New version 3.3 of the DeCA code

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Abstract

The new version 3.3 of the DeCA (Design Cyclic Accelerators) code is aimed at solving the problems involved in the design of cyclic accelerators. In this version realized are the following complementary possibilities: a new file with geometric binding of lattice magnetic elements which in future could be used in the AUTOCAD code for design documentation development; a local correction of the reference orbit; calculations of the beam integral characteristics (lifetime, damping time, spread of energies, acceptance, beam equilibrium size, etc.) and the synchrotron radiation characteristics; simulation of the spin motion and calculations of the equilibrium degree of polarization in the linear approach. The service system of the code is considerably extended.

The examples of characteristic calculations for the Pulse Stretcher Ring PSR-2000 are given.

1. INTRODUCTION

The DeCA code (Design Cyclic Accelerators) is intended for solving a wide range of problems associated with the development of charged-particle cyclic accelerators and storage rings [1]. This paper offers the third version of the code which extends the capabilities of the functional blocks already available (new control commands are introduced) and comprises a new functional block for calculating the equilibrium degree of polarization. Besides, new models of lattice elements are introduced.

All code modules are written in the programming language FORTRAN-77, the program size is 25000 lines, the number of subprograms is 250, the working memory is 3 megabytes.

2. FUNCTION OF THE PACKAGE

The new version of the package DeCA includes four independent functional blocks and system programs. On developing the programs we retained the main principle of the package design, i.e., any combination of the functional blocks (given the system programs) can be used independently provided that the block employed needs no preliminary data computed in another block.

The system programs are supplemented by the command which provides a link with the operation system of the VM/CMS computer and the editing of data files (input particle coordinates, storage ring lattice file, command file, etc.) without exit from the package. Besides, the input format is simplified. The functional blocks of DeCA version 3.3 perform the following new (as compared with version 2.2 [2]) functions :

1. The GAC (Geometry of Accelerators) block- computation and plotting of space coordinates of the lattice elements.

The program is now capable to compose the file with the coordinates of lattice elements that were recorded in the input format of the AUTOCAD program intended for producing design plans and specifications.

2. The REFTL (Reference Trajectory Linear) block- computation of physical parameters of accelerator and storage ring lattice to the linear approximation and analytical approximation computation of the nonlinear characteristics of the lattice:

-calculation and plotting of the lattice resonances;

-local correction of the reference orbit;

-computation of the integral beam characteristics, namely, lifetimes τ_{scat}, τ_{brem}, τ_T; acceptance ε_{RF}; energy spread σ_ε; bunch length σ_L; RMS beam size σ_x, σ_y;

-computation of synchrotron radiation characteristics, namely, spectral brightness, angular divergence;

-computation of coefficients determining the dependence of the linear tune shift on the oscillation amplitude; these coefficients are then used to calculate the region of oscillation stability (dynamic aperture);

-computation of stable fixed point coordinates for the second- and third-order resonances.

The model of the lattice element imitating the orbital oscillation damping has been introduce in the block.

3. The MDP (Modeling Dynamics of Particles) block: simulation of beam dynamics with due account of higher-order nonlinearities.

To ensure the capability of investigating the slow extraction uniformity, the program provides for:

- the definition of the initial particle coordinates by distributing them in the phase 6-D-space along separatrix boundary;
- simulation of power instability.

To be capable of investigating the chromatic beam extraction, the program has been supplemented by the model of RF-cavity with a variable RF-field amplitude.

Besides, nonlinear edge effects have been taken into account in the model of the bending magnet [3], and the model has been introduced for the multipole lens with the number of poles up to 12 and the field intensity varying in the poles in accordance with the prescribed law.

4. The SOM (Spin Orbit Motion) block- simulation of spin motion and computation of the equilibrium degree of polarization: simulation of the spin motion of the particles with inducing of reference orbit perturbations; computation of spin tune, times of polarization and depolarization, equilibrium degree of polarization.

The calculation of the equilibrium degree of polarization, was made with the algorithm developed by Chao [4] and Mais [5], using the eigenvectors of the cyclic matrix of spin-orbit coupling.

3. COMPUTATION EXAMPLES

The DeCA code has been used for designing the 3 GeV electron pulse stretcher ring PSR-2000 [6]. Figure 1 shows the cell of the resonance network in the vicinity of the tune point Qx=5.314 Qz=5.123. The PSR parameters at this point are: momentum compaction factor $\alpha=4.294*10^{-2}$, damping times $\tau_x=7.194s$, $\tau_z=6.024s$, $\tau_s=2.786s$; energy spread $\sigma_E^2=7.95*10^{-4}$, emittance $\varepsilon=1.028*10^{-6}$. Fig.2 shows the spectral brightness of synchrotron radiation from the bending magnet of the PSR-2000 in the "SR source" mode of operation at beam energy of 3 GeV. Fig.3 shows the beam phase map for the process of chromatic extraction. Fig. 4 shows the equilibrium degree of electron beam polarization in the PSR-2000 lattice for the tune point Qx=5.314, Qz=5.123 with the reference orbit perturbation taken into account. The RMS errors of lattice element alignment. were found to be $x=10^{-4}$ m, $x'=10^{-4}$, $z=10^{-4}$ m, $z'=10^{-4}$, $s=10^{-4}$ m, $s'=10^{-4}$, while the RMS deviations of the reference orbit were $x=6*10^{-4}$ m, $z=10^{-3}$ m before the correction and $x=6*10^{-5}$m, $z=6*10^{-5}$ m after the correction.

4. FURTHER PACKAGE DEVELOPMENT

The next version of the DeCA code is supposed to provide for: the Hamiltonian formalism in order to study slow polarized electron beam extraction and the stability region of oscillations (dynamic aperture); simulation of spin-orbit motion of particles with due account of the influence of nonlinear magnetic fields; simulation of orbital motion of particles with allowance for quantum fluctuations; optimization of the lattice parameters.

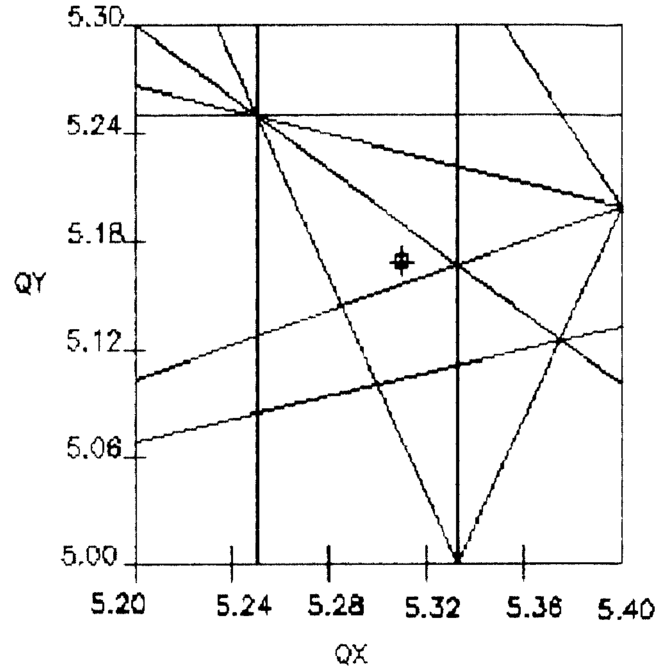

Figure 1. Resonance network.

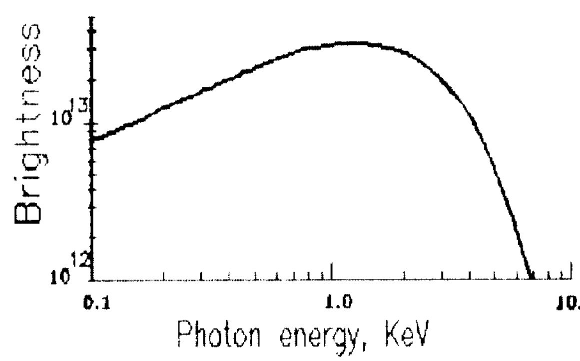

Figure 2. Spectral brightness of the synhrotron radiation from the PSR-2000 dipole magnets.

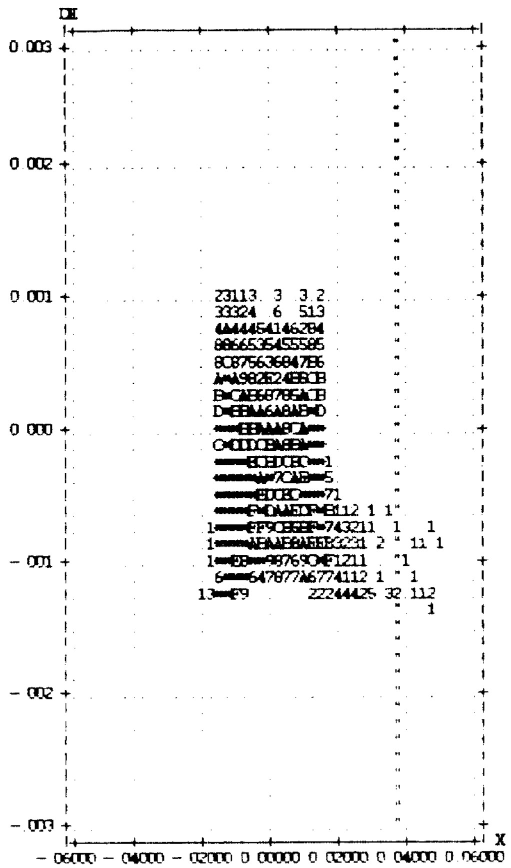

Figure 3. Beam phase map for the procces of chromatic extraction.

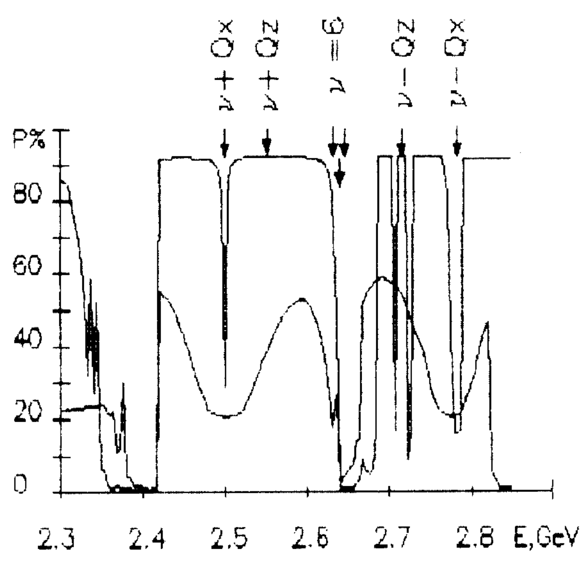

Figure 4. Equilibrium degree of polarization for the PSR-2000 lattice.

5. REFERENCES:

[1] Gladkikh P.I., Zelinsky A.Yu., Strelkov M.A. " DeCA code. Organization of package", Preprint KFTI 89-42,Moscow, TcNIIAtominform,1989,16p.

[2] Gladkikh P.I., Zelinsky A.Yu., Strelkov M.A. "DeCA - Code for analysing and design of cyclic Accelerators", Proceeding of the EPAC - 2, vol. 2, pp 1234-1236, 1991.

[3] Bulyak E.V., Efimov S.V. "Nonlinear effects occuring due to fringe fields of cyclic accelerators dipoles",Poceeding of the EPAC-90, vol.2,, p.1455-1457

[4] Chao A.W. " Evaluation of radiative spin polarization in an electron storage ring", Nucl. Instr.&Meth.,v.A180(1981), pp.29-36.

[5] Mais H., Ripken G. "Theory of spin-orbit motion in electron-positron storage rings. Summary of results." DESY 83-062, July 1983.

[6] Gladkikh P.I., Gonchar V.Yu., Grigor'ev Yu.N. etc."PSR-2000. The pulse stretcher ring for the Kharkov linear electron accelerator", Preprint KFTI 90-22,Moscow,TcNIIAtominform,1990,34 p.