Field Guide to

Laser Pulse Generation

Rüdiger Paschotta

SPIE Field Guides
Volume FG14

John E. Greivenkamp, Series Editor

SPIE
PRESS

Bellingham, Washington USA

Library of Congress Cataloging-in-Publication Data

Paschotta, Rüdiger.
Field guide to laser pulse generation / Rudiger Paschotta.
p. cm. -- (SPIE field guides ; FG14)
Includes bibliographical references and index.
ISBN 978-0-8194-7248-9 (alk. paper)
1. Laser pulses, Ultrashort. 2. Pulse generators. 3. Pulse techniques (Electronics) I. Title.
QC689.5.L37P37 2008
621.36'6--dc22

2008038193

Published by

SPIE
P.O. Box 10
Bellingham, Washington 98227-0010 USA
Phone: +1 360 676 3290
Fax: +1 360 647 1445
E-mail: books@spie.org
Web: http://spie.org

Printed in the United States of America.

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Field Guide to Laser Pulse Generation

Lasers and related devices have an amazing potential for generating both very intense and extremely short light pulses. Within four decades, a wide range of techniques for pulse generation has been developed; these techniques can be applied to different laser types and span a huge parameter space in terms of pulse duration, peak power, and pulse repetition rate. It is therefore not surprising that laser pulses have found an extremely wide range of applications.

The primary objective of this *Field Guide* is to provide an overview of all essential methods of laser pulse generation, including Q switching, gain switching, mode locking, and also the amplification of ultrashort pulses to high energies. Some material on pulse characterization is also provided. Both the physical aspects involved and the various technical limitations are discussed in significant depth. This *Field Guide* should therefore be very useful for a wide audience, including practitioners in industry as well as researchers. Even those who only apply, but do not themselves develop, pulsed and ultrafast laser systems can learn, for example, about the potential of different pulse generation methods.

I am greatly indebted to my wife, Christine, who strongly supported the creation of this *Field Guide* by improving many of the figures.

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$A(t)$	electric field envelope function
c	velocity of light in vacuum
D_2	group delay dispersion
E	electric field strength
E_p	pulse energy
E_sat	saturation energy (e.g., of a laser medium)
f	frequency (e.g., noise frequency)
f_m	modulation frequency
f_rep	pulse repetition rate
g	gain coefficient
g_f	final gain coefficient
g_i	initial gain coefficient
g_ss	gain coefficient in the steady state
G	power amplification factor [= exp(g)]
h	Planck's constant
I	optical intensity (power per unit area)
I_sat	saturation intensity (e.g., of a laser medium)
l	loss coefficient (e.g., for round-trip losses of a resonator)
n	refractive index
n_2	nonlinear index
P	optical power
P_av	average power
P_p	peak power
q	coefficient saturable loss
ΔR	modulation depth of saturable absorber
t	time
T_rt	round-trip time of a resonator
T_oc	output coupler transmission

γ	nonlinear coefficient
φ	change of spectral phase
λ	wavelength
ν	optical frequency
$\nu(t)$	instantaneous frequency
ν_{ceo}	carrier–envelope offset frequency
$\Delta\nu$	optical bandwidth
$\Delta\nu_{\gamma}$	gain bandwidth
τ_g	upper-state lifetime
τ_p	pulse duration
ω	angular frequency