Institution:
University of Glasgow

Unit of Assessment:
B15 General Engineering

Title of case study:
Modern global telecom systems powered by technology from the University of Glasgow

1. Summary of the impact

Today's global telecom systems are powered by technology developed at the University of Glasgow. This technology has been utilised, endorsed and developed by a series of internationally successful companies, facilitating multimillion pound investment from across Europe and the USA for the companies.

Gemfire Europe acquired the University of Glasgow IP and technology and between 2008 and 2012 launched a range of 'green' products with reduced power consumption. The company's revenues reached $12m annually and in 2013, Gemfire was one of the world's top five planar lightwave circuit companies. Gemfire was bought by Kaiam, one of the world's market-leading optical networking companies in April 2013, stimulating further innovation and investment in the production of high-speed components for the global data networking market.

2. Underpinning research

The rapid growth of global telecom traffic in the early 1990s required a new approach to the miniaturisation of components within the optical fibre circuits that were encircling the globe. At the University of Glasgow's School of Engineering, two research teams led by Professor Stewart Aitchison (Lecturer 1990-99, Professor 1999-2001) and Professor Chris Wilkinson (James Watt Professor of Electrical Engineering, 1992-2005) embarked on a twin-pronged technology development project, the aim of which was to replace numerous discrete devices with a single monolithic device. The research teams included: Research Assistant Mike Jubber (1996-98) and PhD students Andrew McLaughlin (1995-98), James Bonar (1992-95), John Bebbington (1990-93), Paulo Marques, Marcos Vermelho (1996-99) and Jesus Ruano (1996-99).

From 1993, Aitchison and Professor John Arnold (Lecturer 1985-94, Professor of Applied Electromagnetics, 1994-2012), funded by EPSRC (GR/H85311/01 1993-96) and in collaboration with British Telecom, developed devices utilising flame hydrolysis deposition techniques (FHD)[1,2, P3]. FHD was an existing technology used to build microstructures on silicon but which lacked the precision required for optical componentry. In parallel, Wilkinson led a second research group developing microfabrication technology including advanced deep etching techniques. This permitted Aitchison and Richard De La Rue (Professor, 1986-present) to make significant progress in the use of FHD [P2] and the associated semiconductor processing required to create advanced planar lightwave circuits (PLCs) [3, 4] (EPSRC (GR/K24963/01 1994-97). PLCs are key components of functional devices used in optical fibre communication systems. Compared with bulk optics devices, they offer compactness, excellent stability and reliability in addition to high functionality. This research resulted in several publications and four patents which were licensed to the start-up company Kymata, formed in 1998.

Aitchison and his team developed FHD technologies so that layers of sufficient quality to make high-performance Arrayed Waveguide Gratings (AWG) could be deposited on silicon [P4]. Wilkinson and his team used their advanced microfabrication technologies to manufacture these components. An AWG is a PLC-based component and they are now pervasive in optical telecommunications networks, used to physically combine and separate optical channels, enabling multiple channels from a single optical fibre thereby increasing the transmission capacity of optical networks considerably. This technique is known as Wavelength Division Multiplexing (WDM). AWGs have a number of advantages over competing technologies to perform the task of WDM that has led to them being ubiquitous in modern global telecom systems.

A key output of the collaboration between the FHD and microfabrication research groups was a technique for deep vertical etching of flame hydrolysis deposited high silica glass films [P1]. The work was initiated through a feasibility study with Lucas Advanced Engineering Centre in 1994 and the technique (which proved key to the development of low power optoelectronic components), was fully verified in 1998 [5].

From 1997-1998, Professor John Marsh (Lecturer 1986-96, Professor of Optoelectronic Systems 1996-present) worked with Aitchison on building this PLC capability and utilising the newly developed FHD techniques [6]. The research was influenced by the drive for improved performance of photonics in the aerospace sector and resulted in the demonstration of a number of devices and subsystems including AWGs.

3. References to the research

[1] J.R. Bonar, J.A. Bebbington, J.S. Aitchison, G.D. Maxwell and B.J. Ainslie, Low threshold Nd-doped silica planar waveguide laser**,** *Electronic Letters*, 1994, Vol. 30, No. 3. doi: 10.1049/el:19940190.

[2] J.R. Bonar, J.A. Bebbington, J.S. Aitchison, G.D. Maxwell and B.J. Ainslie, Aerosol doped Nd planar silica waveguide laser, *Electronics Letters*, 1995, Vol. 31, No. 2. doi: 10.1049/el:19950086.

[3] J.R. Bonar, M.V.D. Vermelho, A.J. McLaughlin, P.V.S. Marques, J.S. Aitchison, J.F. Martins-filho, A.G. Bezerra-Jr., A.S.L. Gomes, Blue light emission in thulium doped silica-on-silicon waveguides, *Optics Communications*, 1997, Vol. 141, pp.137-140. doi: 10.1016/S0030-4018(97)00233-2.

[4] J.R. Bonar, M.V.D. Vermelho, P.V.S. Marques, A.J. McLaughlin, J.S. Aitchison, Fluorescence lifetime measurements of aerosol doped erbium in phosphosilicate planar waveguides, *Optics Communications*, 1998, Vol. 148, pp.27-32. http://www.sciencedirect.com/science/article/pii/S0030401897005282.

[5] A.J. McLaughlin, J.R. Bonar, M.G. Jubber, P.V.S. Marques, S.E. Hicks, C.D.W. Wilkinson, J.S. Aitchison, Deep, vertical etching of flame hydrolysis deposited hi-silica glass films for optoelectronic and bioelectronic applications, *Journal of Vacuum Science & Technology B*, 1998, Vol. 16, Issue:4, pp. 1860-1863, doi: 10.1116/1.590098.

[6] M.V.D. Vermelho, M.T. de Araujo, E.A. Gouveia, A.S. Gouveia-Neto, J.S. Aitchison, Efficient and thermally enhanced frequency upconversion in Yb3+ -sensitized Tm3+ -doped silica-on-silicon buried waveguides excited at 1.064 µm, *Optical Materials*, 2001, Vol. 17, pp.419-423. doi: 10.1016/S0925-3467(01)00064-7.

The patents involved are:

[P1] J. M. Ruano-Lopez, J R. Bonar, A. J. McLaughlin, P.V. Da Silva-Marques, C.D.W. Wilkinson, M. G. Jubber, and J. S. Aitchison ‘Reactive ion etching (RIE) process used for the fabrication of an optical waveguide with low surface and sidewall roughness.’ Patent Numbers: WO200059020-A; EP1166341-A; GB2348399-A; WO200059020-A1; AU200035685-A; GB2363361-A; EP1166341-A1; GB2363361-B

[P2] P.V. Da Silva-Marques, J R. Bonar, A. J. McLaughlin, and J. S. Aitchison ‘Burner for manufacturing aerosol-doped waveguides includes inlet ports connected to respective torch conduits and gas expansion chamber provided between at least one inlet port and gas mixing region.’ Patent Numbers: WO200046162-A; EP1150925-A; WO200046162-A1; GB2346683-A; AU200023084-A; EP1150925-A1; GB2363637-A; GB2363637-B

[P3] P.V. Da Silva-Marques, J R. Bonar, and J. S. Aitchison ‘Optical waveguide has photosensitive doped core and upper cladding layer’ Patent Numbers: WO200046619-A; EP1151333-A; WO200046619-A1; GB2346706-A; AU200023077-A; EP1151333-A1; GB2363474-A; GB2363474-B

[P4] P.V. Da Silva-Marques, J R. Bonar, and J. S. Aitchison 'Waveguide for optical circuit has a rounded, elliptical or circular core obtained by isotropic diffusion of dopants in a core layer of phosphosilicate wafer.' Patent Numbers: WO200046618-A; EP1151332-A; GB2346452-A; WO200046618-A1; AU200023076-A; EP1151332-A1; GB2362963-A; GB2362963-B

4. Details of the impact

The University of Glasgow has developed an integrated suite of microfabrication processes that now sits within the photonic systems at the heart of today's global data transmission networks.

Commercialisation of silicon planar waveguide technology and associated fabrication techniques began in 1998 with the formation of spin-out Kymata, an optical components company based in Livingston, Scotland. Kymata licensed IP, including a range of patents, from the Universities of Glasgow and Southampton. The company grew rapidly and was successful in securing multimillion pound venture capital backing from investors across Europe and the US. In 2001, it was bought by French company Alcatel Optronics for more than $119m; Alcatel Optronics was subsequently taken over by Avanex in 2003.

The US-based company Gemfire acquired Avanex and the associated Livingston plant in 2004. The University of Glasgow technology has been used by Gemfire since then in both manufacturing and R&D, underpinning product development and supporting market growth in the area of optical component integration. The technology base has been used to develop planar lightwave circuits (PLCs) that are compact, stable and reliable. These products have played a significant role in the building of optical data transmission capacity to meet demand caused by the explosion in video over the internet.

Gemfire has continued to develop their portfolio using the flame hydrolysis deposition techniques (FHD) and deep vertical etching technology research from the University of Glasgow. The technology base allowed a new, greener range of Arrayed Waveguide Grating (AWG) products with low power consumption to be introduced in 2008 – Gemfire's 'athermal' AWG. The athermal AWG gained significant market share as the design is temperature-insensitive and requires no electrical power, reducing overall system power requirements.

Gemfire added six new products to the athermal range in April 2012, followed by a further two PLC-based product families in August 2012. These offer higher channel count, and narrower channel spacing for long haul/metro systems; and lower channel count, wider channel spacing for access and datacoms applications. The VP for Sales & Marketing (PLC Products), Kaiam Corp., stated that 'these new products have enabled Gemfire to increase market share in the telecom market, and also to attract new customers in the adjacent metro and datacom market segments.' Based on the athermal platform, the company's revenues reached $12m annually and the company went through a period of recruitment, with staff numbers at the Livingston operation increasing from 19 in 2004 to around 70 in 2013. In 2013, Gemfire was one of the world's top 5 PLC companies.

In April 2013, Gemfire was acquired by Kaiam Corporation (http://www.kaiamcorp.com) a California-based developer and manufacturer of innovative components primarily for the optical interconnect market, in a multimillion dollar deal. Kaiam acquired the company to access their PLC technology and Gemfire's 8-inch wafer fabrication facility in Livingston. Kaiam now plans further investment to build production of high-speed optical modules for the global data networking and datacentre markets.

5. Sources to corroborate the impact

Corroborating commercial and innovation impact

- Statement from VP Sales and Marketing, (PLC Products), Kaiam Corporation [contact details provided]
- Optical Keyhole (telecommunications newsletter): Gemfire release new athermal products, April 2012
- Light Reading (communications business website): Gemfire introduce new athermal products, August 2012
- Businesswire (communications business website): Kaiam finalise agreement to acquire Gemfire, 30 April 2013
- Kaiam Press Release: Kaiam finalizes agreement to acquire Gemfire, 30 April 2013