

The code COSY INFINITY

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Abstract

In the last years there has been a considerable advance in the ability to compute high order maps of accelerators and optical systems providing new insight and accuracy that could not be reached previously. COSY INFINITY is a new generation design and simulation code for particle accelerators, guidance systems and spectrometers utilizing the new techniques. It allows the computation and manipulation of maps of arbitrary systems including fringe fields and other s-dependent effects to arbitrary order, including the dependence of system parameters. Maps can be analyzed and manipulated in a variety of ways, including normal form techniques. COSY's object oriented language concept allows to phrase very complicated layouts, boundary conditions, optimizations strategies and control requirements in a very natural way and also provides a very powerful environment to treat general problems with differential algebraic methods. Besides its analytical power, the code allows a highly interactive graphics based study and design of systems.

1 Introduction

Differential algebraic methods [1, 2] allow a very efficient and direct computation of very high order properties even for very complicated systems. In practice, this requires efficient implementations of DA methods, which represents several challenges. Besides the differential algebra package [1] and precompiler [3] developed by the author, two others have been developed recently [4, 5].

An efficient differential algebra package represents half of the way to the efficient computation of maps. The other half is the driver code. COSY INFINITY [6, 7, 8] is such a driver code written in standard FORTRAN 77. Its command language is unique in that it actually represents a full programming language. It has object oriented features which allow direct use of the differential algebraic data type and makes DA very manageable. The language is so general and powerful that even most parts of the code are written in it.

A full language environment provides the user with utmost power to express nontrivial tasks. Yet at the same time, because of the conciseness of modern languages, the whole concept is very simple to learn, even simpler than that of most other code command languages.

The virtues of COSY INFINITY are perhaps best demonstrated through examples. While during the conference, we could show the actual use of the code with an interactive, self controlled demonstration that automatically showed some of the code's features, we do not have these options in the printed media. In order to give a feeling for the abilities of the code, we present several short examples of its use, if applicable combined with a snapshot of the resulting interactive display on the screen. Necessarily, these examples cannot cover the whole spectrum of COSY's abilities, and we refer to the reference manual [8] for more complete information.

2 High Order Maps of Very Complex Elements

In this first example, we want to demonstrate that COSY indeed can compute high order maps of the most complicated elements. We illustrate this here for an inhomogeneous bending magnet that is off center, tilted and rotated. The map is computed to ninth order. If desired, even curved edges could be added. After execution, which here takes about a second, the result is written to unit 7. The COSY INPUT for this run has the following form:

```
PROCEDURE HOBEND ; {NINTH ORDER INHOMOGENEOUS
MAGNET WITH AXIS OFFSET, TILT AND ROTATION}
OV 9 2 0 ; RP .1 4 1 ;
UM ;
RA .1 ;
SA 1E-6 0 ;
TA .02 0 ; WRITE 6 ' BEGINNING WORK ' ;
MS 2 45 .05 .1 .2 .3 .4 .5 ;
WRITE 6 ' WRITING MAP ' ;
PM 7 ; WRITE 6 ' DONE ' ;
ENDPROCEDURE ;
```

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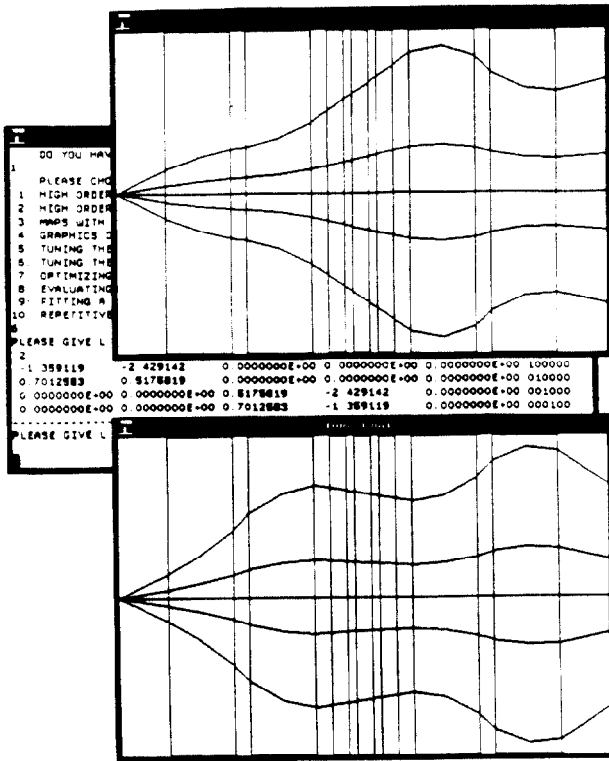


Figure 1: Interactive tuning of a quad quadruplet to perform stigmatic imaging; beginning

3 Tuning and Optimization

Besides being able to compute maps of very high orders, COSY can be used for optimization. Because of the language concept, very complicated optimization tasks can be expressed, even combinations of manual adjustments and automatic optimization. We present here a simple example showing the manual tuning of a quadruplet. In each step, we are asked to input the value of a quadrupole strength. Then the map is computed, and the momentary transfer map as well as the trajectories of several rays are displayed on the screen. Figures 1 and 2 present the contents of the display at the beginning of the optimization and at the end.

If high resolution is required, it is usually necessary to correct higher orders as well. This is most easily done using automatic optimization and not manual tuning. The following input optimizes the quadruplet to third order by adjusting some octupole strengths:

```
PROCEDURE MAGIC3 ;
  VARIABLE L 1 ; VARIABLE O1 1 ; VARIABLE O2 1 ;
  VARIABLE O3 1 ; VARIABLE OX 1 ; VARIABLE OY 1 ;
  OV 3 2 0 ; RP .1 4 1 ; L := .258538902555212 ;
  SB 0 .01 0 .01 0 0 ;
  O1 := -1E-2 ; O2 := 2E-2 ; O3 := -1E-2 ;
  FIT O1 O2 O3 ;
  UM ; CR ; ER 1 4 1 4 1 1 1 1 ;
  MAGIC_SYSTEM .05 L O1 O2 O3 ;
  BP ; DL 1E-3 ; EP ;
  OX := ABS(MA(1,222))+ABS(MA(1,233)) ;
```

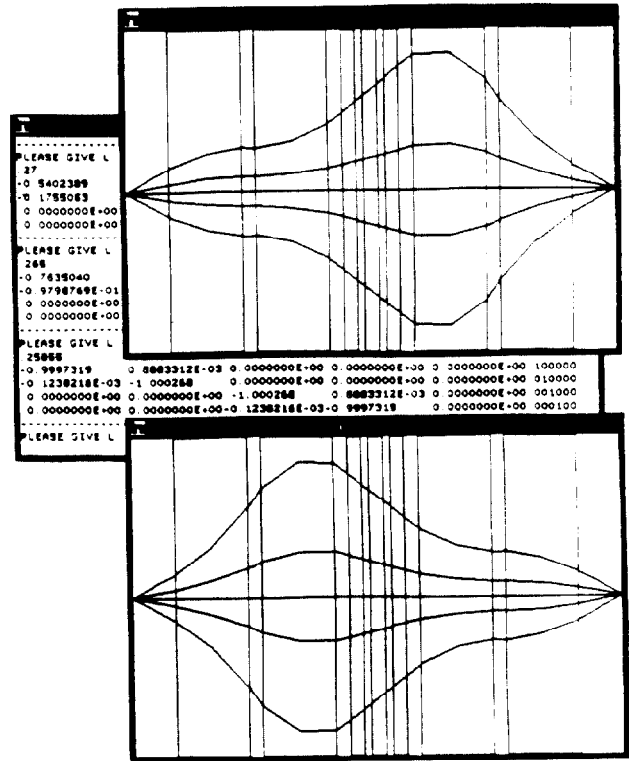


Figure 2: Interactive tuning of a quad quadruplet to perform stigmatic imaging; end

```
OY := ABS(MA(3,444))+ABS(MA(3,422)) ;
WRITE 6 ' OCT. STR. O1, O2, O3: ' O1 O2 O3 ;
WRITE 6 ' SUM OF THIRD ORDER ABERRATIONS
      (ANGSTROM): ' (OX+OY)*1E10 ; PG 1 ;
ENDFIT OX+OY 1E-12 1000 1 ;
ENDPROCEDURE ;
```

In order to see the residual third order effects, it is necessary to look at the image blown up 1000 fold at the beginning of the third order optimization. At the end, within the resolution of the graphics display, all the rays pass through one point.

4 Repetitive Systems

In this section we illustrate how the interactive features of COSY INFINITY are helpful for the study of repetitive systems. The strength of COSY lies in the ability to study these systems analytically, especially allowing direct computations of parameter tune shifts and chromaticities [9] as well as amplitude tune shifts in the framework of the differential algebraic normal form algorithm [10]. These analytical tools being extensively documented elsewhere, we here show an example demonstrating the power of the code for interactive tracking studies.

We are given a lattice with a variable sextupole strength k . We would like to see how changing the strength affects the behaviour if we are close to a resonance. Figure 4 shows the situation for two different interactively chosen

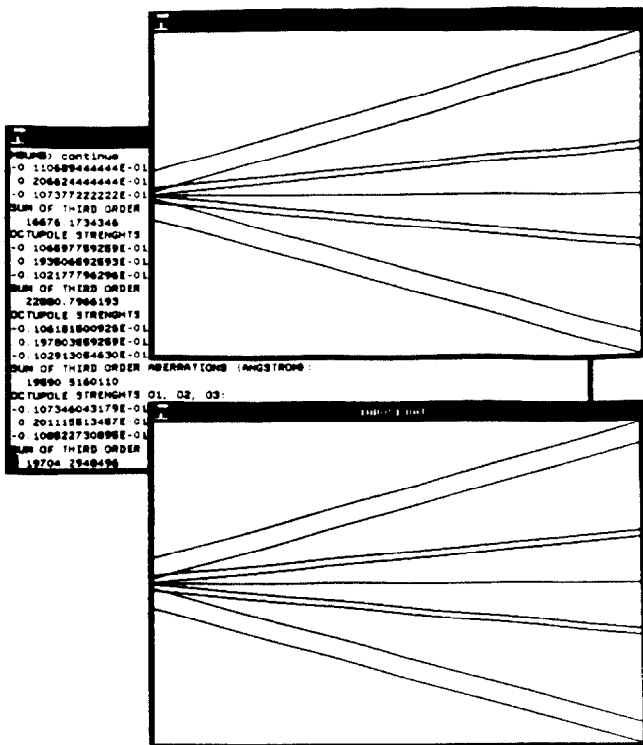


Figure 3: Interactive third order optimization of a quadruplet before correction

values of the sextupole strength. The COSY code for this problem has the following form:

```
PROCEDURE TRACK ; VARIABLE I 1 ;
  OV 7 1 0 ; RPP 1000 ; I := 1 ;
  WHILE I#0 ;
    WRITE 6 ' GIVE NUMBER OF TURNS ' ; READ 5 I ;
    WRITE 6 ' GIVE K ' ; READ 5 K ;
    UM ; LATTICE K 1 ; WRITE 6 ' TRANSFER MAP ' ;
    PM 6 ; CR ;
    SR 0 0 0 0 0 0 0 0 ; SR .1 0 0 0 0 0 0 0 ;
    SR .2 0 0 0 0 0 0 0 ; SR .3 0 0 0 0 0 0 0 ;
    SR .4 0 0 0 0 0 0 0 ; SR .5 0 0 0 0 0 0 0 ;
    SR .6 0 0 0 0 0 0 0 ;
    TR I 1 10 1 1 IPIC1 ;           {TRACKING}
  ENDWHILE ;
ENDPROCEDURE ;
```

References

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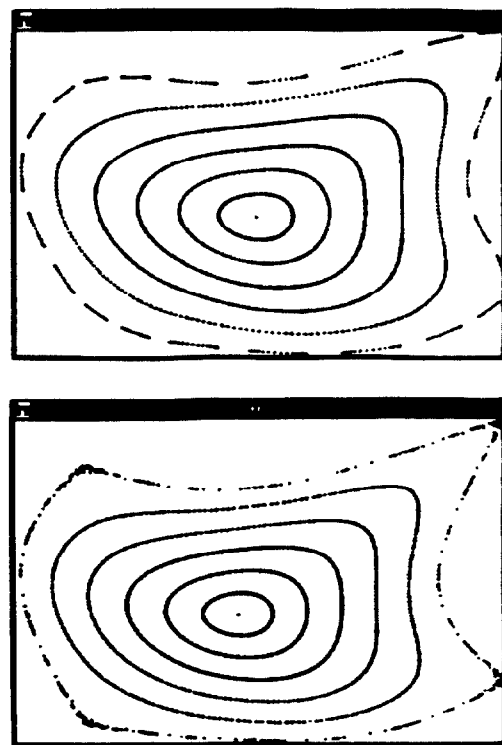


Figure 4: Interactive study of behaviour of nonlinear lattice near a resonance for two different values of the sextupole strength

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