R&D in Laser Materials Processing

Part 2
Competency map of top-level UK providers of R&D in laser materials processing

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Contents

Established research in laser material processing in the UK

1. Introduction and 'modus operandi'

This survey was carried out to identify the current lead players in research and development (R&D) into laser materials processing (LMP) in the UK. The work involved making contact with hundreds of companies and universities via approximately 1700 emails and 100 interviews and/or visits. The work was carried out during the summer of 2008 by Dr. J. Powell and Prof. W.M. Steen. The project was divided into a survey of industries conducted by Dr. Powell and an academic/RTO survey, conducted by Professor Steen.

1.1 Industrial survey

The industrial survey involved contacting over 600 firms who use, or are connected with the use of, lasers for materials processing. After an initial contact it was established that approximately 90% of these organisations carry out no laser materials processing R&D. Further contact with the remaining ~60 industrial organisations divided them into three groups:

1. Those that carry out significant disclosed LMP R&D in the UK
2. Those that only carry out commercially sensitive (i.e. undisclosed) customer-based process trials
3. Those that carry out significant disclosed LMP R&D outside the UK

All companies in Group 1 and those in Group 2 that expressed a significant interest in future R&D projects were divided into two groups according to their current strength and activity. The remainder of Group 2 companies and all those in Group 3 were not included in the primary/secondary assessment, as they did not fit the required profile for this survey.

Finally, a list was prepared which gives details of the currently strongest industrial players in laser materials processing research in the UK (Table 2). A further list (shown in Appendices 1 and 2) provides information on companies that might be persuaded to get involved in future research activities.

1.2 Academic and RTO survey

The academic and RTO survey involved sending a questionnaire by email to all AILU members working in universities or research institutes (300); following this up with phone calls (approximately 60) as appropriate and in some cases a visit. The websites of all UK universities (90 in total) were examined and those having a reference to laser material processing (40 institutions) further contacted by email, phone or visit, if they had not already been identified through the AILU network. From the resulting data their level of activity were noted: Those currently active groups that are established and have contributed strongly to the field in the last five to ten years are listed in Table 1; new groups and groups with a medium level of activity and interest are listed in Appendix 3; and those groups that did not responded to the survey are listed in Appendix 4. Each of the established groups and those groups listed in Appendix 3 completed a questionnaire from which their size and areas of research interest were identified. Only the results from the established groups are shown in more detail in Appendix 5.

Table 1:

Established academic and RTO groups with strong LMP activity.

Institution	Type of work with lasers	Contact	T.N	email
Birmingham University	Direct fabrication	Dr. Isaac Chang Prof X.Wu	0121 4145167 0121 4147842	i.t.chang@bham.ac.uk X.Wu.1@bham.ac.uk
Cambridge University	Centre for Industrial Photonics: Laser cutting, beam analysis, deposition	Dr. Bill O'Neill	01223 764834	wo207@cam.ac.uk
Cardiff University	Manufacturing Eng. Centre micro, nano process XGEN Extreme u/v lasers	Prof Duc T. Pham Prof David Barrow	029 208 74641 078 0983 9979	phamdt@Cardiff.ac.uk Barrow@cf.ac.uk
Coventry University	Centre for Advanced Joining: Welding, cutting, cladding, PALW	Mr. Edmund du Bois	02476 887688	pdqa@aim.com
Cranfield University	Welding Engineering Research Centre: high power fibre laser, processing, hyperbaric welding, hybrid laser welding, laser additive manufacture, laser microwelding	Prof. Stewart Williams	01234 754693	s.williams@cranfield.ac.uk
Heriot-Watt University	Micro, adaptive optics, fibre optics, precision cutting, ultra short pulse CO_2 laser, glass proc.	Prof. Duncan P. Hand Prof. Howard J Baker	0131 449 3020 0131 449 3085	D.P.Hand@hw.ac.uk H.J.Baker@hw.ac.uk
Hull University	Laser soldering, ablation, hole drilling, ultra short pulses.	Prof. Peter Dyer	01482 465501	p.e.dyer@hull.ac.uk
Imperial College London	Modelling of multi-pulse ablation processes; laser transfer processes; MEMS device fabrication; large area polymer machining	Prof. Andrew S. Holmes Prof. Malcolm C. Gower	020 7594 6239 020 7594 9756	a.holmes@imperial.ac.uk m.gower@imperial.ac.uk
Liverpool John Moores University	Cutting, Drilling, Joining, Prototyping, Marking, Laser processing of composites Laser microprocessing Laser processing of SolGels	Dr Martin Sharp Dr Paul French	0151 231 2031	m.sharp@ljmu.ac.uk p.french@ljmu.ac.uk
Liverpool University	Micro nano applications; fibre applications, optical trapping, ink curing, direct write, sol gel, micro forming, buckling. High throughput ultrafast Surface micro-structuring using Dynamic Holograms. Lairdside Laser Engineering Centre	Prof Ken Watkins To be appointed	0151 794 4820 0151 794 4839 0151 650 2305	k.watkins@liverpool.ac.uk --@llec.co.uk
Loughborough University	Micro-machining, surface treatment of polymers, fibre laser welding, DOE, 3D textiles, repair of ceramics, annealing	Dr John Tyrer Dr Fiona Warner	01509 227531 01509 228733	J.R.Tyrer@lboro.ac.uk f.warner@lboro.ac.uk
Manchester University	Laser Processing Research Centre: Cutting, welding, drilling, additive manufacture, nano fabrication, laser synthesis, cleaning.	Prof Lin Li Dr. Zhu Liu	0161 306 3814 0161 200 4845	Lin.li@manchester.ac.uk zhu.liu@manchester.ac.uk
Nottingham University	Innovative Manufacturing Process Group, The Laser centre: Fibre laser welding, cutting, surface modification, process control, laser deposition, coating removal; drilling	Dr Janet Folkes Dr Joel Segal Dr Katy Voisey	0115 951 4051 0115 951 4010 0115 951 4139	Janet.Folkes@nottingham.ac.uk joel.segal@nottingham.ac.uk Katy.voisey@nottingham.ac.uk
Salford University	LIBS; drilling carbon composites; scabbling	Dr Richard Pilkington	0161 295 4176	r.d.pilkington@salford.ac.uk
TWI	Cutting, welding, direct metal deposition, surface modification, plastics welding ++	Dr Paul Hilton	01223 891162	paul.hilton@twi.co.uk
Warwick University	IMRC Agile Manufacturing Technology, rapid prototyping; Adv Technology Centre in Warwick Manufacturing Group: laser coat wood treatment, Remote fibre laser welding	Mr. Peter Hancocks Dr Ken Young	02476 574332 02476 522764	j.p.hancocks@warwick.ac.uk k.w.young@warwick.ac.uk
A new research group has been formed at Liverpool John Moores University in September 2008 and is expected to be very active in this area. Contact is Martin Sharp (m.sharp@ljmu.ac.uk)				

Table 2:

Established industrial groups with strong disclosed LMP activity

All the companies below have R & D expertise, carry out R & D in the UK, and are willing to collaborate with other workers on future R & D. Some, but not all, of the ongoing R & D is (commercially sensitive) customer application trials.

Company	Range of R & D	Contact
BAE Systems	**Micromachining (cutting, drilling) composites, metals, other** **Surface treatment and modification** **Welding –laser and hybrid** **Laser consolidation (ALM) –Metals, plastics** **Laser curing –Direct Write electronic/sensors** **Laser delivery systems –novel fibres**	Jagjit Sidhu Jagjit.sidhu@baesystems.com 0117 3028154
Ceram	**Micromachining** ceramics **Marking** ceramics **Welding** ceramics **Sintering** ceramic surfaces 1kW CO_2, 40W pulsed YAG	Dave Cartlidge Dave.cartlidge@ceram.com 01782 764237
Corus	**Hybrid welding**; Thick section (5-20mm) strip. (Fibrelaser /MAG – with Cranfield). **Remote automotive welding** (fibre laser – with Warwick uni). Some **hardening** and **cladding**. Some (materials based) **cutting.**	Alan Thompson Alan.Thompson@corusgroup.com 01709 825224
Electrox	**Marking** (fibre, diode, CO_2 and UV). **Cladding** (TSB application with De Montford has been OK'ed).	Neil Croxford 01462 472400
GSI lasers	**Fibre laser** applications**; Cutting, Welding, Drilling, Surface treatment.** All in macro and micro	John Chinn Jchinn@gsig.com 01788 517865
Laser Cladding Technology Ltd.	**Cladding** (5kW diode lasers – mostly hard facing with tungsten carbide for the oil industry.)	Paul Goodwin 01909 470589
Laser Expertise Ltd.	**Cutting** (Fibre laser cutting with Nottingham University).	Dr. John Powell jpowell@laserexp.co.uk 01159 851273
Laser Micromachining Ltd.	**Micromachining** polymers, metals, silicon, semiconductors, thin films, composites & ceramics. **Marking** metals, glasses**,** ceramics. Wide range of in-house high precision laser tools from UV to IR.	Nadeem Rizvi n.rizvi:@lasermicromachining.com 01745 535165
Laser Optical Eng.	**Marking, Ceramic Welding.**	Fiona Walker 01909 470589
Metal Improvement Co.	**Laser Peening** (for aerospace, formula 1 etc.)	Peter O'Hara Peter_ohara@metalimprovement.com 01282 843350
Midaz Lasers Ltd.	**Cutting** and **Drilling.** IR for metals and non-metals, UV for **Micromachining silicon** and thin films	Prof. Mike Damzen m.damzen@midaz.co.uk 020 7594 7783
Optek	**Scribing/ablation** of solar cells.(1064/532/355 um – below 20W). **Welding polymers. Microwelding** (10μm wires) **Processing optical fibres**	Mike Osborne Mike.Osborne@opteksystems.com 01235 539182 or 079739 575587
Oxford Lasers	**Micromachining; (Cutting, Drilling, Patterning, Scribing, ablation).** DPSS lasers. Femto, pico and nano second pulses.	Andrew Kearsley andrew.kearsley@oxfordlasers.com 01235 8180088
Powerlase	**Patterning/ablation** for solar panels. **Thin film stripping**	Paul Harrison paulharrison@powerlase.com 01293 456215

Rolls-Royce	**Drilling;** Aerospace alloys **Cladding/additive manufacture.** **Surface cleaning**	Clive Grafton –Reed Clive.Grafton-Reed@Rolls-Royce.com 01332 243311
Spectrum Technologies	**Marking** and **stripping** wire insulation. Interested in **microwelding** wires.	Dr. Paul Taylor 01656 655437
SPI Lasers	**Fibre Laser Cutting** and **Welding** in collaboration with Cambridge (Bill O'Neill)	Dr. Jack Gabzdyl 01489 779694 mob 07717 456386
Stadco	**Remote fibre laser welding** in TSB 22198	Paul Meeson Pi.meeson@stadco.co.uk 01743 452585

Table 3.

Characterisation of established academic and RTO groups with strong LMP activity: R&D areas.

Research area	Birmingham	Cambridge	Cardiff	Coventry	Cranfield	Heriot-Watt	Hull	Liverpool JM U	Liverpool	Imperial	Loughborough	Manchester	Nottingham	Salford	TWI	Warwick
Cutting																
High brightness		x										x	x		x	
Thick section		x										x				
Micro Precision cutting		x				x		x				x			x	
Gas flows in cutting		x														
Hole drilling							x	x	x			x	x			
In-process control of cutting																
Numerical modelling of cutting		x								x					x	
Welding																
Metal welding				x				x	x		x	x	x		x	x
Plastics welding								x			x	x			x	x
Ceramic welding											x	x			x	
Soldering						x	x									
Hybrid welding				x	x				x						x	
Hyperbaric welding					x											
Numerical modelling of welding								x					x			
In-process control of welding													x		x	x
Micro-joining (intermediate layers)								x								
Deposition processes																
Rapid manufacture	x	x	x		x			x	x		x	x	x		x	x
Micro-nano manufacture		x	x			x		x	x		x	x	x		x	
PVD							x									
Printed electronics		x						x	x							
Sol gel suspensions								x	x			x				
Additive inks									x			x				
Rapid prototyping	x		x					x					x			
Ablation processes																
Lithography		x	x						x	x						
Ultra fast patterning		x	x				x		x			x				
Cleaning and paint removal				x				x	x			x	x	x		
Lab on a chip		x					x									
Laser machining ceramics						x		x				x			x	
Laser machining polymers						x		x		x						
Glass smoothing and micro machining						x	x	x			x					
										x						
Surface Treatments																
Metal of metals					x			x	x		x		x		x	
Plastic surfaces								x			x					x
Bending																
Laser forming						x			x		x					
Optics development																
Adaptive optics						x					x					
Diffractive optic elements (DOE)											x					
Medical																
Photodynamic therapy (PDT)							x									
Mixed wavelength studies							x									
Medical general																x
General science																
Radiation interactions with material		x					x									
LIBS ablation processes										x				x		
										x						

Table 4.

Characterisation of established industrial groups with strong disclosed LMP activity: R&D areas.

Research area	Ceram	Corus	Electrox	GSI Lasers	Laser Cladding Tech.	Laser Optical Eng.	Laser Expertise	Laser Micromachining	Metal Improvement	Midaz Lasers	Optek	Oxford lasers	Powerlase	Rolls-Royce	Spectrum Tech.	SPI lasers	Stadco
Cutting																	
High brightness				X						X						x	
Thick section		X															
Micro Precision cutting	X							X		X	X	X					
Silicon								X		X		X					
Hole drilling	X			X				X		X	X	X		X			
Welding																	
Metal welding		X		X												x	x
Plastics welding											X						
Ceramic welding	X					X											
Hybrid welding		X															
Remote welding		X															x
Micro welding											X				X		
Deposition Processes																	
Printed electronics	X										X						
Cladding		X	X		X									X			
Sintering onto ceramics	X																
Ablation processes																	
Milling								X			X	X					
Patterning/ Thin film stripping								X			X	X	X				
Cleaning and paint removal														X			
Scribing								X			X	X	X				
Laser machining ceramics	X							X			X	X	X				
Wire Stripping											X				X		
Glass smoothing / micro machining								X			X	X					
Surface Treatments																	
Heat Treatment		X		X										X			
Peening									X								
Marking																	
Metals			X			X		X							X		
Non-metals	X		X			X		X							X		

Table 5.

Characterisation of established academic groups with strong LMP activity: Major equipment.

Institution	Laser equipment	Support equipment
Birmingham University	1. 100W CO_2 2. 1750W CO_2	1. Sinterstation 2500, allowing a part size of 380 mm x 330 mm x 410 mm to an accuracy of ± 0.125 - 0.25 mm with a surface finish of 5.5 µm Ra 2. A purpose built facility with three-axis CNC table, and a powder feed unit. Working area of 350 mm x 350 mm x 250 mm within a glove box providing an atmosphere of less than 5 ppm O_2.
Cambridge University	1. Avia 20W DPSS @ 355nm 2. Spectra Physics Hurricane Ultrafast Laser 3. MOPA Yb fibre laser 20W 4 &5. Yb fibre lasers 200W 6. 1kW SM Yb fibre laser 7. 1kW CO_2 Slab Laser 8. Assorted DPSS, CO_2, Ar+, Diode, HeNe, lasers for diagnostic tools	Micro and nano machining capabilities FIB/EBL/Laser High speed manipulation positioning systems, robotic motion systems Metal deposition technology Metallurgical and chemical analysis High power computing facility
Cardiff University	1. Picolaser1000 from Oxford Lasers (532 +355nm and 12 axis) 2. Deep u/v lasers	"Microbridge" facility for micro machining Dual beam line Automated trepanning Confocal depth sensor Extreme ultra violet facility
Coventry University	Rofin/Mechtronic 2kW CO_2 slab laser Rofin/Kuka 2kW Nd:YAG laser Rofin 100W CO_2 scanning laser	Mounted on 2 axis flat bed with rotary option Fibre optic coupled to robot. Scanning system
Cranfield University	8kW IPG Fibre Laser 1.5kW CO_2 laser 100W Pulsed Nd-YAG laser	Hybrid laser arc facilities and usual welding back up
Heriot-Watt University	a) ns Nd:YVO_4, 30W@1064nm, 532nm, 355nm b) ms Nd:YAG 1064nm (x2) few hundred Watts average c) 200 W diode laser array d) 2 kW CO_2 laser e) Two 200W CO_2 lasers	Scan head delivered through 200 micron fibre + scan head
Hull University	1. Pulsed and CW CO_2; 2. Nd:YAG; 3. Diode lasers; 4. ArF, KrF, and XeCl excimer lasers; 5. nitrogen laser; 6. dye lasers: 7. 157nm Lambda Physik excimer 8. AOT micro V laser freq doubled, or tripled. 9. fs Hurricane Spectra Physik 1mJ 100fs 10. other excimers 11. modest CO_2 (50W) for medical work	
Imperial College London	1. Coherent LPX220i excimer laser, KrF, 80W; 2. Coherent AVIA DPSS laser, 355nm, 7W.	Workstation with Aerotech CNC XYZ table (200 mm x 200 mm x 5 mm travel). Mask projection capability for excimer laser with range of projection lenses (refractive & reflective). Separate beam path for DPSS laser with galvanometer scanner (100mm fl). Housed in 80 m^2 cleanroom. Associated cleanrooms and labs (160 m^2) with extensive range of microfabrication and metrology equipment.
Liverpool John Moores University	1 Quantronix Osprey 355nm DPSS laser (2W) 2 Quantronix Osprey 532nm DPSS Laser (8W) 3 GSI JK701H 400W pulsed YAG laser 4 Haas 5W pulsed YAG laser	GSI / Cambridge Scanners for DPSS lasers 800mm x 600mmx 300mm Aerotech System 300mm x 300mm x 300mm Aerotech linear motor system

	5 SLA RP machine	
Liverpool University and Lairdside Laser Engineering Centre (LLEC)	University Based: 1. Laser Ecosse 8kW FAF CO_2 laser, 2. OPL 2.5kW FAF CO_2 laser, 3. Electrox 1.5kW FAF CO_2 laser, 4. Lynton Laser YAG: 10Hz Q Switch YAG 1064nm, ~10nS 5. Lynton Laser YAG, 50Hz Q Switch YAG 1064nm, 532nm, 355nm, ~10nS pulse length. 6. GSI Lumonics Lightwriter Laser Marking System: 40W CW YAG (1064nm) Q switch to 50kHz, Pulse lengths >50nS. Lairdside Laser Engineering Centre: 1. PRC 3500W FAF CO_2 laser, 2. GSI Lumonics JK704 Pulsed YAG laser . 3. Raycon : 240W Pulsed YAG laser 1064nm Pulse lengths 0.3 to 20mS Pulse Energy to 50J, rep rate to 200Hz 4. Rofin YAG 500W: Pulse length 0.3mS to 20mS, Pulse Energy to 75J, Rep Rate to 500Hz. 5. Rofin Sinar 300W slab CO_2: 6. Synrad 25W sealed CO_2 laser marker 7. Clark-MXR Femtosecond laser – 1W, wavelength 775nm, Pulse length 180fS typ, minimum. Rep rate 1kHz, max pulse energy 1mJ 8. Hi Q IC1500 Picosecond laser: 2W at 1064nm 10pS laser repetition rate to 50kHz: output at 532nm and 355nm available by selection 9. Coherent Verdi 2W CW laser for trapping. Single frequency 532nm CW source used in optical trapping set up. 10. Fianium pS fibre laser 2W 1064nm 10pS fibre laser, rep rate to 20MHz, Pulse energies <5µJ	CNC XYZ Table approx 1200mm x 1200mm x 150mm CNC Machine tool approx 300mm x 300mm x 300mm Computer controlled XY stage, Manual Z. Stage 300mm x 300mm Articulated Arm delivery Articulated Arm delivery Galvanometer scanning system 250mm focal length (7” field size) f-theta lens Laserdyne 890 5 axis system5 axis CNC controlled system: X1800mm: Y2400mm: Z750mm: C390° D±110°: Rotary Table (A-axis) – Continuous rotation Capacitative Height Sensing system for cutting and forming 127mm and 190mm focal length cutting and welding optics. CNC Controlled system: X500mm: Y500mm: Z400mm: A(tilt) +150°, -45°: C(rotary) continuous. Fibre delivery, 600µm diameter fibre optic delivery: CNC XYZ tables 300mm per axis: Anaerobic chamber (<10ppm O_2) 6 Axis (3 linear + 3 rotary) manipulator based on Cyberman design: Linear axes – 300mm. Galvanometer scanning head with 240mm focal length f-theta lens (marking field 100mm x 100mm). Current configuration: 30% transmitted at 775nm to a scanning head (100mm fl) over a 3 axis CNC controlled Aerotech stage: Remainder split into 2 beam paths, 1 to Aerotech stage (used by Pat Scully, Uni of Manchester for fibre sensor work), the other is frequency doubled to 388nm, fixed optics and 3 axis Aerotech stages. IR and Green path to galvanometer scanner (100mm fl) over 5 axis Aerotech CNC stage (XYZ and 2 goniometric tilt axes): UV path to galvanometer head (100mm fl) Optical trapping microscope arrangement Beam path to either 5x telescope and galvanometer scanning head or fixed optics over 3 Axis Aerotech stages (100mm, XYZ) Items 7-10 all mounted on optical tables and are, to various degrees, reconfigurable.
Loughborough University	1. 1.2 kW slow flow CO_2 2. 600 W sealed tube CO_2 3. Nd:YAG 700 W pulse shaped 4. 400 and 200 W CO_2 primarily for student teaching 5. 20 W CO_2 6. 150 W Q switched Nd YAG 7. 300 W 1075nm fibre laser 8. 300 W excimer 248nm	incorporating switchable diffractive head diffractive system with heated stages fibre delivered metal deposition/SLS system 2 x 2 x 1 m high precision cutting systems marking system marking system with conventional and diffractive optic heads micro machining laser with diffractive optics head Ebeam/electron microscope: ebeam/ focussed ion beam/electron microscope: reactive ion etcher
Manchester University	1. 1kW single mode fibre laser 2. 80W excimer laser 3. 1.5kW CW direct diode laser 4. 400W DPSS laser 30 -200ns pulses 5. Diode pumped Nd:YVO4 Q-	Numerous work stations and adequate analytic equipment

	switched laser (1064, 532, 355 nm) 6. 1W Ti-Sapphire laser 80fs pulse 7. 2.5 kW CO2 slab laser 8. 1 kW CO2 slab laser 9. 400W flashlamp-pumped Nd:YAG laser 10. Flashlamp pumped Nd:YAG Q-switched laser (1064, 532 nm) 11. 120W Direct Diode laser 12. Q-switched Nd:YAG laser marking system 13. Q-switched Nd:YAG laser machining system 14. 100W CO2 laser machining system 15. Diode pumped 532 nm Nd:YVO4 laser	

Nottingham University	1. 2kW diode laser 2. 2kW IPG fibre laser 3. 400W Lumonics pulsed Nd:YAG drilling laser 4 100W SPI fibre laser 5. 100W Rofin Nd:YAG laser	Numerous work stations and sufficient analytic back up.
Salford University	1 and 2. Two Large excimers (plus one spare) 3. YAGs 2x; 3x;4x (1 main plus spares) 4. femtosecond laser	
TWI	1. Trumpf 4kW cw Nd:YAG rod laser 2. Trumpf 3kW cw Nd:YAG rod laser 3. GSI Group JK1002 modulated Nd:YAG rod laser 4. IPG Photonics 7kW CW fibre laser 5. Spectron SL804T Q switched frequency multiplied Nd:YAG rod laser 6. Lumonics JK700 pulsed Nd:YAG rod laser 7. GSI JK125P pulsed Nd:YAG laser 8. Laserline dual wavelength 300W diode laser 9. Laserline 500W diode laser 10. 2kW FAF CO_2 laser 11. 2kW FAF PRC CO_2 laser 12. 7kW IPG Photonics fibre laser 13. 50W IPG Photonics fibre laser 14. 200W IPG Photonics fibre laser	Beam manipulation via Kawasaki JS30 articulated arm robots Hybrid laser-arc welding capability Twin spot laser welding capability Beam manipulation via Kawasaki ZX130L articulated arm robot Hybrid laser-arc welding capability with fibre optic beam delivery ANORAD precision XYZ Cartesian motion control systems XYZ gantry Fibre optic beam delivery and Motoman articulated arm robot Trumpf DMD 505 Cartesian gantry 5 axis direct metal deposition system with 2kW laser. 2m x 1.1m x 0.75m working envelope. Huffman HC-205 5 axis direct metal deposition system with 2kW laser High deposition rate direct metal deposition system based on a 7kW IPG Photonics fibre laser and ABB articulated arm robot. MCP Tooling Technologies Ltd Realizer SLM100, powder bed additive layer manufacturing system with 50W IPG Photonics fibre laser. MCP Tooling Technologies Ltd Realizer SLM250, powder bed additive layer manufacturing system with 200W IPG Photonics fibre laser
Warwick University and Manufacturing Group and Warwick Laser Systems.	1. High power diodes 1kW or more 2. IPG YRL-4000-C-WW 4kW fibre laser 3. Trumpf TLF6000 6kW CO_2 4. 200W Synrad FireStar CO_2 laser 5. 1.2 & 1.8kW Rofin direct diode lasers. 6. JK701 Pulsed YAG laser 7. Quantum Laser 60W Q Switched YAG	on Comau SmartLaser robotic remote laser welding system. Primarily used for RFLW project. ScanLab scanner remote laser welding system. An XYZ cutting system is currently being integrated with this laser source. ScanLab scanner and CNC XYZ table. Primarily used for LaserCoat project. CNC XYZ table. Used for transmission laser welding, cladding and student projects. on CNC XYZ table. Used for workshop cutting and welding. Laser marker for workshop use.

Table 6.

Characterisation of established academic groups with strong LMP activity: Space and Staff.

Numbers refer to staff and space mainly employed on LMP

Institution	Space	Staff				
	m^2	permanent	contract	student	admin	total
Birmingham		3				
Cambridge	300	1+1tech	7+1tech	9	1	20
Cardiff	>500	9		3	3	15
Coventry	120	2	3	5	0	10
Cranfield	330	7	3	7	1	17
Heriot-Watt	155 + 200	4	3	8	0	15
Hull	>500 (There are 5 labs one air conditioned)	5	1	3-10		9-16
Imperial	80 (laser lab) + 160 (other cleanrooms/labs)	1	3	1		5
Liverpool John Moores University	20 – 10 in advanced manufacturing lab	2	0	1	0	3
Liverpool + LLEC	500	2	9	12	2	25
Loughborough	200	2	1 + 2tech	16	1	22
Manchester	700	6	10	26	0	42
Nottingham		5	0	13	1	18
Salford	‘enough’ including 1 air conditioned excimer lab	3	1	2+	2-5	8+
TWI	250	14	1	2	3	20
Warwick (+WMG)	4 laser labs + mezzanine storage	1+	2 +2tech	2+	0	6-8

Table 7.

Characterisation of established academic groups with strong LMP activity: Aspirations.

Stated aspirations of established research groups.
The industrial groups have their aim of making a profit and staying in business.

Institution	Staff	Lab area m^2	Aspiration statement	summary
Birmingham	2		Net Shape Centre: Net Shape manufacturing Laboratory.	
Cambridge	20	300	Centre for Industrial Photonics (CIP): To gain greater understanding and control of the manipulation of matter using optical, electrical, chemical and biological toolsets. To apply these tools and create radical advances that will form the basis of manufacturing principles and practices implemented in 21st century industry	Basic understanding
Cardiff	15	>500	a) Manufacturing Engineering centre (MEC): To promote the introduction of new manufacturing technology and practice to industry (completed 4000 projects with local companies). b) Next Generation Engineering XGEN (a consortium of 3 companies): pursues industrial applications of micronanotechnology in engineering aiming to be a one stop shop for the *next generation engineering*.	Consultancy Micro/nano work
Coventry	10	120	*Continue as a service laboratory* Though in good order and well used, our laser-based cutting and welding equipment is elderly and no longer suitable for serious research into techniques of laser based material processing; rather, the equipment competes for our research interests with other methods of joining, including adhesives and electrical welding. On the other hand, the equipment continues to provide good service to students, researchers and local SMEs through provision of a rapid prototyping service and specialised precision welding for product development. Whilst in the fullness of time we hope to update our laser processing equipment in pursuit of new research projects, in the meantime and provided the equipment continues to earn its keep we will continue to offer its facilities to the local manufacturing community.	Job shop
Cranfield	17	330	To be the world leading institute for laser welding and additive manufacture. To provide a good stream of educated or trained (laser) welding engineers and scientists.	Laser weld with wire
Heriot-Watt	15	355	Duncan Hand: To continue our leading role in the development of novel laser-based manufacturing processes, and in the delivery and manipulation of high power laser light; to develop new application areas, including in the medical sector. Howard Baker: Over next 3 years, to make: a) Laser produced micro optics b) Cheap high efficiency pulsed diode lasers c) Sub ns pulsed diode lasers that are cheap and efficient	Novel processes and delivery techniques:

Hull	9-16	>500	Peter Dyer laser group: *Ablation studies:* smoothing glass with 157nm; micro machining Si, SiO_2 polymers with Clive Ireland's Q switched DPSS laser for lab-on-chip; fs processing of tissue, films, glasses; micro ablation; ophthalmic studies; Pulsed laser deposition (PLD) for novel thin films for superconductors *Photodynamic therapy* (PDT) and 2 photon excitation of porphyrin at 830nm; *Active waveguides*, and magnetic micro-devices and organic LEDs; laser patterning Jim Gilbert SOLDAT: Research laser soldering by laser type; different surface mounts; various assemblies and modelling Paul Fletcher Surfactant and colloidal group: laser tweezer for studying forces between colloidal particles. Chemical Physics group: Understanding fundamental processes during laser ablation, photo-modification; study of MALDI (matrix assisted laser desorption ionization) for mass spectroscopy	Ablation: soldering
Imperial College London	5	240	To develop computer models for multi-pulse ablation that are useful for industrial process development; To develop novel laser-based processes for the fabrication of micro- and nano-scale devices; To improve understanding of laser transfer processes and apply such processes to microfabrication and micro-assembly	Ablation - fundamentals & applications
Liverpool John Moores University	80	2	To conduct research in novel LMP areas, revisit previous work with new laser types and respond to industrial requirements through collaborative R&D activity. The group is highly responsive to industrial needs and intends to transfer its knowledge of all types of LMP processes, gained by a combined 40 years of industrial and research experience between the two permanent academic staff, into real applications. Working in conjunction with the other research groups in the General Engineering Research Institute at LJMU, we want to deliver multidisciplinary research including photonics related non LMP applications	Photonics in Engineering
Liverpool	25	1500	Maintain a leading position in developing new processes for industry based on optical and laser energy. North West Laser Engineering Consortium (NWLEC) to be leading national region for laser engineering. Lairdside Laser Engineering Centre (LLEC): to develop prototype laser processes in partnership with industry.	New process: micro nano work
Loughborough	22	200	Innovative Manufacturing Research Centre (IMRC) Phil Dickens; John Tyrer: laser safety; optical non destructive testing; speckle; holography underwater laser applications DOE. Spin off company 'Laser Optical Engineering'	DOE Safety Kinoforms speckle
Manchester	42	700	Part of North West Laser Engineering Consortium (NWLEC): Teamwork and taking challenges; Maintain a leading position in innovation with laser processing.	New proc:
Nottingham	18	enough	Raising the group profile and interaction with industry – Department of Mechanical Materials and Manufacturing Engineering "Innovative Manufacturing Process Group, The Laser Centre". Consolidating our position as one of the leading laser processing research groups. The Laser Centre, Innovative Manufacturing Process Group, Department of Mechanical, Materials and Manufacturing Engineering.	Fibre and diode laser material processing
Salford	8+	enough	To develop LIBS as a quantitative analytic tool	ablation
TWI	19	250	To maintain and expand TWI influence in the global marketplace of laser materials processing, by stimulation and development of economic value and quality of life. Specific areas of interest involve laser welding and cutting of metals, process control, laser direct metal deposition, metal powder bed technology, surface structuring with laser beams, laser welding of plastics and technical textiles and the use of lasers in the production of micro and nano scale particles and structures.	Process development

Warwick	6-8	4 labs+	Innovative Manufacturing Research Centre (IMRC): To be a world leader in issues enabling effective manufacture by companies. To be a focus for "ahead of the art" knowledge and capability; an environment to demonstrate the latest thinking; the hub of a highly accessible network; a channel leading to the creation and development of innovative products and processes; a knowledge base and partner for companies; to address problems in agile engineering. IMRC brings together the work of three groups: Warwick Manufacturing group (WMG), the wider school of Engineering and the Warwick Business School. It will enable a new focus on photonics manufacturing driven by new strategic appointments by WMG's close relations with Marconi. Optics Engineering Laboratory (OEL): Engine flame diagnostics and biomedical research. WMG: The group is actively investigating projects in areas not usually associated with lasers – horticulture and surface treatment of wood for example as well as possible medical applications. In conjunction with industrial partners it is also involved in replacing lasers with specialised non-coherent sources for plastic welding applications. Within the last few years the group has developed an expertise and resource within the high power laser welding field specifically within automotive applications. In conjunction with our industrial partners we aim to continue development within this area to support local industry and extend the industrial application of this technology, both within the automotive sector and to other sectors of the economy.	Photonics manufacture: welding,. surfacing

Appendix 1

Other industrial organisations with LMP research activity: listing of contact details.

The companies below have R & D expertise and carry out some level of process development work in the UK. The work involved is usually commercially sensitive and driven by the immediate needs of customers. If a project needs extra collaborators then these contacts might prove fruitful.

Company	Range of R & D	Contact
Carrs Welding	Cladding – for surface repair of components and dies etc.	Phil Carr (MD) 01536 412828
Coherent	Microprocessing	Chris Dorman 0141 945 8150
Dawson Shanahan	Nozzles for Cutting	Mark Jennings 01707 602000
Lasers are Us	Drilling small holes. Micro machining	Simon Lau simon@lasersareus.com 01656 745090
Longstaff	Cutting non-metals	Robert Longstaff 01865 820206
Power photonic.	Machining glass optics	Dr. Roy McBride 01383 825911
Rofin Sinar	General laser Processing	Dr Jason Lee 01482 650088
Winbro	Drilling, Cladding/Building	Malcolm Whitmore 0150 9890295
Wolstenholme Machine Knives	Welding stellite to steel	David Clowes davec@wolstenholme.co.uk 0114 2445600

Appendix 2.

Other industrial organisations with LMP research activity: identification of LMP areas.

Research area	Carrs Welding	Coherent	Dawson Shanahan	Lasers are Us	Longstaff	Power photonic	Rofin Sinar	Winbro	Wolstenholme
Cutting									
High brightness									
Thick section							X		
Micro Precision cutting		X		X					
Gas flows in cutting			X						
Hole drilling				X			X	X	
Non Metals							X		
Nozzles			X		X				
Welding									
Metal welding							X		X
Ceramic welding									
Deposition									
Cladding	X						X	X	
Building								X	
Ablation									
Ultra fast patterning									
Glass smoothing / micro machining						X			
Surface Treatments									
Metals									
Marking				X		X	X		

Appendix 3

Characterisation of academic groups currently reporting medium LMP activity.

University/Research Institute	Extent of LMP activity
Aberdeen University	Very little LMP activity: hopes of developing work in underwater cutting and welding.
Aston University	Small LMP activity: Mainly photonics interests in communications and optics: part of **Photonics Cluster**. Some micromachining and laser ablation studies – large physics group
Bangor University	Low-level LMP activity but do have two Exitech machines. Professor Pethig has just left for Edinburgh University and Nadeem Rizvi has formed Laser Micromachining Ltd. at St Asaph. See Tables 2 and 4. Dr. Julian Burt in charge of laser-based fabrication activities.
Birmingham City University	Small level of LMP effort: .mainly in jewellery: laser spot welders, markers, 50W laser cutter. 0.5 permanent staff - Anne-Marie Carey.
Brighton:	Dr Raymond Whitby with Toyo University found that firing a laser into carbonated water led to carbon nano particles.
Brunel University	Small scale activity in laser bending – Dr. Sarah Silve.
Daresbury Laboratories	Mainly Physics: connected to the **Central Laser Facility**: PetaWatt laser at Rutherford Appleton; synchrotron radiation source LIGA at Daresbury.
Exeter University	Small activity in LMP: **Advanced Technology Research Institute (ATRI)** £5.4M femto second laser facility for nano fabrication. Main interest is physics.
Hertfordshire	SLS unit, laser cutter as tool, some micro engineering.
Imperial College, Dept of Physics	No LMP activity: strong laser physics, fibre technology; electromagnetic theory, biomedical optics.
London Birbeck	Laser cleaning of paintings, laser scanning, laser analysis
London Goldsmiths	Sarah King laser welding for jewellery
London Metropolitan University	Little research in LMP: Laser cutting, welding for jewellery; digital manufacturing courses; biological laser applications; laser cutting service.
London University College	Prof Ian Boyd, Laser processing group, pulsed laser deposition.
Middlesex	Robotic production line including laser cutter.
Northumbria University	Small activity: **Manufacturing Design Group**: laser hardening; laser calibration and measuring.
PERA	No specific laser work, done by contract to develop prototype processes
QinetiQ	Military laser applications; measurement, sensors; mid IR laser (3.3-3.9mm) based on InSb for medical applications.
Queen Mary College, London	Small laser activity: cutting waveguide apertures for THz work
St Andrews University	Small LMP activity: main interest in photonics, laser physics and optical phenomenon: ultra short pulses, non-linear optics; **Photonics Innovation Centre**; optical trapping; nanotechnology; organic lasers
Southampton	Laser physics: SPI is a spin out company: Prof David Payne **Optoelectronics Research Centre (ORC)**; nanotechnology lasers with Ukraine, optical fibres. **Quantum and Functional Matter Research Group**, where lasers are used as tools to investigate novel physics in solids. Photonics of structural transformations in a single nanoparticle: Light-Assisted Growth of nanoparticles: Pulsed Laser deposition of thin films: Micro structured optical materials
Sowerby Laboratories BAEsystems	Small LMP activity: Additive manufacturing; surface treatments (CONCORWELD); laser curing direct write inks.
Strathclyde University	No LMP activity: Institute of Photonics (partner in SUPA - Scottish Universities Physics Alliance: six Scottish Universities): Strathclyde University. micromachining, laser direct writing, micro-optics, laser lift-off, novel laser sources (both solid-state, semiconductor and hybrid) from UV to mid-IR, ultra-fast lasers, adaptive optics, free space comms, biophotonics, biomedical imaging, sensors, UV curing of specialist polymers
Sussex University	Small LMP activity: "lab on a chip" machining; modelling; holography Prof. Chris Chatwin.
West of England University	Small activity: powder sintering – Dr. John Kamalu.
Wolverhampton	**Innovative Product Development Centre**: In 2007 they were granted a rapid manufacturing facility for Ti. Sited on the Telford Campus.

Yellow highlight signifies type of LMP work undertaken.
Green represents some grouping
* New group in a period of rapid expansion

Appendix 4

Characterisation of academic groups currently reporting no or low LMP activity.

Institute	Level of Activity
Abertay in Dundee	Alan MacLeod working on FEL with Dundee University.
Aberystwyth	LIDAR for aerosol measurements. Contracts with QinetiQ. Laser holography and confocal microscopy.
Anglia Ruskin	Nanostructures and photo molecular systems; SPIE technical group; Prof David Andrews.
Bath University	No LMP activity: Centre for Photonics and photonic materials in Physics Department. Semi conductor lasers, spectroscopy, photonic crystals. Non linear optics.
Bradford	Some work on non lethal weapons.
Bristol University	no LMP activity: Laser chemistry, spectroscopy, maser emission
Buckingham	Nothing reported
Derby	Some activity in beauty treatments.
Dundee	Biomedical laser development £8M grant with 18 EU partners.
Durham	Large grant in photo-voltaics using nanotechnology.
East Anglia	Advertising for two optical engineers also see Anglia above.
East London	Nothing
Edinburgh	Resonance enhanced multi-photon ionisation spectroscopy (REMPI) Condensed matter group.
Essex	Semi-conductor lasers and communications studies.
Glasgow	**James Watt Nano Fabrication Centre** based on EB machining.
Greenwich	Laser marks meridian and they have laser printers.
Huddersfield	Nothing
Keele	Research Institute in science and technology in medicine with small laser interest.
Kent at Canterbury	Laser spectroscopy
Kingston	Biophotonics spectroscopy
Lancaster	Laser printer, aquatic analysis by ablation.
Laser University	On-line course at a price
Leeds metropolitan	Nothing
Leeds University	No LMP activity: Leeds Centre for photobiology and PDT: Centre for Nano Device Technology.
Leicester	Earthquake mapping by laser from aircraft,
Leicester De Montford	Laser hologram plotter. Some cladding work may start with Electrox.
London Kings	Skin cancer, eye surgery.
London Royal Holloway	John Adam Institute for accelerator science.
London Queen Mary & Westfield	Medical School with small interest in lasers
London Wye	Agriculture
Newcastle upon Tyne	Laser scanning,
Nottingham Trent	Nothing reported
North London	Nothing reported
Open	Nothing reported
Oxford	(Justin Wark) atomic and laser physics research group
Oxford Brookes	Nothing reported
Plymouth	Nothing reported
Preston	Nothing reported
Queen's Belfast	Some activity in flow cytometry, X-ray lasers and use of Central Laser Facility.
Reading University	Small LMP activity: Ultra fast laser laboratory: fundamental physics, DNA sequencing, chemical analysis.
Rutherford Appleton Laboratories	No LMP activity: fundamental physics: Central Laser Facility: Vulcan Project; 10 Peta Watt optical parametric chirped pulse amplification (OPCPA); Vulcan Target Area West (TAW) project – 100J in 1ps 3xtimes diffraction limited spot.
Sheffield	Mid infra red network member
Sheffield Hallam	THz imaging
South Wales Glamorgan	Nothing reported
Stirling	Quantum cascade lasers for THz

Sunderland	Nothing.
Surrey	Optoelectronic devices: strained quantum well lasers
Swansea University	No LMP activity: Multi Disciplinary Nanotechnology Centre; (does not have any lasers?); Laser diodes; laser scanning tunnelling microscopy; matrix assisted laser/ desorption/ionisation post source decay.
Teesside	Nothing reported
Ulster	Some medical work
Westminster	Nothing reported
York	Astrophysics and fusion research

Appendix 5

Summary tables of selected established academic and RTO institutes

Birmingham University		Number
Current projects	Laser Direct fabrication in IRC	
Laser equipment	Atmospheric controlled laser direct fabrication chamber (suspect sintering) Netshape Centre Netshape manufacturing laboratory £8M.	
Laboratory space for lasers		
Number staff		≥ 2
Latest papers	Xu on fatigue; Chang 2003 paper on laser sintering Mat Sci and Tech vol 19 pp897-901 "Fracture behavior of selective laser sintered Rapidsteel2.0 under static and dynamic loading"	
Aspirations of laser group		
Contacts	Dr Isaac Chang (T.N. 0121 414 5167) i.t.chang@bham.ac.uk and Prof X.Wu Materials Department t.n.o121 414 7842 Email: X.Wu.1@bham.ac.uk General 0121 414 3344 IRC in Materials Processing, The University of Birmingham, Edgbaston, Birmingham, B15 2TT	

Cambridge University		Number
Current projects	Centre of Industrial Photonics Current laser projects: The CIP has a research portfolio that aims to provide new manufacturing capability for a wide range of sectors. Current projects cover advanced laser cutting and machining technologies, rapid manufacturing processes, focused ion beam and laser micro and nano-processing, micro-systems design and production, printed electronics, modelling and simulation. The CIP has the current research activities. Cutting: • High brightness Yb fibre & Disc laser cutting • Numerical modelling and simulation • Thick section reactive gas cutting • High efficiency gas assisted laser cutting Rapid manufacturing • Laser assisted cold gas dynamic manufacturing • Discharge metal deposition • Wire feed metal deposition • Focused ion beam and laser machining • MOPA based Yb fibre laser precision machining and structuring • FIB and laser based lithography • Ultrafast laser patterning Microsystems design • Microfluidic blood separator	

	• Nano-CMM measuring probe • Micro induction coil Printed electronics • Laser print forming • Micro print tooling • Nano suspensions and additive inks Modelling and Simulation • Development of high performance algorithms • Melt flow characteristics	
Laser equipment	• Avia 20W DPSS @ 355nm • Spectra Physics Hurricane Ultrafast Laser • MOPA Yb fibre laser 20W • 2 Yb fibre lasers at 200W • 1kW SM Yb fibre laser • 1kW CO2 Slab Laser • Assorted DPSS, CO2, Ar+, Diode, HeNe, lasers for diagnostic tools • Micro and nano machining capabilities FIB/EBL/Laser • High speed manipulation positioning systems, robotic motion systems • Metal deposition technology • Metallurgical and chemical analysis • High power computing facility	
Laboratory space for lasers	$300m^2$	
Number staff	a) Permanent research or academic staff: b) Temporary or contract staff: Staff, c) Students – PhD or MSc: 5 PhD and 4 M.Phil d) Administrative staff (secretaries etc.): 1 Administrator	1 Academic 7 Post docsl
Some of the latest papers	a. Sparkes. M., Gross. M., O'Neill. W. "A novel non-intrusive sampling technique for CO2 laser on-line beam monitoring utilizing a silicon mirror" Opt Las Eng, 46, 620-627, 2008. b. *New aspects of melt flow phenomena through narrow kerfs", M S Gross., W. O'Neill, J. Phys. D: Appl. Phys, 40, 1201-1205, (2007).* c. *"The manufacture of a very high precision x-ray collimator array for rapid tomographic energy dispersive diffraction imaging (TEDDI)", L Tunna, P Barclay, R J Cernik, K H Khor, P Seller, and W. O'Neill Meas. Sci. Technol. 17 No 7, 1767-1775, (July 2007).* d. *"Experimental study of titanium/aluminium deposits produced by cold gas dynamic spray", T. Novoselovaa, P. Foxa, R. Morgan and W. O'Neill Surface and Coatings Technology , 200, Issue 8 , 2775-2783, (2007).*	
Aspirations of laser group	To gain greater understanding and control of the manipulation of matter using optical, electrical, chemical and biological toolsets. To apply these tools and create radical advances that will form the basis of manufacturing principles and practices implemented in 21st century industry	

Contacts	Bill O'Neill (Martin Sparkes); wo207@cam.ac.uk Richard Penty (Photonics Systems Group)	

Cardiff University		Number
Current projects	Manufacturing Eng. Centre (MEC) including MicroBridge facility (£7.5M) XGEN next generation engineering 1. micro machining 2. nano technology 3. rapid manufacture (SLS, SLA, FDM) 4. laser fabrication and characterization 5. Extreme laser facility (hybrid 157nm/150fs laser)	
Laser equipment	1. Picolaser1000 from Oxford Lasers (532 +355nm and 12 axis) 2. Dual beam line 3. Automated trepanning 4. Confocal depth sensor 5. Deep u/v lasers	
Laboratory space for lasers	5 rooms >500m^2	>500m^2
Number staff	XGEN 2 MEC permanent 7 total MEC 60 staff PhD students 3 30 students	9 staff 3 students
Latest papers		
Aspirations of laser group	MEC: To promote the introduction of new manufacturing technology and practice to industry XGEN: pursue industrial applications in nano and micro technology aiming at next generation engineering.	
Contacts	1. Prof Duc Truong Pham (Director MEC); phamdt@cardiff.ac.uk 2. Mr Petko Vladev Petkov (Project manager laser milling); petkovpv@cf.ac.uk 3. Prof David Barrow (XGEN); barrow@cf.ac.uk	

Coventry University		Number
Current projects	Laser welding, cutting, selective ablation of painted plastics for recyclable automotive parts, other joining processes, hybrid technologies plasma augmented laser welding (PALW). Centre for Advanced Laser Welding Future Manufacturing Applied Research Centre A service to local industry and groups.	
Laser equipment	1. Rofin/Mechtronic 2kW CO_2 slab laser mounted on 2 axis flat bed with rotary option. 2. Rofin/Kuka 2kW Nd:YAG laser fibre optic coupled to robot. 3. Rofin 100W CO_2 scanning laser	
Laboratory space for lasers	New labs at 120m^2 in two rooms for advanced joining studies including robotic welding and adhesive bonding	120m^2
Number staff	1. Permanent 2. Academic staff concerned with laser based welding 3. Temporary staff 4. Students PhD 5. Students MSc 6. Undergrads	2 3 0 1 4 2

	7. Administrative staff	0

Latest papers	A number of papers on plasma augmented laser welding (4 quoted in their return)	
Aspirations of laser group	Though in good order and well used, our laser-based cutting and welding equipment is elderly and no longer suitable for serious research into techniques of laser based material processing; rather, the equipment competes for our research interests with other methods of joining, including adhesives and electrical welding. On the other hand, the equipment continues to provide good service to students, researchers and local SMEs through provision of a rapid prototyping service and specialised precision welding for product development. Whilst in the fullness of time we hope tp update our laser processing equipment in pursuit of new research projects, in the meantime and provided the equipment continues to earn its keep we will continue to offer its facilities to the local manufacturing community.	
Contacts	Edmund du Bois, project manager www.lampproject.co.uk	

Cranfield University		Number
Current projects	Next Generation Laser Processing Hybrid welding of pipelines Hyperbaric Laser welding Ready to use manufacture Hybrid welding of thin section Aluminium Gas mix effects in laser welding Next generation armour alloys Laser Welding of thick section tailored blanks High Efficiency Laser Processing Systems	
Laser equipment	8kW IPG fibre Laser 1.5kW CO_2 laser 100W Pulsed Nd-YAG laser	
Laboratory space for lasers	330m^2	330
Number staff	Academic staff 4 Research Staff 3 PhD Students 4 MSc students 3 Administrative 1 +3 technician	18
Latest papers	• Welding with high power fiber lasers – A preliminary study • Analysis of Beam Material Interaction in Welding of Titanium with Fiber Lasers • And many others	
Aspirations of laser group	To be the world leading institute for laser welding and additive manufacture using wire. To produce a steady stream educated or trained (laser) welding engineers and scientists.	
Contacts	Professor Stewart Williams s.williams@cranfield.ac.uk T.N.01234 754693	

Heriot-Watt University		Number
Current projects	*Major projects Duncan Hands section*: (a) laser joining in micro-manufacture (diode laser array) – application MEMS; sensors (b) adaptive optics in high power laser processes (micro-machining) (c) high precision laser micromachining (d) stress engineering / laser forming of aerospace components (e) laser machining of ceramics (ns/ms lasers) including on-line monitoring (f) fibre optic delivery of high peak power laser light Plus a number of minor projects, mainly precision cutting or micromachining *Howard Baker section:* g) Processing glass: cutting, smoothing and micro machining h). ceramic cooler for laser diodes i). Making laser diodes for LAMPS project with Baes	
Laser equipment	(a) ns Nd:YVO_4, 30W@1064nm, 532nm, 355nm + scan heads (b) ms Nd:YAG 1064nm (x2) (few hundred Watts average) (c) 200 W diode laser array (delivered through 200 micron fibre) + scan head (d) 2 kW CO_2 laser e) Two 200W CO_2 lasers for ceramic work and glass work	
Laboratory space for lasers	155 m^2 +200m^2	355m^2
Number staff	a) Permanent research or academic staff 3 academic staff +1 (Howard Baker) b) Temporary or contract staff number fluctuates, typically 2 to 4 c) Students – PhD or MSc 4 PhD, 2 masters +2 (HB group) d) Administrative staff (secretaries etc.) - no dedicated admin staff	4 3 8 0
Latest papers	18 journal papers and 28 conference papers on laser materials processing since 2004: Proc SPIE on diode lasers for LAMPS project	
Aspirations of laser group	*Hands*: To continue to our leading role in the development of novel laser-based manufacturing processes, and in the delivery and manipulation of high power laser light; to develop new application areas, including in the medical sector. *Baker:* Next 3 years before HB retires: a) Laser produced micro optics b) Cheap high efficiency pulsed diode lasers c) Sub nano second diode laser – cheap + efficient	
Contacts	Professor Duncan Hands 0131 451 3020 Professor Howard Baker 0131 451 3085	

Hull University		Number
Current projects	1. Laser soldering SOLDAT 2. Laser ablation patterning micro scale 3. Laser hole drilling in micro electronics 4. Laser annealing interaction radiation with semi conductors 5. Fibre Bragg grating production 6. Pulsed laser deposition – novel thin films by PVD (superconductors) organic LEDs 7. Ultra short pulse processes femtosecond (biology) 8. *Peter Dyer Laser Group*: smoothing glass with 157nm; micro machining Si, SiO_2 polymers with Clive Ireland Q switched DPSS laser for lab-on-chip; fs processing of tissue, films, glasses; PDT and 2 photon excitation of porphyrin at 830nm; micro ablation; ophthalmic studies; Pulsed laser deposition (PLD) for novel thin films for superconductors, active waveguides, and magnetic micro-devices and organic LEDs; laser patterning 9. Jim Gilbert SOLDAT: Research laser soldering by laser type; different surface mounts; various assemblies and modelling 10. Paul Fletcher Surfactant and colloidal group: laser tweezer for studying forces between colloidal particles. 11. Chemical Physics group: Understanding fundamental processes during laser ablation, photo-modification; study of MALDI (matrix assisted laser desorption ionization) for mass spectroscopy	
Laser equipment	• Pulsed and CW CO_2; • Nd:YAG; Diode lasers; • ArF, KrF, and XeCl excimer lasers; • nitrogen laser; • dye lasers • 157nm Lambda Physik excimer • AOT micro V laser freq doubled, tripled • fs Hurricane Spectra Physik 1mJ 100fs • other excimers modest CO2 (50W) for medical work	
Laboratory space for lasers	Ample: There are 5 labs, one air conditioned	
Number staff	1. Permanent staff Prof, Sen: Lect; 3 lecturers 2. Contract research assistant 3. Students 4. Admin	5 1 3-10 1 +2.5tech
Latest papers	App Phys; Chem Rev, App Surf Science, Ophthalmic Surg Las; Semicond Sci Tech.	
Aspirations of laser group	To study the science of radiation interaction with matter at the sub micron scale using short pulses and short wavelengths. They are interested in photo mechanical effects on which Dyer has published. They are interested in developing small lasers such as AOL's	
Contacts	1. Dr Jim Gilbert SOLDAT Dept Eng. J.M.Gilbert@hull.ac.uk 2. Prof Peter Dyer Laser Group Physics Department; p.e.dyer@hull.ac.uk	

Imperial College London		Number
Current projects	Modelling of multi-pulse ablation processes Laser forward transfer of ferroelectric films for RF MEMS devices Laser machining of polymers for MEMS devices	
Laser equipment	1. Coherent LPX220i excimer laser, KrF, 80W 2. Coherent AVIA DPSS laser, 355nm, 7W	
Laboratory space for lasers	80 m^2 with room for expansion	
Number staff	1. Permanent academic staff 2. Visiting Professor 3. Research Associates 4. PhD students	1 1 2 1
Latest papers	Gower M.C., "From laser micromachining to nanomachining: considerations", Int. J. of Technol. Transfer & Commercialisation, **7**, 142, (2008) Pedder J.E.A., Holmes A.S., Dyer P.E., "Improved model for the angular dependence of excimer laser ablation rates in polymer materials", Applied Physics Letters, 95, paper 174105, (2009)	
Aspirations of laser group	To develop computer models for multi-pulse ablation that are useful for industrial process development; To develop novel laser-based processes for the fabrication of micro- and nano-scale devices; To improve understanding of laser transfer processes and apply such processes to microfabrication and micro-assembly	
Contacts	Prof. Andrew S. Holmes, a.holmes@imperial.ac.uk Prof. Malcolm C. Gower, m.gower@imperial.ac.uk	

Liverpool University		Number
Current projects	NWLEC micro and nano applications 1. micro machining; refractive index modification 2. Fibre laser applications; surface modification; welding 3. Engineering applications; optical trapping 4. Laser curing of inks 5. Direct write processes 6. Sol gel deposition processes 7. Micro forming 8. forming of metal polymer composites 9. Buckling in laser welding 10. High throughput ultrafast Surface micro-structuring using Dynamic Holograms	9
Laser equipment	CO2 – 8kW Laser Ecosse; 2.5kW OPL; 1.5kW Electrox; YAG: - Lynton Laser 10Hz 10ns; Lynton Laser 50Hz x2,x3,x4 10ns; GSI Lumonics Lightwriter 40W 50ns LLEC: CO2 – 3.5kW PRC; GSI Lumonics JK704 240W 20ms; Rofin Sinar 300W slab laser; Rofin YAG 500W; Synrad 25W marker. Clark-MXR Femto second laser 1W 180fs 1kHz; Hi Q IC1500 pico second laser 2W 10ps Coherent Verdi 2W CW laser for trapping Fianium ps fibre laser 2W 10ps	 3 CO_2 3 YAG 5 CO_2 4 specials
Laboratory space for lasers	University site lab space only LLEC lab space only	500m^2 1000m^2
Number staff	Permanent RAs Technicians PhD students Admin secretary part time	2 9 1 12 1
Latest papers	See www.lasers.org.uk	
Aspirations of laser group		
Contacts	Prof Ken Watkins Dr Geoff Dearden g.dearden@liv.ac.uk Walter Perrie wpfemto1@liverpool.ac.uk	

Loughborough University		Number
Current projects	1. In-line debris control during laser micromachining. 2. Laser surface treatment of polymer implant materials for enhanced biocompatibility. 3. UC consolidated active structures - Lasers are used to firstly machine channels in aluminum aerospace alloys for SMA fibres before UC consolidation in order to produce active control surfaces. 4. Optimisation of fibre laser beam delivery devices for hermetic welding of controlled expansion metal alloys. 5. Laser surface sealing and treatment of ceramic fuel cell tubes - CO2 and fibre lasers. 6. Fabrication of Diffractive optic elements. 7. Laser fabrication of 3D textile structures for architectural and medical applications - fusion of current and novel fabrication techniques to provide natural and man made fibre constructs without tooling. 8. The use diffractive optical elements to control deposition profile and micro cracking in the repair of vitreous and ceramic glazes. 9. Diffractive beam shaping to control the microstructure and profile in Nimonic powder deposition. 10. Annealing of silicon wafers using diffractive optics. 11. Direct writing of 3D diffractive structures into materials using excimer lasers for machine readable security. 12. Conductive track polymer deposition, diffractive polymer welding, biomedical deposition of bone materials, laser drilling of human skin.	
Laser equipment	• 1.2 kW slow flow CO_2 for pure Gaussian work, incorporating switchable diffractive head • 600 W sealed tube CO2 diffractive system with heated stages • NdYAG 700 W pulse shaped fibre delivered metal deposition/SLS system • Two 2 x 1 m high precision cutting systems with 400 and 200 w CO_2 for student teaching • 20 W CO_2 marking system • 150 W Q switched Nd YAG marking system • 300 W 1075nm fibre laser with conventional and diffractive optic heads. • 300 W excimer 248nm micro machining laser with diffractive optics head • ebeam/electron microscope • ebeam/ focussed ion beam/electron microscope • reactive ion etcher	
Laboratory space for lasers	Main laboratory approx 120m^2, Dedicated clean room for optics manufacture approx 20m^2, Vibration isolated ebeam laboratory approx 25m^2 Dedicated and fully equipped machine shop approx 40m^2	205m^2
Number staff	Permanent: Professor : senior lecturer	2

	Technicians: senior + laboratory Secretary Contract staff: Post Doc research fellow Students: 11PhD; 5 M.Sc.	2 1 1 16
Aspirations of laser group	Step change technology for next generation high power laser equipment, pioneer disruptive high power laser technology to maintain international lead in process control, beam/material interaction, designer metalurgy.	
Contacts	John Tyrer (J.R.Tyrer@lboro.ac.uk) Fiona Warner	

Manchester University		Number
Current projects	Laser Cutting(composites, glass, wood and metal) Laser Welding (dissimilar materials, fibre laser welding, porosity) Laser Drilling (aerospace) Rapid additive manufacture (Ni alloys, Ti Alloys, functionally graded, modeling, 100% powder deposition) Laser nano fabrication (nano texturing, nano surface structuring, nano particle generation) Laser synthesis and coating (nano composite coatings, functionally graded coating, PZT coating) Laser micro processing (periodic structures, micro surface texture, micro hole drilling) Laser surface cleaning (de-coating, degreasing)	4 PhD 3PhD/EngD 1EngD + 1PD 3 PD+2 PhD/M 2PD+2PhD 1PD+2PhD 1PhD + 2 PD 2PD
Laser equipment	1kW single mode fibre laser 80W 248nm excimer laser micro processing system 1.5kW CW direct diode laser. 400W DPSS laser 30 -200ns pulses Diode pumped Nd:YVO4 Q-switched laser: 18W @ 1064 nm, 9W @ 532 nm, 4W @ 355 nm. 1W Ti-Sapphire laser 80fs pulse 2.5 kW CO2 slab laser processing system 1 kW CO2 slab laser processing system 400W flashlamp-pumped Nd:YAG laser ms pulse 3-D laser processing system Flashlamp pumped Nd:YAG Q-switched laser: 4W @ 1064 nm, 0.2W @ 532 nm. 120W Direct Diode 3-axis laser processing system. Q-switched Nd:YAG laser marking/ engraving system Q-switched Nd:YAG laser machining system 100W CO2 laser machining system Diode pumped 532 nm Nd:YVO4 marking system	8
Laboratory space for lasers	700m^2	
Number staff	Permanent Temporary Students PhD or M.Sc Administrative secretaries	6 10 26 0
Latest papers 2005-2008	63 papers; 6 patents; 55 conference papers	
Aspirations of laser group	Teamwork and taking challenges	
Contacts	Laser Processing Research Centre: Prof Lin Li, lin.li@manchester.ac.uk, School of Materials: Dr Zhu Liu, zhu.liu@manchester.ac.uk Photon Science Institute: Dr Patricia Scully Patricia.Scully@manchester.ac.uk	

	Mark Dickinson Mark.Dickinson@manchester.ac.uk	

Nottingham University		Number
Current projects	1. Fibre laser cutting 2. Modification of corrosion behaviour by laser surface treatment 3. Optimisation of laser milling for micro-die manufacture. 4. Fibre laser welding 5. Process control of fibre laser deposition 6. Laser deposition of metals (Ti, Waspaloy, S/S) 7. Laser drilling (DePech project and M.Sc projects) 8. Laser selected area coating removal	
Laser equipment	1. 2kW diode laser 2. 2kW IPG fibre laser 3. 400W Lumonics pulsed Nd:YAG drilling laser 4. 100W SPI fibre laser	
Number staff	1. Permanent 3 + 1 in Malaysia 2. Temporary or contract 3. Students 10 PhD + 3 MSc 4. Admin shared school facilities: 1 full time technician	3 +1 0 13 1
Latest papers	Papers related to laser deposition, cutting, drilling, welding and surface treatment using fibre, diode and Nd:YAG lasers (J Phys D 2009-1 paper, Mat Sci Eng A 2008 -1 paper , Lasers in manufacturing 2009-2 papers, ICALEO 2007- 3 papers, 2008 - 1 paper, PICALO 2008 - 1 paper, Lasers in manufacturing 2007-2 papers), patent on laser transformation notching	
Aspirations of laser group	Raising the group profile and interaction with industry – Department of Mechanical Materials and manufacturing Engineering "Innovative Manufacturing Process group The Laser Centre" Consolidating our position as one of the leading laser processing research groups. The Laser Centre, Innovative Manufacturing Process Group, Department of Mechanical, Materials and Manufacturing Engineering.	
Contact	Janet Folkes; Janet.Folkes@nottingham.ac.uk Joel Segal; joel.segal@nottingham.ac.uk Katy Voisey; Katy.Voisey@nottingham.ac.uk	

Salford University		Number
Current projects	1. Carbon/Carbon composites drilling = 2. Lasers used as tools in cutting 3. Cleaning oil paintings (LIBS) 4. LIBS 5. Photovoltaics (aspiration) 6. Magnetic materials (Dr Tiehanshen)	
Laser equipment	Large excimers x 2 (plus one spare) s/s YAGs 2x; 3x;4x (1 main plus spares) femtosecond laser (Dr Tiehanshen)	
Laboratory space for lasers	Enough including air-conditioned excimer lab	
Number staff	Permanent RA PhD Secretary MRI Other secretaries in Physics dept. Technicians (mainly for teaching)	2 +1pt 1 2+ 1 2-3 1

Aspirations of laser group	Develop LIBS as a quantitative analysis system	
Contacts	Professor A.E.Hill (Robin) retd. Joule Physics Dr Richard D. Pilkington (in charge of laser lab) r.d.pilkington@salford.ac.uk Prof. Alan Boardman retd.	

TWI		Number
Current projects	• Welding with the new generation of high brightness fibre-delivered laser beams • High quality laser beam welding of titanium alloys • Characterisation and testing of laser deposited metallic materials • Modelling of the laser DMD process • Cutting with high power fibre delivered beams • Laser induced modification of the surface of materials using the Surfi-Sculpt process • Laser welding of ultra-high strength steels • Effects of material surface on the quality of laser cutting • Process monitoring and control of laser welding for improved weld quality • Laser-arc hybrid process variants for improved productivity • Laser and hybrid laser-arc welding of thick section aluminium alloy • Laser direct metal deposition of functionally graded material • Laser cladding repair of turbine components • Laser powder bed build of complex parts • Direct laser metal deposition of tall free-form Ti alloy components • High speed, low distortion, gap tolerant hybrid Yb fibre laser- MIG welding of aluminium alloys for lightweight construction • Development of fast, on-line monitoring and NDT inspection systems for thin sheet laser welded automotive components • Laser welding of plastic materials • Laser patterning of polymers • Laser welding of technical textiles • Laser heating of nano materials • Laser welding of copper wire	
Laser equipment	• Trumpf 4kW cw Nd:YAG rod laser • Trumpf 3kW cw Nd:YAG rod laser • GSI Group JK1002 modulated Nd:YAG rod laser • Beam manipulation via Kawasaki JS30 articulated arm robots • Hybrid laser-arc welding capability • Twin spot laser welding capability • IPG Photonics 7kW cw fibre laser • Beam manipulation via Kawasaki ZX130L articulated arm robot • Hybrid laser-arc welding capability • Spectron SL804T Q switched frequency multiplied Nd:YAG rod laser	

	• Lumonics JK700 pulsed Nd:YAG rod laser • GSI JK125P pulsed Nd:YAG laser with fibre optic beam delivery • ANORAD precision XYZ Cartesian motion control systems • Laserline dual wavelength 300W diode laser and XYZ gantry • Laserline 500W diode laser with fibre optic beam delivery and Motoman articulated arm robot • Trumpf DMD 505 Cartesian gantry 5 axis direct metal deposition system with 2kW fast axial flow CO2 laser. 2m x 1.1m x 0.75m working envelope • Huffman HC-205 5 axis direct metal deposition system with 2kW PRC Corporation CO2 laser • High deposition rate direct metal deposition system based on a 7kW IPG Photonics fibre laser and ABB articulated arm robot • MCP Tooling Technologies Ltd Realizer SLM100, powder bed additive layer manufacturing system with 50W IPG Photonics fibre laser • MCP Tooling Technologies Ltd Realizer SLM250, powder bed additive layer manufacturing system with 200W IPG Photonics fibre laser	
Laboratory space for lasers	~250 square m (note this excludes all materials testing capability)	250m^2
Number staff	Permanent research 14 Temporary or contract 1 Students - EngDoc 1 - PhD 1 Administrative staff 3	20
Aspirations of laser group	To maintain and expand its influence in the global marketplace of laser materials processing, by stimulation and development of economic value and quality of life. Specific areas of interest involve laser welding and cutting of metals, process control, laser direct metal deposition, metal powder bed technology, surface structuring with laser beams, laser welding of plastics and technical textiles and the use of lasers in the production of micro and nano scale particles and structures.	
Contacts	Dr Paul Hilton paul.hilton@twi.co.uk Rob Scudamore	

Warwick University		Number
Current projects	International Manufacturing Centre Innovative Manufacturing Research centre: agile manufacturing technology Rapid prototyping and tooling ATC Dept. Advanced Technology Centre Warwick Manufacturing Group Warwick Laser Systems Ltd (WLS): transmission laser welding of plastics. Optical Engineering Centre: mid infra red laser ablation studies on tissue; updating the ophthalmoscope; spectroscopy of flames and tissue; fluorescence of human lens; optical techniques for detecting glaucoma.	
Laser equipment	High power diodes 1kW or more (Warwick Laser)	
Number staff	See Warwick Manufacturing Group (WMG)	
Contacts	Mr.Richard Icke (Warwick Laser Systems)	

Warwick Manufacturing Group		Number
Current projects	Two major laser related projects are currently running, LaserCoat and Remote Fibre Laser Welding. *LaserCoat* is a part TSB funded initiative aimed at enhancing the appearance and value of lower grade wood and wood based materials by laser processing. Enhancement has been achieved by direct etching and by controlled placement of powder coating. This project runs until March 09 in conjunction with a group of two trade associations and five industrial partners. The laser group within WIMRC is responsible for the laser processing aspects of the project under overall control of a Project Leader from FIRA Furniture Industry Research Association. *Remote Fibre Laser Welding* is also part TSB funded initiative aimed at developing fibre laser applications within the automotive arena; specifically the 1st Tier sub-assembly supply. A facility is now on site utilising a Comau Smart Laser and a 4kW IPG Laser; trials are progressing to evaluate process and parameter settings and robustness to expected process variation. This programme runs until March 1010 in conjunction with 7 industrial partners, the lead partners being Stadco Ltd. This programme was initiated following initial trials on a CO_2 Remote Laser System within the Premier Automotive Research and Development, based in the IARC, the programme was sponsored by Advantage West Midlands the regional development agency.	
Laser equipment	• IPG YRL-4000-C-WW 4kW fibre laser on Comau SmartLaser robotic remote laser welding system. Primarily used for RFLW project. • Trumpf TLF6000 6kW CO_2 laser and ScanLab scanner remote laser welding system. An XYZ cutting system is currently being integrated with this laser source.	

	Primarily used for comparison with fibre in RFLW project. Cutting facility will be for workshop use. • 200W Synrad FireStar CO_2 laser with ScanLab scanner and CNC XYZ table. Primarily used for LaserCoat project. • 1.2 & 1.8kW Rofin direct diode lasers with CNC XYZ table. Used for transmission laser welding, cladding and student projects. • JK701 Pulsed YAG laser on CNC XYZ table. Used for workshop cutting and welding. • Quantum Laser 60W Q Switched YAG laser marker. Workshop use.	

Laboratory space for lasers	All laser equipment is currently located in WMG's IMC (International Manufacturing Centre) building within the engineering hall. There is a suite of four laser laboratories along one side of the hall in which the majority of the equipment is housed. In order to maximise usable space a mezzanine floor has been constructed to provide storage space and location for several laser chillers.	
Number staff	a) Permanent research 1 professor. b) Temporary or contract staff c) Technician d) Students e) Administrative	1 2 2 2 0
Latest papers	LaserCoat: • Ongoing partners and TSB reports • Presentations during MACH08 and press releases. • Paper(s) anticipated towards end of project. Remote Fibre Laser Welding Programme: • Ongoing partners and TSB reports. • AILU Cambridge 20th February 2008 – 'The future use and adoption of Remote laser Welding for First Tier Automotive Suppliers', Charles Marine (Stadco Group) & Richard Hewitt (WMG). • 4th International Symposium on High-Power Lasers and Their Applications 25th February 2008 – 'The Future Use and Adoption of Remote Laser Welding for First Tier Automotive Suppliers', Alexey A. Ilyin (Stadco Group) & Richard Hewitt (WMG). • Paper(s) anticipated towards end of project.	
Aspirations of laser group	The group is actively investigating projects in areas not usually associated with lasers – horticulture for example as well as possible medical applications. In conjunction with industrial partners it is also involved in replacing lasers with specialised none coherent sources for plastic welding applications. Within the last few years the group has developed an expertise and resource within the high power laser welding field specifically within automotive	

	applications. In conjunction with our industrial partners we aim to continue development within this area to support local industry and extend the industrial application of this technology, both within the automotive sector and to other sectors of the economy.	
Contacts	J. Peter Hancocks: 02476 574332. j.p.hancocks@warwick.ac.uk	

Appendix 6

Projects in laser materials processing established as a result of DTI/TSB Competitions for funding, post 2005.

Lead Company	Partners	University	Title	Start Date
Advanced Optical Technology		Hull	Generation of TEMoo pulses down to 500ps at kHz rates and their use in fine cutting	2006
AIRBUS (UK)	Bae, Econolyst, McLaren Racing Ltd Castings technology International, TWI	Exeter	Direct Additive Manufacture Of Safety Critical Primary Structures	2/1/07
Attiger	Epichem	Teesside Liverpool	Direct Laser Point of Process	30/1/06
BAE SYSTEMS	Airbus, GSIG, GEM, Ceram, QinetiQ	Manchester	Direct Write (Elements and Systems)	1/10/06
BAE SYSTEMS	Arttech Circuits, Ceram, Intense, Mass spec analytical, OptoCap, Power Photonic, Rofin Sinar, Selex, XACT,	Southampton Heriot Watt	Laser technology and Micro-optic beam delivery, manipulation, and Shaping	2/5/06
BAE SYSTEMS	Powerlase, Pro-Lite, SELEX	Strathclyde	Intra-Cavity Adaptive Optics	3/4/06
BAE SYSTEMS		Liverpool Laser Group plus 10 other Universities	BAE Systems Grand Challenge: Integrated programme of research in aeronautical engineering: Affordable manufacturing for composite and metallic airframe (FLAVIIR).	01/01/07
BAE SYSTEMS	CERAM Research Ltd University of Southampton PowerPhotonic Intense Photonics Ltd. Optocap Ltd Heriot Watt University SELEX Sensors and Airborne Systems Mass Spec Analytical Ltd. Rofin-Sinar UK Ltd. Xactpcb Ltd. Artetch		LAMP - LAser technology and Micro-oPtic beam delivery, manipulation, and Shaping	

CERAM Research Ltd	Authentix Ltd Johnson Matthey Plc, Colour Technologies Xaar Plc Dynamic – Ceramic Ltd Printed Electronics Ltd Dudson Ltd Ross Ceramics Ltd	Birmingham City	IdAAt - Durable and Permanent Product Identification, Authentication and Anti Theft Marking which uses laser to sinter ceramic pigments	
CERAM Research Ltd	Johnson Matthey Plc, Colour Technologies Clean Burner Systems Ltd Laser Optical Engineering Ltd Aga Rayburn Ltd Ideal Standard Ltd Josiah Wedgwood Plc		Vitrep - Non Firing Repairs of Vitreous Surfaces which is using lasers to sinter glass systems i.e. glazes and vitreous enamel inks	
Fianium	PPM (Bath) , UoL Laser Group	Bath Liverpool	Ultrafast fibre lasers for materials processing and imaging applications	1/4/06
FIRA	Excel finishing, Granwax, Herman Millar, Howarth Windows and Doors, Norbord, Sonneborne and Rick, TRADA tech	Warwick	The development of pulsed laser-scanning patination of three-dimensional wood surfaces	6/3/06
GEM		Liverpool	Direct write of Sensors	1/10/08
GSI Group	PowerPhotonic Ltd	Cranfield Heriot-Watt	HELPSYS: High Efficiency Laser Processing Systems	1/10/2008
Gwent Group Ltd	Intellident Ltd, Zettlex Ltd,	Liverpool	High Throughput Precision Parallel Laser Micro-processing (PARALASE)	01/01/07
JP Imaging	Fianium, PJS Chemicals,	Liverpool	Sustainable approach to digital imaging and printing	15/1/07
Liverpool	Coherent (Scotland) Ltd		Passive RFID Integrated Sensor Matrix (PRISM)	01/09/08
MCP Tooling Ltd	Dynamic Ceramic, Eminate, Extec hybrids, Feonic, Simpleware	Exeter	Selective Laser Manufacturing for Advanced Functionality	3/7/06
NWLEC	NWDA / NWSF	Manchester	Novel Laser Processes for Microtechnology	01/04/06
Oxford Lasers	Fibrelogix	Aston	Advanced fs laser machining and inscription system	1/2/06
Oxford Lasers	Coherent (Scotland) Ltd	Liverpool	PARALASE: Parallel laser processing	1/10/08
Plasma Quest		Nottingham Trent	High Efficiency Solid State Light Sources deposited by HITUS	1/2/07
Renishaw	CST	Heriot Watt	Next Generation Encoder Manufacture	1/7/08

Stadco	Comau, Corus, Jaguar / Land Rover, Prima, SPI,	Warwick	Remote fibre laser welding	25/9/06
Teer Coatings	Rolls Royce, Agie, Rainford Precision, Hanson, Innovation Biotech, Microsystems	Manchester	Extended life tooling by advanced coating technology	2/4/07
TWI Ltd	EADS UK Bombardier Aerospace plc TISICS Ltd Materialise UK	Exeter	Added Value by Laser Assisted Additive Manufacture - AVLAM	01/02/08
Uni of Cambridge	SPI,	Cambridge Southampton	High efficiency gas-assisted cutting using optimised next generation fibre lasers	1/7/06
UoL Liverpool Laser Group	EPSRC GR/S43276/01	Liverpool	Laser Forming for the Correction of Distortion and Design Shape in Aluminium Structures	
Vivid Components	Denfotex Light Systems, Sifam	St Andrews	Novel dental laser microdrilling technique	5/12/05

Appendix 7

Recent publications (2006 onwards) in the area of laser materials processing.

Birmingham University		
Z. Jiang, C.L. Falticeanu and I.T.H. Chang	"Warm compaction of Al alloy PM blends"	Materials Science Forum, Vol, 534-536, pp333-336 (2007).
J. S. Kim, I.T.H. Chang and K. Jiang	" Pressure free fabrication of 3D microcomponents using Al powders"	Advanced Engineering Materials, Volume 8, Issue 1-2 , pp 38-41(2006)
J. S. Kim, I.T.H. Chang and K. Jiang	"A net shape process for metallic microcomponents fabrication"	Journal of Micromech and Micromachining., Vol. 16,pp48-52 (2006)
X.Yong, I.T.H. Chang and I.P. Jones	"Synthesis and characterization of quasicrystalline Al-based composites Powder Metallurgy"	Powder Metallurgy, Vol.49(2), pp140-145(2006)

Cambridge University		
Articles		
Cockburn, A, Bray, M. and O'Neill, W. (2008)	Laser assisted Cold Spray: LCS can reduce process costs and increase application range	Industrial Laser Solutions, 23 (11), November 2008.
Hu, Q., Hu, P. and O'Neill, W. (2008)	Laser-assisted micro structure fabrication by using nano-particles	The Laser User, 52 (Autumn 2008). ISSN 1775-5140
O'Neill, W. (2008)	Laser cutting: a technology with some surprises in store	The Laser User (51). ISSN 1755-5140
O'Neill, W. (2008)	MOPA -based fibre lasers offer processing options.	Optics & Laser Europe, September 2008, pp. 17-19
Sparkes, M., Gross, M. and O'Neill, W. (2008)	A novel non-intrusive sampling technique for CO2 laser on-line beam monitoring utilising a silicon mirror	Optics and Lasers in Engineering, 46 (8). pp. 620-627. ISSN 0143-8166
Sparkes, M., Gross, M., Celotto, S., Zhang, T. and O'Neill, W. (2008)	Practical and theoretical investigations into inert gas cutting of 304 stainless steel using a high brightness fiber laser	Journal of Laser Applications, 20 (1). pp. 59-67. ISSN 1042-346X
Pattison, J., Celotto, S., Khan, A. H. and O'Neill, W. (2008)	Standoff distance and bow shock phenomena in the cold spray process	Surface and Coatings Technology, 202 (8). pp. 1443-1454. ISSN 0257-8972
Pattison, J., Celotto, S., Morgan, R., Bray, M. and O'Neill, W. (2007)	Cold gas dynamic manufacturing: a non-thermal approach to freeform fabrication	International Journal of Machine Tools and Manufacture, 47 (3-4). pp. 627-634. ISSN 0890-6955
Gross, M. S. and O'Neill, W. (2007)	New aspects of melt flow phenomena through narrow kerfs	Journal of Physics D: Applied Physics, 40 (4). pp. 1201-1205. ISSN 0022-3727
Novoselova, T., Celotto, S., Morgan, R., Fox, P. and O'Neill, W. (2007)	Formation of TiAl intermetallics by heat treatment of cold-sprayed precursor deposits	Journal of Alloys And Compounds , 436 (1-2). pp. 69-77. ISSN 0925-8388
Khan, A. H., Celotto, S., Tunna, L., O'Neill, W. and Sutcliffe, C. J. (2007)	Influence of microsupersonic gas jets on nanosecond laser percussion drilling	Optics and Lasers in Engineering, 45 (6). pp. 709-718. ISSN 0143-8166
Tunna, L., Khan, A., O'Neill, W. and Sutcliffe, C.J. (2006)	The effect of processing wavelength and fluence on the microdrilling of 316 L stainless steel with a diode pumped solid state laser	Journal of Laser Applications, 18 (3). pp. 205-209. ISSN 1042-346X
Gross, M. S. (2006)	On gas dynamic effects in the modelling of laser cutting processes	Applied Mathematical Modelling, 30 (4). pp. 307-318. ISSN 0307-904X
Tunna, L., Barclay, P., Cernik, R. J., Khor, K. H., O'Neill, W. and Seller, P. (2006)	The manufacture of a very high precision x-ray collimator array for rapid tomographic energy dispersive diffraction imaging (TEDDI)	Measurement Science and Technology, 17 (7). pp. 1767-1775. ISSN 0957-0233

Novoselova, T., Fox, P., Morgan, R. and O'Neill, W. (2006)	Experimental study of titanium/aluminium deposits produced by cold gas dynamic spray	Surface and Coatings Technology, 200 (8). pp. 2775-2783. ISSN 0257-8972
Khan, A.H., O'Neill, W., Tunna, L. and Sutcliffe, C. (2006)	Numerical analysis of gas-dynamic instabilities during the laser drilling process	Optics and Lasers in Engineering, 44 (8). pp. 826-841. ISSN 0143-8166
Book Section		
Celotto, S., Pattison, J., Ho, J.S., Johnson, A.N. and O'Neill, W. (2007)	The economics of the cold spray process	Champagne, V.K., (ed.) The Cold Spray Materials Deposition Process: Fundamentals and Applications. CRC Press, 2007. ISBN 1420066706
Conference or Workshop Item		
O'Neill, W. (2008)	Hi repetition rate MOPA based fibre laser for micro machining applications	4th International Workshop on Fiber Lasers, 5-6 November, Dresden, Germany.
O'Neill, W. (2008)	Microfabrication using a Single Mode Yb Fiber Laser	Multi-Material Micro Manufacture 2008 (4M2008), 9-11 September 2008, Cardiff, UK (in press)
Hu, Q. and O'Neill, W. (2008)	Laser assisted micro and nano replication	3rd Pacific International Conference on Applications of Lasers and Optics (PICALO 2008), 16 - 18 April 2008, Beijing, China.
Bray, M., Cockburn, A. and O'Neill, W. (2008)	Recent developments of the laser-assisted cold spray process and deposit characterisation	3rd Pacific International Conference on Application of Lasers and Optics (PICALO), 16 - 18 April 2008, Beijing, China.
O'Neill, W. and Li, K. (2008)	High precision machining of Si using a single mode fibre laser	3rd Pacific International Conference on Applications of Lasers and Optics, 16 - 18 April 2008, Beijing, China.
Zhang, T., Sparkes, M.R., Gross, M. S. and O'Neill, W. (2008)	The studies of laser oxygen thick section cutting using disk laser	3rd Pacific International Conference on Application of Lasers and Optics (PICALO), 16-18 April 2008, Beijing, China.
O'Neill, W., Pattison, J. and Bray, M. (2007)	Development of the cold spray process for additive fabrication	Advanced Laser Applications Conference, 24-26 Sep 2007, Burlington, USA.
Sparkes, M., Gross, M. and O'Neill, W. (2007)	High brightness fiber and disc laser cutting	Advanced Laser Applications Conference, 24-26 Sep 2007, Burlington, USA.
O'Neill, W. and Seefeld, T. (2007)	High brightness laser cutting and welding	Lasers in Manufacturing (LIM 2007), 18-21 Jun 2007, Munich, Germany.
Sparkes, M., Gross, M. and O'Neill, W. (2007)	A novel non-intrusive technique for CO2 laser on-line beam monitoring	Advanced Laser Applications Conference, 24-26 September 2007, Burlington, VT, US.
Sparkes, M.R., Gross, M.S., Celotto, S., Zhang, T. and O'Neill, W. (2006)	Inert cutting of medium section stainless steel using a 2.2kW high brightness fibre laser	International Congress on Applications of Lasers & Electro-Optics (ICALEO 2006), 29-31 October 2006, Scottsdale, AZ, US.
Pattison, J. and O'Neill, W. (2006)	Cold gas dynamic manufacturing: a non-thermal approach to additive manufacturing	7th National Conference on Rapid Design, Prototyping and Manufacture, 16 Jun 2006, High Wycombe, UK.
Sparkes, M.R., Gross, M.S., Celotto, S. and O'Neill, W. (2006)	A novel non-intrusive technique for CO2 laser on-line beam monitoring	Laser Materials Processing Conference (part of ICALEO' 06), 30 October - 2 November 2006, Scottsdale, AZ, USA.
Bray, M.J., Celotto, S. and O'Neill, W. (2006)	Development of a laser assisted material spray process	Laser Materials Processing Conference (part of ICALEO' 06), 30 October - 2 November 2006, Scottsdale, AZ, USA.
Gross, M., Celotto, S. and O'Neill, W. (2006)	Melt flow in narrow thick section kerfs	Laser Materials Processing Conference (part of ICALEO' 06), 30 October - 2 November 2006, Scottsdale, AZ, USA.

O'Neill, W. and Li, K.	Applications of Yb lasers in microelectronics fabrication	Conference on Photonic Applications, Systems and Technologies, PHAST"08, 6-8 May 2008, San Jose, USA. (In Press)
O'Neill, W., Jewell, S. and Hu, Q.	Laser hot forging of micro and meso components	Advanced Laser Applications Conference, 24-26 September 2007, Burlington, MA, US

Cardiff University		
Newest publications:		
Petkov, P.V., Dimov S.S., Minev R., Pham D.T	Laser milling: pulse duration effects on surface integrity"	manuscript to be published
Petkov, Dobrev Pham and Dimov	Strategies for laser milling with microsecond pulses"	manuscript to be published
Dobrev Pham and Dimov	"Techniques for improving surface quality after laser milling"	manuscript to be published
Pham, Dimov, Petkov	"Laser milling of ceramic components"	Int. Journ. machine tools and manuf. 47 (2007) 618-626
Dobrev, Dimov, Thomas	"Laser milling: modelling crater and surface formation"	manuscript to be published

Coventry University		
P Swanson, C J Page, E Read	'Plasma augmented welding of steel plate'	The Industrial Laser User, Issue 43, pp 22-25 2006
P Swanson, C J Page, E Read, H Wu	'Plasma augmented laser welding of 6 mm steel plate'	Science and Technology of Welding and Joining, Vol 12, No 2, pp 1-8 2007

Cranfield University		
	Welding with high power fiber lasers – A preliminary study	Materials and Design
	Analysis of Beam Material Interaction in Welding of Titanium with Fiber Lasers	Materials and Manufacturing
	Rapid prototyping with high power fiber lasers	Materials and Design
Conference Papers		
	Additive manufacturing of Ti-6Al-4V based components with high power fiber lasers	VRAP Conference
	The micro-welding ability of 100w high brightness fibre laser on 316l stainless steel	ICALEO 2007
	Evaluation of a Drilling Model Approach to Represent Laser Spot Microwelding	8th International Conference on Trends in welding Research
	The impact of different types of welding processes on the residual Research stress and distortion in 4mm thick butt welds of ship plate	8th International Conference on Trends in welding Research
Conference and Symposium Presentations		
	Hyrbid Laser-Arc Pipeline Welding	4th International Symposium on High Power Fibre Lasers and their Applications
	High Quality Lasers and Beam Delivery – the Benefits – a Users Perspective	AILU Workshop

Reports		
	The effect of gas mixtures on fibre laser welding of high strength steels	
	Investigation of the use of high power fibre lasers in additive manufacture	
MSc Theses		
	Evaluation of a drilling modelling approach to represent laser welding	
	Laser welding of nitinol alloys for endovascular medical devices	
	Evaluating the Effect of Different Welding Processes on the Distortion of 4mm Thick DH36 Ship Panels	

Imperial College London		
Articles		
Holmes A.S., Pedder J.E.A.	Laser micromachining in 3D and large area applications	The Industrial Laser User, Issue 45, 27-29, (2006)
Sugioka K., Gu B., Holmes A.S.	The state of the art and future prospects for laser direct-write for industrial and commercial applications	MRS Bulletin, 32, 47-54, (2007)
Gower M.C.	From laser micromachining to nanomachining: considerations	Int. J. of Technol. Transfer & Commercialisation, **7**, 142, (2008)
Pedder J.E.A., Holmes A.S., Dyer P.E.	Improved model for the angular dependence of excimer laser ablation rates in polymer materials	Applied Physics Letters, 95, paper 174105, (2009)
Conference Papers		
Booth H., Brunton A., Cashmore J., Elbourn P., Elliner G., Gower M., Greuters J., Hirsch J., Kling L., McEntee N., Richards P., Truffert V., Wallhead I., Whitfield M.	RIM-13: A high-resolution imaging tool for aerial image monitoring of patterned and blank EUV reticles	Proc. SPIE 6151, B1-12 (2006)
Pedder J.E.A., Holmes A.S.	A study of angular dependence in the ablation rate of polymers by nanosecond pulses	SPIE Proceedings vol. 6106, Proc. Photonics West LASE 2006, San Jose, USA, 21-26 January 2006, pp. 286-294
Holmes A.S., Pedder J.E.A., Boehlen K.	Advanced laser micromachining processes for MEMS and optical applications	SPIE Proceedings Vol. 6261, Proc. High Power Laser Ablation Conference 2006, Taos, New Mexico, 7-12 May 2006, pp. 1E1-1E9
Pedder J.E.A., Boehlen K., Allott R., Holmes A.S.	Pulsed laser ablation for volume fabrication of micro-optical arrays on large area substrates	SPIE Proceedings vol. 6462, Proc. Photonics West MOEMS-MEMS 2007, San Jose, USA, 20-25 January 2007, paper no. 64620W
Holmes A.S., Sugioka K., Gu B.	Industrial Applications of Laser Direct-Write Processing: A Review	PhAST 2007 Photonics Applications Systems and Technologies Conference, Baltimorre, Mayland, 7-10 May 2007
Pedder J.E.A., Holmes A.S.	Pulsed laser processing of shallow micro-optical structures: ablation vs lithography	SPIE Proceedings vol. 6458, Proc. Photonics West LASE 2007, San Jose, USA, 20-25 January 2007, paper no. 645818
Gower M.C.	Laser microfabrication in industry – perspectives from the past, present and future	Proc. SPIE 6879, 687902-1 (2008)
Pedder J.E.A., Holmes A.S., Booth H.	Pulsed Laser Ablation of Polymers for Display Applications	SPIE Proceedings vol. 6879, Proc. Photonics West LASE 2008, San Jose, California, USA, 19-24 Jan

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Conference and Symposium Presentations		
Gower M.C.	EUV lasers - potential applications in EUV lithography	Corporate Advisory Committee Meeting, EUV Engineering Research Center, University of California, Berkeley, California (Feb 2006)
Gower M.C.	Laser microprocessing of materials	Invited talk. Welsh Development Agency Optoelectronics Forum, Cardiff. (Feb 2006)
Gower M.C.	Laser Microfabrication – industrial applications	11th World Micromachine Summit, Beijing, China (Apr 2006)
Gower M.C.	Laser micromachining of materials for industrial manufacturing	Keynote presentation. IEE Seminar and Exhibition on Sensors and Actuators, Savoy Place, London (Apr 2006)
Holmes A.S., Pedder J.E.A.	Laser micromachining of 3D structures for MEMS and optical applications	AILU Workshop, Oxford, 14 June 2006
Ali M., Ashworth D., Baker P., Cashmore J., Fuller S., Gower M.C., McEntee N., Piscani E., Rudack A., Stark D., Caffrey A., Malach J., Parker G., Webb J.	Design and Performance of a Hyper-NA 193nm Immersion Microstepper System	193nm Immersion Lithography Symposium, Kyoto, Japan, (Oct 2006)
Gower M.C.	From microfabrication to nanofabrication - taking laser processing to nanoscale dimensions	AILU Workshop on Micromachining, Cardiff (Jul 2007)
Gower M.C.	Laser micromachining to nanomachining – considerations	COMS 2007, Melbourne, Australia (Sept 2007)
Gower M.C.	Industrial applications of laser micromachining – current status and future opportunities	COMS 2008, Puerto Vallarta, Mexico (Sept 2008)
Gower M.C.	Laser micromachining & MEMS manufacturing	COMS 2009, Copenhagen, Denmark (Sept 2009)
Holmes A.S.	Laser processing for the fabrication of MEMS devices	AILU Workshop, Oxford, 22 Sept. 2009

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Z. B. Wang, B. S. Luk’yanchuk, W.	The influences of particle number on	The Journal of Chemical Physics 128,

Guo, S. P. Edwardson, D. J. Whitehead, L. Li, Z. Liu, K. G. Watkins	hot spots in strongly coupled metal nanoparticles chain	094705 (2008)1-5.
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S. P. Edwardson, K. Edwards, C. Carey, G. Dearden, K.G. Watkins	Laser Forming for Ship Building Applications	Steel Tech Vol. 2 No. 4, July 2008 42 - 46
Z.B.Wang, B.S. Luk'yanchuk L. Li, P.L. Crouse, Z. liu, G. Dearden, K.G. Watkins	Optical near-field distribution in an asymmetrically illuminated tip–sample system for laser/STM nanopatterning	Appl. Phys. A 89 (2007) 363–368
R Dodd, J D Mullett, S Carroll, G Dearden, A T Shenton, K G Watkins, G Triantos, S Keen	Laser ignition of an IC test engine using an Nd:YAG laser and the effect of key laser parameters on engine combustion performance	Lasers in Engineering, (2007) Vol. 17, pp. 213-231.
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D. Liu, J. Cheng, W. Perrie, A. Baum, P. Scully, M. Sharp, S. P. Edwardson, Z. Kuang, N. G. Semaltianos, P. French, G. Dearden, L .Li, K. G. Watkins	Femtosecond Laser Micro-structuring of Materials in the NIR and UV regime	ICALEO® 2007 Congress Proceedings, Laser Microprocessing Conference Paper M 103 pp12 - 18 IBSN:13#978-0-912035-88-8 & 10#0-912035-88-9
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K Edwards, S P Edwardson, C Carey, C J Williams, G Dearden, K G Watkins	Laser Peen Forming For 2D Shaping And Micro Adjustment	ICALEO® 2007 Congress Proceedings, Laser Microprocessing Conference Paper M 605 pp156 - 165 IBSN:13#978-0-912035-88-8 & 10#0-912035-88-9
S. P. Edwardson, E.Abed, C. Carey, K. R. Edwards, K. Bartkowiak, G. Dearden, K. G. Watkins	Key Factors Influencing The Bend Per Pass In Laser Forming	ICALEO® 2007 Congress Proceedings, Laser Materials Processing Conference Paper P506 pp508-514 IBSN:13#978-0-912035-88-8 & 10#0-912035-88-9
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E. Fearon, T. Sato, D. Wellburn, K.G. Watkins, G. Dearden	Thermal Effects of substrate Materials used in the Laser Curing of Particulate Silver Inks	Laser Assisted Net Shape Engingeering 5, LANE 2007, pp379-390 IBSN 978-3-87525-261-3
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P.W.French T. Li , J.Clowes, W.Perrie, M.Sharp,D.Liu, K.G. Watkins	Ultrafast Short Pulse Laser Material Processing of Aerospace Materials	Proceedings of the Fourth International WLT-Conference on Lasers in Manufacturing 2007, Munich, June 2007
A Baum, P J Scully, W Perrie, M Sharp, K G Watkins, D Jones, R Issac and D A Jaroszynski	NUV and NIR Femtosecond Laser Modification of PMMA	Proceedings of LPM20007-the 8th International Symposium on Laser Precision Microfabrication
Nikolaos G. Semaltianos, Walter Perrie, Stuart P. Edwardson, Geoff Dearden, Martin Sharp, K. G.Watkins	Silicon Nanoparticles Produced by Femtosecond Laser Ablation	Proceedings of LPM2007-the 8th International Symposium on Laser Precision Microfabrication
G Dearden, S P Edwardson, E Abed, K Bartkowiak, K G Watkins	Correction Of Distortion And Design Shape In Aluminium Structures Using Laser Forming	25th International Congress on Applications of Lasers & Electro-Optics (ICALEO 2006), Paper No. 505, Laser Institute of America, Publication No 599, Vol. 99, ISBN 0-912035-85-4 (2006)
S P Edwardson, E Abed, K Bartkowiak, G Dearden and K G Watkins	Geometrical Influences on Multi-pass Laser Forming	J. Phys. D: Appl. Phys. 39 (2006) 382–389
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A.R.Choudhury, T. Ezz, S. Chatterjee and L.Li	Microstructure and tribological behaviour of nano-structured metal matrix composite boride coatings synthesized by combined laser and sol-gel technology	Surface & Coatings Technology, Vol 202, 2008, 2817-2829
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A.Abdolvand, S.Z.Khan, Y.Yuan, P.L.Crouse, M.J.J.Schmidt, M.Sharp, Z.Liu and L.Li	Generation of titanium-oxide nanoparticles in liquid using a high-power, high-brightness continuous-wave fibre laser	Applied Physics A, 2008
A. Biswas, U.K. Chatterjee, L.Li, I. Manna and J.D. Majumdar	Laser assisted surface modification for bio-implant application	Surface Review and Letters, Vol. 14 (4), 2007, 531-534
M.Sobih, P.I. Crouse and L.Li	Striation-free laser cutting of mild steel sheets	Applied Physics A – Materials Science and Processing, Vol. 91(1), 2008, 171-174.
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W. Guo, Z.B. Wang, L.Li, and Z. Liu	Near-field laser parallel nanofabrication of arbitrary-shaped patterns	App. Phys. Lett. Vol. 90(24), 2007, 243101
M.W. Turner, P.L.Crouse and L.Li	Comparative interaction mechanisms for different laser systems with selected materials on titanium alloys	Applied Surface Science, Vol 253 (19), 2007, 7992-7997
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S.Safda, L.Li, M.Sheikh and Z.Liu	The effect of non-conventional laser beam geometry on stress distribution and distortions in laser bending of tubes	ASME Transactions, Journal of Manufacturing Science and Engineering, Vol. 129(3), 2007, 592-600
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N.Mir-Hosseini, P.L.Crouse, M.J.J.Schmidt, L.Li and D.Garrod	"Laser micro-surface texturing of Ti-6Al-4V substrates for improved cell integration"	Applied Surface Science, Vol 253, 2007, 7738-7743
S.Safdar, L.Li and M.A. Sheikh,	Numerical analysis of the effects of	Journal of Physics D: Applied

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L.Li, W.U.H.Syed and A.J. Pinkerton	Rapid additive manufacturing of functionally graded structures using simultaneous wire and powder laser deposition	Virtual and Physical Prototyping, Vol.1, 2006, 217-225
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K.Minami, P.L.Crouse and L.Li	A three-dimensional transient model for the analysis of thermal history during laser-based grout removal	Proceedings of IMech.E, Part B: Journal of Engineering Manufacture, Vol. 220, 2006, 869-870
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Conference Papers – (CR: refereed, C: not refereed)		
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W.Guo, Z.B.Wang, L.Li, Z.Liu, B.Luk'yanchuk, D.J.Whitehead	"Large area nanopatterning of silicon surface by chemical assisted laser processing using near-field enhancement by particle-lens arrays"	Proceedings of 3rd Pacific International Conference on Applications of Lasers and Optoelectronics (PICALO'08), Laser Institute of America, Beijing, China, 16-18 April 2008. (C)
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A.J. Pinkerton, A.M.Kamara, K.Shah, L.Li	"Three dimensional analytical and finite element methods for simulating a moving melt pool with mass addition"	Proceedings of 3rd Pacific International Conference on Applications of Lasers and Optoelectronics (PICALO'08), Laser Institute of America, Beijing, China, 16-18 April 2008. (C)
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S.Khan, Y.Yuan, A.Abdolvand, P.Crouse, M.Schmidt, L.Li and Z.Liu	"CW laser generation of titanium oxide nanoparticles in liquid: characterisation and phase investigation"	26th International Congress on Applications of Lasers & Electro-optics (ICALEO), 29 October – 1 Nov, 2007, Orlando, FL, USA, Laser Institute of America, Vol 100 (ISBN13#978-912035-88-8), Nano-manufacturing Conference, pp55-62 (C)
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R. Lloyd, A.Abdolvand, M.Schmidt, P.Crouse, D.Whitehead, L.Li and Z.Liu	Laser-assisted generation of self-assembled microstructures on stainless steel	9th International Conference on Laser Ablation (COLA2007), Tenerife, Spain, 24-28 Sept. 2007 (C)
D.J.Whitehead, P.L.Crouse, M.J.J.Schmidt, L.Li, M.W.Turner and A.J.E Smith	Monitoring laser cleaning of titanium alloys by probe beam reflection and emission spectroscopy	9th International Conference on Laser Ablation (COLA2007), Tenerife, Spain, 24-28 Sept. 2007 (C)
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J.Spencer, P.Crouse and L.Li	Potential application of high power lasers in nuclear decontamination and decommissioning	Photon06 Conference, 4-7 Sept. 2006 Manchester, UK, by Institute of Physics, (invited). (C)
P. Warren, J.M.Williams, L.Li and W.Wang	Chip free high speed laser cutting of float glass	Photon06 Conference, 4-7 Sept.2006 Manchester, UK, by Institute of Physics, (invited). (C)
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M.Sobih, P.Crouse and L.Li	Laser cutting of variable thickness materials – understanding the problem	25th International Congress on Applications of Lasers & Electro-Optics (ICALEO'06), 30 Oct. -2 Nov. 2006, Scottsdale, AZ. USA, Laser Institute of America. (C)
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T.Ezz, P.Crouse, Z.Liu and L.Li	Laser/Sol-gel synthesis and deposition of nano-crystalline/amorphous Tin/Si3N4 composites	25th International Congress on Applications of Lasers & Electro-Optics (ICALEO'06), 30 Oct. -2 Nov. 2006, Scottsdale, AZ. USA, Laser Institute of America. (C)
S.Safder, L.Li, M.A.Shikh and Z.Liu	Non-conventional beam geometry for laser transformation hardening of mild steels	2nd Pacific International Conference on Applications of Lasers and Optics (PICALO), 3-5 April 2006, Melbourne Australia, publ. by Laser Institute of America. (CR)
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