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Staples, John

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LBL-4843 c.1
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LATTICE AN INTERACTIVE LATTICE COMPUTER CODE

John Staples

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October 1976

Prepared for the U. S. Energy Research and
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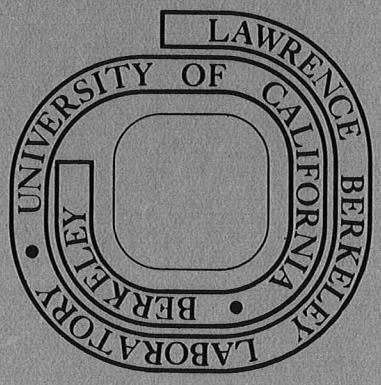

LBL-4843
c.1

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LBL-4843

LATTICE

An interactive lattice computer code

John Staples

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

October 1976

Work performed under the auspices of the U. S. Energy Research and Development Administration.

0 0 0 0 4 5 0 2 2 6 0

ABSTRACT

LATTICE is a computer code which enables an interactive user to calculate the functions of a synchrotron lattice. This program satisfies the requirements at LBL for a simple interactive lattice program, borrowing ideas from both TRANSPORT[1] and SYNCH[2]. A fitting routine is included.

1. A.C. Paul, LBL-2097.

2. A.A. Garren and A.S. Kenney, UCID-10153.

0 0 0 0 4 5 0 2 2 6 1

Introduction

LATTICE is an interactive computer code which allows one to determine the various functions of a synchrotron lattice. A lattice period is defined in terms of its magnetic elements. These elements are defined and assembled to form a period of the lattice. The code then calculates and displays the matched functions for the lattice.

Lattice elements may be changed in three ways: by re-entering the entire element, by modifying any parameter of an element, or by a fitting routine contained within the code.

This code is not meant to replace other codes such as SYNCH, MAGIC, or AGS. Rather, this is an easy-to-use interactive first-order code which permits the user to calculate quickly most items of interest. This code supplements other existing codes which together give the user a powerful tool in the calculation of synchrotron lattices. In addition, this code can be used to calculate many parameters of beam transport systems.

Theory

Courant and Snyder[1] show that for a synchrotron which consits of N periods of a group of elements of 2 X 2 matrix M, the motion of particles exhibits stable oscillations if:

$$\left|\frac{1}{2}\ \text{Trace}\ (M)\right| < 1$$

The phase advance μ for one period is:

$$\mu = \cos^{-1}\left(\frac{M_{11} + M_{12}}{2}\right) \qquad \begin{array}{l} 0 < \mu < \pi \text{ if } M_{12} > 0 \\ \pi < \mu < 2\pi \text{ if } M_{12} < 0 \end{array}$$

The matched functions β, α at the end of the period are then given by:

$$\beta = \left(\frac{M_{12}^{\,2}}{1 - \left(\frac{M_{11} + M_{22}}{2}\right)^2}\right)^{\frac{1}{2}}$$

$$\alpha = \frac{M_{11} - M_{22}}{2M_{12}}\,\beta$$

$$\nu = \frac{\mu N}{2\pi}$$

1. E.D. Courant and H.S. Snyder, Annals of Physics 3, p. 1 (1958).

If the matrices representing the motion of the particle are expanded to 6 X 6 which operate on the vector :

$$\begin{pmatrix} x \\ x' \\ y \\ y' \\ \delta S \\ \delta P/P \end{pmatrix}$$

where δS is the longitudinal displacement of a particle and $\delta P/P$ is the momentum error from design momentum, then the matched off-orbit functions can be determined:

$$\eta = \frac{M_{16}(1-M_{22})+M_{12}\,M_{26}}{2-M_{11}-M_{22}}$$

$$\eta^1 = \frac{M_{26}(1-M_{11})+M_{21}\,M_{16}}{2-M_{11}-M_{22}}$$

The momentum compaction α_p is defined as:

$$\alpha_p = \frac{\Delta L/L}{\Delta P/P}$$

$$= \frac{\Delta L}{L} \text{ for } \frac{\Delta P}{P} = 1$$

$$= \frac{M_{51}\eta + M_{52}\eta' + M_{56}}{L_{period}}$$

and $$\gamma_{transition} = \alpha_p^{-\frac{1}{2}}$$

0 0 0 0 4 5 0 2 2 6 2

This code assumes all bends to occur in the horizontal plane so that off-orbit functions in the vertical plane are not defined.

Use of the Program

The program is designed to run on LBL's CDC 6600 computer. It is available from the data cell as an absolute core load about 26K words long. Input data may be entered from the teletype or off-line from a previously prepared file on the file INPUT. Two suggested starting sequences are given for these two alternatives.

1. On-line (teletype) data entry:

```
(Log onto computer)
LIBCOPY, LATTICE, LGOB, LATLGOB.
LGOB.
```

2. Off-line data entry:

```
(Log onto SESAME)
```

The SESAME text buffer would then have the following card sequence:

```
LIBCOPY, LATTICE, LGOB, LATLGOB.
LGOB.
EOR
(Input to program starts here)
```

and the program is executed by ↑RUN. At the end of the input record, control is turned over to the interactive terminal for further instructions, including processing of additional input records in the INPUT file.

All input data and operations are written on the teletype file and, in addition, to the output file under the control of the WRITE ON/OFF instruction which suppresses off-line output. All off-line output can be suppressed by a ↑WIPE at the termination of the program.

The source code is on subset LATTICE, library LATTICE. Two additional subroutines, ZSYSTM and UERTST, are located on the IMSL library tape in compiled format. The source code will be made available to other laboratories upon request.

Program Conventions

The period of the lattice can contain up to 200 elements. Each element is entered into a dictionary which can contain up to 30 definitions. Each definition consists of a unique name of 6 or less characters, starting with an alphameric symbol, a character which defines the element type, a vary code designator,

and then the properties (length, magnetic field, etc.) of the element. The lattice period is then defined by naming, in order, the elements which constitute the period. The beam properties of rigidity and emittance are entered, as well as the number of periods in the total lattice.

The program can then be commanded to find the matched functions at the ends or at each location in the period, to display or edit the input data, to store and recall lattice definitions in temporary registers, or to vary the parameters of elements to fit any of a large variety of functions to required values.

Instructions, either on- or off-line are key words, which can usually be abbreviated by the first letter, followed by optional parameters. All input lines are free-form and parameters are separated by blanks or commas.

A summary of available instructions is printed out when H or HELP is typed in.

Parameters of an element can be changed with an ALTER instruction. A lattice string can not be altered after it is entered, but three temporary storage registers are provided for STOREing or RECALLing a previously defined lattice string.

The program is terminated by QUIT, or reinitialized by NEWCASE.

Units

Lengths of elements are expressed in meters. Magnetic fields and beam rigidity may be any self-consistent set of units. Magnet edge angles, phase advance, and total bend angles are expressed in degrees. The 6 X 6 matrix operates on a vector with the following units:

$$\begin{pmatrix} x\ (m) \\ x'(rad) \\ y\ (m) \\ y'(rad) \\ \delta S\ (m) \\ \delta P/P\ (unit) \end{pmatrix}$$

The one exception to this is the specification of the emittance areas on the BEAM command which are expressed in cm-mrad/π and the x and y beam half-widths calculated by the CYCLE command, which are expressed in cm.

0 0 0 0 4 5 0 2 2 6 3

Fitting

It is often desirable to specify values for the matched functions and cause lattice parameters to be adjusted until these conditions be met. A routine is included which varies lattice parameters that have been specified as variables so that a desired lattice solution can be found.

The vary code is the third parameter of each element definition and consists of the variable N, M. If the problem consists of Q variables, then each element has a distinctive value of N from 1 to Q. If two or more elements are to have their values changed together, then they will have the same value of N, or, if they are to be varied in equal but opposite directions, one will have the value N and the other the value -N. M takes on the value 1, 2, or 3 specifying whether the 1st, 2nd, or 3rd parameter is to be made variable. If no parameter is variable, the vary code is 0. Note that only one parameter in each element can be made variable.

To specify the target values for the matched functions, the FIT instruction is used. Q values for the Q lattice functions are entered and are stored until altered with a later FIT instruction.

As an example, consider a case where a quadrupole is included whose gradient and longitudinal position are to be adjusted, while keeping the total length constant, to produce a required transition gamma and horizontal and vertical tunes. The lattice elements and function specifications would appear as follows:

Included in element definitions:

```
.       .       .       .
.       .       .       .
L1      D       1.1     5
QF      Q       2.2     2     5
L2      D      -1.1     3
QD      Q       3.2     2    -5
.       .       .       .
.       .       .       .
```

where the first parameter of each drift L1 and L2 are variable in equal but opposite directions, and the second parameters of QF and QD are variable, for a total of three variables. For a machine of 8 periods, the FIT instruction would look like

```
FIT     3     8
        6     γ_tr
        7     ν_x
       10     ν_y
```

where three target function values are entered. The fitting is initiated on the ITERATE command.

Control Statement Summary

COMMENT (or *)

BEAM R ε_x, ε_y

ELEMENTS NEL

NAME D N.M ℓ

NAME B N.M ℓ B n

NAME Q N.M ℓ B′

NAME E N.M β B g

LATTICE NLAT

PERIODS NPD

FIT NFIT NP

1	β_x	9	α_y	17	M_{34}
2	α_x	10	ν_y	18	M_{43}
3	η_x	11	$\Sigma\theta$	19	M_{44}
4	η'_x	12	M_{11}	20	M_{16}
5	$\Sigma\ell$	13	M_{12}	21	M_{26}
6	γ_{tr}	14	M_{21}	22	Trace x
7	ν_x	15	M_{22}	23	Trace y
8	β_y	16	M_{33}		

NEWCASE

QUIT

DATA

MATRIX PWR

GO

ITERATE

CYCLE N

HELP

ALTER NAME N VAL

SAVE NSAVE

RECALL NRCL

WRITE ON/OFF

GRAPH SCALEX SCALEY SCALEE

0 0 0 0 4 5 0 2 2 6 4

Control Statements

BEAM R ε_x ε_y
B R ε_x ε_y

The beam rigidity R (kgauss-m or tesla-m) is defined. The unnormalized x and y emittance areas in cm-mrad/π can be optionally entered, also. A call without any parameters prints out the current values of the parameters.

HELP

H

A summary of the control statements is printed out to aid the user.

WRITE ON

W ON

WRITE OFF

W OFF

This command controls the off-line printing on the file output. The default is WRITE ON which causes all output that appears on the on-line terminal to be reproduced off-line.

ELEMENTS NEL

E NEL

This command notifies the code that NEL lattice element definitions are about to be entered. Each element consists of the following parameters, all on one input line.

A unique alphameric name
A type description
A vary code
One to three parameters

four element types are defined:

Type	Input String
Drift Length	Name D N.M L
Dipole	Name B N.M L B n
Quadrupole	Name Q N.M L B′
Magnet Edge	Name E N.M β B g

These elements are described below.

Drift Length

A field-free drift region of length L is specified, L in meters. L may be any real value.

Dipole

A dipole of length L with gap field B is specified, L in meters and B in kilogauss or tesla, consistent with the rigidity definition on the BEAM card. The field index n is $-\rho/B\ (dB/d\rho)$ where ρ is the radius of curvature of the central orbit. A negative field B defines a magnet which bends outward from the center of the machine.

Quadrupole

A quadrupole of length L and field gradient B' is specified. A positive field gradient produces focussing in the radial plane.

Magnet Edge

An edge to an associated dipole magnet is specified. The edge angle β is the angle between the beam trajectory and the normal to the edge of the magnet. If $\beta \cdot B > 0$, the case for a rectangular magnet, the edge is vertically focussing. The field B must be equal to the field in the associated dipole. If the magnetic field in a dipole is a variable, the B specified in the edge must be coupled to it.

The term g is the half height in meters of the magnetic gap. If this parameter is zero or omitted, no fringing field correction is made.

LATTICE NLAT

L NLAT

This command notifies the code that a string of NLAT names are about to be entered, defining the order of elements in the period. As many input lines as necessary can be used to input the names.

A call to LATTICE with no parameters prints out the current lattice string.

0 0 0 0 4 5 0 2 2 6 5

A lattice can consist of up to 200 elements.

SAVE NSAVE

S NSAVE

The current lattice string is saved in a storage register. There are three registers available.

RECALL NRCL

R NRCL

The lattice previously saved in storage register NRCL is loaded back into the working area. The lattice previously in the working area is lost.

FIT NFIT NP

F NFIT NP

This command notifies the code that NFIT parameters are about to be entered, and that the parameters Σ length, $\Sigma\Theta$, ν_x, ν_y will be treated at though they are calculated for a lattice of NP periods. NP is an optional parameter, and if omitted, is assumed to be one.

The fitting parameters are entered as two variables per line, the first variable specifying the significance (β, ν, etc.) and the second variable specifying the numerical value. The options are listed below.

1st Parameter	2nd Parameter	1st Parameter	2nd Parameter
1	β_x	13	M_{12}
2	α_x	14	M_{21}
3	η_x	15	M_{22}
4	η_x'	16	M_{33}
5	Σ length	17	M_{34}
6	γ_{tr}	18	M_{43}
7	ν_x	19	M_{44}
8	β_y	20	M_{16}
9	α_y	21	M_{26}
10	ν_y	22	Trace x
11	$\Sigma\Theta$	23	Trace y
12	M_{11}		

The number of parameters, NFIT, must be equal to the number of independant variables which were specified in the vary codes of the definitions of the elements.

A call to FIT with no parameters prints the current values of the fitting variables.

DATA

D

This instruction causes the definitions of the elements to be printed out in lattice order. This is useful in checking whether the elements and lattice were entered correctly.

ALTER NAME N V

A NAME N V

The Nth parameter ($-1 \leq N \leq 3$) of the element with name NAME is changed to value V. N is 1 to 3 for parameters 1 to 3, zero for the vary code and -1 for the type code. The name of an element cannot be changed.

MATRIX PWR

M PWR

The 6 X 6 matrix for the lattice is printed out, after it is raised to the PWR power. If PWR is omitted or zero, it is assumed to be one.

ITERATE CRIT

I CRIT

A fitting routine is activated to adjust the parameters of the elements that were specified by their non-zero vary code to be variable. The conditions specified by the FIT instructions are satisfied. CRIT is a convergence criterion, set by default if CRIT is not specified to .001.

GO

G

The matched functions at the ends of the period are calculated and printed out.

CYCLE N

C N

The matched functions at each element in the period are calculated and printed out. If N, an optional parameter, is included, each element is divided into N subunits.

---

0 0 0 0 4 5 0 2 2 6 6

COMMENT

*

The next input line will be printed out as a comment line. This is useful in annotating off-line input.

NEWCASE

N

The program is reinitialized and a new case is started. Note that by using the three lattice storage registers that as long as no more than a total of thirty elements are defined, three independant lattices can be calculated without reinitialization. This is useful when comparing different lattices. NEWCASE clears the element lattice and fitting parameter storage registers.

QUIT

Q

The program is terminated and control is transferred back to RECC. If desired, the program can be restarted by typing LGOB. All off-line output can be deleted by typing ↑WIPE instead of ↑STOP.

GRAPH SCALEX SCALEY SCALEE

GR SCALEX SCALEY SCALEE

The β_x, β_y, and η_x functions are graphed for one period. SCALEX, SCALEY, and SCALEE are the scale factors for β_x, β_y, and η_x. If omitted, they have the default values 20, 20 and 10 meters full scale. Once entered, they are retained until entered again.

Acknowledgements

This program borrows ideas freely from LBL TRANSPORT written by Art Paul and SYNCH written by Al Garren. The free-form input routine was written by Art Paul, and Elon Close suggested the use of ZSYSTM, an IMSL library routine, due to Karl Brown, as the fitting procedure package.

Example

A complete problem is worked out here. A separated function machine of 8 periods with a ODOFODOF structure is read in and the quadrupole gradients are adjusted to attain a desired tune.

In this example, data which the user enters is underlined. The commands are written out in full, but can be abbreviated by their first letter. To start with, the user logs on and enters the beam rigidity, emittance, and the characteristics of the five elements used to construct the lattice. Then the lattice of 18 elements is defined by naming the elements in the order that comprise the lattice. The total machine is defined to contain 8 periods.

```
>LOG!
LOGIN  CP-17  TTY-052  10.01.23.**BKY65A*B*10/08/76.
ENTER JOB CARD OR ^STOP
JOHN,[redacted],STAPLES!
JOHN042 LOGGED IN.  SESAME 2.4
OK - SESAME
LIBCOPY,LATTICE,LGOB,LATLGOB.!
OK - SESAME
LGOB.!

 LATTICE PROGRAM RUN 08 OCT 76 AT 10.02.54

 IS DATA TO BE ENTERED OFF-LINE?

NO!
NEXT

BEAM 65 30 5!

 BEAM RIGIDITY = 65.000 KG-M   EMITT X,Y =     30.00      5.00 CM-MRAD/PI

NEXT

ELEMENTS 5!

 ENTER  5 ELEMENTS

M B 0 1.06356 8 0!
E E 0 9 8!
D Q 1.2 .5 -50!
F Q 2.2 .5 50!
L D 0 2!

 ELEMENT LIST CURRENTLY CONTAINS  5 DEFINITIONS

 M      E      D      F      L
```

0 0 0 0 4 5 0 2 2 6 7


```
LATTICE 18!

ENTER 18 LATTICE ELEMENTS

M E D E M M E F L L D E M M E F E M!
 M    E    D    E    M    M    E    F    L    L

 D    E    M    M    E    F    E    M

NEXT

PERIODS 8!

MACHINE CONSISTS OF  8 PERIOD(S)
```

The lattice is then printed out to check it for accuracy.

```
DATA!
```

NAME	TYPE	VARY CODE	PAR 1	PAR 2	PAR 3
M	B (BEND)	0.	1.06356	8.00000	0.
E	E (EDGE)	0.	9.00000	8.00000	-0.
D	Q (QUAD)	1.2	.50000	-50.00000	
E	E (EDGE)	0.	9.00000	8.00000	-0.
M	B (BEND)	0.	1.06356	8.00000	0.
M	B (BEND)	0.	1.06356	8.00000	0.
E	E (EDGE)	0.	9.00000	8.00000	-0.
F	Q (QUAD)	2.2	.50000	50.00000	
L	D (DRIFT)	0.	2.00000		
L	D (DRIFT)	0.	2.00000		
D	Q (QUAD)	1.2	.50000	-50.00000	
E	E (EDGE)	0.	9.00000	8.00000	-0.
M	B (BEND)	0.	1.06356	8.00000	0.
M	B (BEND)	0.	1.06356	8.00000	0.
E	E (EDGE)	0.	9.00000	8.00000	-0.
F	Q (QUAD)	2.2	.50000	50.00000	
E	E (EDGE)	0.	9.00000	8.00000	-0.
M	B (BEND)	0.	1.06356	8.00000	0.

The matched functions at the end of the period for this as-of-yet unoptimized lattice are displayed.

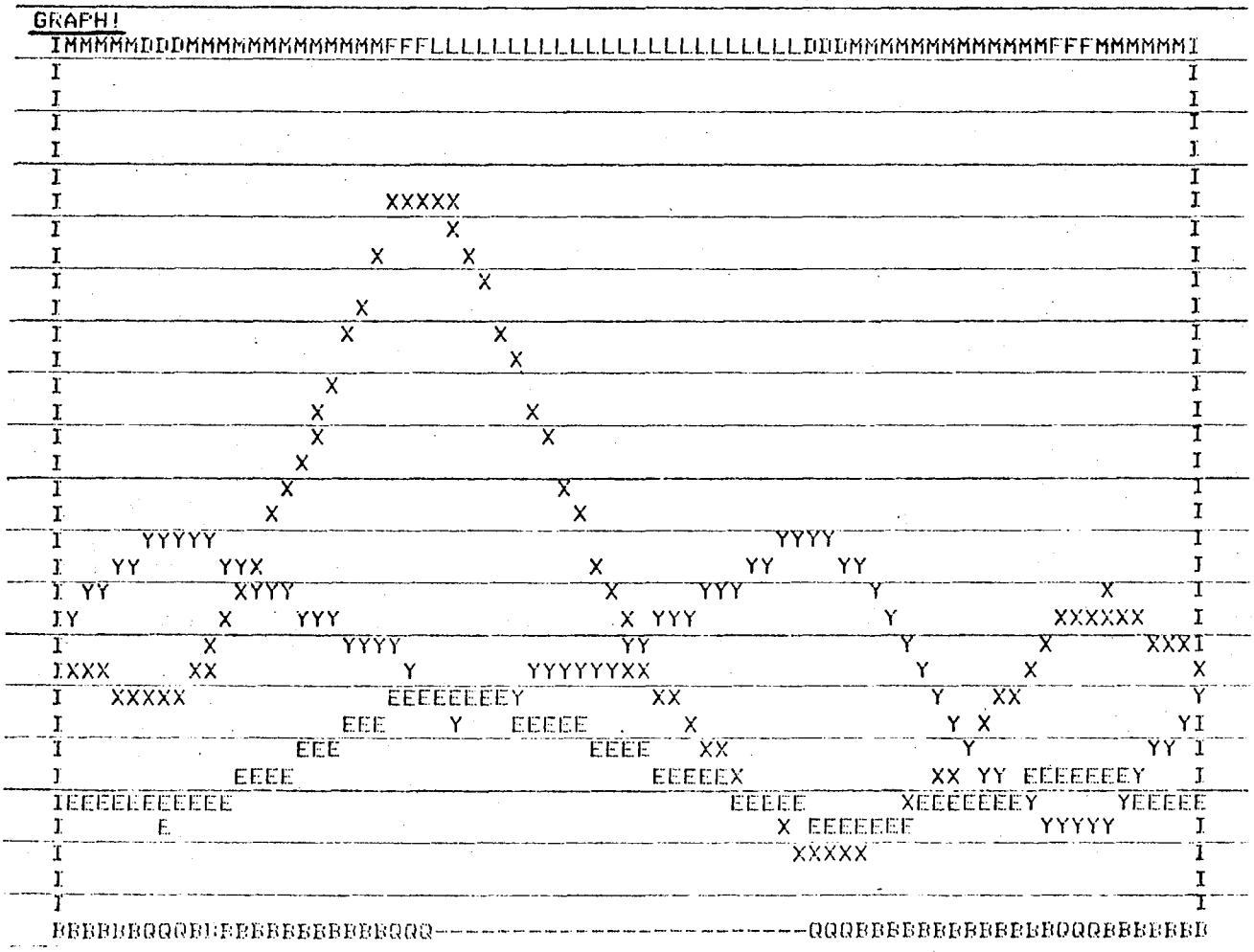
```
GO!

MATCHED FUNCTIONS FOR  8 PERIOD(S).
TOTAL LENGTH =  99.051 METERS.  TOTAL BEND = 360.000 DEGREES
BETAX =  6.046 METERS.  ALPHAX =   .687   NUX =  2.992
BETAY = 11.273 METERS.  ALPHAY =  -.749   NUY =  3.720
ETAX =  1.724 METERS.  ETAX PRIME =  -.228   TRANSITION GAMMA =  2.880
```

The radial and vertical tunes are both required to be 3.25. We enter these first two fit parameters to be evaluated for a machine of 8 periods. The vary codes of the F and D quads have been specified in the ELEMENTS input to render the second parameter, the field gradient, variable. The gradients are then iterated and a solution is found. The matched functions at the end of the period, the matched functions at each element in the lattice, the matrix to the 8th power for one period, and a graph of the beta and eta functions are displayed.

```
NEXT

FIT 2 8!

 ENTER  2 FITTING PAIRS

7 3.25!
10 3.25!

 VARIABLE   TARGET VALUE

 NU X            3.2500
 NU Y            3.2500
NEXT

ITERATE!

 ITERATION SUCCESSFUL.  CONVERGED IN 3 STEPS

 VARIABLE      INITIAL VALUE   FINAL VALUE   TARGET VALUE

 NU X             2.9915         3.2500         3.2500
 NU Y             3.7201         3.2511         3.2500

 INITIAL AND FINAL VALUES OF ELEMENT PARAMETERS

 ELEMENT   VARY CODE  INITIAL VALUE   FINAL VALUE

 D           1.2       -50.0000       -47.0048
 F           2.2        50.0000        51.3409
```

0 0 0 0 4 5 0 2 2 6 8


```
GO!

 MATCHED FUNCTIONS FOR  8 PERIOD(S).
 TOTAL LENGTH =   99.051 METERS. TOTAL BEND = 360.000 DEGREES
 BETAX =  6.104 METERS.  ALPHAX =   .546   NUX =  3.250
 BETAY =  6.756 METERS.  ALPHAY =  -.788   NUY =  3.251
 ETAX =  1.458 METERS   ETAX PRIME =  -.182   TRANSITION GAMMA =  3.110

NEXT

CYCLE!

 ELEMT  LTH   SUM L.  BETAX ALPHAX ETAX ETAPX  PSIX    X  BETAY ALPHAY  PSIY    Y
        0.0   0.0    6.10    .55  1.46  -.18   0.0   4.3  6.76   -.79   0.0   1.8
 M      1.06  1.06   5.09    .40  1.32  -.07  11.0   3.9  8.70  -1.04   8.0   2.1
 E      0.    1.06   5.09    .30  1.32  -.05  11.0   3.9  8.70   -.87   8.0   2.1
 D       .50  1.56   5.79  -1.77  1.42   .44  16.4   4.2  8.04   2.12  11.3   2.0
 E      0.    1.56   5.79  -1.89  1.42   .47  16.4   4.2  8.04   2.27  11.3   2.0
 M      1.06  2.63  10.54  -2.56  1.97   .57  24.2   5.6  4.08   1.46  22.0   1.4
 M      1.06  3.69  16.55  -3.06  2.63   .67  28.8   7.0  1.84    .64  44.8   1.0
 E      0.    3.69  16.55  -3.38  2.63   .72  28.8   7.0  1.84    .68  44.8   1.0
 F       .50  4.19  16.62   3.25  2.72  -.36  30.5   7.1  1.67   -.31  61.9    .9
 L      2.00  6.19   6.40   1.86  2.01  -.36  41.7   4.4  5.55  -1.63 103.0   1.7
 L      2.00  8.19   1.75    .47  1.29  -.36  78.4   2.3 14.69  -2.94 115.7   2.7
 D       .50  8.69   1.75   -.46  1.22   .09  95.5   2.3 14.95   2.46 117.6   2.7
 E      0.    8.69   1.75   -.49  1.22   .11  95.5   2.3 14.95   2.76 117.6   2.7
 M      1.06  9.75   3.55  -1.19  1.40   .22 120.7   3.3  9.74   2.14 122.7   2.2
 M      1.06 10.82   6.77  -1.82  1.70   .33 133.2   4.5  5.82   1.53 130.8   1.7
 E      0.   10.82   6.77  -1.95  1.70   .36 133.2   4.5  5.82   1.65 130.8   1.7
 F       .50 11.32   7.39    .80  1.71  -.32 137.2   4.7  5.35   -.64 136.1   1.6
 E      0.   11.32   7.39    .65  1.71  -.29 137.2   4.7  5.35   -.53 136.1   1.6
 M      1.06 12.38   6.10    .55  1.46  -.18 146.3   4.3  6.76   -.79 146.3   1.8

 ELEMT  LTH   SUM L.  BETAX ALPHAX ETAX ETAPX  PSIX    X  BETAY ALPHAY  PSIY    Y

NEXT

MATRIX 8!

 MATRIX FOR LATTICE TO THE  8 POWER FOR 1 PERIOD IS

    .5457   6.1041   0.       0.       0.      1.7761

   -.2126   -.5458   0.       0.       0.       .0280

    0.       0.     -.7948   6.7561   0.      0.

    0.       0.     -.2399    .7814   0.      0.

   -.3929  -1.1406   0.       0.      1.0000  -9.8754

    0.       0.     0.       0.       0.      1.0000
```



The gap parameter of the magnet edge is changed from zero (fringe field ignored) to .05 m half height. The vertical tune is shown to be altered, and the quadrupole fields are found that bring the tune back to the required value.

```
ALTER E 3 .05!
GO!
NEXT

MATCHED FUNCTIONS FOR  8 PERIOD(S).
TOTAL LENGTH =  99.051 METERS. TOTAL BEND = 360.000 DEGREES
BETAX =  6.104 METERS.  ALPHAX =   .546   NUX =  3.250
BETAY =  6.689 METERS.  ALPHAY =  -.787   NUY =  3.228
ETAX =  1.458 METERS   ETAX PRIME =  -.182   TRANSITION GAMMA =  3.110
```

ITERATE!

ITERATION SUCCESSFUL. CONVERGED IN 2 STEPS

VARIABLE	INITIAL VALUE	FINAL VALUE	TARGET VALUE
NU X	3.2500	3.2500	3.2500
NU Y	3.2282	3.2501	3.2500

INITIAL AND FINAL VALUES OF ELEMENT PARAMETERS

ELEMENT	VARY CODE	INITIAL VALUE	FINAL VALUE
D	1.2	-47.0048	-47.2090
F	2.2	51.3409	51.3987

The program is terminated and all off-line output is suppressed.

QUIT!

```
 END OF PROGRAM
OK - SESAME
SWIPE!
 *J JH1001B [redacted] 76/10/08 B N 000019          STAPLES
 ..............................
 CP SECONDS                 2.477
 MONITOR REQUESTS             129
 TTY MINUTES                   13
 ..............................
 TOTAL JOB CUS                 19
 COST + OVERHEAD    $        2.03
 ..............................
JOB ENDED - DISCONNECTED
```

0 0 0 0 4 5 0 2 2 7 0

This report was done with support from the United States Energy Research and Development Administration. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the United States Energy Research and Development Administration.