A LINAC GENERATOR PROGRAM AS PRE-PROCESSOR FOR THE SIMULATION CODE DYNAC

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Abstract

A linac generator program, GENAC, has been developed, capable of generating an accelerating structure through interpolation of SUPERFISH output files. GENAC can handle long and complex accelerating elements, such as asymmetric ones or elements consisting of several accelerating gaps in one go. GENAC is a pre-processor to the beam simulation code DYNAC [1]; both programs are based on the same set of quasi-Liouvillian beam dynamics equations.

With the DYNAC code one has the possibility of using multistep space-charge calculations [2],[3],[4] within the accelerating elements of a linac. Therefore, the combination of the linac generator GENAC with the simulation code DYNAC constitutes a powerful tool for the development of new types of accelerators.

Introduction

New types of accelerators, such as ones devoted to medical or industrial applications or nuclear waste transmutation, often consist of long cells generating complex (multi-gap) fields including asymmetric ones. The simulation program DYNAC and its pre-processor GENAC, both based on the same set of quasi Liouvillian equations, can handle such long complex fields, including asymmetric ones. It is important to note that codes such as PARMILA [2] and MAPRO [3] assume symmetric fields and assume the accelerating gaps to be short (i.e. the velocity of the particles are assumed constant across the gap). Such codes are therefore not suited for the new types of accelerators mentioned above.

Short description of GENAC

GENAC needs two types of input files : firstly an input file giving the basic linac parameters such as input and output energy, particle type and synchronous phase; and secondly a set of SUPERFISH files for different relativistic β corresponding to different points along the accelerator.

GENAC reads the axial field distributions $E_z(z)$ from the SUPERFISH files and interpolates for the actual β (or βλ) in a way similar to one described in [5]: the two fields in the SUPERFISH files nearest to the actual βλ are found and a logarithmic interpolation on the field is made such that :

$$E_c(i) = E_k(i)\left(\frac{E_{k+1}(i)}{E_k(i)}\right)^R$$

where E_c is the interpolated field at the position i between the given SUPERFISH fields E_k and E_{k+1} and R is defined as :

$$R = \frac{\beta\lambda_c - \beta\lambda_k}{\beta\lambda_{k+1} - \beta\lambda_k}$$

Given the field thus obtained, the transit time factors are computed as in [1] and a first value for the energy gain is obtained. From here starts an iterative process, acting on the field based on the following three criteria : the synchronous phase, the accelerating field E_0 and the cell length.

Once the criteria have been met, GENAC will start generating the next accelerating field and this process continues until the final energy wanted has been reached.

It is important to note that the previous set of quasi-Liouvillian equations [6], used by MAPRO and PARMILA, needs the value of the synchronous phase and velocity at the middle of the accelerating gap. These values can only be obtained through supplementary computations as the synchronous phase and velocity are only known at the input of the accelerating element. This makes the linac generator complicated. The beam dynamics equations used in GENAC and DYNAC make use of an equivalent travelling wave for which the phase can be obtained at any point ; it is sufficient to have the above mentioned values at the input of the accelerating element. These analytic equations also allow any beam parameters at any given point along the accelerating element to be obtained. Another important difference is that GENAC can generate cells containing a single accelerating gap as well as ones containing two or more accelerating gaps. An example will be shown later.

GENAC produces three sets of output. During the generation process, the total length and obtained energy are printed on the terminal. At the same time an output file is written containing more detailed information of the linac generated through the iterations. Finally an output file, containing a description of the generated linac, is written to serve as input file to DYNAC.

Application to a proton linac design

A typical application is the generation of a linac containing long asymmetric fields such as in [7]. In this design, each superperiod consists of two periods, which in their turn contain two cells of three gaps each, arranged in a

FODO lattice (see Fig.1.). The electric field distribution for one of such cells is shown in Fig.2.

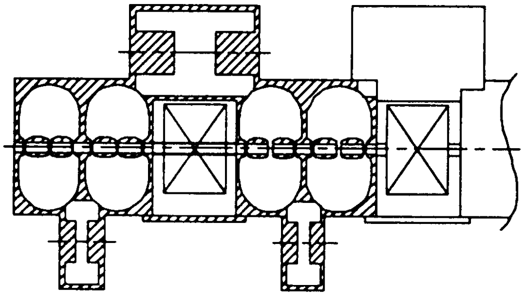

Fig.1. Layout of a superperiod of the LANL medical linac

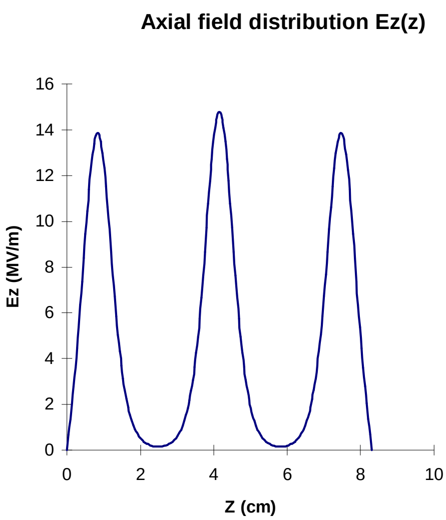

Fig. 2. The axial field distribution of a three gap cell in the LANL medical linac. One notes the asymmetry in the first and third field.

To generate a linac consisting of such multi-gap elements one can either generate gap by gap or several gaps in one go. The linac section studied here has an energy range from 10 to 30 MeV over a length of 9.1 m and is operated at 1300 MHz. Table 1 shows some results from the output file corresponding to the first three accelerating elements of the linac for a generation made gap by gap.

```
ACCELERATING ELEMENT N : 1
********************************
FREQUENCY :  .13000E+10 Hz
GAP LENGTH :  .25060E+01 cm
FIELD FACTOR :  .10426E-01

*** CHARACTERISTICS AT THE INPUT OF THE ACCELERATING
ELEMENT
      BETA     GAMMA     ENERGY(MeV)      TOF(deg)     TOF(sec)
REF  .14485     .10107E+01  .10000E+02   -.35991E+02   -.76904E-10

*** CHARACTERISTICS AT THE MIDDLE OF THE EQUIVALENT
FIELD
      BETA     GAMMA     ENERGY(MeV) SYNCHRONOUS PHASE (deg)
REF  .14501     .10107E+01  .10024E+02   -.29990E+02

*** CHARACTERISTICS AT THE OUTPUT OF THE ACCELERATING
ELEMENT
      BETA     dW(MeV)    ENERGY(MeV)    TOF(deg)     TOF(sec)
REF  .14546     .086544     10.087     .23399E+03    .49999E-09

ACCELERATING ELEMENT N : 2
********************************
FREQUENCY :  .13000E+10 Hz
GAP LENGTH :  .33537E+01 cm
FIELD FACTOR :  .10107E-01

*** CHARACTERISTICS AT THE INPUT OF THE ACCELERATING
ELEMENT
      BETA     GAMMA     ENERGY(MeV)      TOF(deg)     TOF(sec)
REF  .14546     .10108E+01  .10087E+02    .21069E+03    .45019E-09

*** CHARACTERISTICS AT THE MIDDLE OF THE EQUIVALENT
FIELD
      BETA     GAMMA     ENERGY(MeV) SYNCHRONOUS PHASE (deg)
REF  .14592     .10108E+01  .10152E+02   -.30014E+02

*** CHARACTERISTICS AT THE OUTPUT OF THE ACCELERATING
ELEMENT
      BETA     dW(MeV)    ENERGY(MeV)    TOF(deg)     TOF(sec)
REF  .14613     .093969     10.181     .57069E+03    .12194E-08

ACCELERATING ELEMENT N : 3
********************************
FREQUENCY :  .13000E+10 Hz
GAP LENGTH :  .25236E+01 cm
FIELD FACTOR :  .10413E-01

*** CHARACTERISTICS AT THE INPUT OF THE ACCELERATING
ELEMENT
      BETA     GAMMA     ENERGY(MeV)      TOF(deg)     TOF(sec)
REF  .14613     .10109E+01  .10181E+02    .57632E+03    .12315E-08

*** CHARACTERISTICS AT THE MIDDLE OF THE EQUIVALENT
FIELD
      BETA     GAMMA     ENERGY(MeV) SYNCHRONOUS PHASE (deg)
REF  .14657     .10109E+01  .10244E+02   -.29969E+02

*** CHARACTERISTICS AT THE OUTPUT OF THE ACCELERATING
ELEMENT
      BETA     dW(MeV)    ENERGY(MeV)    TOF(deg)     TOF(sec)
REF  .14674     .087411     10.268     .84632E+03    .18084E-08
```

Table 1: Typical data from the GENAC output file. The total length after three gaps is 8.33 cm.

Table 2 shows results for the first three gaps as in table 1, this time treating the three gaps as one long accelerating element. Note that in this case the phase law is slightly different.

```
ACCELERATING ELEMENT N : 1
*****************************
FREQUENCY :  .13000E+10 Hz
GAP LENGTH :  .82931E+01 cm
FIELD FACTOR :  .10639E-01

*** CHARACTERISTICS AT THE INPUT OF THE ACCELERATING
ELEMENT
      BETA     GAMMA     ENERGY(MeV)      TOF(deg)     TOF(sec)
REF  .14485     .10107E+01  .10000E+02   -.30.100E+02   -.66667E-10
```

*** CHARACTERISTICS AT THE MIDDLE OF THE EQUIVALENT FIELD
BETA GAMMA ENERGY(MeV) SYNCHRONOUS PHASE (deg)
REF .14586 .10108E+01 .10144E+02 -.30013E+02

*** CHARACTERISTICS AT THE OUTPUT OF THE ACCELERATING ELEMENT
BETA dW(MeV) ENERGY(MeV) TOF(deg) TOF(sec)
REF .14685 .283081 10.283 .86007E+03 .18418E-08

Table 2: Typical data from the GENAC output file. Treating the 3 gaps as one long accelerating element a total length of 8.29 cm is obtained.

Conclusion

The combination of the linac generator GENAC with the simulation code DYNAC constitutes a powerful tool for the development of new types of accelerators. The automatic adjustment of the quadrupoles in presence of space charge can be included using the fast and accurate new space charge method in reference [4].

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