Issues on Beam Optics in the KEKB Rings

MAC2001
2001.2.23

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History of KEKB Optics

LER						HER						
β_x^* / β_y^* (cm)	ε_x (nm)	α 10^{-4}	σ_z (mm)	ν_s	V_c (MV)	β_x^* / β_y^* (cm)	ε_x (nm)	α 10^{-4}	σ_z (mm)	ν_s	V_c (MV)	
100/1	17	1.1	3.4	0.011	5	100/1	18	1.9	4.8	0.013	9	'99 Jun
100/1	29	2.4	5.2	0.016	5	100/1	30	3.4	6.4	0.017	9	'99 Dec
70/0.7	29	2.9	5.6	0.018	5	70/0.7	30	3.4	6.4	0.017	9	'00 Apr
70/0.7	18	2.9	5.6	0.018	5							'00 Jul
70/0.7	19	3.4	5.5	0.021	6	70/0.7	30	4.8	6.2	0.025	13	'00 Oct
						70/0.7	18	4.9	6.9	0.023	11	
						70/0.7	18	3.4	5.7	0.019	11	
						70/0.7	30	3.4	5.7	0.019	11	
63/0.7	19	3.4	5.5	0.021	6	63/0.7	30	3.4	5.7	0.019	11	'00 Nov
						63/0.7	24	3.4	5.7	0.019	11	'00 Dec
						80/0.7	24	24	5.7	0.019	11	
63/0.7	19	3.4	5.5	0.021	6	63/0.7	24	3.4	5.7	0.019	11	'01 Feb

Optimization of beam optics

Horizontal emittance and momentum compaction factor

The horizontal emittance ε_x and the momentum compaction factor α can be optimized independently, by adjusting the horizontal dispersion at dipoles in unit cells.

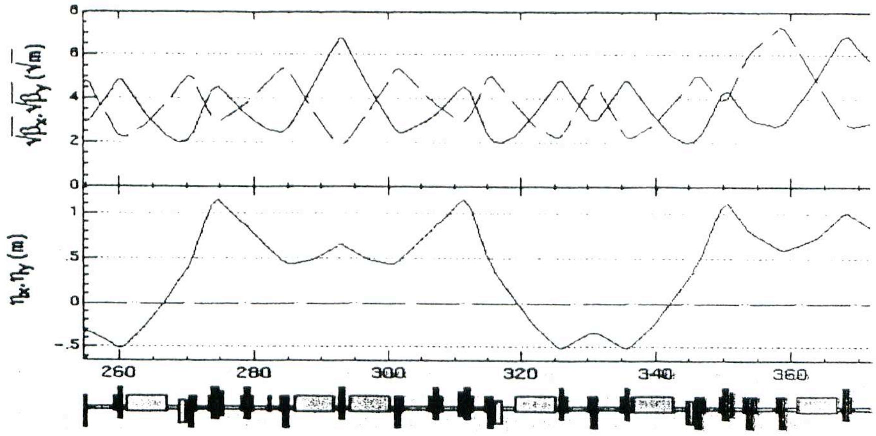
There are seven quadrupole families changeable in the 2.5π unit cells, keeping 6 constraints(4 for the pseudo -*I* conditions between sextupoles, and one each for ε_x and α). Remaining one parameter is utilized to suppress beta beat as small as possible. In general, higher ε_x brings about larger beta beat.

Wiggler magnets in LER are also used for emittance control. The bending radius of the wigglers is almost equal to that of the main dipoles, so the momentum spread is kept unchanged at ON/OFF of wigglers. ε_x can be changed by a factor 2 by adjusting η_x at wigglers. a is also changed at the same time, but remains acceptable value in case ε_x = 30 <-> 18 nm in LER.

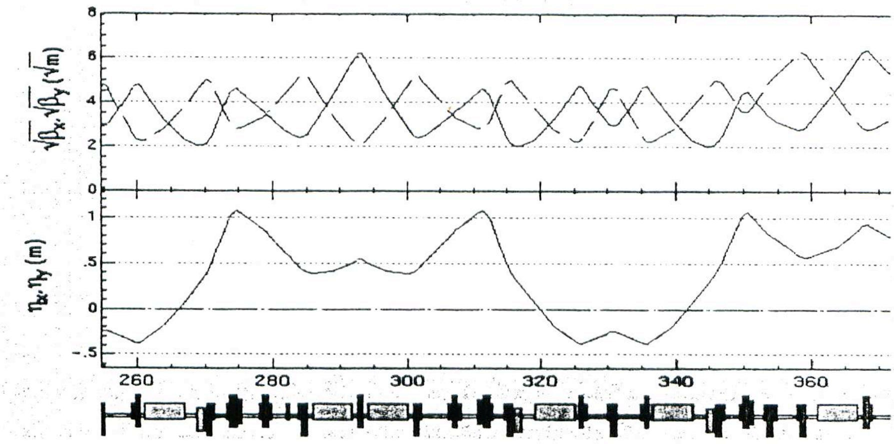
Tune

The betatron tunes can be changed in the range ~ 0.5 by adjusting quadrupoles only in Fuji straight section, keeping conditions for injection and bunch-by-bunch feedback elements.

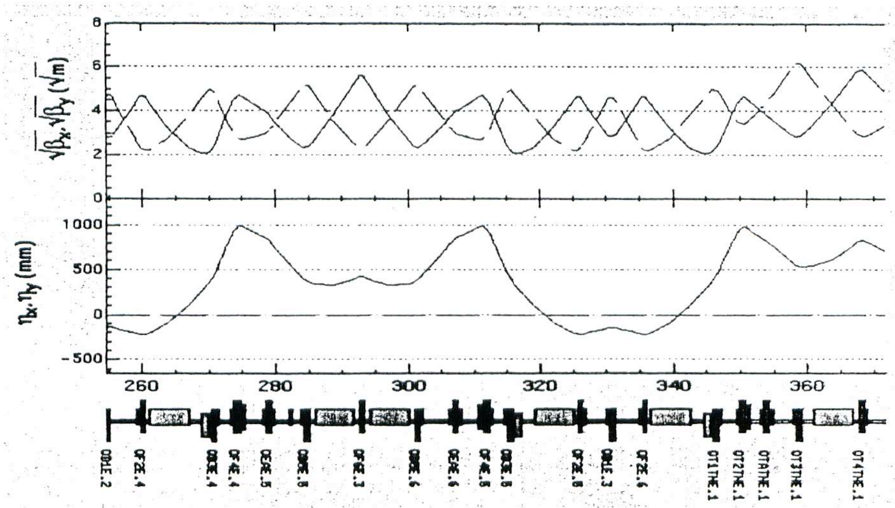
HER normal cell with different ε_x



30 nm



24 nm



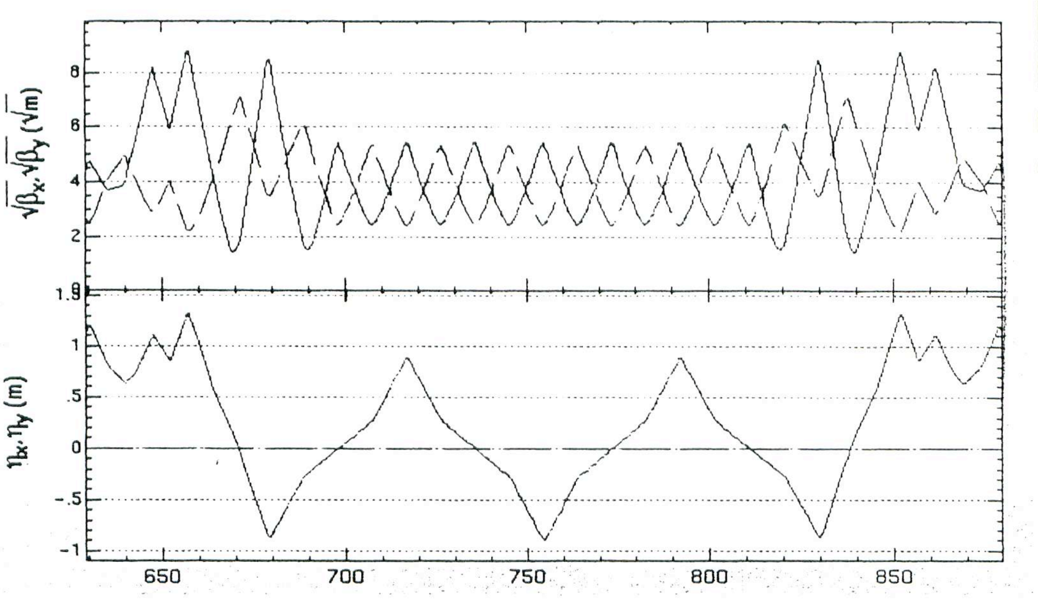
18 nm

Seven quadrupole families in 2.5 π unit cells.

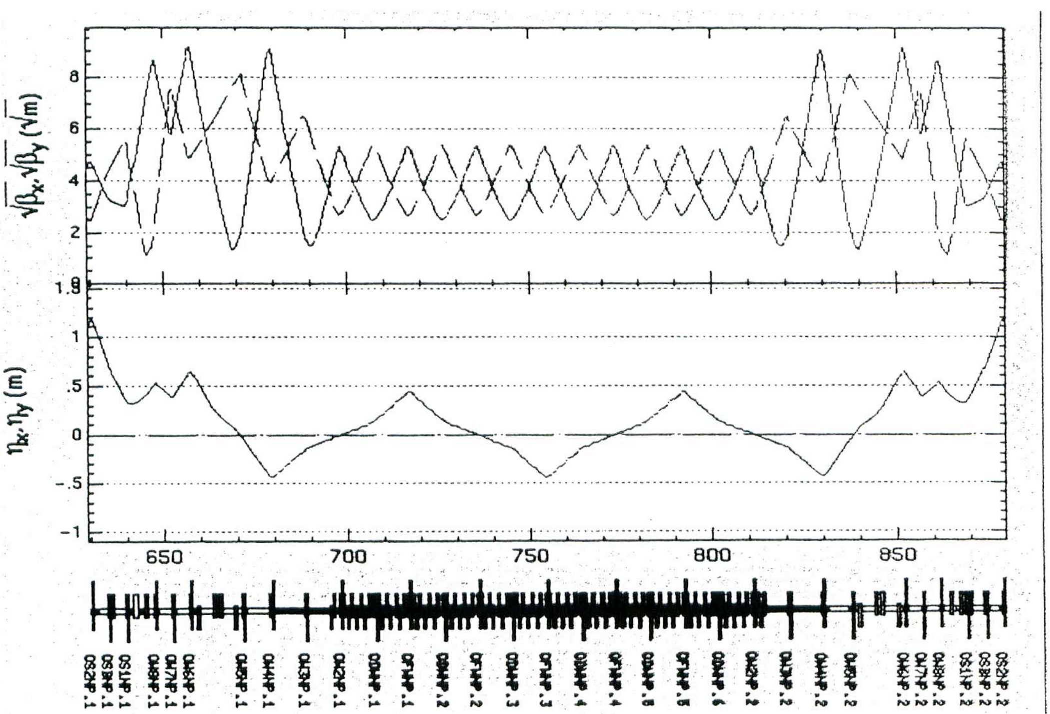
The horizontal emittance and the momentum compaction factor can be optimized independently, by adjusting η_x at dipoles.

The pseudo *-I* conditions between noninterleaved sextupoles are always kept.

LER wiggler section with different ε_X



30 nm



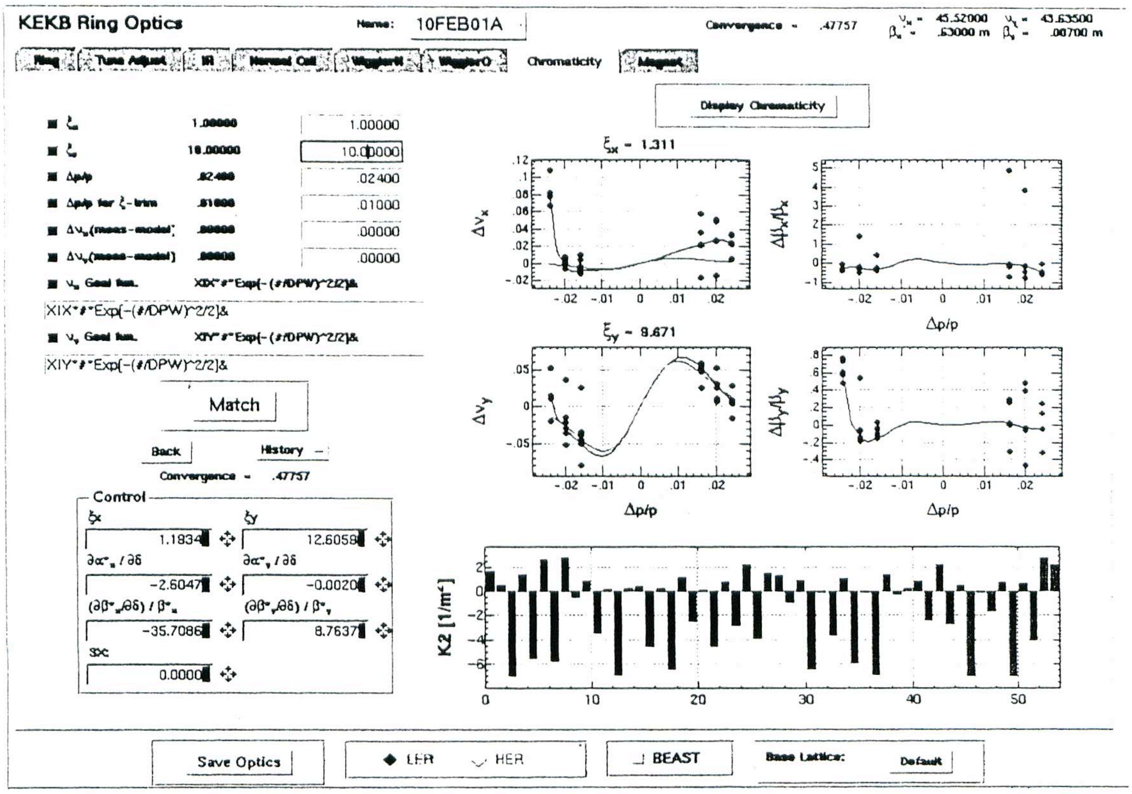
18 nm

<- arc wigglers arc->

Wiggler magnets are placed in Oho and Nikko straight section.

The horizontal emittance can be controlled by adjusting η_X at the wigglers.

Example of chromaticity correction



There are 52 sextupole pairs + 2 pairs for the local correction in LER.

Optics with finite momentum deviations (1-2%) and finite transverse amplitudes are optimized.

In fine tuning, the linear chromaticity and the momentum dependence of Twiss parameters at IP are adjusted using conventional perturbation formulae in order to avoid a rapid change of sextupole strengths.

Optics Correction

The fitting method for beta function was improved. Before mid November last year, however, the number of iteration loops for fitting was too small, so the measured beta deviations were too underestimated.

After increasing the number of iteration, the global beta measurement gives consistent results with the tune measurement and the phase advance measurement by OctoPos in single-pass mode.

At present, the global corrections of beam optics work well.

Residual optics errors at IP can be tuned by local tuning knobs, by trial and error.

The IR optics (in particular, vertical optics of LER) may need more precise correction because bumps are not well localized and consistency between three successive BPMs is poor.

The "golden orbit" determined by optics correction is maintained by continuous closed-orbit correction (CCC) every 20-30 sec.

Under development

Utilization of sextupole mover for optics correction
IP coupling measurement by OctoPos
Correction with single-pass BPMs

Optics correction

global

item	knob
beta function	fudge factors of quadrupole power supplies
dispersion	asymmetric bumps at sextupole pairs
x-y coupling	symmetric bumps at sextupole pairs

local (IP)

item	knob
waist	fudge factors of final quadrupoles (QCSs and QC1s)
dispersion at IP	asymmetric bumps at 2 sextupole pairs closest in each side of IP
coupling parameters at IP	skew quadrupoles
vertical angle at IP (LER)	IP angle bump + asymmetric bumps at the closest pair in each side of IP

New fitting method to derive b functions at BPMs from single-kick orbits

(by N. Akasaka)

An orbit x_{ia} at the i-th BPM kicked by a steering at a is given as

$$\begin{aligned}
x_{ia} &= \frac{\sqrt{\beta_i \beta_a}}{2\sin \pi\nu} \cos(\pi\nu - |\varphi_i - \varphi_a|) \cdot \theta_a \\
&= f_a \sqrt{\beta_i} \cos(\pi\nu - |\varphi_i - \varphi_a|) \\
&= f_a \cos(\pi\nu \pm \varphi_a) \cdot \sqrt{\beta_i} \cos\varphi_i \mp f_a \sin(\pi\nu \pm \varphi_a) \cdot \sqrt{\beta_i} \sin\varphi_i \quad (1) \\
&= \sqrt{\beta_i} \cos(\pi\nu \pm \varphi_i) \cdot f_a \cos\varphi_a \pm \sqrt{\beta_i} \sin(\pi\nu \pm \varphi_i) \cdot f_a \sin\varphi_a \quad (2) \\
&\equiv F(i, \beta_i, \varphi_i, f_a, \varphi_a),
\end{aligned}$$

where

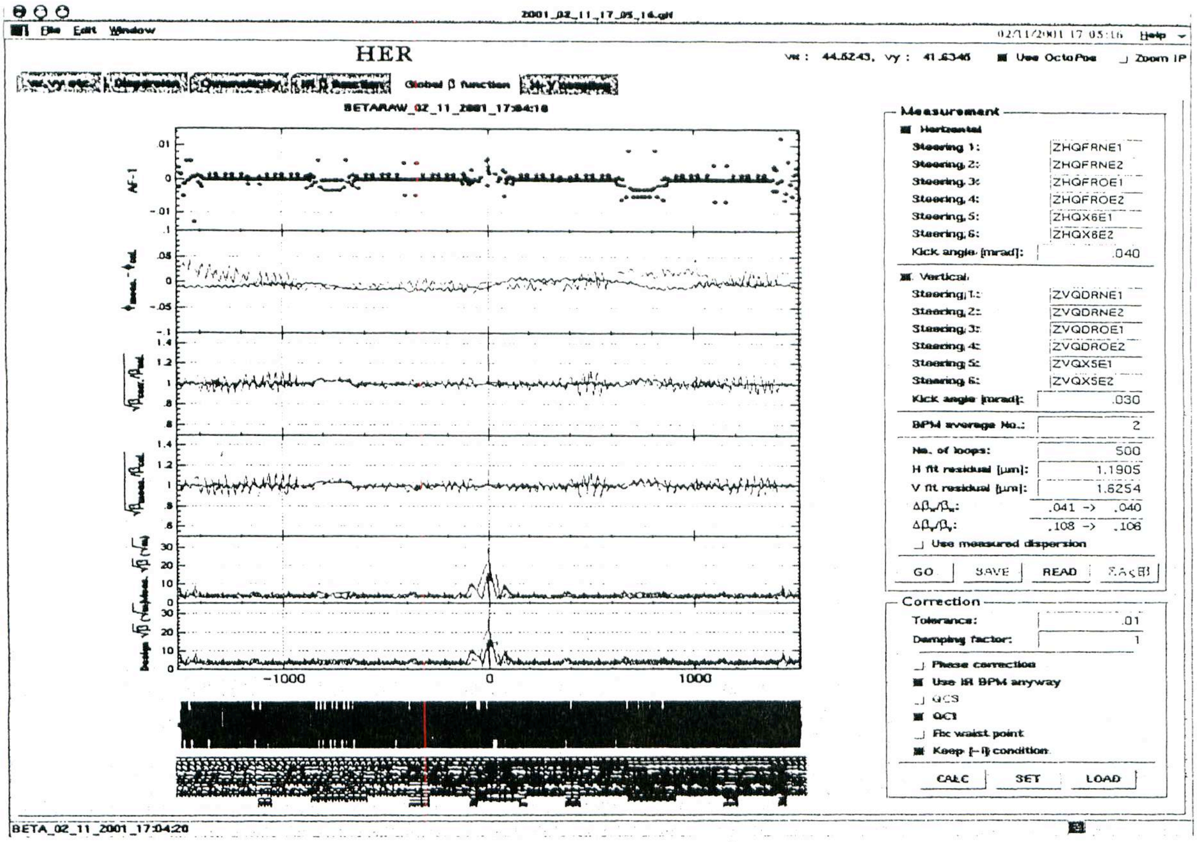
$$f_a \equiv \frac{\sqrt{\beta_a}}{2\sin \pi\nu} \theta_a .$$

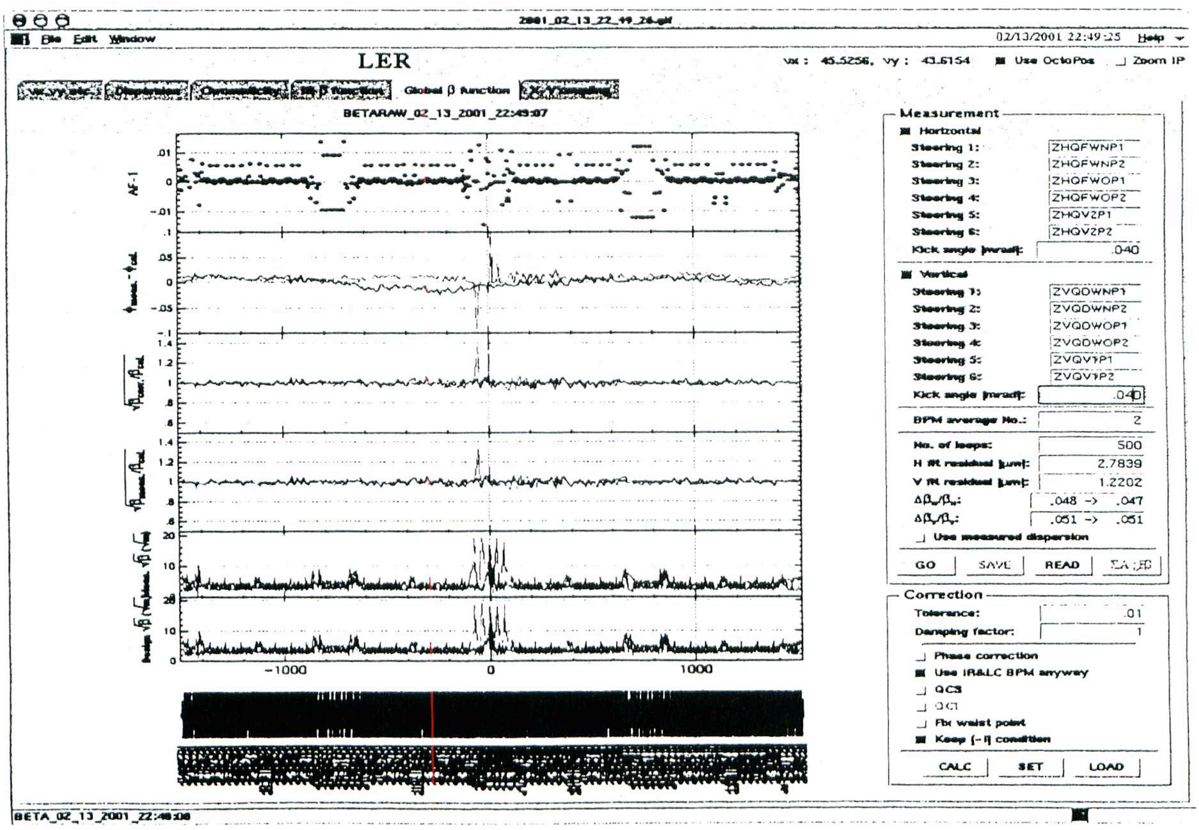
$\beta_i, \varphi_i, f_a, \varphi_a$ are obtained by minimizing a function

$$\chi^2 = \sum_{i,a} \left(x_{meas} - F(i, \beta_i, \varphi_i, f_a, \varphi_a) \right)^2 .$$

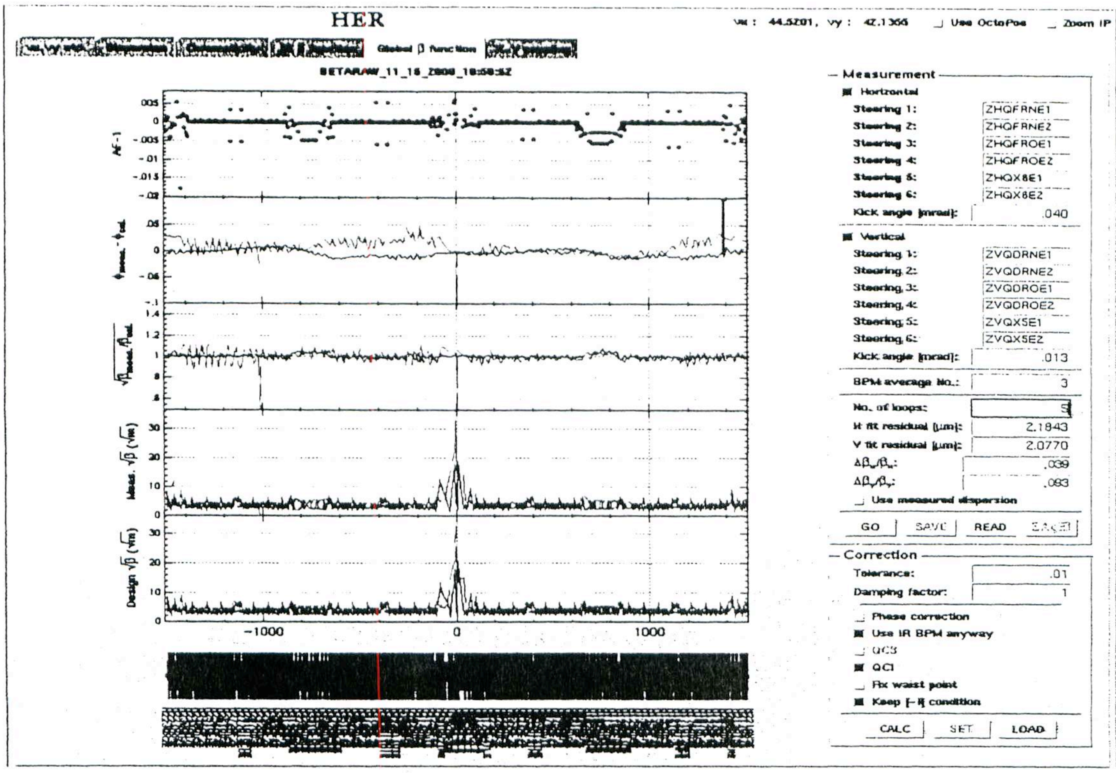
(β_i, φ_i) and (f_a, φ_a) are evaluated using (1) and (2) alternately.

Typical example of global β correction

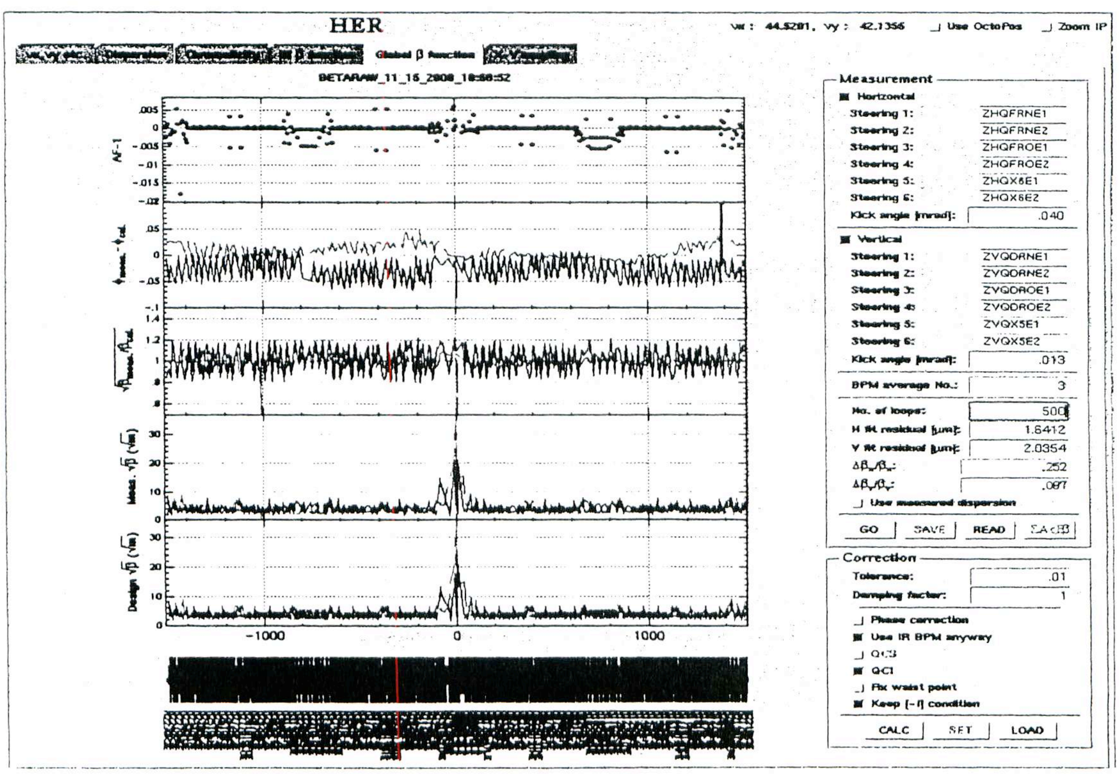




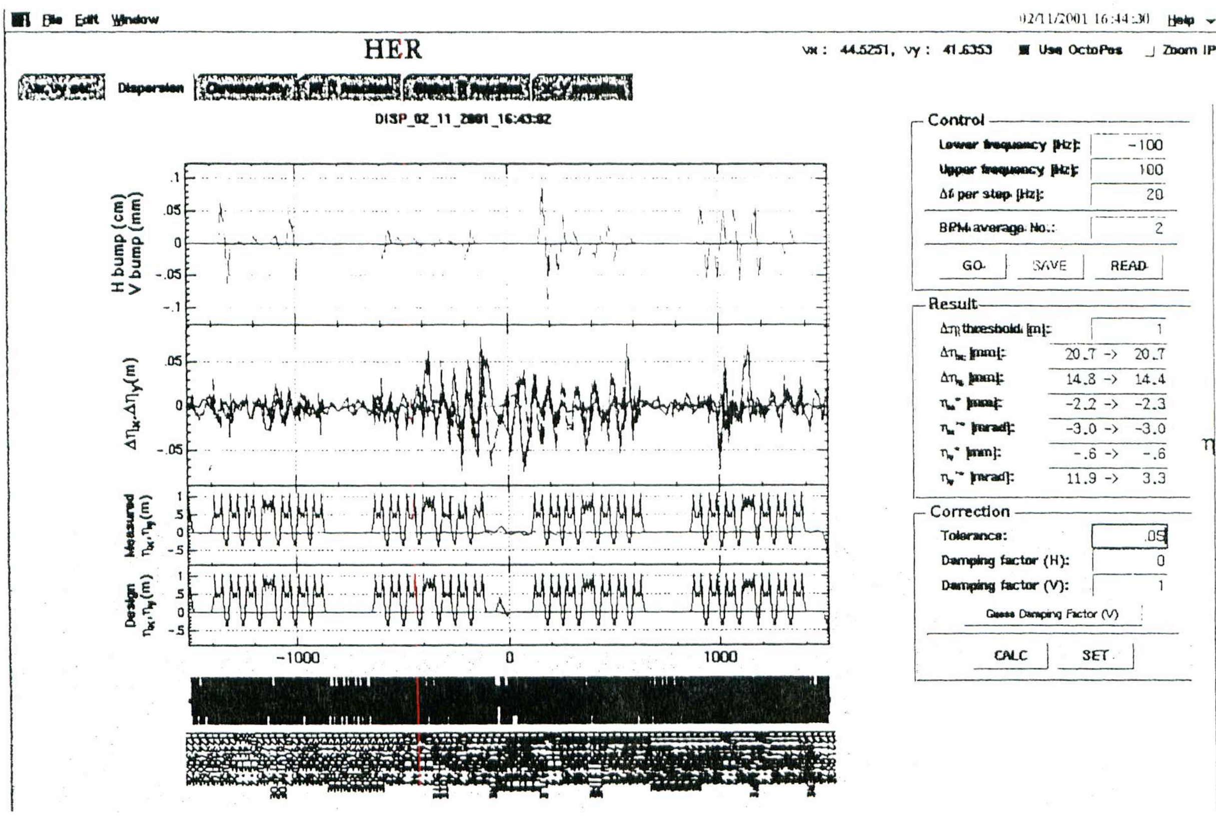
Number of iteration loops = 5



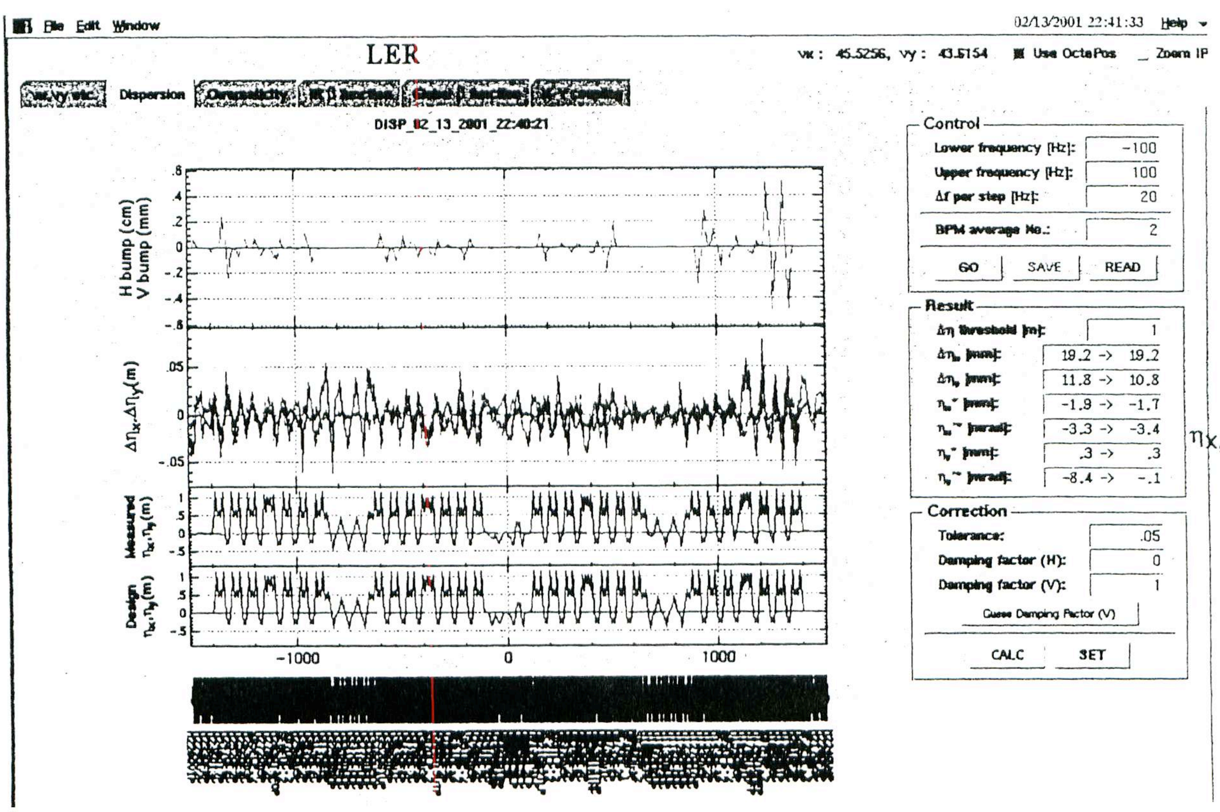
Number of iteration loops = ˜500 (H), a few ×10 (V)



Typical example of global dispersion correction

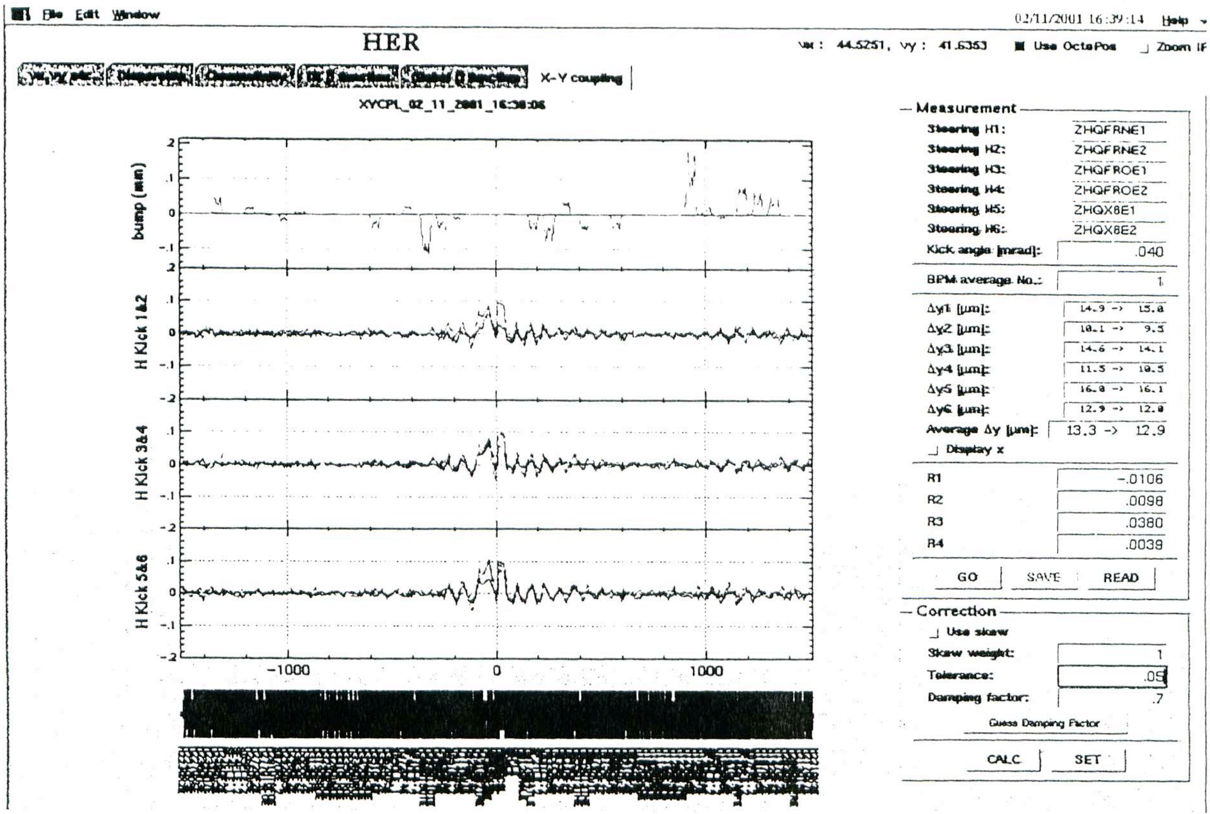


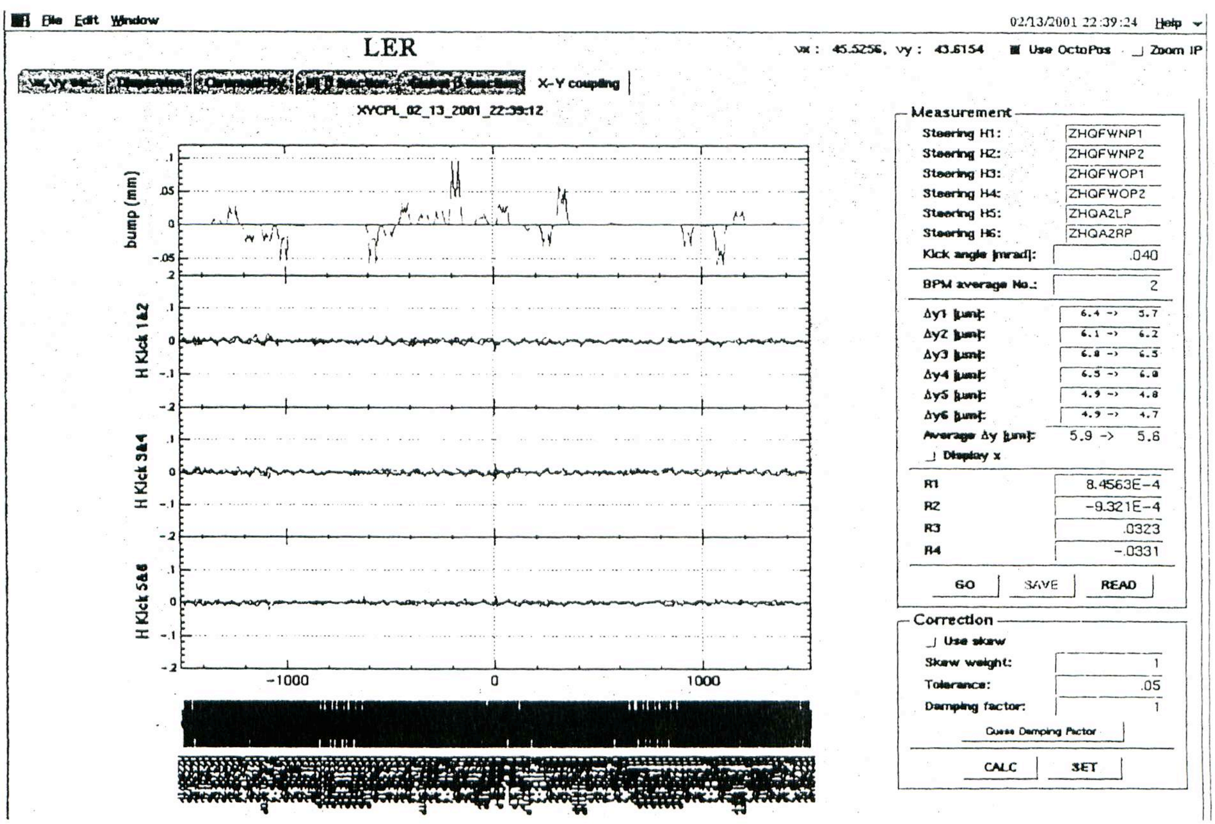
ηx,y @IP

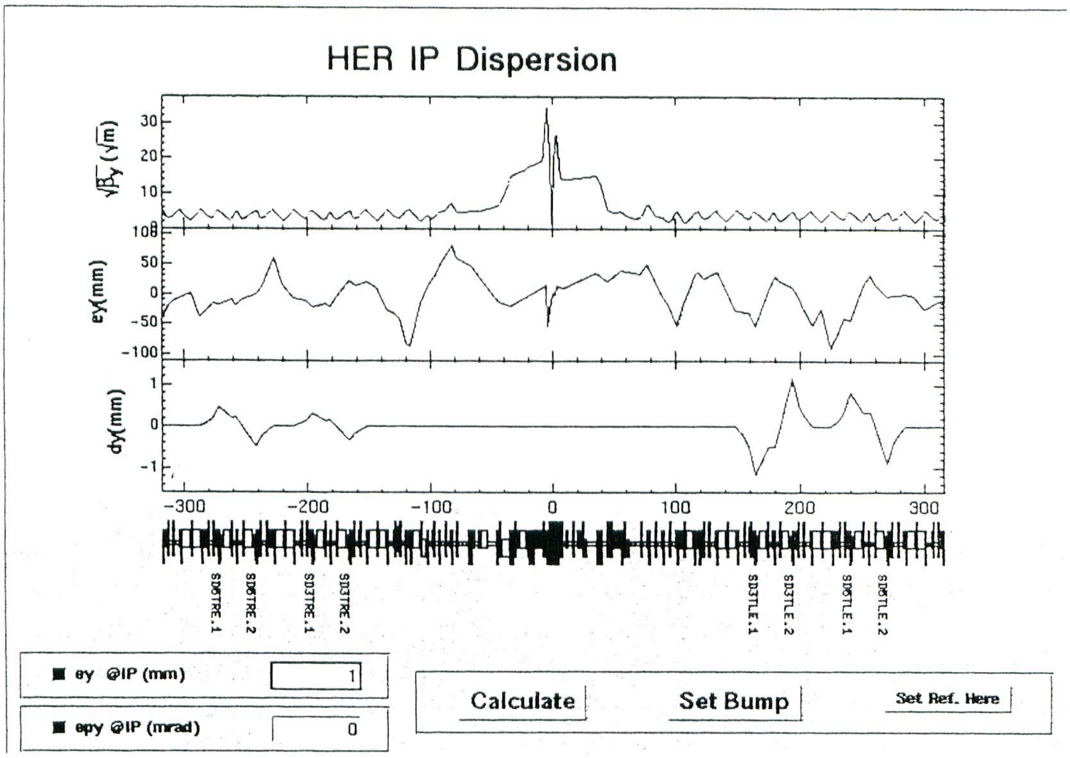


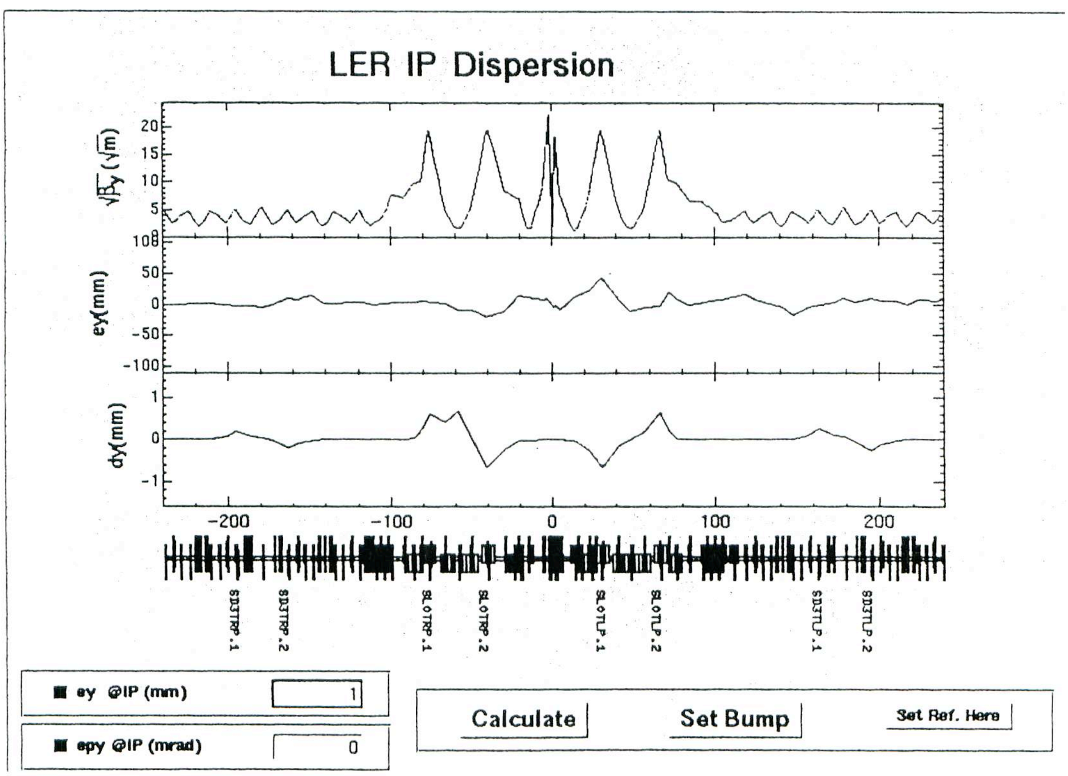
ηx,y @IP

Typical example of global x-y coupling correction






HER IP Dispersion
$\sqrt{\beta_y}$ ($\sqrt{m}$)
30
20
10
0
ey(mm)
100
50
0
-50
-100
dy(mm)
1
0
-1
-300
-200
-100
0
100
200
300
SD6TRE.1
SD6TRE.2
SD3TRE.1
SD3TRE.2
SD3TLE.1
SD3TLE.2
SD6TLE.1
SD6TLE.2
ey @IP (mm)
1
epy @IP (mrad)
0
Calculate
Set Bump
Set Ref. Here


LER IP Dispersion
$\sqrt{\beta_y}$ ($\sqrt{m}$)
20
15
10
5
0
ey(mm)
100
50
0
-50
-100
dy(mm)
1
0
-1
-200
-100
0
100
200
SD3TRP.1
SD3TRP.2
SL0TRP.1
SL0TRP.2
SL0TLP.1
SL0TLP.2
SD3TLP.1
SD3TLP.2
ey @IP (mm)
1
epy @IP (mrad)
0
Calculate
Set Bump
Set Ref. Here