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Peter Strehl

Beam Instrumentation and Diagnostics

With 301 Figures

Springer

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To Irene,
showing always sympathy for my professional work

Schreiben ist hart;
man kommt nur schwer dahinter,
wann man aufhören muss.

PETER USTINOV

Preface

This book summarizes the experience of many years of teamwork with my group, the beam diagnostics group of GSI. For a long time the group was also responsible for operating the machines and application programming. In my opinion, this connection was very efficient: first, because a beam diagnostic system has to place powerful tools at the operators' disposal; second, because data evaluation and presentation of results for machine operation demand application programs which can be handled not only by skilled experts.

On the other hand, accelerator developments and improvements as well as commissioning of new machines by specialists require more complex measurements than those for routine machine operation. A modern beam diagnostic system, including the software tools, has to cover these demands, too.

Therefore, this book should motivate physicists, constructors, electronic engineers, and computer experts to work together during the design and daily use of a beam diagnostic system. This book aims to give them ideas and tools for their work.

I would not have been able to write this book without a good education in physics and many discussions with competent leaders, mentors, and colleagues. After working about 40 years in teams on accelerators, there are so many people I have to thank that it is impossible to mention them all by name here.

In recognition, of all, I would like to thank very much my first teachers, Peter Brix and Friedrich Gudden for filling me with enthusiasm for nuclear physics, electron scattering, and accelerator physics at the DALINAC nearly 40 years ago. Starting in 1970 at GSI, it was Christoph Schmelzer, who was always a sympathetic listener, helping me with discussions and many suggestions. Under the leadership of Dieter Böhne, who managed most accelerator projects of GSI, the beam diagnostics group, responsible for all beam diagnostics up to the target, was established. I gratefully acknowledge this in memory of both.

I thank Norbert Angert and Klaus Blasche for helpful discussions and support during their leadership of the accelerator department. Furthermore,

I would especially like to thank Jürgen Klabunde for many years of collaboration. Specification of beam diagnostic elements, elaboration of program algorithms, performing of accelerator experiments, and organization of machine operation was our common job.

This job could not have been done without the members of the beam diagnostics group. Especially, many thanks to Volker Schaa, for implementing many application programs and together with his team always available in case of software problems. Many thanks also to Fritz Bock, keeping the process computer system available day and night. In memory of Helgi Vilhjalmsson, I gratefully acknowledge his professional work and his very much respected engagement in the group.

It would be unforgivable not to acknowledge here Frank Peldzinski, together with Alfons Suderleith who were responsible for service, maintenance, and new installations of beam diagnostic elements. In this connection, the work of Günther Grimm and Horst Graf in the small beam diagnostics workshop contributed a big part to constructing the beam diagnostics system; thanks to both of them. I thank gratefully also Jörg Glatz and Ludwig Dahl for numerous physics discussions, resulting mostly in suggestions and improvements for operating the machines. In this connection, the good collaboration with Dieter Wilms and Uwe Scheeler, now both responsible for the operations group, is gratefully acknowledged.

In recognition of all members of the diagnostic group, I would like to mention Mohamed Fradj, Manfred Hartung, Tobias Hofmann, Wolfgang Kaufmann, Wilhelm Losert, Rolf Mayr, Peter Moritz, Hansjörg Reeg, and Norbert Schneider for professional discussions and their great engagement as operators, shift leaders, and designers. Many thanks to them and all other members of the beam diagnostics group.

Construction design and procuring of nearly all mechanical parts of the GSI beam diagnostic systems were managed by Hubert Kraus with the help of Jochen Störmer. I thank them both very much for their work and many years of close collaboration.

My special thanks go to Andreas Peters and Peter Forck, who now are the leaders of the beam diagnostics group. Designing together the beam diagnostic systems for SIS, ESR (partly), and the high energy beam lines, the collaboration could not have been better. In 2002, Peter Forck took over my courses on “Beam Instrumentation and Diagnostics” at the Joint University Accelerator School (JUAS). He improved and supplemented my lecture notes. Some of the contributions to this book are adapted from our common work.

After retirement, I miss very much the short meetings with Claus Riedel. We met nearly every day for half an hour or even more for discussion. I thank him very much for many suggestions concerning the solution of mathematical-physical problems.

For pictures marked GSI-Foto, I acknowledge the work of Achim Zschau and Gabriele Otto for taking them. The draft version of the book was written

with Scientific Workplace of MacKichan Software Inc. I can recommend it as a powerful tool.

I also thank the editorial board of Springer for helpful suggestions. Finally, I wish to express my special thanks to my editor, Dr. Christian Caron, and his team, especially, Gabriele Hakuba and Birgit Münch.

Darmstadt *Peter Strehl*
December 2005

Commonly Used Abbreviations

AC alternating current
ADC analog-to-digital converter
AlN aluminum nitrite
ATF accelerator test facility (KEK)
BCT beam current transformer
BPM beam position monitor
BNL Brookhaven National Laboratory
BTF beam transfer function
BeO beryllium oxide
CAD computer-aided design
CCC cryogenic current comparator
CCD charge-coupled device
COG center of gravity
CERN European Organisation for Nuclear Research
CT computer tomography
CVD chemical vapor deposition
CW continuous wave
DAC digital-to-analog converter
dc direct current
DESY Deutsches Elektronen Synchrotron
DSP digital signal processing
ECR electron cyclotron resonance
ESR experimental storage ring
FC Faraday cup
FD finite difference
FE finite element
FFT fast Fourier transformation
FWHM full width half-maximum
GSI Gesellschaft für Schwerionenforschung
HILAC heacy ion linear accelerator
IC ionization chamber
IF intermediate frequency

ICT integrating current transformer
ISR intersecting storage ring (CERN)
KEK High Energy Accelerator Research Organisation
LEP large electron-positron storage ring
LHC large hadron collider
LBL Lawrence Berkeley Laboratory
MART multiplicative algebraic reconstruction technique
MCP multichannel plate
MCA multichannel analyzer
MEVVA metal vapor vacuum
MUCIS multicusp ion source
MWPC multiwire proportional chambers
ODR optical diffraction radiation
OTR optical transmission radiation
OTDR optical time domain reflectometer
PC personal computer
PCI industrial personal computer
PIG Penning (ion source)
PLL phase-locked loop
PMT photomultiplier tube
pps particles per second
PS proton synchrotron (CERN)
PSI Paul Scherrer Institut (SIN)
RAM random access memory
RCT resonant current transformer
RHIC Relativistic Heavy Ion Collider
rf radio frequency
RFQ radio-frequency quadrupole
rms root-mean-square
SCM scintillation current monitor
SEM secondary electron emission monitor
SI International Unit System
SIS Schwer Ionen Synchrotron
SLAC Stanford Linear Accelerator Center
SPS super proton synchrotron
SQUID superconducting quantum interference device
TAC time-to-amplitude converter
TDC time to digital converter
TESLA TeV-Energy Superconducting Linear Accelerator
TDR time domain reflectometer
TOF time of flight
UNILAC Universal Linear Accelerator
UV ultraviolet
VCO voltage-controlled oscillator
VSWR voltage standing wave ratio
WEB WorldWide Web

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