MAIN BEAM DUMP TRANSFER LINE FOR THE FERMI@ELETTRA LINAC

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Abstract

A beam dump transfer line (Main Beam Dump TL) has been designed to transport the electrons from each FERMI radiator to the beam dump. The line matches the e-beam optics from the end of the undulator chains of FEL1 and FEL2 for all photon wavelengths and polarizations required by the FERMI project. The transfer line is also equipped with different types of instrumentation to characterize the beam in terms of emittance, energy spread and jitter of the electron bunches and so demands a flexible optics interchangeable between measurements and normal operations. The line may also accommodate a coherent infrared source with particular requirements on the optics. The beam optics, the line design, and the various operating modes will be presented and discussed.

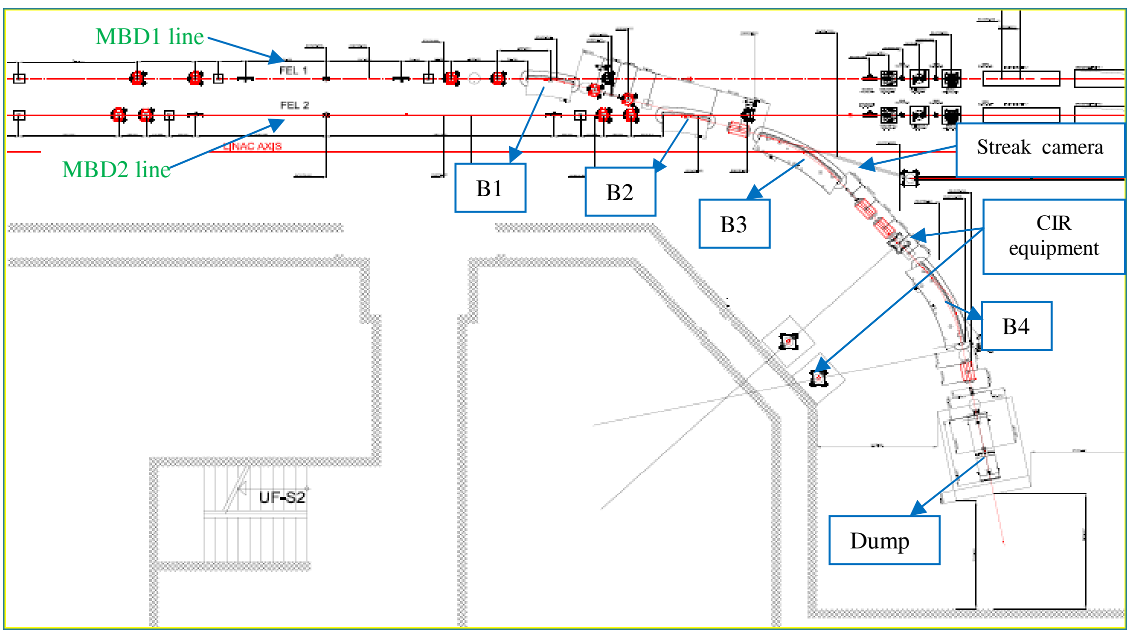

Figure 1: Main Beam Dump Transfer Line Layout.

INTRODUCTION

The transfer line has two branches called MBD1 line and MBD2 line, converging together after the B2 bending magnet, into the common transfer line section leading to the beam dump (Fig. 1). The MBD line includes 14 quadrupoles, 4 bending magnets (B1, B2, B3, B4) and 8 steering magnets. The MBD TL will be also used for :

- Emittance measurements using a screen downstream of the first two quadrupoles of MBD1 line.
- Energy spread measurements using a screen at the end of the MBD line.
- Jitter measurement using a streak camera located downstream of the third MBD bending magnet.

Before the last bending magnet of MBD TL a space has been foreseen to accommodate the coherent infrared source (CIR) of the TERAFERMI Project.

After the bending magnet B1 and B2, about 1 meter away, a permanent magnet will be installed for safety reasons, ensuring that no electrons will be accidentally transmitted through the beam lines.

BEAM LINE OPTICS

At the design electron energies of 1.8 GeV and 1.2 GeV (normalized emittance 1 μrad), the optics model [1] satisfies the following requirements:

1. Low beta functions and a dispersion value less than 0.5 m are required at the centre of B3 where the light port for the streak camera measurements is installed.
2. Zero dispersion and low beta functions are needed after B3, where the CIR equipment will be installed, in order to satisfy the source optics requirements.
3. High dispersion and low beta functions at the end of the MBD line are needed for energy spread measurements

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4. High beta functions and high dispersion at the end of the line are specified for normal operation (no beam measurements along the MBD TL).

Fig. 2 shows the beta functions and the dispersion in the region from the exit of FEL1undulator (MBD1 line) to the dump, that satisfy requirements 1 and 2. The maximum horizontal beam size for this optics is 3 mm (at 1σ) at the end of the line. The maximum vertical beam size is 110 μm (at 1σ).

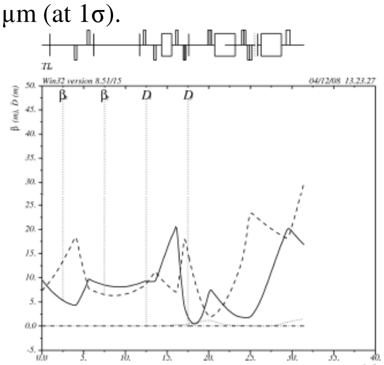

Figure 2: MBD line optics from FEL1 exit to the dump.

Fig. 3 shows the optics used for high dispersion and low beta functions at the line end, as needed for energy spread measurements. The 1σ maximum horizontal and vertical beam sizes along the line are respectively 4 mm and 110 μm.

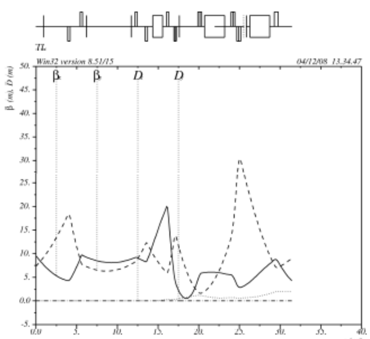

Figure 3: MBD line optics required for energy spread measurements.

The computed optics for the transport of the FEL2 beam (MBD2 line) is shown in Fig. 4. In this case the maximum beam dimension (at 1σ) in the horizontal and vertical plane are respectively 3 mm and 120 μm.

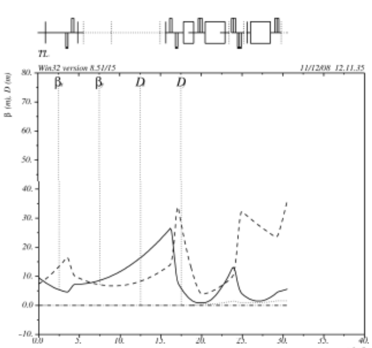

Figure 4: MBD line optics from FEL2 exit to the dump.

For normal user operation (no beam measurements on the line), the beam cross section at the line end must be as large as possible to minimize the electron beam power density on the exit window and on the dump. The optics for this mode of operation is shown in Fig. 5 for FEL1 beam and in Fig. 6 for FEL2 beam. The largest beam sizes are obtained by switching off the last quadrupole. The maximum 1σ horizontal size at the line end is about 4 mm and 120 μm in the vertical plane.

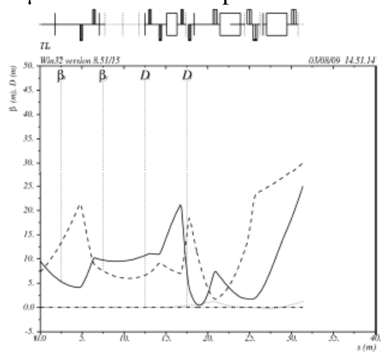

Figure 5: FEL 1 normal operation MBD line optics.

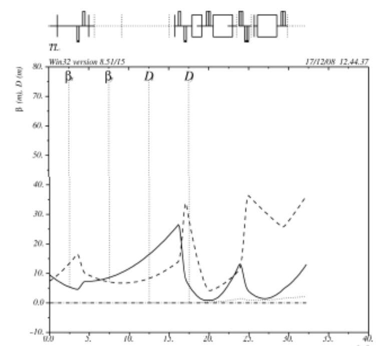

Figure 6: FEL 2 normal operation MBD line.

Beam Stay Clear

In the vertical plane the maximum beam dimension is very small (< 120 μm at 1σ) due to the low emittance. In the horizontal plane the major contribution to the beam enlargement is due to the dispersion produced by the bending magnets. Because of the horizontal beam spreading, we considered a beam pipe with an inner diameter of 38 mm starting from the last bending magnet B4 (where the dispersion becomes relevant) to the dump.

The vacuum chamber from the exit of the undulators FEL1 and FEL2 to B4 will have a inner diameter of 22 mm. The beam stay clear was calculated considering a total beam size of 6 σ in both planes and a trajectory error of ± 2 mm. In the vacuum chamber starting from FEL1 and FEL2 exit to B4 (inner diameter of 22 mm), the maximum horizontal beam dimension (at 1 σ) is ~1.5 mm and the maximum vertical dimension (at 1 σ) is ~110 μm. The beam stay clear for this chamber section is 13 mm in the horizontal plane and 4.7 mm in the vertical plane. In the vacuum chamber starting from B4 to the dump (inner diameter of 38 mm), the maximum beam size (at 1 σ) is about 4 mm at the line end and about 120 μm (at 1 σ) in the vertical plane. The beam stay clear in this chamber tract is ~5 mm in the vertical plane and ~28 mm in the horizontal plane.

TRANSFER LINE COMPONENTS

The parameters of the transfer line components are presented in this section.

Bending Magnets

The four bending magnets of the MBD transfer line are elements already existing on the Elettra site and recovered from a dismantled transfer line which transported the e-beam from the old Linac to the Storage Ring. The bending parameters are presented in Table1.

Table 1: Bending Magnet Parameters

	@1.2 GeV	@1.8 GeV
Bending B1, B2		
Yoke Length (m)	1.183	1.183
Bending Angle (deg)	15.7	15.7
Integrated Field (Tm)	1.096	1. 644
Bending B3,B4		
Yoke Length (m)	2.373	2.3732
Angle (deg)	31.4	31.4
Integrated Field (Tm)	2.192	3.29

Quadrupoles

The MBD line uses 14 quadrupoles: the last four elements are recovered from the old Linac to Storage Ring TL while the remaining 10 elements must be procured. The quadrupole parameters are shown in Table 2.

Table 2: Quadrupole Parameters

integrated Gradient (T) ranges		
	@ 1.2 GeV	@ 1.8 GeV
New Quadrupoles magnetic length : 0.285 m bore radius : 13 mm maximum int. grad.: 7.7 T	0.6 ÷ 4	1 ÷ 5
Old Quadrupoles magnetic length : 0.495 m bore radius : 25 mm maximum int. grad.: 11 T	0.8 ÷ 3	1.2 ÷ 5

Steering Magnets

Eight combined vertical and horizontal steering magnets are foreseen to correct the trajectory along the line. Specifications for the steerers are presented in Table 3.

Table 3: Steering Magnets Parameters

8 combined H&V steerers	@1.2 GeV	@1.8 GeV
Maximum kick (mrad)	0.6	0.6
Integrated field (mT m)	2.4	3.6

Power Supply Requirements

At the aim to have a stable beam trajectory and a safe electron transport along the line up to the dump, the requested power supply stabilities for the magnetic components were calculated and reported in Table 4.

Table 4: Power Supply Stability (rms values)

	$f \geq 1$ Hz	$f < 1$ Hz
Bending Magnets	0.02%	0.05%
Quadrupoles	0.01%	0.05%
Steering Magnets	0.01%	0.02%

Alignment Tolerances

Trajectory corrections simulations were performed to compute the alignment tolerances of quadrupoles and bending magnets (Table 5).

Table 5: Alignment Magnet Tolerances (rms values)

	Δx, Δy	$\Delta\theta$, $\Delta\varphi$, $\Delta\psi$
Bending Magnets	200 µm	100 µrad
Quadrupoles	200 µm	100 µrad

Diagnostics Equipment

The diagnostic tools needed to monitor the beam parameters are:

- 6 beam position monitors for trajectory monitoring and corrections
- 3 fluorescence screens, two located downstream the first quadrupoles of FEL1 and FEL2 lines. These screens will be used for beam emittance measurements with the quadrupole scanning method. The third screen will be installed at the end of the MBD line for energy spread measurements.
- 3 current transformers: two of them at the beginning of FEL1 and FEL2 lines and the third at the end of MBD line. The transformers will monitor the beam current. The difference between the current values at the line entrance and exit will indicate the total beam loss along the line.

CONCLUSION

The Main Beam Dump TL design has been presented. The line will be used to measure the major beam characteristics such as emittance, energy spread and jitter. A flexible optics is needed to fulfil the beam measurement requirements and operations modes. For this reason different optics have been studied for beam tests and normal operation. The line installation will be completed at the middle of 2010. Testing of the transfer line components and the beam commissioning are foreseen in august 2010.

REFERENCES

[1] The MAD-X Program. User's Reference Manual.