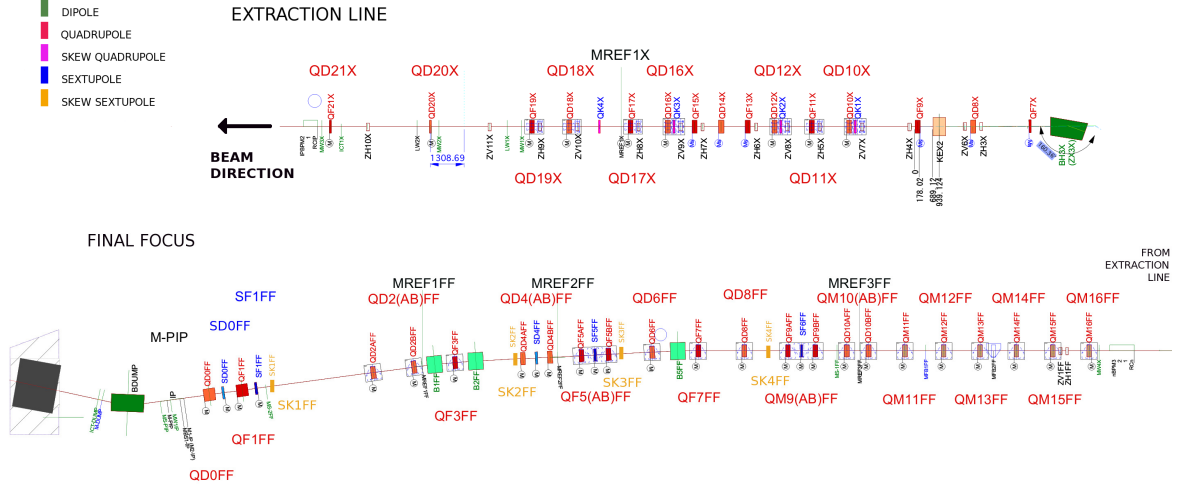


FIG. 2. Scheme of the ATF2. The beam line on the left represents the extraction beam line (EXT). The beam line on the right represents the FFS as the continuation of the EXT line (Figure courtesy of S. Araki).

III. ATF PARAMETERS

Damping Ring

Figure 3 shows a close-up at the extraction point (label as **kicker 1**) of the ATF ring.

Septum is divided in 3 sector bend magnets BS1X, BS2X and BS3X to complete the extraction. The distances between BS1X and BS2X and between BS2X and BS3X are the same and equal to 0.2 m.

IV. EXERCISE OBJECTIVES

This exercise is composed on the following 6 steps:

- First thing is to decide which extraction scheme is best suited for the ATF damping ring. To this end we need to know the available space at the extraction location, and physical constraints for our equipment.
- Decide kicker requirements according to the necessary horizontal offset at the septum for safety extraction.

Once you have the sketch of the extraction line, match the Twiss at the extraction point to the Twiss at the exit of the entrance of the FFS.

- Designed an emittance measurement section that consists of 4 beam size measurements, preserving the match conditions from previous step. Decide on cell structure, phase advanced in both planes.
- Obtain plots for the survey coordinates, Twiss functions ($\beta_{x,y}$) and dispersion ($\eta_{x,y}$). Plot the aperture and beam size ($\sigma_{x,y}$) along the extraction line.
- Determine what is the jitter tolerance to preserve the emittance delivered by the DR. How would you relax this tolerance?

V. SOLUTION

A. Step 1

kicker + plus offset quadrupoles due to space constraints from the DR

B. Step 2

kicker length 0.5 m. Angle equals to 0.005. Beam offset at QM6R and QM7R is 0.65 cm and 2.25 cm respectively.

C. Step 3

Dogleg section.

TABLE III. Damping Ring Parameters at extraction point **kicker 1**.

Magnet	Length	Angle
	[m]	[rad]
BS1X	0.6	0.028
BS2X	0.8	0.072
BS3X	1.0	0.234

D. Step 4

Match command MAD-X

E. Step 5

Figure 4 shows the survey coordinates along the ATF2.

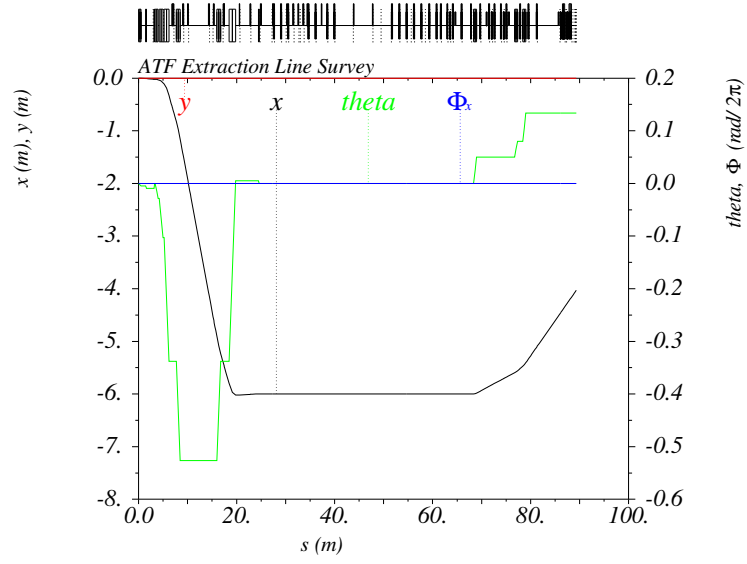


FIG. 4. Survey coordinates of the ATF2 beam line.

Figure 5 shows the $\beta_{x,y}$ and η_x -functions along the extraction and final focus system beam line.

Figure 6 shows the aperture and $10 \cdot \sigma_{x,y}$ along the ATF2 beam line.

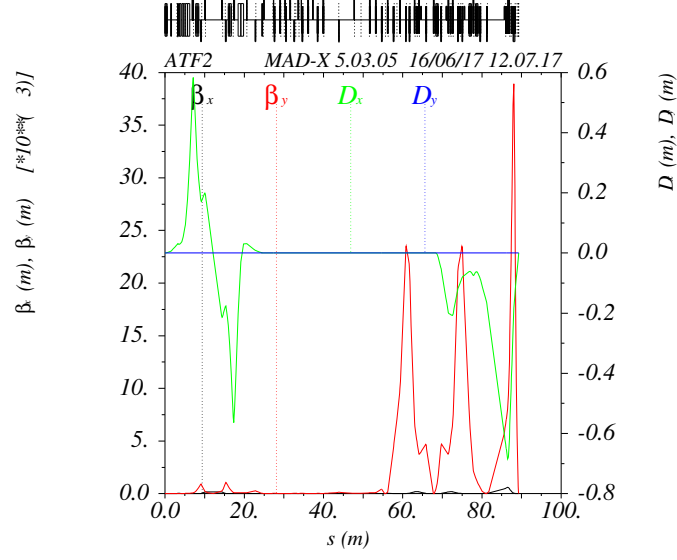


FIG. 5. The $\beta_{x,y}$ -functions and the η_x -function for the ATF2 nominal lattice throughout the ATF2 beam line.

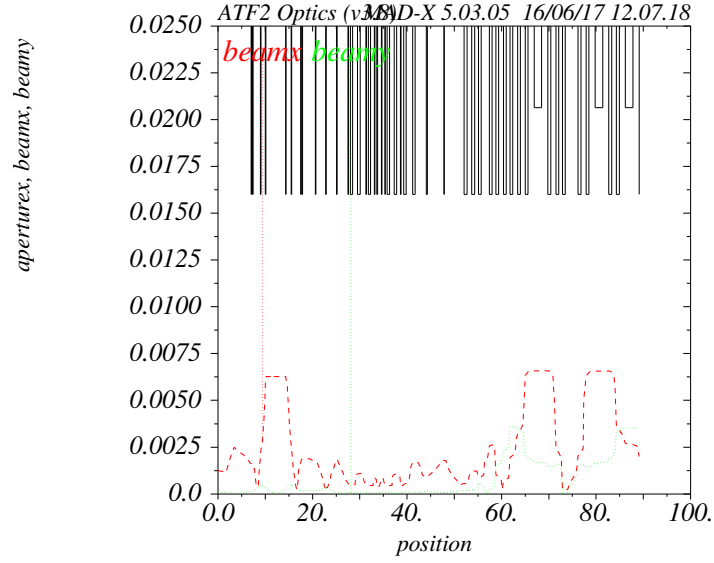


FIG. 6. Machine aperture and beam size throughout the ATF2 beam line.

F. Step 6

MAD-X script

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