Institution: University of Strathclyde

Unit of Assessment: 9 - Physics

Title of case study:
Increased employment and wealth creation from a spin out technology company - Cascade Technologies

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

Cascade Technologies is a rapidly expanding technology company that contributes significantly to the UK economy. The company, a spin out from the Physics Department, manufactures gas sensors based on Strathclyde research that are used for environmental monitoring, security monitoring and process monitoring. From 2008 to 2013 the company has expanded to employ 50 people and sales have increased from £0.9 million to £6.4 million. From 2008 the company's products are used on a number of commercial shipping fleets to monitor emissions, and from 2010 until 2011 have been used to increase traveller safety at Glasgow airport

2. Underpinning research (indicative maximum 500 words)

Context
The Kyoto protocol (1997) was agreed with the intention that industrial nations would reduce the emissions of key atmospheric pollutants (carbon dioxide, methane, nitrous oxide and sulphur hexaflouride). This commitment to reducing the production of greenhouse gases was reaffirmed at the 2012 Doha climate change talks. The drive to reduce greenhouse gas emission means that there is an obvious need for instrumentation that can detect and quantify rapidly the concentration of these gases in the atmosphere, or from polluting sources such as industrial plants, aeroplanes and ships. Laser based spectroscopy has been shown to be a suitable basis for such instrumentation. Furthermore, laser based spectroscopy has the necessary sensitivity to detect the trace levels of gases emitted by the gaseous pre-cursor of improvised explosive devices and so the instrumentation developed for pollution monitoring can also be applied to homeland security.

Key Researchers
The underpinning research was undertaken from 1999 in the Department of Physics at the University of Strathclyde by Dr Nigel Langford (employed January 1990 as Lecturer, promoted April 1999 to Senior Lecturer, promoted May 2005 to current post as Reader), Professor Geoff Duxbury (employed January 1981, Professor from January 1987, Emeritus Professor from October 2006) and Mr E Normand (PhD student at time of research).

Key Research Findings
History - In 1999 Dr N Langford and Prof G Duxbury were funded by EPSRC to investigate the use of the newly developed mid infrared light source, the pulsed quantum cascade (QC) laser, for the optical detection of trace gases. Although the first demonstration of this class of laser was in 1994, it was not until 1997 that a variant suitable for optical spectroscopy, the distributed feedback (DFB) quantum cascade laser, was available. A student, Mr E Normand, was employed on this grant. The key outcome from this research was the development of a laser-based spectrometer that combined the recently developed pulsed DFB QC laser with well-established multi-mirror long path cells, thereby enabling the rapid detection and quantification of trace gases.

Methodology - The approach developed by Duxbury, Normand and Langford, intrapulse spectroscopy, was significantly different from the methodology used by other researchers for the detection of traces gases. In contrast to the other research groups that used short duration (< 20 ns) optical pulses to detect trace gases, the Strathclyde approach was to use long duration optical pulses (300 – 2000 ns). A consequence of operating the QC laser in pulsed mode is that the frequency of the laser's output radiation changes during the pulse giving a time varying frequency or frequency chirp.

Advantages of Intrapulse Spectroscopy – The frequency chirp associated with the intrapulse spectroscopy technique is of crucial importance as it (i) eliminates optical interference effects in the multiple mirror cell (these interference effects have been a major issue in the use of multiple mirror cells for optical spectroscopy as they limit the sensitivity of the spectrometer) and (ii) allows the absorption spectrum of the trace gas to be written on to the time profile of the pulse so giving a simple way of observing the spectrum. Furthermore, the approach generates frequency windows that are large enough (typically 100 GHz) to enable the observation of many absorption lines of trace gases simultaneously, giving the user the ability to determine the concentration of a single gas using several different lines or to monitor the variation of gases during different processes, such as changes in methane and nitrogen dioxide in the atmosphere or acetylene in the growth of synthetic diamond.

The initial intrapulse spectrometer that was developed under the EPSRC funding was further refined with funding from the NERC (P2 in Section 3). This research funded both ground level measurements and airborne measurements through flights on the Airborne Research and Survey Facility aeroplane and in these flights the effectiveness of the instrumentation was demonstrated further. The key development discussed in point (i) was patented in 2003 (see P1 in Section 3). The scientific content of the work that resulted in the patent is detailed in R1 and R2 of Section 3 and examples of applications are given R3 and R4 of Section 3.

3. References to the research (indicative maximum of six references)

The references numbered R1 - R3 best indicate the quality of the research.

R1. "Fast, real-time spectrometer based on a pulsed quantum-cascade laser." E. Normand, M. Mcculloch, G. Duxbury, and N. Langford Optics Letters, 28, 16-18, 2003; DOI: 10.1364/OL.28.000016

R2. "Highly sensitive detection of trace gases using the time-resolved frequency downchirp from pulsed quantum-cascade lasers." M. T. McCulloch, E. L. Normand, N. Langford, G. Duxbury, and D. A. Newnham, Journal of the Optical Society of America B20, 1761-1768, 2003; DOI: 10.1364/JOSAB.20.001761

R3. "In-flight measurements of ambient methane, nitrous oxide and water using a quantum cascade laser based spectrometer" K. G. Hay, S. Wright, G. Duxbury, N. Langford, Applied Physics B: Phys. B90, 329–337, 2008; DOI: 10.1007/s00340-007-2926-x

R4. "A compact quantum-cascade laser based spectrometer for monitoring the concentrations of methane and nitrous oxide in the troposphere" S. Wright, G. Duxbury, N. Langford, Appl. Phys. B85, 243-249, 2006; DOI: 10.1007/s00340-006-2384-x

Evidence for quality of research (grants, patents etc.).

P1 A semiconductor diode arrangement GB0208100.8, E. Normand, G. Duxbury and N. Langford, Semiconductor diode laser spectrometer arrangement and method - US Patent 7,283,243, 2007,?E Normand, G Duxbury, N Langford

P2 2002 £95,253 From NERC NERC/T/S/2002/0052 "A portable sensitive mid-infrared spectrometer for detection of atmospheric trace species. Core strategic measurements for atmospheric science (COSMAS) programme

P3 2004 £15,000 AWE Technical Outreach Programme "Development of a mid-infrared quantum cascade laser based intra-pulse spectrometer for applications in time resolved spectroscopy of chemical reaction intermediates

P4 2005 £18,000 Engineering Doctorate Award with Cascade Technologies Limited.

P5 2009 £18,000 Engineering Doctorate Award with Cascade Technologies Limited

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

Process from research to impact

The fact that the intrapulse spectroscopy technique allows interference-free operation to be achieved in multi-pass optical cells was patented by Langford, Duxbury and Normand in 2003. The patent was assigned to Cascade Technologies, a company started by Normand in 2003. The transfer of intellectual property developed in the Physics Department to Cascade Technologies has allowed the company to build systems that have been applied to many different gas sensing scenarios. The company has negotiated licence agreements with industry, leading to the application of the technology in a variety of fields

Types of impact

The initial impact of the research was in the formation of a company that brought economic benefit to the UK and in the growth of a highly skilled international workforce. Over the period from 2008 to 2013 the company workforce has continued to expand from 25 to 50 employees (eight possess PhD degrees and nine have BSc / BEng degrees). The benefits are now more wide ranging, as the instrumentation solutions sold by Cascade Technologies are used in the monitoring of pollution (both marine and automotive), detection of leaks in aerosol systems, and the detection of minute traces of explosives. The sensors developed by Cascade Technologies are used to ensure that the companies that have purchased the instrumentation meet the strict emission guidelines set out by EU and USA regulatory bodies.

Reach and Significance

Economic benefits in UK

Cascade Technologies was the first supplier of quantum cascade laser based spectrometers capable of making trace gas measurements. Over the period 2008 to 2013 Cascade Technologies' turnover has increased year-on-year from just under £1 million to £6 million, as shown in Figure 1.

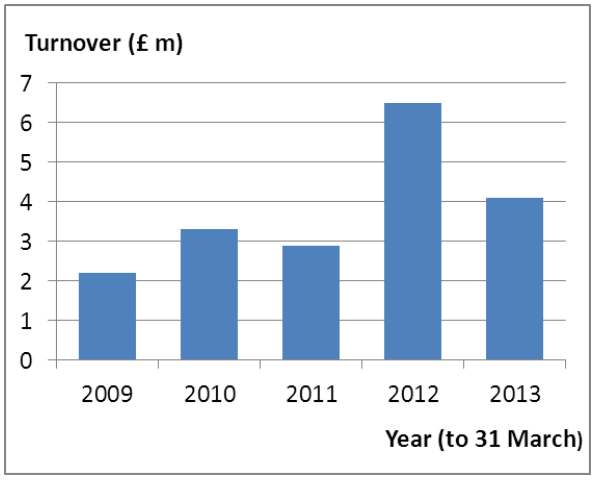

Figure 1: Annual turnover over the REF period

In the financial year 2012/13 Cascade Technologies sold instrumentation solutions all over the world and the breakdown of sales was: Far East 46%; Europe 32%; USA 17%; Australasia 5%. Cascade Technologies core markets are in supporting the automotive industry (44% of sales), process monitoring (31% of sales) pollution monitoring (24% of sales) and other markets took up the final 2% of sales (Source C1).

In the year 2011/12 Cascade Technologies was recognised as one of the 100 fastest growing privately owned technology companies by Panoramic Growth Equity (Source C3) and in 2012 Cascade Technologies was ranked 94th in the annual league table of Britain's fastest-growing private technology companies compiled by Fast Track in association with The Sunday Times.

The impact of the Strathclyde research has continued to expand as illustrated by the following examples:

Environmental process monitoring – The intrapulse spectroscopy technique is a key feature of an aerosol leak detection system that was released in by Cascade Technologies in 2010. The CT2210 Micro Leak Detector offers a simple cost-effective approach to detecting defective aerosol cans when compared with the existing approaches of monitoring bubbles in water baths, using acoustic sensors or flame ionisation detectors. It can operate on production lines running at up to 500 cans per minute compared with the 150-200 cans per minute limitation for conventional systems (Source C4). The system satisfies the leak detection performance requirements as specified by the Fédération Européenne des Aérosols (FEA) in its FEA Waterbath Alternative Guidelines and has been certified to comply with EU transport regulations. To date (June 2013), 50 of the CT2210 units have been sold worldwide, from the UK to Argentina. The effectiveness of the

instrumentation for process control was recognised by the British Aerosol Manufacturers Association through the award of the "Environmental Benefits" Award in 2012 (Source C5).

Global Pollution monitoring – In 2008, Cascade Technologies agreed a technology licensing agreement with BP to supply emissions monitoring systems for use in the marine industry. Following trials of the instrumentation (CT2100) the technology licensing agreement was extended in 2008 for a further five years to 2013 (Source C6), and the instrumentation is currently being installed on the commercial fleets of a number of shipping companies both in Europe and the US to monitor emissions and check that these emissions meet EU defined levels. These fleets include both cargo ships and cruise liners. The American Bureau of Shipping has issued the CT2100 a confirmation of Product Type Approval (Source C7). The Cascade Technologies system is also the basis of the MEXA-1400QL-NX measurement system supplied by Horiba International to the automotive industry for the detection of NO, N_2O, NO_2 and NH_3 from car engines (Sources C8, C9).

Defence and security at a major international airport – The potential of the intrapulse technique to detect explosives was demonstrated in 2005 and in 2009 Cascade entered a partnership with Morpho a division of the Sarfan group to develop a system for detecting the pre-cursors of improvised explosive devices (Source C10). A walk-through portal containing an intrapulse spectrometer was installed at Glasgow International Airport in 2010 (Source C10). Over the period of the trial approximately 12 million people were scanned by the device. There are on-going discussions between Cascade, Morpho and civil aviation authorities regarding the implementation of the Cascade Technologies sensor system and these are subject to confidentiality agreements.

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

C1. Managing Director – Cascade Technologies, can corroborate the claim that the company would not exist without the transfer of IP from Strathclyde University to the company and can verify sales data and turnover data stated in case.
C2. Cascade Technologies web-site http://www.cascade-technologies.com/Cascade/Company-History/ supports the claim that the company was founded on research undertaken at the University of Strathclyde and the IP generated as a result of that research
C3. Press release from Panoramic Equity Growth can be found at http://www.pgequity.com/privacy-policy/118-19092012-cascade-technolo...ed-one-of-britains-100-fastest-growing-private-technology-companies.
C4. "From Water to Lasers", article in The Canmaker, March 2011; http://www.cascade-technologies.com/Resources/Articles/The-Can-makerbrbFrom-Water-to-Lasersb/ corroborates the enhances performance of the Cascade leak detection system compared with conventional systems.
C5. Announcement of BAMA prize - http://www.cosmeticsbusiness.com/news/article_page/BAMA_Awards_2012_winners_announced/81538 supports the claim that the aerosol detection system is recognised by aerosol industry body
C6. Announcement from Cascade Technologies giving details of extension of BP agreement downloaded from http://www.cascade-technologies.com/Resources/Press-Releases/1MILLION-FUNDING-BOOST-FOR-CASCADE-TECHNOLOGIES/
C7. Confirmation of Product Type Approval 11/FEB/2011 downloaded from http://www.cascade-technologies.com/Confirmation-of-Product-Type-Approval--CT2100/
C8. Article from CryoGas International February 2013 pg 38 stating that Cascade Technologies instrument in the basis of the Horiba device.
C9. Article from Electro-Optics February 2011 pg 16 showing applications of Cascade Technologies spectrometers for various measurement applications. http://www.cascade-technologies.com/Resources/Articles/Quantum-Leap/
C10. Morpho-Cascade Technologies press release http://www.cascade-technologies.com/Resources/Press-Releases/2010--Morpho-and-Cascade-Technologies-to-Test-a-Next-Generation-Security-Solution-at-Glasgow-International-Airport/

Date stamped print-outs of C2 – C10 are available from the University.