

## The Computer Program LIAR for the Simulation and Modeling of High Performance Linacs\*

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### Abstract

High performance linear accelerators are the central components of the proposed next generation of linear colliders. They must provide acceleration of up to 750 GeV per beam while maintaining small normalized emittances. Standard simulation programs, mainly developed for storage rings, do not meet the specific requirements for high performance linacs with high bunch charges and strong wakefields. We present the program LIAR ("Linear Accelerator Research code") that includes single and multi-bunch wakefield effects, a 6D coupled beam description, specific optimization algorithms and other advanced features. LIAR has been applied to and checked against the existing Stanford Linear Collider (SLC), the linacs of the proposed Next Linear Collider (NLC) and the proposed Linac Coherent Light Source (LCLS) at SLAC. Its modular structure allows easy extension for different purposes. The program is available for UNIX workstations and Windows PC's.

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# THE COMPUTER PROGRAM LIAR FOR THE SIMULATION AND MODELING OF HIGH PERFORMANCE LINACS\*

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High performance linear accelerators are the central components of the proposed next generation of linear colliders. They must provide acceleration of up to 750 GeV per beam while maintaining small normalized emittances. Standard simulation programs, mainly developed for storage rings, do not meet the specific requirements for high performance linacs with high bunch charges and strong wakefields. We present the program LIAR ("Linear Accelerator Research code") that includes single and multi-bunch wakefield effects, a 6D coupled beam description, specific optimization algorithms and other advanced features. LIAR has been applied to and checked against the existing Stanford Linear Collider (SLC), the linacs of the proposed Next Linear Collider (NLC) and the proposed Linac Coherent Light Source (LCLS) at SLAC. Its modular structure allows easy extension for different purposes. The program is available for UNIX workstations and Windows PC's.

A major objective of the LIAR project is to provide an open programming platform for the accelerator physics community. We invite interested scientists to join this project. The LIAR home page and the ONLINE version of the user's manual can be accessed under:

<http://www.slac.stanford.edu/grp/arb/rwa/liar.htm>

## 1 THE LIAR PROJECT

The LIAR ("Linear Accelerator Research code") project was started at SLAC in August 1995 in order to provide a computing and simulation tool that addresses the needs of high performance linear accelerators. Its first objective was to implement advanced simulations for the main linacs of SLC (50 GeV) and NLC (500 GeV) at SLAC. Since then it has been applied to the LCLS project at SLAC (15 GeV), the CLIC project at CERN and to studies of a possible future 2.5 TeV linac. The program can be applied to a broad range of problems that vary widely in energy and beam parameters. Interested scientists are explicitly invited to join the LIAR project and to contribute new features (commands).

## 2 DISTRIBUTION

The LIAR code is put into the public domain and can be used and distributed freely. However, we expect that publi-

cations that contain LIAR results make proper reference to the user's guide [1]. In addition we ask that any extensions and modifications to this program are made available to the scientific community for free usage.

The most recent information on LIAR is available through its home page on the World Wide Web:

<http://www.slac.stanford.edu/grp/arb/rwa/liar.htm>

Please check for changes in the User's Manual or use the ONLINE manual with the most recent information.

The LIAR source code and executables are available through its AFS site:

[/afs/slac.stanford.edu/public/software/liar/release](afs/slac.stanford.edu/public/software/liar/release)

This directory is world-readable and can be used to download the LIAR files. The present release version of LIAR is 1.9. New versions and updates will be put into this directory. Bug fixes will generally not result in a new version number. The existing version of LIAR will just be updated. Every 1-2 months, however, a new version will be released that contains all the old features plus the new commands that have been added since the last release. If existing commands are enhanced or significantly changed they will be available under a new name. The original commands with their old functionality will be available with their original names. We thus will try to maintain backward compatibility.

## 3 PORTABILITY

The LIAR code is mainly written in standard Fortran 77. It, however, takes advantage of the STRUCTURE and RECORD extensions that are available in most Fortran compilers. The code is stand-alone, apart from a few system calls (random number generator, time) that need to be adjusted to the actual computer system. No specific libraries are required for the compilation. LIAR version 1.9 is presently running under those operating systems:

- UNIX: (IBM AIX 3.2, etc.).  
Computer: UNIX RISC workstations.
- Windows 95 / Windows NT: (Personal Computers).  
Computer: > Pentium 133 MHz, > 32 MB RAM.  
Compiler: Microsoft Powerstation Fortran 4.0.

The code is easily ported, as long as Fortran compilers are available that support the STRUCTURE and RECORD extensions.

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```

SET_INITIAL, y      = 200.d-6,
                energy = 1.19,
                espread = 0.014,
                nemitx = 3.0d-5,
                nemity = 0.3d-5,
                betax  = 3.40,
                betay  = 3.08,
                alphax = 0.156d0,
                alphay = 0.066d0

```

Everything is prepared now to set-up the beam. We specify the bunch population, the bunch length, the number of bunches, the number of slices per bunch and the number of mono-energetic beam ellipses per slice:

```

SET_BEAM, current = 4.d10,
          blength  = 1100.d-6,
          nb       = 1,
          ns      = 20,
          nm      = 3

```

Next we must define the wakefields. They are read in from external input files. We only define short-range wakefields:

```

SET_SR_WF, file = 'input/srwf_slc.dat'

```

Before we track the beam through the lattice, we misalign all quadrupoles vertically by 200  $\mu\text{m}$  RMS:

```

ERROR_GAUSS_QUAD, name      = '*',
                  y_sigma   = 200.e-6

```

Now we can finally track the beam through the lattice:

```

TRACK

```

and measure the normalized beam offsets at the BPM's:

```

MEAS_BPM, file = 'output.data',
          norm = .t.

```

The output is saved into a file. As already mentioned, many more parameters and commands are available in LIAR. For example the command TRACKC would have tracked the beam through the lattice while applying a 1-to-1 trajectory correction. The complete reference information is available in the LIAR manual [1].

During the execution of the commands LIAR provides extensive information. For example the progress of the tracking is indicated by a "trackometer":

```

TRACKOMETER :
0  10  20  30  40  50  60  70  80  90  100 %
|____|____|____|____|____|____|____|____|____|____|
.....

```

At the end of the tracking, summary information is printed to the standard output. We just show the first few lines:

```

End of tracking ANALYSIS :
Beam energy
- acceleration:  E_0 = 1.190 GeV --> E_f = 45.998 GeV
- spread:       E_sig = .016 GeV --> E_sig = .126 GeV
- rel. spread   SIGE/E = 1.322 % --> SIGE/E = .274 %
Beam blow-up
- Emittance (b1): g_x = 0.000 %          g_y = 205.158 %

```

The observables are defined in [1]. We just mention a few of the summary results: emittance growth in the linac, lattice mismatch, RMS trajectory offsets, beam energy, .... In addition most of the results are saved at every BPM location. They can be printed out into files, for example in order to study the emittance growth along the linac.

## 6 SUMMARY

The computer program LIAR ("Linear Accelerator Research code") is a numerical modeling and simulation tool for high performance linacs. Amongst others, it addresses the needs of state-of-the-art linear colliders where low emittance, high-intensity beams must be accelerated to energies in the 0.05-1 TeV range. LIAR is designed to be used for a variety of different projects. It has been applied to and checked against the existing Stanford Linear Collider (SLC), the linacs of the proposed Next Linear Collider (NLC) and the proposed Linac Coherent Light Source (LCLS) at SLAC.

LIAR allows the study of single- and multi-particle beam dynamics in linear accelerators. It calculates emittance dilutions due to wakefield deflections, linear and non-linear dispersion and chromatic effects in the presence of multiple accelerator imperfections. Both single-bunch and multi-bunch beams can be simulated. It is possible to simultaneously study the acceleration of positive and negative charges in a linac. Diagnostic and correction devices include beam position monitors, RF pickups, dipole correctors, magnet movers, beam-based feedbacks, multi-device knobs and emittance bumps. Several basic and advanced optimization schemes are implemented. Present limitations arise from the incomplete treatment of bending magnets and sextupoles.

A major objective of the LIAR project is to provide an open programming platform for the accelerator physics community. We invite interested scientists to join this project. Due to its design, LIAR allows straight-forward access to its internal FORTRAN data structures. The program can easily be extended and its interactive command language ensures maximum ease of use. Presently, versions of LIAR are compiled for UNIX and MS Windows operating systems. An interface for the graphical visualization of results is provided. Scientific graphs can be saved in the PS and EPS file formats. In addition a Mathematica interface has been developed. LIAR now contains more than 40,000 lines of source code in more than 130 subroutines.

In the future we will add the ability to include bunch compression into the simulation.

## 7 REFERENCES

- [1] R. Assmann et al., "LIAR - A Computer Program for the Modeling and Simulation of High Performance Linacs", SLAC/AP-103 (1997).