A COMPUTING OPTIMIZATION SYSTEM FOR ION LINAC ACCELERATING/FOCUSING CHANNELS

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Computing code package LIDOS (Linac Ion Dynamics Optimization and Simulation) has been designed. LIDOS makes it possible to solve problems connected with the choice of structure and optimal parameters of all accelerator types including RFQ, DTL, High-Beta Linac etc. LIDOS permits users to make choice of accelerating/focusing channel parameters and channel tolerances, to carry out matching of various channel parts and to simulate beam dynamics with space charge as well. Unlike the other existing codes LIDOS is an expert system, so it not only solves equations of ion motion, but gives intellectual advise and helps users to come to the optimal decision.

Computation codes are supplemented by a number of service programs, allowing to visualize and quickly asses computation results. They are also supplemented by optimization programs allowing to automate the process of the parameters choice which is often labor consuming and troublesome. In particular, matching of the injected beam to the RFQ with any LEBT (Low Energy Beam Transport) structure and a number of other processes have been automated. The codes for the investigation of correction algorithms allowing to carry out "correction" of a single or two component beam on the display are also included in the package.

LIDOS is a three-level code making computation and estimation, having various computation speed and accuracy at different levels.

Programs of the first level are based on simple models, which are characterized by segmentally constant ("rectangular") fields *E(z)* in acceleration gaps and *B(z)*, *H(z)* in focusing elements and by a beam represented by a uniformly charged cylinder having an ellipsoidal phase portraits in the phase space of transverse coordinates and velocities.

It is expedient to use these codes at the initial stage of a linac design, for example when choosing the type of focusing, the focusing period structure, the pattern of the synchronous phase variation and so on.

Though the simple model does not give the resonator design geometrical parameters, it allows fairly well for the main factors, influencing the beam dynamics in the process of its acceleration and transport. High speed of the computation makes possible to use multivariant optimization methods for choosing the parameters variation patterns. The accumulated experience shows to a good quality of the patterns obtained at this stage which are in good agreement with the results produced by more sophisticated models.

Programs of the second level are based on models with the real distribution of external accelerating and focusing fields. It is expedient to use these models when designing geometrical parameters of an accelerating channel and focusing fields. Computation of the channel parameters in the real fields are carried out with the allowance being made for the results obtained at the previous level with the aid of simpler models, for example, using the pattern of a synchronous phase variation, optimal positioning of focusing elements and so on. The statistic simulation codes allowing to estimate the individual and overall contribution of destabilizing factors to the deterioration of the beam parameters. which is especially important for a high energy linac part, also to the second level.

Programs of the third level are based on the most sophisticated models which represents the beam as the ensemble of "big" particles and on the Poison equation solutions. These programs make allowance for the nonlinear influence exerted on the beam both by external and by the proper fields. It is expedient to use the third-level codes for final estimations of the beam quality (for example, the beam emittance growth, particles losses and so on) in channels with preset parameters computed at the previous stage.

A few example follow.

Example 1. RFQ Linac. (First Level)

One of the branches of the LIDOS allows to estimate operatively the beam parameters in RFQ linac and to optimize it. The codes is analogous to the well-known program RFQSCOPE, but excels it in functional capabilities.

The initial data for the channel computation are as follows: the ions charge *Z* and mass *M* numbers and also the vane modulation *m(n)*, the average bore radius *R(n)* and synchronous phase $\varphi_s(n)$ evolution along the channel. Besides the table containing the channel parameters, the computational results are also visualized on the display showing the trajectory of the operational point on the stability diagram. On the first diagram (Fig.1) is shown the stability region: the strength *q* grows along the ordinate axis, while the defocusing parameter *a* - along the abscissa axis, where q and a are depended on the channel and beam parameters as follows:

$$q = \frac{ZeU}{2Mm_0c^2}\cdot\left[\frac{\lambda}{\pi R(n)}\right]^2, \quad \alpha = \frac{1}{\pi}\cdot\frac{ZeUT(N)}{MW(N)}\cdot \sin\varphi_s(n),$$

(λ is the RF field wave length, U – intervane voltage, e and m_0 – the proton charge and mass, T(n) is transit time factor as a function of the period number n, W(n) the synchronous particle energy, MeV/u). The isolines of transverse oscillations frequency, of the matched beam radius and of the envelope modulation also as the lines of the parametric and ordinary resonances are shown on the diagram.

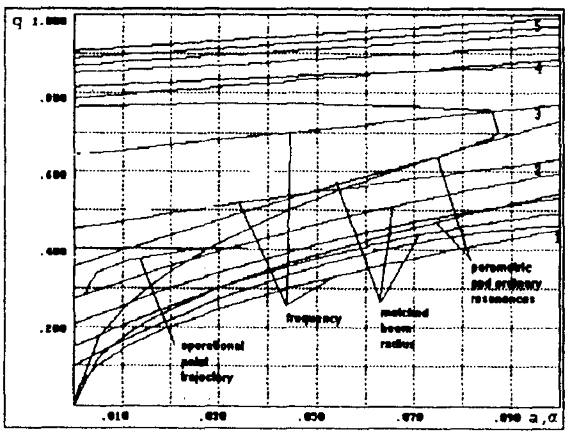

Fig.1

The plane (q,α), where the parameter α depends on the current I and the normalized emittance V as $\alpha = \frac{2IL}{I_0 V\rho^2}$ (L – the focusing period length, ρ – the ion reduced impulse, I_0 = 3.13E7·M/Z A), is shown on second diagram (Fig.2). The operational point trajectory immediately shows the matched beam dimensions at the channel input, and also its maximum growth during acceleration.

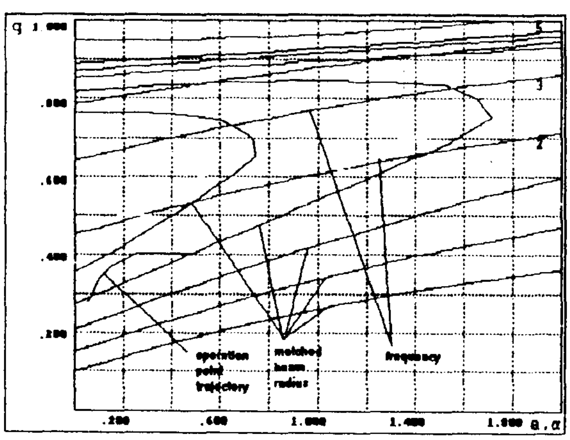

Fig.2

The RFQ codes checks up the Kilpatrick criteria exceeding and chooses the intervane voltage and bore radius if necessary. If the obtained results are satisfactory the beam simulation in the computed channel is carried out.

The envelope trajectories of the transverse cross-sections starting at various initial RF phases are displayed during computation simultaneously with the longitudinal beam phase portrait at the separatrix background. The beam disc model is used when computing the longitudinal motion. The effective beam transverse phase portrait is displayed also as the ion transmission percent.

The whole optimum RFQ version computation takes no more then 40 minutes at the computer of PC AT 386 (33 MHz) type.

The two pictures are shown as the RFQ linac computation illustration. The beam envelopes and phase portraits in (x,x') and $(\Delta\varphi,\Delta p/p)$ planes are shown for zero intensity beam (Fig.3) and for proton current 100 mA (Fig.4).

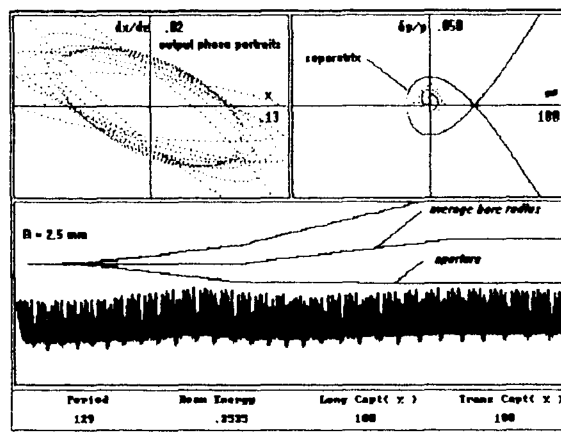

Fig.3

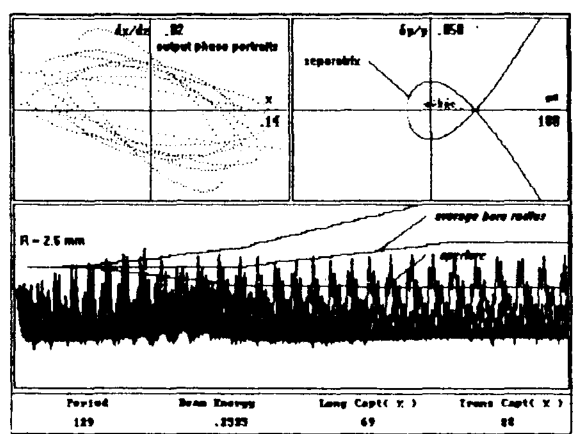

Fig.4

Example 2. LEBTM (Low Beam Transport and Matching). First Level.

Many calculations are needed in order to match different transport channel parts with linac input. In LIDOS search of the matched channel parameters is carried out by means of minimizing a certain function F showing how the beam is matched to the channel [1].

The problem is posed as follows. It is necessary to transform the two preset ellipses in the planes (x,x'), (y,y') into two other ellipses with the aid of a transport channel consisting of a number of quadruple lens, solenoids, bending magnets with drift spaces between them. All the element lengths are preset and the sought-for parameters are magnetic fields in focusing elements. One finds the required field gradients in matching lenses when the aforementioned function F reaches its global minimum. If the transport channel is quadrupole, the solution may be sought separately for x and y planes; the solenoidal channel presents no such a possibility. The global minimum equal to 2 if the accurate matching has been reaches. If the matching is not accurate, $min(F) > 2$. The effective beam radius growth coefficient caused by an inaccurate matching is related to the function F minimum as follows:

$$T_{x,y} = \sqrt{\left(\frac{F_{x,y}}{2}\right) + \sqrt{\left(\frac{F_{x,y}}{2}\right) - 1}}$$

The LEBTM codes demonstrate the beam envelope evolution before and after the channel optimization with the allowance being made for space charge. The degree of the beam mismatch, which decreases when the channel is optimized, is shown by $T_{x,y}$ coefficients and by the simultaneous of the output channel acceptance and of the input linac acceptance in (x,x'), (y,y') and (x,y) planes (Fig.5).

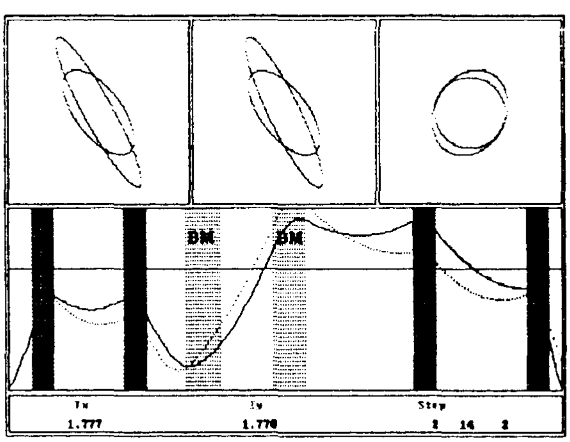

Fig.5

Reference

1. B.I.Bondarev, A.P.Durkin. Different Focusing Channels Matching.- Trudi Radiotechnicheskogo Instituta, No 14, p.17-25, 1973, Moscow.

