Institution: Swansea University
Unit of Assessment: 3a - Allied Health Professions, Dentistry, Nursing and Pharmacy
Title of case study: Economic and health benefits of novel light therapies for the treatment of skin conditions.
1. Summary of the impact

Research at Swansea University on light therapy has contributed to an extensive market in laser and intense pulsed light (IPL) products for the therapeutic and cosmetic treatment of skin conditions. Impacts include: globally registered intellectual property; local manufacturing of a wide range of laser and IPL products; their distribution to over 40 countries; and resulting benefits to health in treating acne, rejuvenating skin and removing hair. The research undertaken by Swansea University and its companies pioneered this market in partnership with Procter & Gamble and Unilever; and established a joint venture with Sony UK to manufacture these laser and IPL products in South Wales. The Welsh government views this collaboration as an exemplar for the resurgence of UK specialist manufacturing.

2. Underpinning research

Research into the use of light energy to treat skin conditions began at Swansea University in 2000 with the appointment of Prof Marc Clement to the Department of Electrical Engineering. (He transferred to his current post as Professor of Medical Innovation in the College of Medicine in 2005.) The research has contributed to the development of light-tissue science and treatments for many debilitating and distressing skin conditions (including acne, aging or sun-damaged skin, hirsutism, wound healing, pigment disorders, and cellulite or stretch marks).

When the research at Swansea University began, light therapy was already being used to treat cervical cancer and to reduce tumours. The therapy consisted of thermal vaporisation of tissue and had been shown to produce a degree of therapeutic benefit, particularly in the treatment of cervical cancer. However, these approaches did not use all the attributes of laser light, including coherence and monochromaticity. Clement began his research in 2000 by consulting clinical experts, including dermatologists, to understand the target physiology and to hypothesise a mode of action of light for each skin condition. A subsequent programme of computer-based predictive modelling from 2002 led to the characterisation of optical light parameters including wavelength, energy, and temporal and spatial profiles designed to engender the hypothesised mode of action – for acne in the first instance [R1]. This modelling was essential as specific wavelengths in the visible spectra differentially penetrate the skin and target discrete structures to mediate the desired effect. A laboratory programme was implemented *in vitro* and *ex vivo* to optimise the optical light parameters and enhance general understanding of biological mechanisms in the development and treatment of acne. Experimental treatments for acne included using specific frequencies of light to initiate a wound-healing cascade in the skin while targeting the naturally occurring photosensitive structures within the acne bacteria [R2]. A similar approach was used to study other skin conditions to show that light treatment for skin rejuvenation targeted oxyhaemoglobin in the blood to initiate a wound-healing response that led to enhanced local collagen production [R3]. Then suppression of hair growth was achieved by targeting melanin within the hair shaft and raising the temperature of local hair follicle stem cells leading to their denaturation [R4].

In summary Clement's research has provided insight into selection of light source (laser or IPL), filtration to provide appropriate wavelengths and energy levels for safety and efficacy, development of electrical drive systems to provide appropriate pulse energy and repetition, and optical systems to provide uniformity of light delivery to tissue. These insights have made light therapy feasible through clinical and home-use systems, which have been developed on the basis of the estimated light parameters published by Clement [R2-R4].

Each of the laser and IPL products developed had to undergo clinical trials to demonstrate efficacy and safety to a range of stakeholders – including global regulators, strategic market partners, investors, users, and the general public. This was achieved through ethically approved multi-centre clinical trials coupled with human factor studies for consumer use (skin rejuvenation trials 2000-3;

acne trials 2001-3; hair removal trials 2005, 2008 & 2011-2; followed by acne, skin rejuvenation and hair removal studies for FDA approval 2010-1). Swansea researchers led trials in the UK, USA, Europe, India and Japan that confirmed efficacy and safety, informed product development and led to 12 product approvals by the US Food and Drug Administration [e.g. R5], as well as ISO registration under the medical device directive (ISO 13485) with 4 CE approvals for the UK and Europe (including 60335 for household and similar appliances and 62233 for domestic use). The Swansea University team's inter-disciplinary research continues to combine laser tissue modelling, innovative system design and testing of hypothesised mode of action, culminating in the design of efficacious laser and IPL products as confirmed in clinical trials. Most recently our spin-off company, Cyden Ltd, has miniaturised the technology for home-use markets that are traditionally harder to access and has now reached over 40 countries. Clement and his team of research fellows and students have recently extended their research to characterise the process of adapting proven technologies to emerging countries for both clinical use and economic development [R6].

3. References to the research

(Swansea University researchers in bold; citations from Scopus in October 2013)

R1) Patel N, **Clement RM**. Selective non-ablative treatment of acne scarring with 585 nm flashlamp pulsed dye laser. *Dermatol. Surg.* 2002; **28**: 942-5. (Impact Factor (IF) 1.9; 71 citations) DOI: 10.1046/j.1524-4725.2002.02062.x

R2) Seaton ED, Charakida A, Mouser PE, Grace I, **Clement RM**, Chu AC. Pulsed-dye laser treatment for inflammatory acne vulgaris: randomised controlled trial. *Lancet* 2003; **362**: 1347-52. (IF 38; 100 citations) DOI: 10.1016/S0140-6736(03)14629-6

R3) Bjerring P, **Clement RM,** Heickendorff L, Egevist H, Kiernan M. Selective non-ablative wrinkle reduction by laser. *J. Cutan. Laser Ther.* 2000; **1**: 9-15. (IF 0.9; 143 citations) DOI: 10.1080/14628830050516542

R4) Allison KP, Kiernan MN, Waters RA, **Clement RM**. Evaluation of the ruby 694 Chromos for hair removal in various skin sites. *Lasers Med. Sci.* 2003; **18**: 165-70. (IF 2.4; 13 citations) DOI: 10.1007/s10103-003-0266-6

R5) Food & Drug Administration. Approval to Cyden Ltd to market IPL iPulse i150 System laser surgical instrument for use in general and plastic surgery. Rockville MD: Department of Health & Human Sciences; 2 February 2009. . http://www.accessdata.fda.gov/cdrh_docs/pdf8/K083748.pdf.

R6) **Doneddu D, Hussain A, Clement RM**. A new paradigm to accelerate the transformation of resource-rich nations into sustainable knowledge economies. *Intl J. Knowl. Innov. Entrep.* 2013; **1**: 117-42. http://tinyurl.com/o9spkyp (new journal 2013; no citations yet)

4. Details of the impact

Technology developed at Swansea University by Clement has yielded several patents and the first FDA approvals for acne treatment, depilation, and skin rejuvenation [R5], thus generating many economic benefits. The underpinning research has spawned spin-off companies from Swansea University (Cyden, Chromgenex and Energist) that develop laser and IPL products to treat acne, aging and sun-damaged skin, hirsutism and wounds. These three organisations employ approximately 150 people and have launched more than 20 light therapy products. Laser treatment has become essential for plastic surgeons, dermatologists and beauticians across the globe to treat acne and damaged skin and remove hair. Clement's role in facilitating this is well recognised:

> "*Professor Clement's early pioneering work has had a real and tangible impact on the development of these treatments and the range of skin conditions which can now be treated".* Head of the Department of Dermatology of Molholm Hospital, Denmark [C1]

> *"Professor Clement's contribution to light-based medicine has facilitated the development of contemporary technologies and safer and optimally effective treatments for patients. As an innovator, he has been instrumental not only in developing new technologies but also in offering a scientific basis for optimising existing technologies".* Vice President of the American Board of Laser Surgery [C2]

According to Cyden sales of professional products have reached 1,700 in over 60 markets worldwide, including the first laser system in the US for acne therapy (FDA approval K024189 in 2003) and skin rejuvenation (FDA approval K000811 in 2000). Cyden and Chromgenex have exploited their patents to develop commercial partnerships, in particular with Procter & Gamble (P&G) ["Gillette Venus Naked Skin"] and Boots ("Smoothskin"), to launch hair-removal products for home use. This shift from the professional to the consumer market required data on efficacy and strong safety protocols to ensure effective and safe use by the general public (FDA approvals K122280 in 2012 & K130315 in 2013). Sales of consumer hair removal devices now exceed 125,000 in total across the UK and Europe. The contribution of the research at Swansea University to the growing global market has been acknowledged by the Head of Marketing and Business Development for Cyden Ltd [C3]:

> *"According to the Kline Report and data via Mintel, the global market for light therapy for hair removal, skin rejuvenation, acne, etc will be worth US$3 billion by 2018. By developing our home-use devices, which use the intellectual property from the research at Swansea University, we aim to win a significant share of this market. We have achieved this penetration by establishing partnerships with global brands like P&G".*

In 2011 manufacturing costs in China increased so much that it became uneconomical to produce there. This led Cyden to develop a strategy to repatriate manufacturing of their products from China to the UK. P&G, the primary partner and customer, were satisfied following a full options appraisal that the UK was competitive enough to return manufacturing to Europe. P&G's decision took account of the success that Cyden had achieved with Boots in the UK market, its research collaboration with Swansea University, and the strength of the underlying intellectual property (IP). Representatives from P&G visited Swansea University frequently and cited the quality of the research as a key differentiator. Production of the IPL device for P&G under the brand name of Braun (a wholly owned subsidiary of P&G) began in 2012 at the Sony UK Technology Centre at Pencoed in South Wales. While the partnership with Sony is not a joint venture, it is a critical manufacturing partnership which uses Sony's manufacturing quality, logistics expertise and supply chain management. Indeed, the Sony UK Technology Centre at Pencoed has used the experience from this partnership to repatriate other manufacturing contracts from the Far East, thereby protecting current jobs and creating further employment in South Wales. The General Manager at Sony UK Technology Centre [C4] confirmed this by stating:

> "*This experience with Cyden Ltd and the College of Medicine changed the way we do business. This can be traced back to Professor Clement's landmark paper in the Lancet. This has influenced Sony Corporate's thinking globally. Recently our Chairman, Sir Howard Stringer, said while visiting Sony Pencoed that this open innovation approach was an exemplar of global best practice".*

As well as the 150 employees at Cyden, Chromogenex and Energyst, the partnership with Sony has created jobs for web designers, product and packaging designers, and applied researchers. Hence the Head of Healthcare Innovation for the Welsh Government [C5] summarises this as:

> *"A prototype for future advanced manufacturing opportunities, and an exemplar for the resurgence of UK specialist manufacturing"*

In economic terms, the research by Clement and collaborators has created more than 1,000 person-years of employment around Swansea, and the city is now one of four global centres of excellence in light therapy alongside Boston and San Francisco in the US and Tel Aviv in Israel. Rigorous scientific research and evaluation has led to widespread adoption of the innovation. Our 1st clinical commentator is confident that Clement's research has increased "*the range of skin conditions which can now be treated"* [C1]; and our 2nd clinical commentator that it has *"facilitated*

safer and optimally effective treatments for patients" [C2]. Both are international authorities: Clement's research has yielded long-term health benefits for thousands of sufferers from distressing skin conditions.

5. Sources to corroborate the impact

C1 Statement – Head of Department of Dermatology, Molholm Hospital, Denmark; Past President of European Society of Laser Dermatology; Past Vice-President of European Society for Laser Aesthetic Surgery; Past President of Scandinavian Society for Laser Therapy; Fellow of American Academy of Dermatology; and Fellow of American Society for Lasers in Medicine and Surgery.

C2 Statement – Vice President of American Board of Laser Surgery; Medical Director of MD TLC Inc; Assistant Clinical Professor of Medicine at Harvard Medical School; and Fellow of American Society for Lasers in Medicine and Surgery.

C3 Statement – Head of Marketing and Business Development, Cyden Ltd, Swansea – who also reported on social media: Boots 'Smoothskin' now has over 2,500 followers on Facebook (ipulsesmoothskin) and Twitter (@ipulseSmooth).

C4 Statement – General Manager, Sony UK Technology Centre, Pencoed, Glamorgan.

C5 Statement – Head of Healthcare Innovation, Department of Health & Social Services, Welsh Government, Cardiff.