Status of ATF2 Lattices: From Nominal to Ultra-low beta*

Edu Marin*
emarinla@slac.stanford.edu

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ATF

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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 challenge β-optics with a chromaticity comparable to that one of CLIC

Ideal Lattice	β_x^*	σ_x^*(rms)	β_y^*	σ_y^*(rms)	L^*	$\xi_y \approx \frac{L^*}{\beta_y^*}$
	[mm]	[μm]	[μm]	[nm]	[m]	[]
ATF2 Nominal	4	3.2	100	37	1.0	≈10000
ILC ($E_{\mathrm{CM}} = 0.5$ TeV)	11	0.474	480	5.9	3.5	≈7300
ATF2 Ultra-low β^*	4	3.2	25	22	1.0	≈40000
CLIC ($E_{\mathrm{CM}} = 3$ TeV)	7	0.04	67	1.1	3.5	≈50000

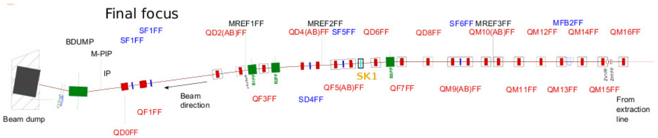
Both ILC & CLIC projects would benefit from experiencing with a higher chromaticity lattice

† **ATF2 Ultra-Low IP Betas Proposal**, Bambade, P. *et al*, CLIC-Note-792 (2009)

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



ATF2 Lattice	β_y^* [μm]	σ_y^* [nm] (Mults OFF)	σ_y^*(rms) [nm] (Mults ON)	σ_y^* (Shi) [nm] (Mults ON)
Nominal	100	37	67	45
Ultra-low β^*	25	22	80 ‡	42

- 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

It was proposed to replace the QF1FF magnet by a 4Q17 from PEP-II

	Unit	4Q17	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

@ R=2 cm	Normal relative multipole component [10^{-5}]			
	Sextupolar	Octupolar	Decapolar	Dodecapolar
Tolerance[§].	30	12	11	3.1
QF1FF	54	23	100	560
4Q17	-2.3	0.76	-0.12	-1.2
	Skew relative multipole component [10^{-5}]			
Tolerance	0.8	2.1	0.6	1.9
QF1FF	2.8	0.9	7.6	6.1
4Q17	0.3	0.9	0.3	-0.1

[§] Each tolerance represents a $\Delta\sigma_y^* = 2\%$

QF1FF field quality

The 4Q17 magnet was installed in November 2012

The motion capabilities of the QF1FF mover have been preserved thanks to a clever engineering design by the ATF staff

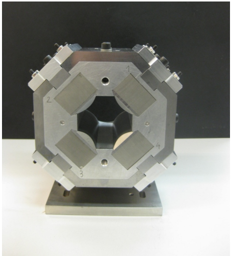
ATF2 lattices optimization

Obtained σ^* when replacing QF1FF by the 4Q17 quadrupole:

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

Cern has designed a quadrupole based in Permanent Magnet technology [¶]



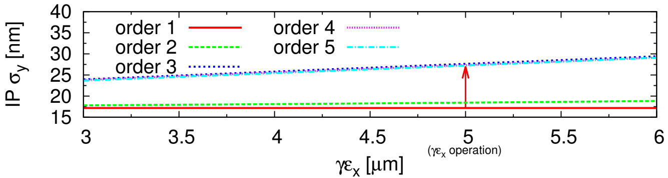
Permanent Material Magnet:
Aperture: 40 mm
Dimensions (h-w-l): 220x220x455 mm
Effective length: 474 mm
Gradient: 6.8 T/m
Tuning: 13%

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

ATF2 Ultra-low β^* lattice with PM QD0FF

@ R=2 cm	Normal relative multipole component $[10^{-4}]$			
	Sextupolar	Octupolar	Decapolar	Dodecapolar
Tolerance[‖]	0.2	2.5	26.3	190
QD0FF	3.7	1.8	5.2	56
PM	0.8	2.5	3.2	8.0
	Skew relative multipole component $[10^{-4}]$			
Tolerance	0.3	3.8	32.0	230
QD0FF	3.5	1.1	2.56	3.5
PM	0.1	0.3	0.5	1.3

Assuming the multipole components of the new PM QD0FF design:



ATF2 Ultra-low lattice with 4Q17 (QF1FF) and PM (QD0FF):

$\sigma_x^* = 3.2\ \mu m$ $\qquad$ $\sigma_y^* = 26$ nm (*19 nm assuming* $\Delta p/p = 0$)

⇓

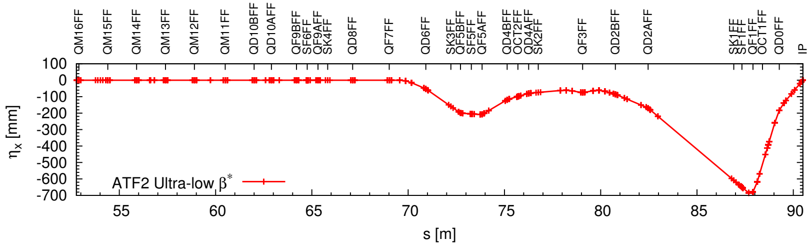
chromatic octupole aberration

‖ QD0FF Tolerances for CLIC, see talk by Y. Inntjore *CLIC QD0 field quality requirements*

OCTUPOLE MAGNETS

Octupole correction

2 octupole magnets (thin lenses) are inserted in the middle of SD0 (OCT1FF) and SD4FF (OCT2FF) dispersive and non-dispersive location



QD0FF	KLOCT1FF	KLOCT2FF
	[m^{-3}]	[m^{-3}]
Current	-24.16	97.90
PM	-13.37	98.24

B field at R=25mm:
L=0.1m
E=1.3GeV $\Rightarrow$ **B<10**mT
KL=100m^{-3}
R=0.025m

The optimization of the sextupole magnets and the pair of octupole lenses permits to obtain a:

σ_y^* =23 nm (PM-QD0FF) σ_y^* =24 nm (Installed QD0FF)

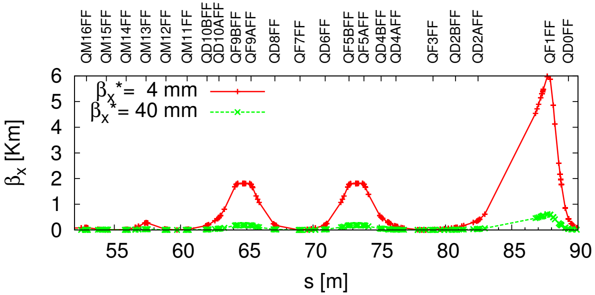
MODIFYING THE OPTICS

Increasing β_x^*

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

Additional benefits:

- bring down the background level
- reduction of tuning difficulties



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 ATF2 run in December 2012 and May 2013 (More details are given by K. Kubo, *ATF2 continuous run in May*

CONCLUSIONS AND FUTURE WORK

Conclusions and Future work

- Replacing the QF1FF magnet represents a step forward for the ATF2 lattices, specially for the Nominal one
- For the ultra-low β^*, the insertion of a pair of octupole magnets allows to reach a smaller beam size than replacing QD0FF magnet
- Increasing β_x^* by a factor 10 leads to a satisfactory design of both ATF2 lattices

Follow up:

- Carry out a more realistic analysis of the octupole magnets (e.g: location, length, multipole components...)