17TH ADVANCED BEAM DYNAMICS WORKSHOP ON
FUTURE LIGHT SOURCES

The Proposed Racetrack Lattice for Third Generation Synchrotron Light Source ASTRID II

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"The proposed Racetrack Lattice for Third Generation Synchrotron Light Source ASTRID II"

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1. Lattice design;
2. The problems of the avoidance of the dynamic aperture reduction in low superperiodical structure;
3. Mechanism of RF phase modulation to increase the life time.

ASTRID is a storage ring used since 1990 as an ion storage ring for atomic physics, and as a synchrotron radiation source.

Inj./Storage energy	100-580 MeV
Emittance	140 nm
Current	150 mA
Lifetime	>30 hours , w/o RF modulation ≈ 15 hours

One undulator (ESRF design, built by DANFYSIK) installed, period 5.5 cm, K< 3

Beamlines:

1) Imaging x-ray microscope, $\lambda = 3$ nm
2) SX-700 monochromator
3) Folding-mirror SGM1 mono (25 mrad)
4) Test beamline
5) UV-1 mono designed

   On undulator:

6) Miyake monochromator
7) SGM2 monochromator
8) SGM3 being built

9) parasitically extracted electron beam

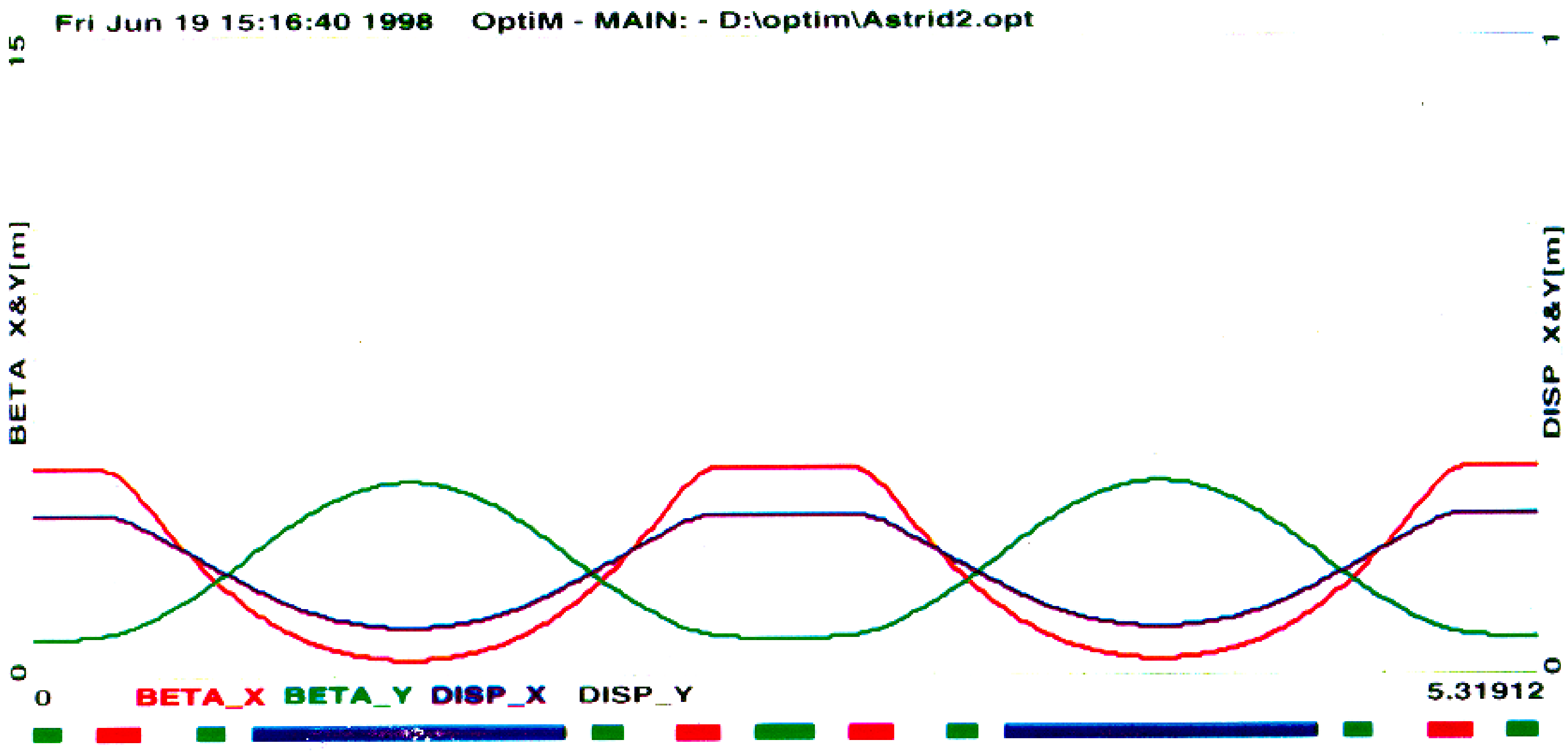
<u>ASTRID II application submitted and the first response is positive!!</u>

What we really want from Synchrotron Light Source:

1. High brightness of the photon beam.
2. Long time of one run ~10 hours
3. Two regimes of work: VUV and SXR

To achieve these parameters we have to have :

1. Small electron emittance ~5-10 nm at 1.4 GeV or 1 nm at 0.6 GeV
2. Sufficiently large dynamic aperture ~ 30-100 mm mrad
3. Long dispersionless straight sections ~3-5 m
4. Long life of electron beam
5. In VUV regime the matching of the electron and photon beam emittances.



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0
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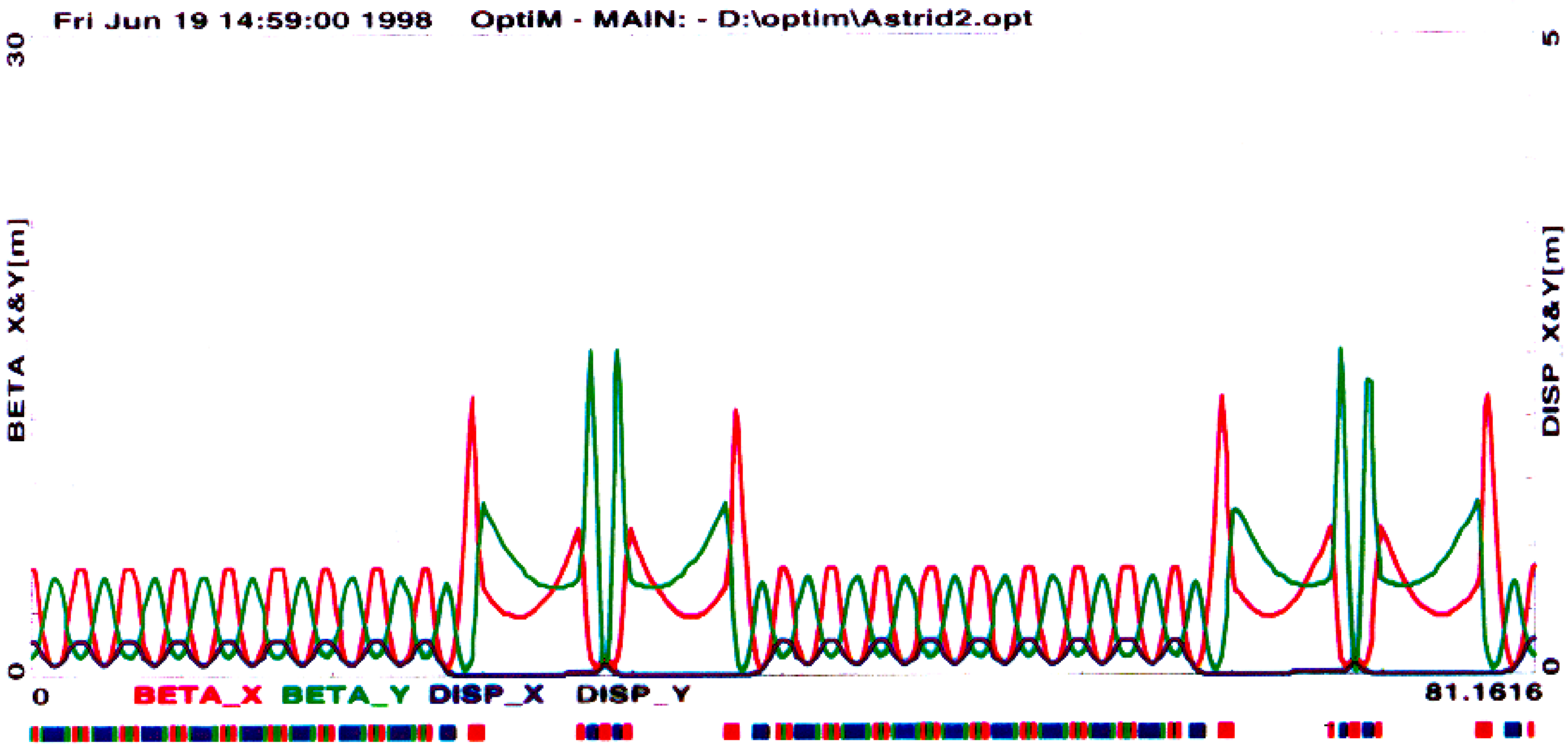
5.31912



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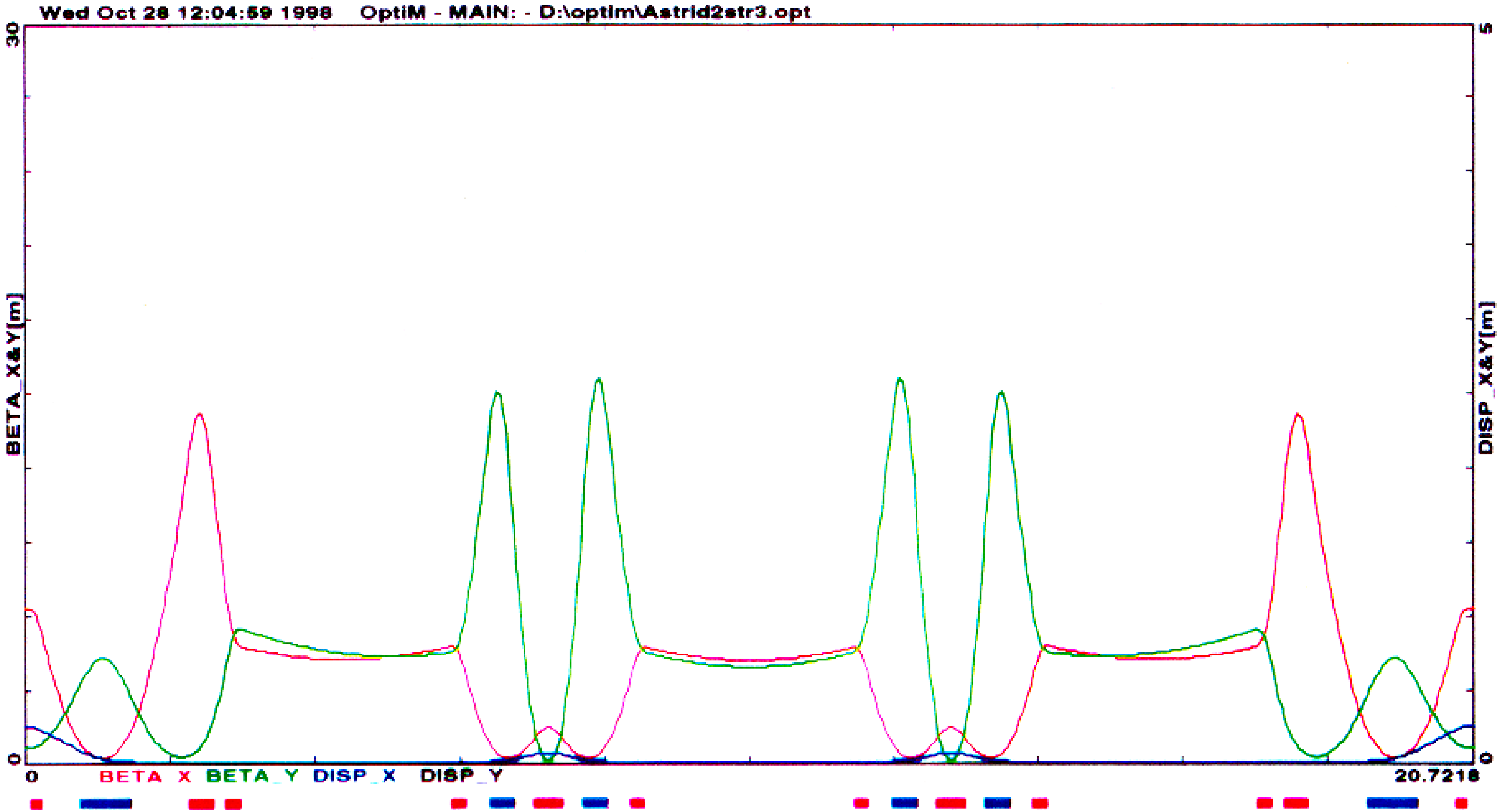
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0
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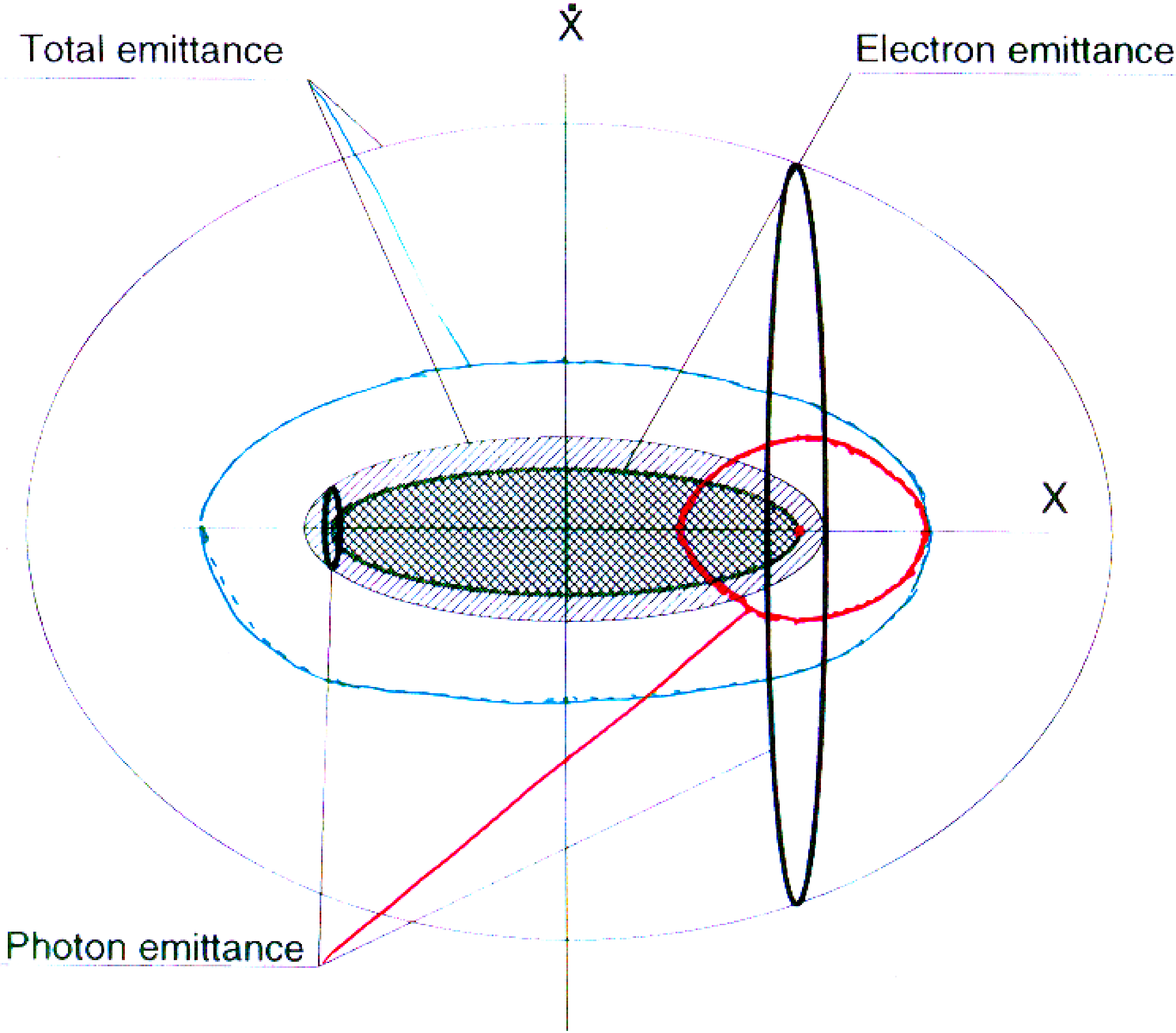
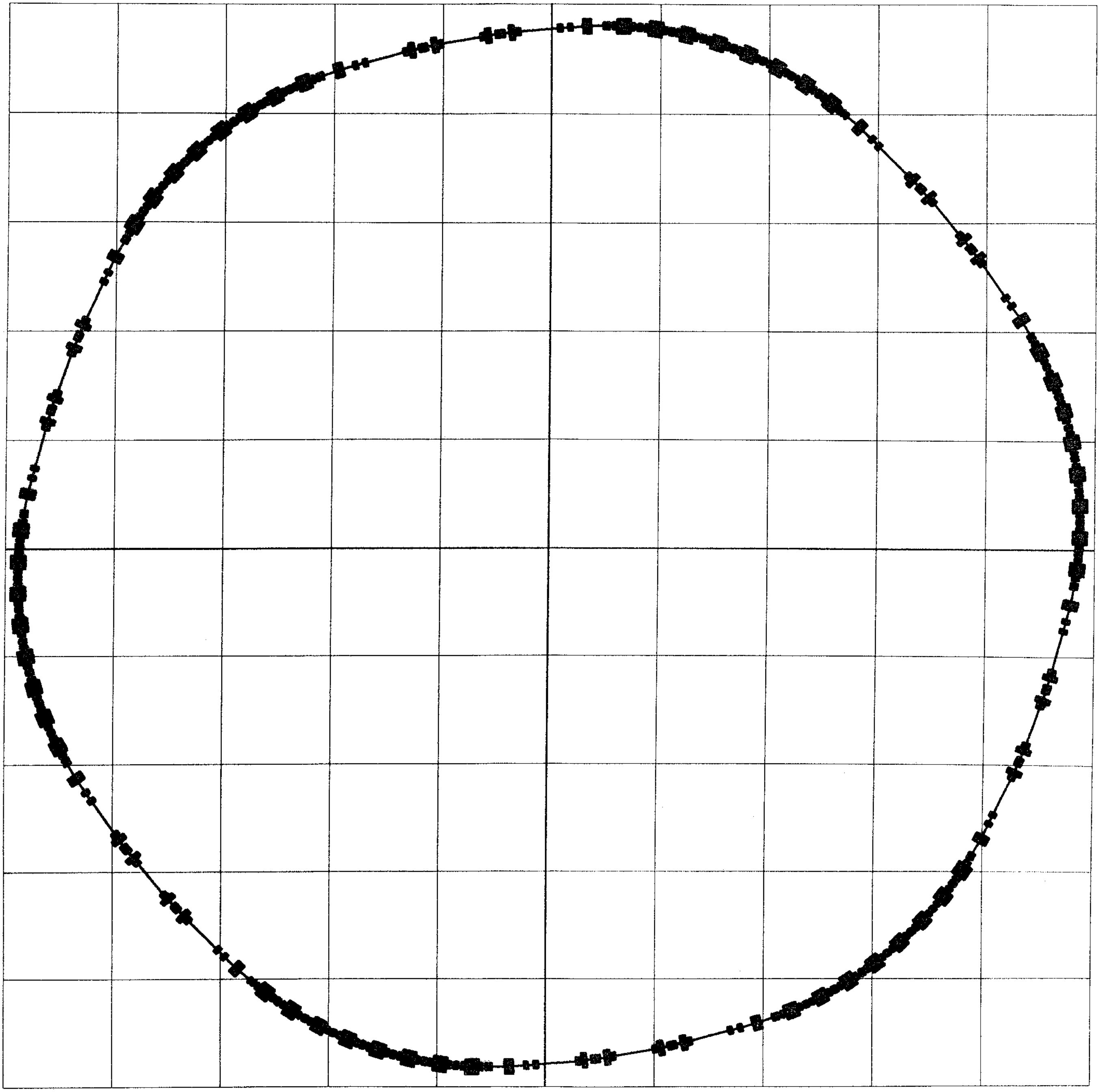


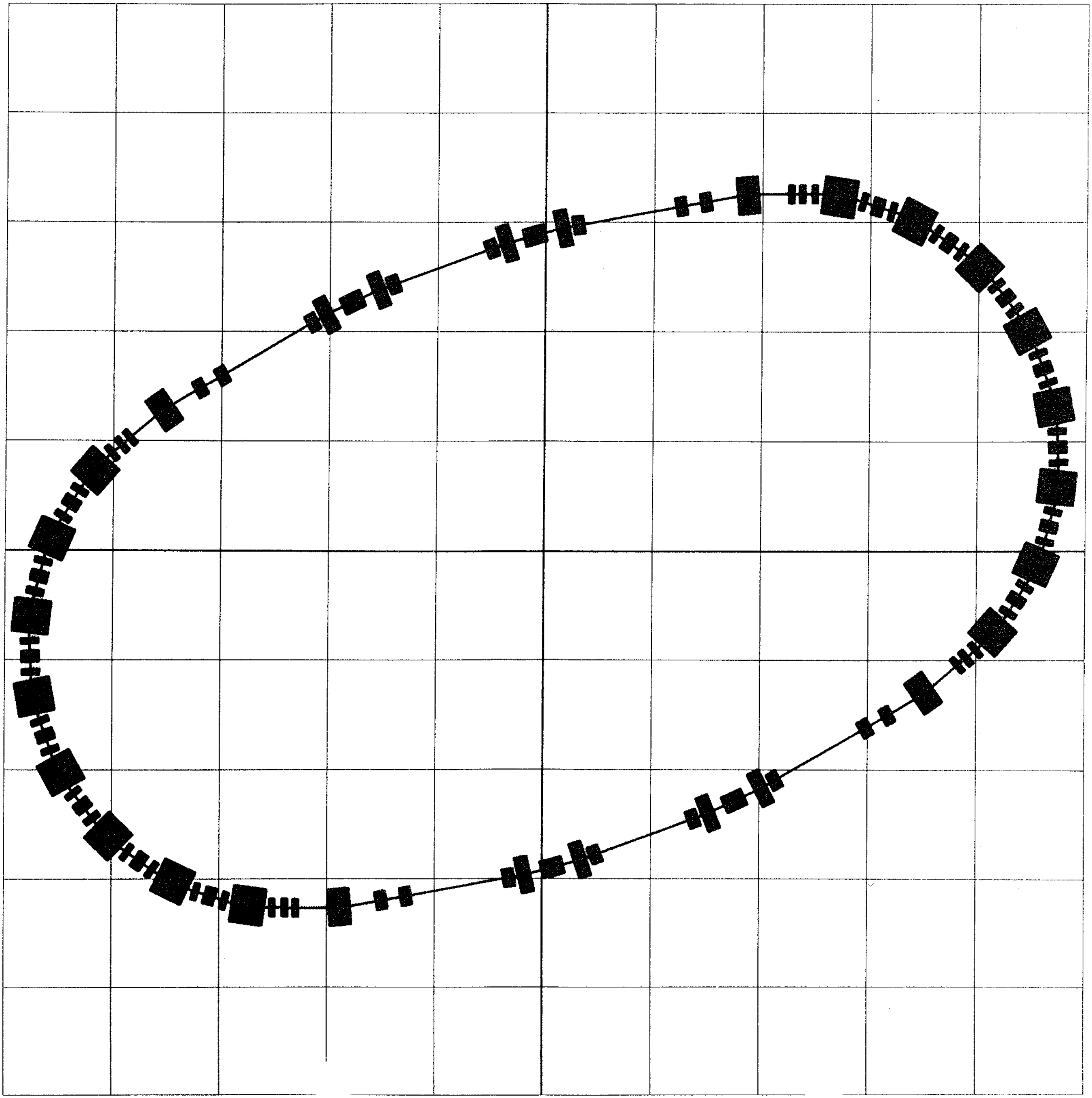
Total emittance
Ẋ
Electron emittance
X
Photon emittance

Plan view of lattice

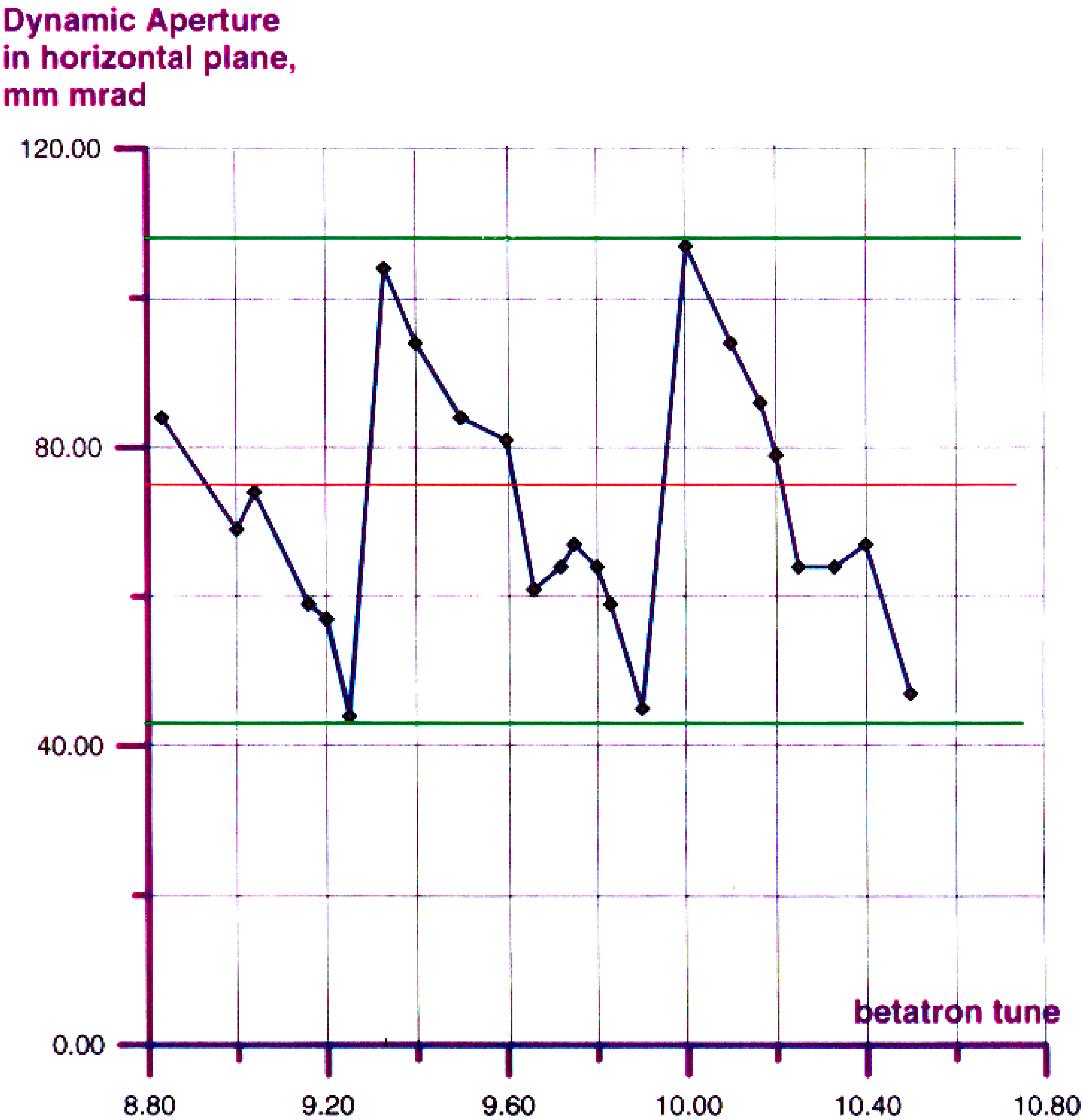


Grid size 7.50 [m]

Plan view of lattice



Grid size 3.00 [m]


Dynamic Aperture
in horizontal plane,
mm mrad
120.00
80.00
40.00
0.00
betatron tune
8.80
9.20
9.60
10.00
10.40
10.80

Sextupole resonances with nonlinear tune shifts:

Hamiltonian of the motion:

$$H(I_x, I_y, \varphi_x, \varphi_y) = \frac{(k_x^2 + k_y^2)^{1/2}}{k_x} \Delta_x I_x + \frac{(k_x^2 + k_y^2)^{1/2}}{k_y} \Delta_y I_y +$$

$$2\langle h_{k_x, k_y, q} \rangle I_x^{k_x/2} I_y^{k_y/2} \cos(k_x \varphi_x + k_y \varphi_y) +$$

$$\zeta_x I_x^2 + \zeta_y I_y^2 + \zeta_{xy} I_x I_y$$

$$\bar{I}_x^{1/2} = -\frac{3 h_{30q} \cos 3\varphi}{8 \zeta_x} \pm \sqrt{\frac{9}{4} h_{30q} - 8 \zeta_x (\Delta + \zeta_{x,y} I_y)} \times \frac{1}{4 \zeta_x}$$

Lattice classification:

1. $\zeta_x << h_{3,0,q}$

2. $\zeta_x \approx h_{3,0,q}$

3. $\zeta_x >> h_{3,0,q}$

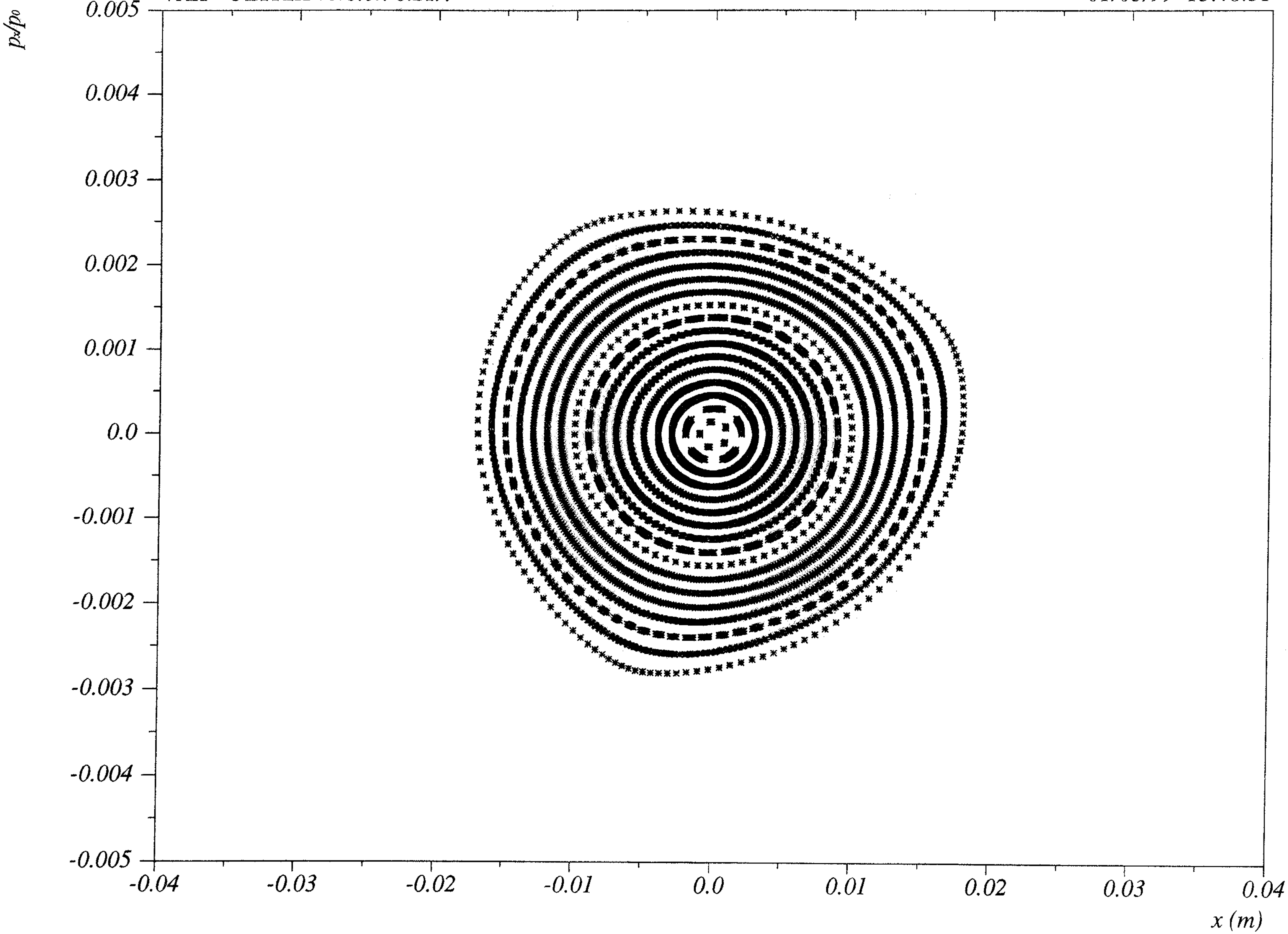
Nekhoroshev's criterium

$$4 \zeta_x \zeta_y \geq \zeta_{xy}^2$$

where $\boxed{\zeta_{x,y} \sim \frac{h_{3,0,q}^2}{\Delta_{arc}}}$

ASTRID 2: Sf is with _jsc, ;d is separated, 2 cell straigth section
VAX - ULTRIX version 8.21/7

01/03/99 15.46.51



$\nu_x = 9.20$

$\xi_x = 0$; $\xi_y = 0$

Table name = TRACK

ASTRID 2: Sf is with Q[illegible] d is separated, 2 cell straigth section
VAX - ULTRIX version 8.21/7

26/02/99 16.32.20

$\nu_x = 9.4$

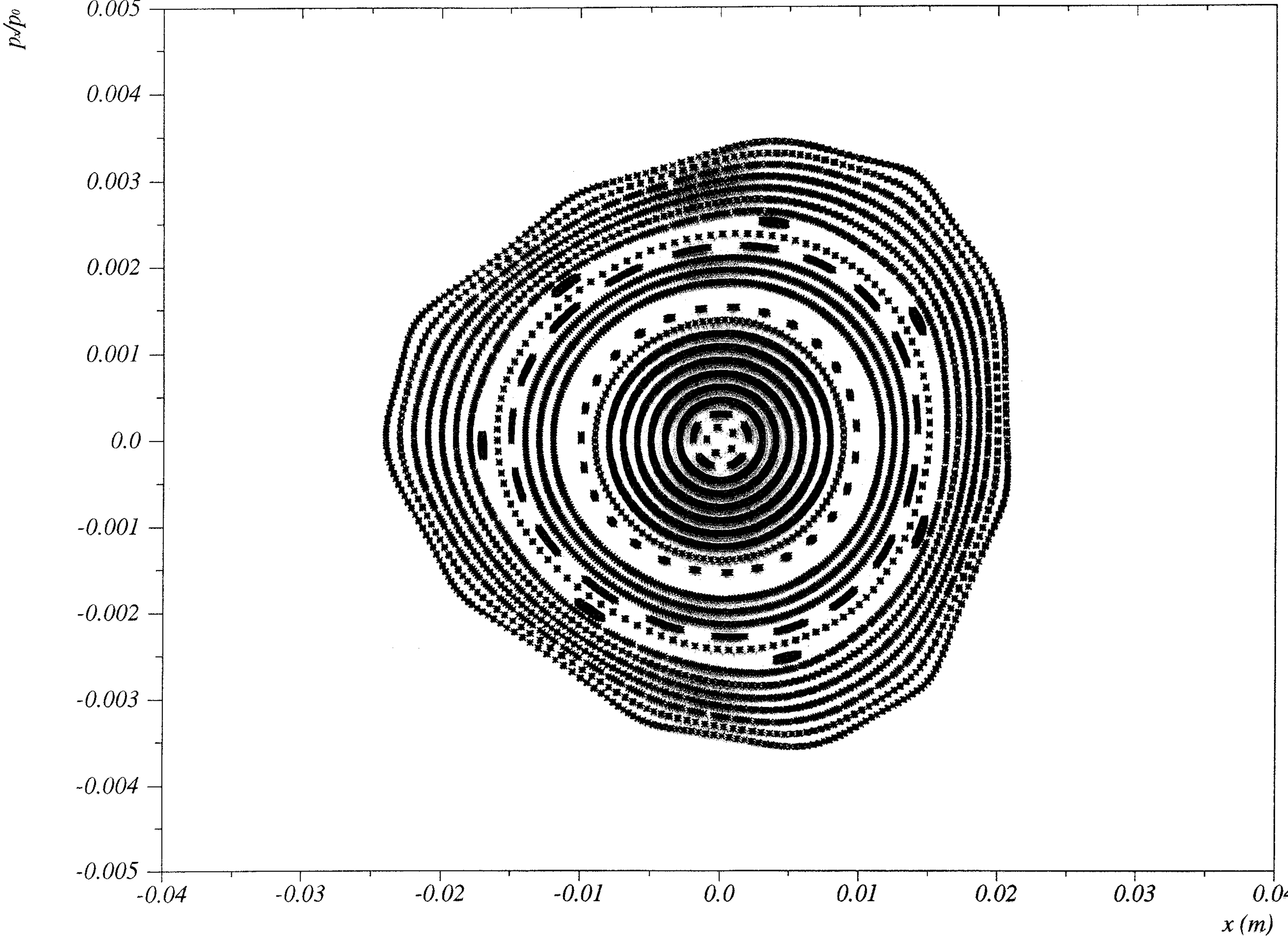


Table name = TRACK

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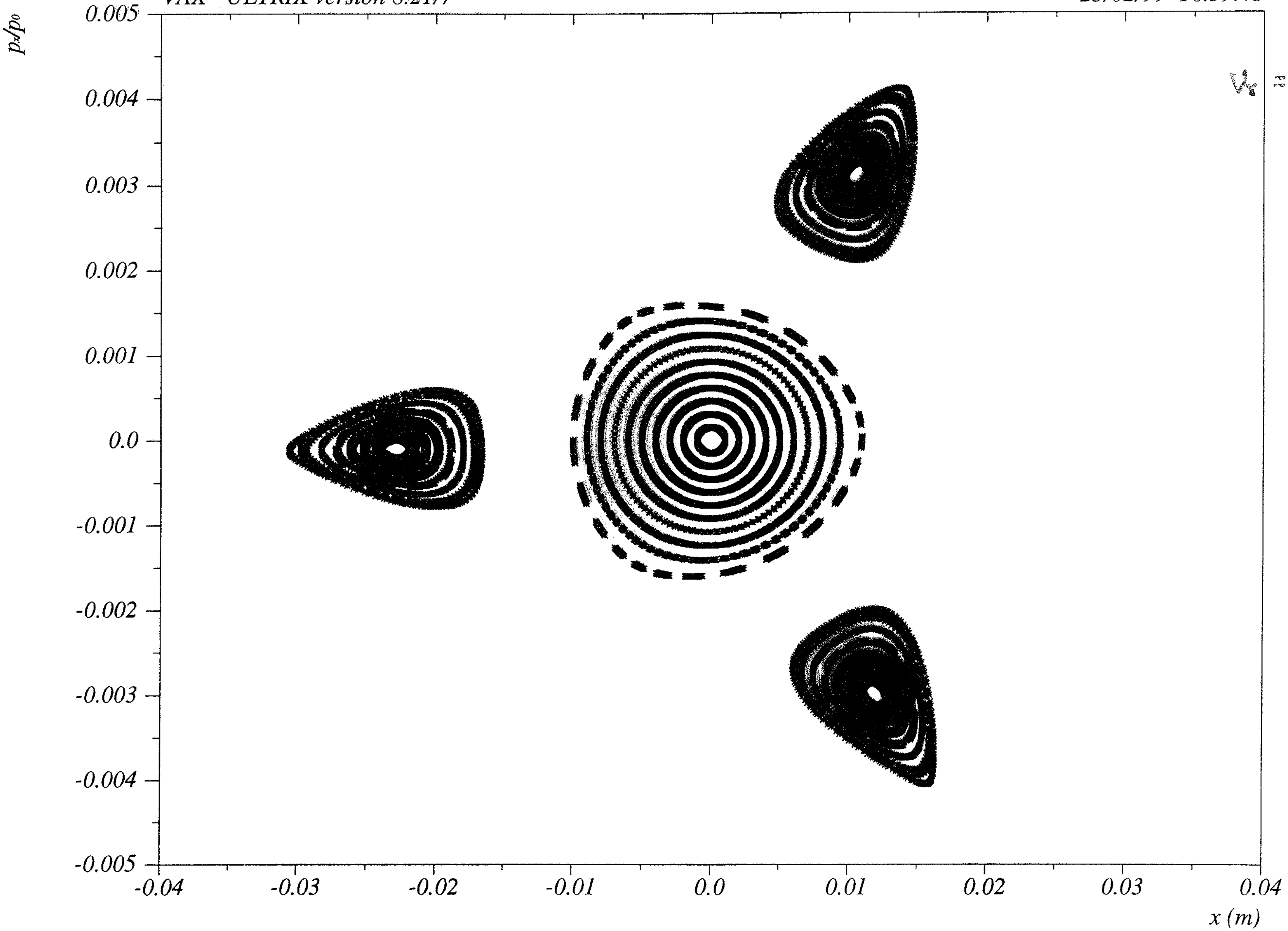


$\nu_x = 9.31$

Table name = TRACK

The proposed lattice consists of many arcs containing combined function (or usual) magnets and focusing (and defocusing) quadrupoles separated by identical channels consisting of either one, two or dispersionless straight sections .

A significant advantage of such a design is:

1. the ability to separate the functions of the arcs and the straight sections;
2. The periodical part of the arcs is a pseudo-second order achromat joined with the straight sections through a dispersion suppressor;
3. It differs from the second order achromat by non-zero chromaticity;
4. Varying the chromaticity of arcs by sextupoles and the chromaticity of straight sections by quadrupoles and keeping the total chromaticity equal zero, we can modify the tune shift at any working point.

Electron beam lifetime:

$$\boxed{\frac{1}{\tau_{\Sigma}} = \frac{1}{\tau_{Touschek}} + \frac{1}{\tau_{brem}} + \frac{1}{\tau_{q}} + \frac{1}{\tau_{scat}}}$$

Touschek lifetime:

$$\boxed{\tau_{Touschek} \propto \frac{1}{\text{local density}} = \frac{\sigma_{x} \cdot \sigma_{y} \cdot \sigma_{z}}{N}}$$

Beam size:

$$\boxed{\sigma_{x,y,z} \propto \frac{1}{J_{x,y,z}^{\frac{1}{2}}}}$$

Robinson criteria:

$$\boxed{\sum_{i=x,y,z} J_{i} = 4}$$

The energy deviation of a particle $\Delta W = W - W_o$:

$$\boxed{W - W_o \propto \left[1 + \frac{\Omega_s^2}{\omega_m^2 - \Omega_s^2} \frac{\omega_m}{\Omega_s} \frac{\psi_m}{\psi_i} e^{i[(\omega_m - \Omega_s)t + \theta - \varphi_i]} \right]}$$

We can represent the radiation loss by view:

$$\boxed{\begin{aligned} \tilde{W}_r = \tilde{W}_{ro} + \frac{P_o}{\omega_r p_o R_o} \Delta W \cdot \overline{[2 - (1 - 2n)\eta]} \\ \cdot \{1 + \chi \cos[(\omega_m - \Omega_s)t + \theta - \varphi_i]\} \end{aligned}}$$

For a beam particle in a circular accelerator, when the RF phase is modulated with an amplitude ψ_m and a frequency ω_m, the equations of the motion are given by:

$$\boxed{\frac{dW}{dt} = eU \sin\left[\varphi + \psi_m \cos(\omega_m t + \theta)\right] - \tilde{W}_r},$$

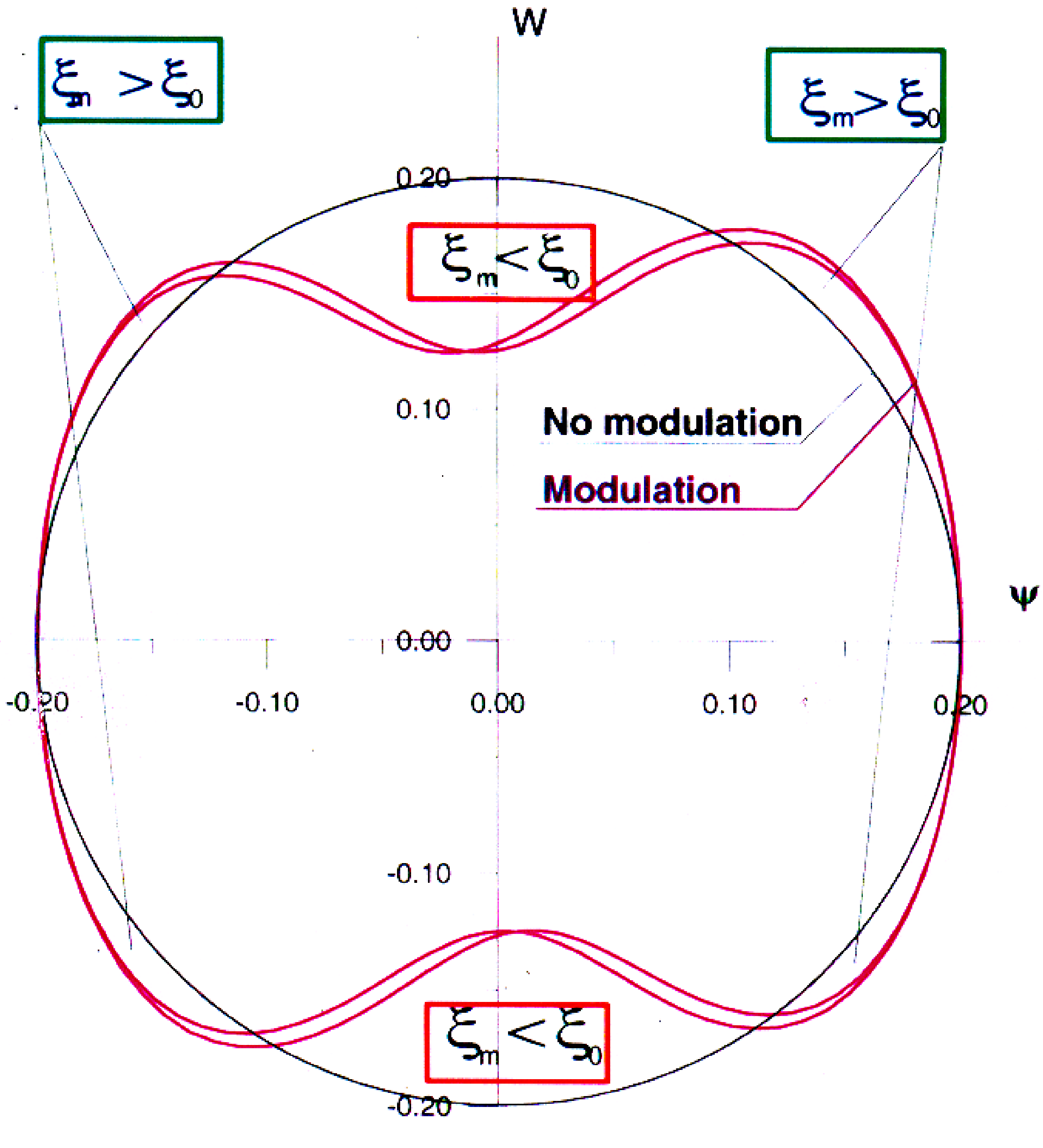
For the non-resonant case $(\omega_m \neq \Omega_s)$:

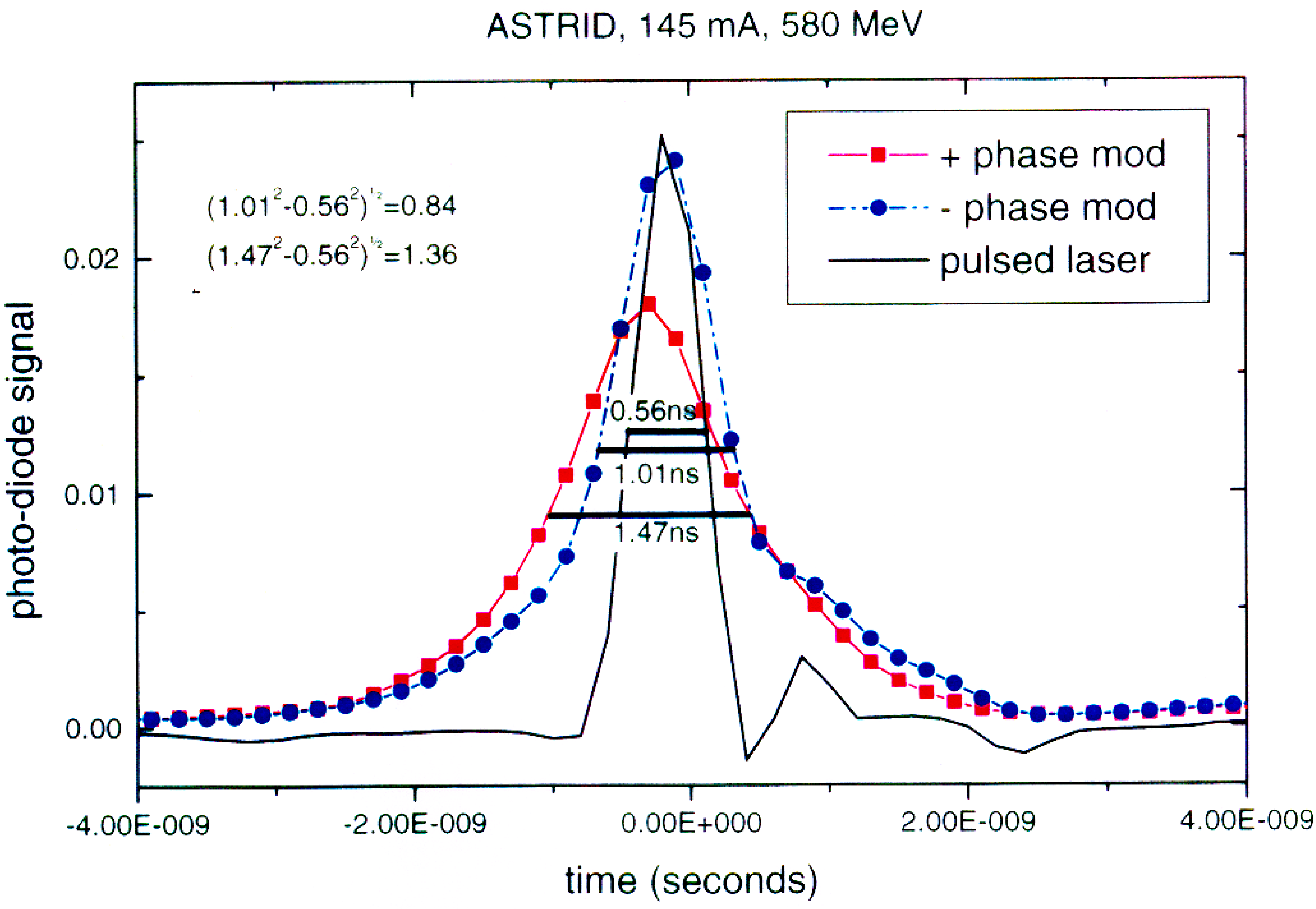
$$\varphi(t) = \psi_i e^{-\xi t} e^{i(\Omega_s t + \varphi_i)} + \psi_m \frac{\Omega_s^2}{\omega_m^2 - \Omega_s^2} e^{i(\Omega_s t + \varphi_i)}$$

The principle of the parametrization of the radiation damping decrement in the longitudinal plane

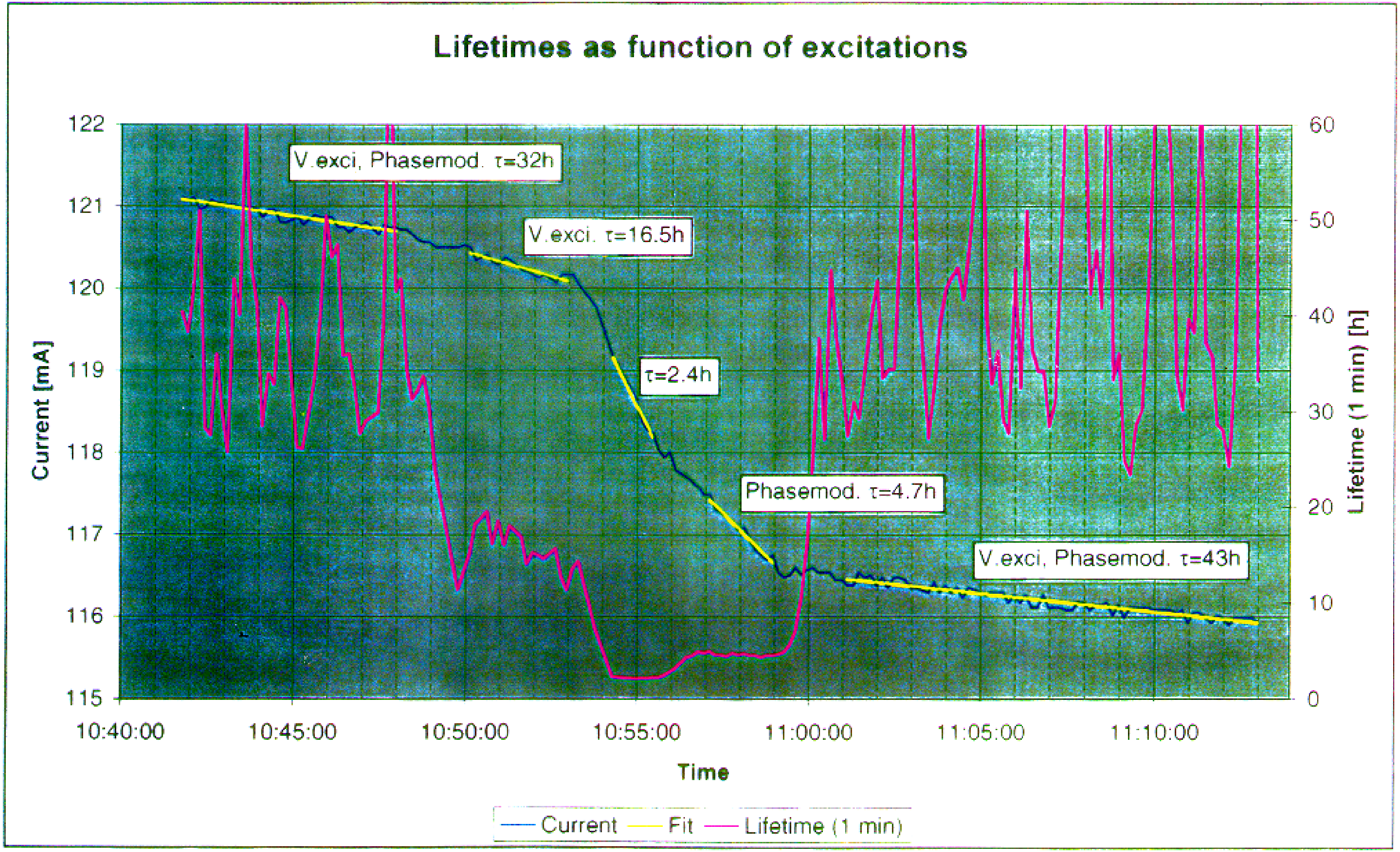
ξ_0 is the radiation damping decrement in the unperturbed case

ξ_m is the radiation damping decrement in the modulated phase case





ASTRID, 145 mA, 580 MeV
+ phase mod
- phase mod
pulsed laser
$(1.01^2-0.56^2)^{1/2}=0.84$
$(1.47^2-0.56^2)^{1/2}=1.36$
0.56ns
1.01ns
1.47ns
photo-diode signal
0.02
0.01
0.00
-4.00E-009
-2.00E-009
0.00E+000
2.00E-009
4.00E-009
time (seconds)



Lifetimes as function of excitations
V.exci, Phasemod. τ=32h
V.exci. τ=16.5h
τ=2.4h
Phasemod. τ=4.7h
V.exci, Phasemod. τ=43h
Current [mA]
Lifetime (1 min) [h]
122
121
120
119
118
117
116
115
60
50
40
30
20
10
0
10:40:00
10:45:00
10:50:00
10:55:00
11:00:00
11:05:00
11:10:00
Time
Current
Fit
Lifetime (1 min)

Hamiltonian for RF phase modulation:

$$H_r(I,\vartheta) = I\cdot\Delta - \frac{I^2}{16} + \frac{\Psi_{ef}}{2}\cdot I^{3/2}\cos 3\vartheta$$

The fixed points are determined:

$$\begin{cases} \Delta + \frac{3}{4}\Psi_{ef}\, I^{1/2}\cos 3\vartheta - \frac{I}{8} = 0 \\ \sin 3\vartheta \end{cases}$$

$$\tilde{I}_{1,2}^{1/2} = 3\Psi_{ef}\cos 3\vartheta \pm \sqrt{9\Psi_{ef}^2 + \Delta}$$

if $\Delta < 0$ and $|\Delta| > 9\Psi_{ef}^2$,

then you have the stable motion