Institution: Imperial College London

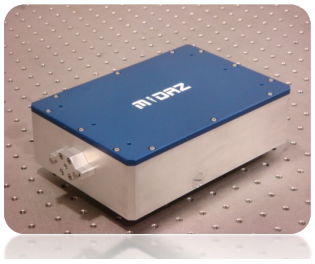
Unit of Assessment: 9 Physics

Title of case study: P7 - Micro-Slab Laser Technology – Midaz Lasers Ltd

1. Summary of the impact (indicative maximum 100 words)

Midaz Lasers Ltd is a spin-out laser company formed by academic founders, Professor Michael Damzen (Director and Chief Technology Officer, CTO) and Dr Ara Minassian (Chief Scientific Officer, CSO), in 2006 as the vehicle for commercial exploitation of patented laser technology [4] arising from Prof Damzen's research group in the Physics Department at Imperial College London.

Midaz has designed and assembled multiple engineered laser and amplifier products, incorporating this patented technology, and has sold units to industrial customers in Europe, N. America and Asia since 2010. The primary market and beneficiary for Midaz laser technology is the industrial laser manufacturing sector and the benefit of the technology is to create laser industrial tools for higher throughput and lower cost manufacturing, including in the semiconductor industry for production of consumer electronics. In July 2012, Midaz was successfully sold to world-leading laser company, Coherent Lasers Ltd, for $3.8 Million.



Midaz A70-W unit. World's highest gain solid-state Laser Amplifier.

2. Underpinning research (indicative maximum 500 words)

PIONEERING RESEARCH:
The original and pioneering research for this laser technology was undertaken in Prof Damzen's group at Imperial over the period 1999 – 2006, prior to company formation. Three key pioneering papers [1-3] and a core patent [4] are listed in section 3, although a total of 30 journal papers were published by the group and 4 patents filed by Prof Damzen on various implementations of this technology.

BREAKTHROUGH LASER PERFORMANCE:
The research was on a new laser technology involving a new diode-pumped micro-slab laser geometry with novel design features. The unique features of this technology provide extensive performance improvement compared to existing lasers. With suitable commercial deployment this leads to a disruptive technological breakthrough in the laser manufacturing sector by offering lasers with:

- unparalleled gain (~10^5), orders of magnitude higher than any other diode-pumped solid-state laser technology;
- much higher efficiency (reducing costs and minimising heating problems);
- order-of-magnitude higher pulse repetition rates (for high processing speed);
- high peak-power capability (outperforming fibre lasers);
- compact size (for ease of integration); and
- simplicity of diode pump delivery (for lower costs).

KEY PUBLICATIONS & PATENTS:

- In 2000 [1], we published our breakthrough research work on the demonstration of the laser architecture in a lab-based version of the system, showing the novel combination of features including higher efficiency than prior technology together with an order of magnitude higher power than previous work for this type of laser.
- In 2003 [2], we published a higher performance design of our original work [1] that later came to define the "standard" configuration of this laser system, as used by later research groups and companies, trying to emulate our work.
- In 2005 [3], we published a novel implementation showing even further performance

enhancement, which underpinned our later company products.

- A UK patent was filed in 2002 on a novel and performance-improving aspect of the technology, prior to the research (public) domain publication of the performance enhancements of the technology [2, 3]. One year later (2003), the patent was filed internationally (PCT) and published in January 2005 [4]. It is now granted in key geographical markets across Europe, US, Japan, China and Australia.

KEY PERSONNEL:

- Prof M Damzen, Professor of Laser Physics, Imperial College London (1984-present). Prof Damzen was head of the research laboratory and the PI on the relevant EPSRC grants [G1, G2].
- Dr Ara Minassian, EPSRC Research Associate in Photonics, Physics Department, Imperial College London (2001-2008), then Chief Scientific Officer, Midaz Lasers (2008-2012)

Prof Damzen and Dr Minassian were co-Founders of the spin-out Company, Midaz Lasers Ltd, formed in 2006 to commercialise this technology.

FUNDING:
The funding for the underpinning research work was through [G1] and [G2]. A later MoD contract from the Electromagnetic Remote Sensing - Defence Technology Centre [G3] helped support further development of the amplifier technology in both theoretical understanding and engineering details.

3. References to the research (* References that best indicate quality of underpinning research)

[1] *M.J. Damzen, M. Trew, E. Rosas, G.J. Crofts, "*Continuous-wave Nd:YVO_4 grazing-incidence laser with 22.5 W output power and 64% conversion efficiency*", Opt. Comm. 196, 237 (2000). DOI, **65 citations (as at 17/9/13)**

[2] *A. Minassian, B. Thompson, M.J. Damzen, "*Ultrahigh-efficiency TEM_{00} diode-side-pumped Nd:YVO_4 laser*", App. Phys B. 76, 341 (2003). DOI, **55 citations (as at 17/9/13)**

[3] A. Minassian, B. Thompson, M.J. Damzen, "*High-power TEM_{00} grazing-incidence Nd:YVO_4 oscillators in single and multiple bounce configurations*", Opt. Comm., 245, 395 (2005). DOI, **26 citations (as at 14/9/13)**

[4] ***PATENT**, "*Optical Amplifying Device*", Publication number: WO/2004/006395 A1, Application number: PCT/GB2003/002956, Inventor: M.J. Damzen, Applicant: M.J. Damzen, Imperial College Innovations Ltd, Publication Date: 15 Jan 2005

Grant support details:

[G1] EPSRC, GR/L96455/01, "Diode-pumped self-adaptive gain-grating lasers", PI: M Damzen, 01/04/98 – 31/03/00, £172,585.

[G2] EPSRC, GR/T08555/01, "Adaptive Interferometric Sensors and Sources", PI: M Damzen, 28/02/05 – 27/08/08, £244,645.

[G3] MoD contract from the Electromagnetic Remote Sensing - Defence Technology Centre (EMRS-DTC Contract No. EMRS-DTC/2/60), Electronic Magnetic Remote Sensing (EMRS)-self Optimising Illuminating and Sensors', PI: M Damzen, 01/04/04 – 31/03/07, £366,508.

4. Details of the impact (indicative maximum 750 words)

- The initial external impact of the research and patented micro-slab laser technology [4] has been through the formation of a spin-out company, Midaz Lasers Ltd [A, B]. Midaz was formed by Prof. Michael Damzen and Dr Ara Minassian (Postdoctoral Research Assistant and former PhD student) in 2006 as a vehicle to commercialise the technology. Until its sale to Coherent Lasers Ltd in July 2012, Prof Damzen was on the Company's Board of Directors and acted as Chief Technology Officer (CTO) and Dr Minassian acted as Chief Scientific Officer (CSO). The initial funding from Imperial Innovations and the business angel, Dr Paul Atherton, in 2006 was followed through with further funding from the same investors in the period 2008 – 2012 [C, D]. The company has employed three full-time and six part-time employees since January 2008.

- The primary market and beneficiary for Midaz laser technology is in the industrial laser manufacturing sector. Midaz high gain technology allows increased speed and precision of manufacturing with a significant cost reduction and decrease in laser size for improved integration of the laser technology. The laser processing market is the single biggest laser application in terms of US dollar sales, with laser sales exceeding 2 billion US dollars annually (Source: *Laser Focus World, Annual Review of Laser Marketplace*). The main customers targeted by Midaz were systems-integrators and laser solutions providers (including other laser companies). Laser processing has grown enormously in recent years, particularly in micro-electronics (e.g. laser processing of silicon) and consumer products (e.g.mobile phones, cameras, LCD TV, touch panel displays), as well as in more traditional sectors (e.g. automotive, aerospace) and new high growth sectors (e.g. laser processing in solar cell production).

- The first laser installation – and the first external revenue income into Midaz - was to the UK Laser Manufacturing Centre (UK-LMC) in North Wales as early as Aug 2006, after just a few months of company operation. An early prototype laser was successfully installed and trialled by UK-LMC leading to the first invoiced income to Midaz [E]. Midaz' main revenue since 2008 evolved from trialling prototype products to customers in a number of industrial processing sectors (e.g. industrial diamond cutting, silicon wafer cutting). Additional company income (~€150,000) arose from contract work to the European Space Agency to develop alexandrite lasers for light detection and ranging (LIDAR) applications [F, G, H].

- Since 2010, Midaz developed a few more fully engineered (production-level) laser products incorporating the micro-slab technology and the core patent [4] that derived from the Imperial group's seminal research. This resulted in international sales of these products, principally in Europe but also in N. America and Asia. In particular, strong market traction of Midaz high gain amplifier products occurred. Midaz amplifier products were both water-cooled (Product Model: A70-W, [I]) and air-cooled (Product Model: A50-A, [J]). These were attractive to other laser companies who could utilise the high gain amplifier products to boost low power picosecond duration lasers to powers relevant to the industrial market where power equates to production speed. This simple step (low cost, low power seed plus Midaz amplifier) offered massive potential cost savings over the current expensive short pulse laser products.

- This market traction led Midaz to interactions with the world-leading laser company, Coherent Lasers Ltd, and resulted in the investors' decision to seek exit by sale of the shareholding of the company. On 23 July 2012, Midaz was successfully acquired by Coherent Lasers for $3.8 million, with a significant return for investors [K]. Coherent, which is headquartered in the USA, reported in their 2012 Annual Report and Form 10-K: "*In July 2012, we acquired all of the outstanding shares of MiDAZ Lasers Limited for approximately $3.8 million in cash. MiDAZ was a technology-based acquisition. We intend to utilize the acquired technology in low cost, compact pulsed solid state lasers*" [L]. As reported in a Coherent press release announcing the purchase of Midaz (the company also acquired Innolight Innovative Laser and Systemtechnik GmbH at the same time), *"'The acquisition of Innolight and MiDAZ fits well into Coherent's mission of providing cutting edge solutions to both industrial and scientific markets" states Mark Sobey, Executive Vice President at Coherent. "We are excited not only with the current Innolight product line, but also about the future ability to extend the performance in many dimensions based on combinations with MiDAZ and other Coherent technologies to address our customers application roadmaps"'* [M]. A later quote by the CEO of Coherent Lasers, detailing the impact of the Midaz acquisition, was published in the online Optics.org newsletter: *"And Coherent has also snapped up Midaz Lasers. The UK-based company, originally a spin-out from Imperial College, London, has developed what [CEO] Ambroseo described as a "very compact and elegant" solid-state amplifier operating across the nanosecond and picosecond regimes. "Everybody at Coherent thinks it is very clever," said Ambroseo of the Midaz technology. "[and that] we should have thought of it first!""* [N]. Before the purchase by Coherent, Midaz had highlighted the very high efficiency of the diode-pumped alexandrite lasers that it has developed for satellite remote sensing applications.

Coherent's plan for the future is to use the Midaz amplifier, in conjunction with both existing Coherent lasers and those acquired from Innolight, to improve capability in the general area of micromachining [N]. The CEO of Coherent assessed that, although the addition of Innolight would have only a small impact on the company's sales in the short term, the combination with Midaz' technology would deliver *"tens of millions of dollars"* in sales by 2015 [N].

5. Sources to corroborate the impact (indicative maximum of 10 references)

[A] Midaz Main Web-site: www.midaz.co.uk (now closed down following company acquisition)
[B] Imperial Innovations: 'Investment in Midaz Lasers Limited', 25/9/06, http://www.imperialinnovations.co.uk/news-centre/news/investment-midaz-lasers-limited/ (archived at https://www.imperial.ac.uk/ref/webarchive/pvf on 11/10/13)
[C] Director of Technology Ventures, Imperial Innovations Ltd
[D] http://www.nexeon.co.uk/about/board-of-directors/ (archived at https://www.imperial.ac.uk/ref/webarchive/qvf on 11/10/13)
[E] Managing Director, UK Laser Micromachining Centre
[F] Technical Manager, ESA ESTEC
[G] Midaz & ESA/ESTEC press release, Dec 2011, http://www.hovemere.com/docs/Midaz_ESA_PR.pdf (archived here)
[H] LaserFocusWorld article, 14/12/09, http://www.laserfocusworld.com/articles/2009/12/esa-and-midaz-lasers-to-develop-alexandrite-lasers-for-lidar.html (archived at https://www.imperial.ac.uk/ref/webarchive/svf on 11/10/13)
[I] Midaz Water-cooled Amplifier A70-W information page, http://pdf.directindustry.com/pdf/midaz/water-cooled-amplifier-a70-w/89141-244003.html (archived at https://www.imperial.ac.uk/ref/webarchive/tvf on 11/10/13)
[J] Midaz Air-cooled Amplifier A50-A information page, http://pdf.directindustry.com/pdf/midaz/air-cooled-amplifier-a50-a/89141-244005.html (archived at https://www.imperial.ac.uk/ref/webarchive/vvf on 11/10/13)
[K] General Manager, Coherent Scotland Ltd
[L] United States Securities and Exchange Commission, Annual Report and form 10-K, Coherent, Inc., http://www.sec.gov/Archives/edgar/data/21510/000002151012000014/a929201210k.htm (archived at https://www.imperial.ac.uk/ref/webarchive/6tf on 11/10/13)
[M] Investor press release of Midaz acquisition, 31/10/12, http://www.coherent.com/investors/index.cfm?fuseaction=Popups.ViewRelease&ID=974 (archived at https://www.imperial.ac.uk/ref/webarchive/4tf on 11/10/13)
[N] Press announcement of Midaz' integration into Coherent Laser company, 2/11/12, http://optics.org/news/3/11/1 (archived at https://www.imperial.ac.uk/ref/webarchive/5tf on 11/10/13)