Status of ultra-low beta optics proposal at ATF2 for ILC and CLIC

Edu Marin
emarinla@slac.stanford.edu

FJPPL-FKPPL Workshop on
ATF2 Accelerator R&D

February 11^{st}, 2013
LAL, Orsay (France)

Motivation

ATF2 is meant to demonstrate the feasibility of the FFS based on the local chromaticity correction scheme

To this end, 2 lattices have been designed:

- **ATF2 Nominal lattice**: it is the scale-down version of the ILC FFS
- **ATF2 Ultra-low β^* lattice**: it is an even pushed β-optics lattice in order to reach a chromaticity comparable to that one of CLIC

Ideal Lattice	β_x^*	σ_x^*(rms)	β_y^*	σ_y^*(rms)	ξ_y
	[mm]	[μm]	[μm]	[nm]	[]
Nominal	4	3.2	100	37	≈10000
Ultra-low β^*	4	3.2	25	22	≈40000

As a result of intense work in 2012, ATF2 is getting closer to its first goal (**37 nm**) *

Experiencing with a higher chromaticity lattice would be very useful for both ILC & CLIC projects

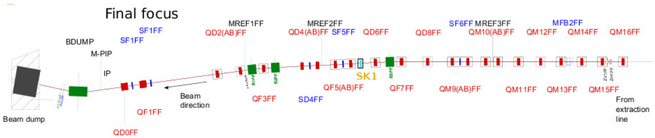
* **ATF2 recent results**, presented by Dr. Glen White on Thursday during the Collaborations on Low Emittance Session

MULTIPOLE COMPONENTS OF ATF2 MAGNETS

Multipole components

The FFS of ATF2 is composed of 3 bending, 22 quadrupoles, 5 normal and 4 skew sextupoles magnets

Up to the 18^{th}-pole component of the FFS magnets are included into the model



Lattice	β_y^* [μm]	σ_y^* [nm] (Mults OFF)	σ_y^* [nm] (Mults ON)
Nominal	100	37	**67**
Ultra-low β^*	25	22	**80** †

- the 6-pole and 12-pole components of QF1FF are the most important contributors to the evaluated $\Delta\sigma_y^*$ for the ATF2-NL
- in addition, the 6-pole component of QD0FF notably increases σ_y^* for the ATF2-UL

† R. Tomás, H. Braun, J.P. Delahaye, E. Marín, D. Schulte, F. Zimmermann, "ATF2 Ultra-Low IP Betas Proposal", Proceedings of PAC09, Vancouver, May 2009, pp. 2540-2542

REPLACEMENT OF QF1FF

Replacement of QF1FF

In September 2012 it was proposed to replace the QF1FF magnet by a re-cycled PEPII quadrupole

	Unit	PEPII	QF1FF
Bore radius	[mm]	50	25
Iron length	[mm]	430	450
Total width	[mm]	646	450
Total height	[mm]	617	450
Weight	[Kg]	1181	400

Field quality of both quadrupole magnets (*tolerance:* $\Delta\sigma_y^* \leq$ *2%*).

@ R=2 cm	Normal relative multipole component $[10^{-5}]$			
	Sextupolar	Octupolar	Decapolar	Dodecapolar
Tolerance	**30**	**12**	**11**	**3.1**
QF1FF	54	23	100	560
PEPII	-2.3	0.76	-0.12	-1.2
PMM	-3.9	3.4	-0.13	-0.7

@ R=2 cm	Skew relative multipole component $[10^{-5}]$			
Tolerance	**0.8**	**2.1**	**0.6**	**1.9**
QF1FF	2.8	0.9	7.6	6.1
PEPII	0.3	0.9	0.3	-0.1
PMM	6.4	0.3	0.6	0.3

QF1FF field quality

The PEPII magnet was installed in November 2012

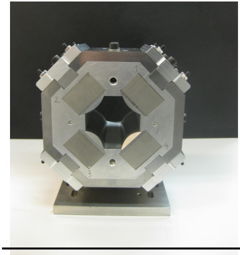
ATF2 lattices optimization

Obtained σ^* when replacing QF1FF by the LER quadrupole and optimizing the sextupoles:

ATF2 Nominal lattice	ATF2 Ultra-low lattice
$\sigma_x^* = 3.2\ \mu$m	$\sigma_x^* = 3.2\ \mu$m
$\sigma_y^* = 37$ nm	$\sigma_y^* = 31$ nm

To further reduce σ_y^* of the ATF2 Ultra-low β^* lattice it would be required to replace QD0FF:

- by PEPII: $\sigma_x^* = 3.2\ \mu$m $\sigma_y^* = 27$ nm
- by PMM [‡]: $\sigma_x^* = 3.3\ \mu$m $\sigma_y^* = 26$ nm



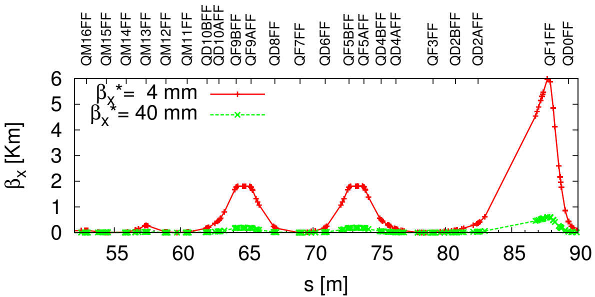
Permanent Material Magnet:
Aperture: 40 mm
Dimensions (h-w-l): 220x220x455 mm
Effective length: 474 mm
Gradient: 6.8 T/m
Tuning: 13%

[‡] A. Vorozhtsov et al. Design, manufacture and measurements of permanent quadrupole magnets for Linac4, Presented at MT-22, September 2011

MODIFYING THE OPTICS

Increasing β_x^*

Alternatively the impact of the multipole components can be reduced by increasing the β_x^*



The obtained σ_y^* when increasing β_x^* a factor 10, are:

ATF2 10Bx1.0By lattice[§]	ATF2 10Bx0.25By lattice
$\sigma_y^* = 36$ nm	$\sigma_y^* = 23$ nm

[§] This lattice was used during the last ATF2 run in December 2012

TUNING OF ATF2 LATTICES

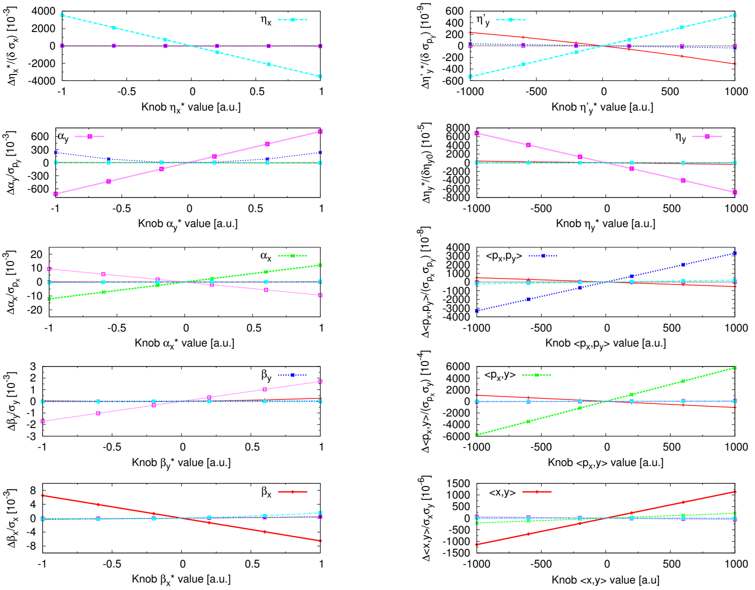
Tuning

- Tuning is the process of bringing the machine to its design performance under realistic error conditions
- The strategy for tuning the ATF2 lattices is based on a set of 10 linear $\perp$-knobs meant correct for the most important IP beam size aberrations (**waist shift, dispersion, coupling**)
- 100 simulated different machines with errors randomly assigned according to a Gaussian distribution of width σ_{error} are simulated

Error	σ_{error}
Transverse misalignments	30 μm
Transverse rotations	300 μrad
Magnet miss-powerings	10^{-4}

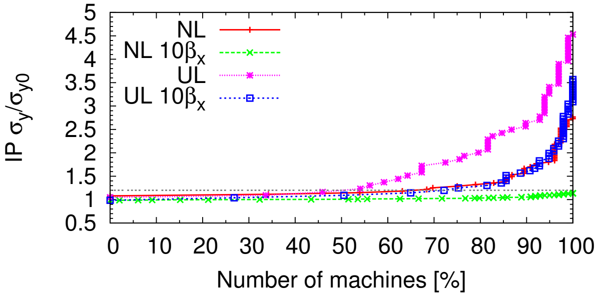
- The knobs are combinations of sextupole transverse displacements
- The tuning algorithm iteratively scans the knobs to bring σ^* to its design value

The designed knobs are: $\langle x, y\rangle$, $\langle p_x, y\rangle$, $\langle p_x, p_y\rangle$, η_y, η_{py}, α_x, α_y and η_x



Tuning Results

Confidence level for ATF2 lattices and the corresponding $10\beta_x$ lattices:



ATF2 Lattice	# machines with $\sigma^*_y/\sigma^*_{y_0} < 1.2$
Nominal	66
10Bx1.0By	100
Ultra-low	52
10Bx0.25By	73

Significant improvement of the tuning performance for the relaxed β_x optics for both lattices

CONCLUSIONS

Conclusions and future work

- Replacing the QF1FF magnet represented a step forward for the ATF2 lattices
- For the ATF2 Ultra-low β^* lattice we need to replace QD0FF to reach σ_y^*=27/26 nm by PEPII/PMM
- Alternatively increasing 10 β_x^* leads to a satisfactory design of both ATF2 lattices
- Satisfactory tuning results are obtained for the Nominal and $10 \cdot \beta_x^*$ optics
- but not for the ATF2 Ultra-low β^* lattice

Follow up:

- Improve the tuning performance of the ATF2 Ultra-low β^* lattice by designing non-linear tuning knobs based on the available skew sextupole magnets
- What is the number of means of replacing QD0 either by a PEPII magnet or PMM...?