





# Innovative Mid-infrared high Power source for resonant ablation of Organic based photovoltaic devices

An EU FP7 collaborative project

















#### Project organisation



- STREP
- Seventh Framework Programme
- ICT-2009.3.7 Photonics
- 3-years: 1 September 2010 to 31 August 2013
- Total budget of 2.43 M€ (EC contribution)
- Grant Agreement no: 257894
- Two global players, two SME's, three research institutes













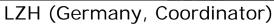




#### Consortium







Multitel (Belgium)

NKTP (Denmark)

Batop (Germany)

TRT (France)

IMEC (Belgium)

Heliatek (Germany)



















#### Project overview



IMPROV develops a short-pulse Mid-IR laser system, based on a multistage configuration operating at wavelengths between  $3-10~\mu m$  using novel

- > Tm fibre oscillator operating between 1.8 and 2 µm as seed-source
- high power Tm fibre amplifier chain as front-end
- efficient OPG/OPA based nonlinear wavelength conversion stage with orientation patterned GaAs, providing radiation in the MIR
- and required components for integration















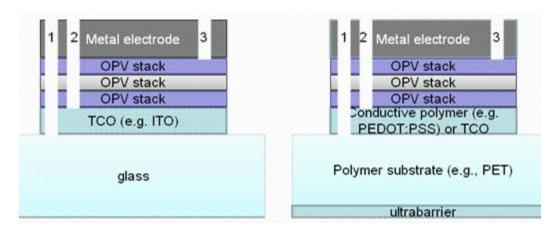


#### Project overview



IMPROV evaluates resonant infrared ablation (RIA) of organic photovoltaic (OPV) stacks with the developed laser system

- integration in a process ablation set-up
- scribing tests of single/multilayer elements



Schematic view of the 3 processes steps in the fabrication of an OPV















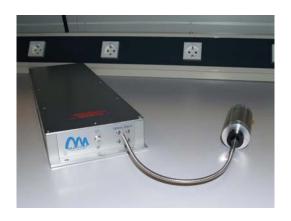


#### Project overview



IMPROV demonstrates the functionality of the Mid-infrared tunable laser source concerning

- mechanical and optical parameters
- integration/compatibility with a practical industrial application























						Ye	ar 1			Ye	ar 2			Ye	ear 3	
Tasks			Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	10	Q11	Q12		
2.1.1: Laser des																
2.1.2: Determin																
2.2.1: Reflectiv	e saturable	absorber														
2.2.2: Transmis	sion saturat	ole absorber											Č.			
2.2.3: Fibre cou													4.			
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2.3.2: Prelimina																
2.3.3: Low repe			ting at 1.98 µm	1												
2.4.1: Design of																
2.4.2: Tunable										con Mari			io.			
2.4.3: All-fibre	tunable osc	illator						Fixed w	avelengtl	h fibre os	c.				1	
3.1.1: Research				m market		II.		1					Tunabl	e fibre o	scillator	
3.1.2: Develops			re amplifier													
3.1.3: LMA pre			10.00					Į.								
3.1.4: LMA cor		ing pumping ev	raluation													
3.1.5: ASE filte																
3.1.6: Prototyp.																
3.2.1: First itera																
3.2.2: All-fibre	pump/signa	l multiplexer (c	ase of clad pur	nping)												
3.2.3: Characte			PCF													
3.3.4: Test of b												13	*			
3.2.5: Prototypi	ing of the H	igh power Tm-l	asers			First p	rototype	with prea	mplifier							
4.1.1: Nonlinea			tion										4	High p	ower syst	em
4.1.2: Design o	f the OPG/C	OPA set-up					,			•						
4.1.3Assembly															l prototyp	
4.2.1: Nonlinea			tion											tunabl	e osc./amp	).
4.2.2: Design o	f OPG/OPA	set-up														
4.2.3: Assembly	y of pulsed	prototype II					First p	rototype	MIR lase	r source						
5.1.1: Single la	ver characte	risation: small r	mol, absorb, ar	d pol. substr.												
5.1.2: Gas barri	ers for flexi	ble devices														
5.1.3: Preparati																
5.2.1: Preparati										-	<b>*</b>					
5.2.2: Integration															1	
5.3.1: Scribing				nary laser												
5.4.1: Integration			otype													
5.4.2: Multilaye	er ablation to	ests									Integ	gration of	second p	rototype	+	
6.1.1: Nonlinea												1				
6.1.2: Demonst	rator integra	ation and final to	ests												100	



















Tasks  2.1.1: Laser design studies 2.1.2: Determination of continuum parameters of saturable aborber	WP2: Saturable absorber and laser										
2.2.1: Reflective saturable 2.2.2: Transmission saturable ab 2.2.3: Fibre coupled saturable absorber	oscillator  Lead Participant: LZH										
2.3.1: Development of fibre components 2.3.2: Preliminary prototype operating at a wavele 2.3.3: Low repetition rate fibre laser operating at 1.98 pm											
2.4.1: Design considerstions 2.4.2: Tunable fibre oscillator 2.4.3: All-fibre tunable oscillator	Development of Thulium-based integrated all fiber oscillators										
3.1.1: Research and test of available 2 um fibre comp. from market 3.1.2: Development of a low power all-fibre amplifier 3.1.3: LMA preamplifier fibre	<ul> <li>wavelength range 1.8 to 2.0 μm</li> </ul>										
3.1.4: LMA core and cladding pumping evaluation 3.1.5: ASE filtering 3.1.6: Prototyp. of the LMA double-clad amp. and int. short pulse laser	pulse duration from 10 ps to hundreds of ps     repetition rate < 1 MHz										
3.2.1: First iteration single clad Booster PCF (case of core pumping) 3.2.2: All-fibre pump/signal multiplexer (case of clad pumping) 3.2.3: Characterisation of the 50 µm LMA PCF	<ul><li>repetition rate &lt; 1 MHz</li><li>average output power 10 mW</li></ul>										
3.3.4: Test of broadband amplification 3.2.5: Prototyping of the High power Tm-lasers 4.1.1: Nonlinear crystal design and fabrication	and related components										
4.1.2: Design of the OPG/OPA set-up 4.1.3Assembly of pulsed prototype 4.2.1: Nonlinear crystal design and fabrication	<ul><li>saturable absorbers</li><li>fiber combiners</li></ul>										
4.2.2: Design of OPG/OPA set-up 4.2.3: Assembly of pulsed prototype II	<ul> <li>wavelength division multiplexers</li> </ul>										
5.1.1: Single laver characterisation: small mol. absorb. and pol. substr. 5.1.2: Gas barriers for flexible devices 5.1.3: Preparation of samples for scribing tests											
5.2.1: Preparation of the scientific ablation set-up 5.2.2: Integration of the preliminary laser source											
5.3.1: Scribing tests on single layer elements with preliminary laser 5.4.1: Integration of first tunable laser prototype 5.4.2: Multilayer ablation tests	Integration of second prototype										
6.1.1: Nonlinear crystal selection 6.1.2: Demonstrator integration and final tests											



















Tasks	M/DO Distanta amental films
2.1.1: Laser design studies	WP3: Photonic crystal fibre,
2.1.2: Determination of optimum parameters of saturable aborber	•
2.2.1: Reflective saturable absorber	combiners and amplifier integration
2.2.2: Transmission saturable absorber	, 3
2.2.3: Fibre coupled saturable absorber	Lead Participant: MULT
2.3.1: Development of fibre components	Lead Farticipant. Well
2.3.2: Preliminary prototype operating at a wavelength of L. 2.3.3: Low repetition rate fibre laser operating at 1.98	
2.4.1: Design considerations	Development of the high power amplifier chain
2.4.1. Design considerations 2.4.2: Tunable fibre oscillator	bevelopment of the high power ampliner chain
2.4.3: All-fibre tunable oscillator	<ul> <li>wavelength 2 μm</li> </ul>
3.1.1: Research and test of av	9 1
3.1.2: Development of a	<ul> <li>spectral linewidth 1 nm</li> </ul>
3.1.3: LMA preamplifier fibre	
3.1.4: LMA core and cladding pumping evaluation 3.1.5: ASE filtering	<ul> <li>pulse duration &lt; 1 ns</li> </ul>
3.1.6: Prototyp. of the LMA double-clad amp. and int. short pulse laser	
3.2.1: First iteration single clad Booster PCF (case of core pumping)	<ul> <li>energy per pulse 100 μJ</li> </ul>
3.2.2: All-fibre pump/signal multiplexer (case of clad pumping)	
3.2.3: Characterisation of the 50 µm LMA PCF	and related components
3.3.4: Test of broadband amplification	and related compenents
3.2.5: Prototyping of the High power Tm-lasers	<ul> <li>LMA photonic crystal fibres</li> </ul>
4.1.1: Nonlinear crystal design and fabrication	Elvin prioterno di gotar nortos
4.1.2: Design of the OPG/OPA set-up	<ul> <li>LMA pump/signal combiners/multipexer based on</li> </ul>
4.1.3Assembly of pulsed prototype 4.2.1: Nonlinear crystal design and fabrication	
4.2.2: Design of OPG/OPA set-up	crystal fibres
4.2.3: Assembly of pulsed prototype II	
5.1.1: Single layer characterisation: small mol, absorb, and pol, substr. 5.1.2: Gas barriers for flexible devices	
5.1.3: Preparation of samples for scribing tests	
5.2.1: Preparation of the scientific ablation set-up	
5.2.2: Integration of the preliminary laser source	
5.3.1: Scribing tests on single layer elements with preliminary laser	
5.4.1: Integration of first tunable laser prototype	
5.4.2: Multilayer ablation tests	Integration of second prototype
6.1.1: Nonlinear crystal selection	
6.1.2: Demonstrator integration and final tests	



















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Tasks	9	58	-81	1899		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	10	Q11	Q12		
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2.2.2: Transn														0					
2.2.3: Fibre c														5					
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		w power all-fit			Kel		Lead Participant: TRT												
3.1.3: LMA 1			ore unipititi	<u></u>		Load Fartioiparit. Titl													
		ling pumping e	valuation																
3.1.5: ASE fi		61 1 6				Development of a mid-infrared laser source													
3.1.6: Prototy	yp. of the LM	A double-clad a	amp. and ir	nt. short pul	se laser	Development of a fina initiated laser source													
3.2.1: First it	eration single	clad Booster P	CF (case o	of core pum	oing)	• wavelength range from 2.5 μm to 11 μm													
3.2.2: All-fib	re pump/sign	al multiplexer (	case of cla	id pumping)		wavelength range from 2.5 µm to 11 µm													
		he 50 µm LMA	\ PCF			• pulse duration < 1 ns													
3.3.4: Test of						• repetition rate < 1 MHz													
		ligh power Tm-																	
		sign and fabrica	ation																
4.1.2: Design		OPA set-up				<ul> <li>energy per pulse up to 30 μJ</li> </ul>													
4.1.3Assemb 4.2.1: Nonlin							chergy per pulse up to 30 µs												
4.2.1: Nonini 4.2.2: Design		A set-III				•	<ul> <li>10 μJ pulse energy at 6 μm wavelength</li> </ul>												
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5.1.2: Gas ba						•	and	cial	leu (	CITIE	JULIE	11113							
5.1.3: Prepara	ation of samp	les for scribing	tests					dino	or or:	rot o l	docia	n 0	horo	atorio	otion	000			
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				7		Y	ear 1			Ye	ar 2		ē.	Ye	ar 3			
Tasks	*	28	- 11	1999	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	10	Q11	Q12		
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	bre tunable os					structuring OPV												
3.1.1: Resea	arch and test of	available 2 um	fibre comp	from market		Lead Participant: IMEC												
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	preamplifier f		10 10 10															
		ling pumping e	valuation			Validation of the maid infrared least serves for												
3.1.5: ASE						Validation of the mid-infrared laser source for												
				short pulse lase	er	structuring organic photovoltais material stocks												
				core pumping)	-	structuring organic photovoltaic material stacks												
		al multiplexer ( the 50 µm LMA	_	pumping)	_													
	of broadband a		IPCF		-	<ul> <li>IR absorption measurements/characterisation</li> </ul>												
		ligh power Tm-	lasers															
		sign and fabric				<ul> <li>preparation of the process evaluation set-up</li> </ul>												
	en of the OPG/		шоп															
	ibly of pulsed p					<ul> <li>integration of the fixed wavelength laser source</li> </ul>												
4.2.1: Nonli	inear crystal de	sign and fabric	ation															
	gn of OPG/OP					<ul> <li>single layer ablation tests</li> </ul>												
	mbly of pulsed					integration of the tunckle least source												
5.1.1: Single	e laver charact	erisation; small				<ul> <li>integration of the tunable laser source</li> </ul>												
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5.1.3: Prepa 5.2.1: Prepa	aration of samp		· mu	пшау	er ab	iatioi	ites	ıs										
		eliminary laser	source															
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	ilayer ablation																	
6.1.1: Nonlinear crystal selection																		
O. L. I. IVOIIII	6.1.2: Demonstrator integration and final tests																	



















								Ye	ar 1			Ye	ar 2		-	Ye	ar 3		
Tasks								Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	10	Q11	Q12	
2.1.1: Laser d													1						
2.1.2: Determ			neters	of saturab	le aborber														
2.2.1: Reflect																			
2.2.2: Transm																			
2.2.3: Fibre co																			
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2.3.3: Low rej			erating	ş at 1.98 p	ım	_	WP6: Validation of the Mid-infrared												
2.4.1: Design						_													
2.4.2: Tunable 2.4.3: All-fibr							laser source												
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3.1.1: Researce 3.1.2: Develo					from market		Lead Participant: TRT												
3.1.2: Develo			-nore a	принег			Leau Fai iicipanii. TKT												
3.1.4: LMA c			o evalı	ation															
3.1.5: ASE fil		ding partiping	5 CVart	attion			Demonstration of the overall functionality of the												
3.1.6: Prototy		A double-cla	damn	and int	short pulse la	ser	Demonstration of the overall functionality of the												
3.2.1: First ite							MIR source concerning												
3.2.2: All-fibr							•	VIIIX	30ui		Orice	JI I III	19						
3.2.3: Charact																			
3.3.4: Test of							•	• me	chan	ical a	and o	ptica	ıl par	ame	ters				
3.2.5: Prototy	ping of the l	ligh power T	m-lase	ers						. ,		·							
4.1.1: Nonline	ear crystal d	esign and fabr	ricatio	n			•	• inte	egrat	ion/c	omp	atıbıl	itywi	th pr	actic	al ind	dustr	ıaı	
4.1.2: Design								anr	olicat	ione	•		J						
4.1.3Assembl	y of pulsed	prototype						app	meat	10113									
4.2.1: Nonline			rication	n		<i></i>													
4.2.2: Design																			
4.2.3: Assemb	oly of pulsed	prototype II																	
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5.1.2: Gas bar				_/															
5.1.3: Prepara				S															
5.2.1: Prepara			tion																
5.2.2: Integrat																			
5.3.1: Scribin					anary laser														
5.4.1: Integral		un		PC															
5.4.2: Multila																			
6.1.1: Nonline			nal tact				- 10					_		_	_				
6.1.2: Demon	sudioi mileg	tauen and Im	an tests	,				1					L				16	8	

















#### Research areas



#### Multi-functional Components

- Saturable absorbers
- Fibre couplers
- PCF based devices
- nonlinear crystals



#### **Resonant Infrared Ablation**

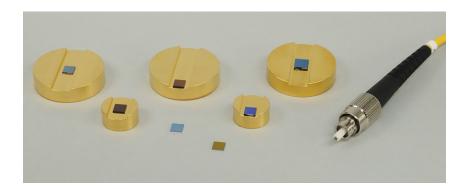
- sample preparation
- process evaluation set-up
- ablation tests

#### Tunable short pulse radiation systems

- Mode-locked Tm fibre oscillators
- Tm fibre amplifiers
- GaAs nonlinear conversion stage

#### Integration, Opto-Mechanical Engineering

- components
- subsystems























Thank you for your attention

Visit our webpage: http://www.fp7project-improv.eu













