Contents

Preface			v
Introduc	ction		1
Chapter	the	plications of Mid-infrared Sources for e Study of the High-order Nonlinear tical Processes in Gases	9
1.1.		ecture of Mid-infrared Lasers Used for	
		nic Generation in Gases	9
		Various schemes of mid-infrared sources Commercially available source of	9
		mid-infrared radiation	12
1.2.	High-o	rder Harmonic Generation in Gases Using	
		ulses	18
	1.2.1.	Infrared two-color multicycle laser field synthesis for generating an intense	
		attosecond pulse	19
	1.2.2.	Attosecond nonlinear optics using	
		gigawatt-scale isolated attosecond pulses	24
	1.2.3.	Generation of coherent radiation	
		in the water window region at 1 kHz	
		repetition rate using a mid-infrared	
		pump source	32
	1.2.4.	Various approaches in the HHG using MIR pulses	36

1.3.	Conclusions to Chapter 1	40	
Refe	rences	42	
Chapter	• 2. Principles of HHG in		
Chapter	Laser-produced Plasmas		
	using MIR Pulses	49	
0.1	Introduction	49	
2.1. 2.2.		43	
2.2.	2. High-Order Harmonic Generation in Graphite Plasma Plumes Using 800 nm and MIR		
	Laser Pulses	52	
		55	
	2.2.1. Experimental arrangements	00	
		58	
	plasma formation	-58 -63	
0.0	2.2.3. Discussion	05	
2.3.	MIR- and 800-nm-Induced High-Order Harmonic Generation in Uracil Laser Plumes	67	
		67	
	2.3.1. Introduction	69	
2.4	2.3.2. Experiment and discussion	09	
2.4.	High-Order Harmonic Generation in Fullerenes		
	Using Few- and Multi-Cycle Pulses of Different	75	
	Wavelengths	75 75	
	$2.4.1. Introduction \dots \dots$		
	2.4.2. Results and discussion	76 95	
2.5.	Conclusions to Chapter 2	85	
Refe	erences	87	
Chanter	r 3. Resonance-induced Enhancement		
emapte	of Harmonics in Metal Plasmas	91	
3.1.	Resonance Enhancement of Harmonics in Metal		
0.11	Plasmas using Tunable Mid-infrared Pulses	92	
	$3.1.1.$ Introduction \ldots	92	
	3.1.2. Experimental conditions for HHG in plasma		
	plumes using tunable MIR pulses	93	
	3.1.3. Experimental studies of resonance		
	enhancement of MIR-induced harmonics		
	in plasmas	95	

Contents

	3.1.4.	Theoretical analysis of resonance-enhanced	
		harmonic spectra from Sn, Sb, and	
		Cr plasmas	. 106
	3.1.5.	Discussion	. 112
3.2		n Plasma in the Single- and Two-color	
		frared Fields: Enhancement of Tunable	
		onics	. 117
	3.2.1.	Introduction	. 117
	3.2.2.	Experimental studies of the resonance	
		enhancement of MIR-induced harmonics	
		in the indium plasma	. 120
	3.2.3.	Theory of resonance enhancement	-
	3.2.4.	Discussion	. 133
3.3		ance Enhancement of Harmonics	
		er-produced Zn II and Zn III Containing	
		as	. 140
	3.3.1.	Method of laser ablation induced	
		MIR-pumped HHG spectroscopy	. 140
	3.3.2.	Experimental conditions of HHG in	
		zinc plasma using tunable MIR pulses	. 141
	3.3.3.	Single- and two-color pumps	
		of zinc plasma	. 143
	3.3.4.	Modification of harmonic spectra	
		at excitation of neutrals and doubly	
	00×	charged ions of Zn	
a 4	3.3.5.	Discussion of results	
3.4		sions to Chapter 3	
Ref	erences .		. 160
Chante	or A Ou	asi-phase-matching in Plasmas	
Chapte		ing Mid-infrared Pulses	165
1 1			100
4.1.		ation of Mid-infrared Pulses	
		asi-phase-matching of High-order Harmonics r Plasma	100
	4.1.1.		
	4.1.1.	Early studies of quasi-phase-matching	. 100

ix

	4.1.2.	Experimental conditions and HHG in silver		
		plasma plumes using tunable 1250–1400 nm,		
		70 fs pulses under the conditions		
		of quasi-phase-matching	. 168	
	4.1.3.	Theory of QPM	. 172	
4.2.	On- and	d Off-axis Quasi-phase-matching		
	of the Harmonics Generated in the Multi-jet			
	Laser-p	roduced Plasmas	. 177	
	4.2.1.	Description of the problem	. 177	
	4.2.2.	Analysis of on- and off-axis conditions		
		of QPM	. 180	
4.3.	Influen	ce of Micro- and Macro-Processes		
		on the High-order Harmonic Generation		
	in Lase	r-produced Plasma	. 193	
	4.3.1.	Two concepts of MIR-induced harmonic		
		$enhancement \ . \ . \ . \ . \ . \ . \ . \ . \ . \ $. 193	
	4.3.2.	Comparative enhancement of harmonics		
		caused by resonance enhancement		
		and QPM	. 196	
	4.3.3.	Discussion on different methods of harmonic	000	
		enhancement		
4.4.		sions to Chapter 4 \ldots \ldots \ldots \ldots		
Refe	rences .		. 213	
Chapter	5. Va	rious Applications of MIR HHG		
Chapter		proach in Different Plasma Plumes	217	
5.1.		on of Boron Carbide for High-order Harmonic		
0.1.		tion of Ultrafast Pulses in Laser-produced		
	Plasma			
	5.1.1.	Application of hard materials for plasma		
	0.1.1.	formation	. 219	
	5.1.2.	Experimental arrangements		
	5.1.2.	Comparison of the plasma and harmonic		
	0.1.0.	emission of ablated targets	. 222	
	5.1.4.	Double-pulse and two-color pump of boron		
	0.2.2.	carbide plasma	. 225	
		r r r r r r r r r r r r r r r r r r r		

Index			281
Summa	ry: Pers	spectives	273
Refe	erences .	• • • • • • • • • • • • • • • • • • • •	. 269
5.4.		sions to Chapter 5	
	5.3.3.	Discussion	
	5.3.2.	1	
		media	. 252
		incommensurate waves in the nonlinear	
		Interaction of commensurate and	
		s of Graphite Plasma	. 252
		ensurate and Incommensurate Mid-infrared	
2.01		ation Using Tunable Two- and Three-color	
5.3.		order Sum and Difference Frequencies	
	5.2.3.		
	5.2.2.		
	0.4.1.	pumps	237
	5.2.1.		. 255
		ating Particle Properties	<u>9</u> 25
0.2.		smas: Efficiency Dependence on the	
5.2.	5.1.7. Two c	Discussion of experiments	. 232
	E 1 7	harmonic yield	
	5.1.6.	Influence of ionic resonances on the	
	F 1 0	of plasma	. 227
	5.1.5.	2 morene concluse of the two color pump	

Contents