

**DTI Global Watch Secondment**

9 months staged over the period

August 2002 to April 2004

Final Report

Dr Andrew I. Whitehouse

## **Contents**

Executive Summary	2
Strategy	2
Objectives and Work Programme	2
Benefits and Lessons Learned	4
Applying the Knowledge	6
R&D funding opportunities in the US	8
Conclusions and Recommendations	8
Acknowledgements	9
References	9

# **DTI Global Watch Secondment**

9 months staged over the period August 2002 to April 2004

Final Report

Dr Andrew I. Whitehouse

## **Executive Summary**

This report summarises the work programme, objectives, benefits, knowledge gained, and positive impact on the employing company of the secondee (Applied Photonics Ltd – APL) during a DTI Global Watch Secondment to the United States. Dr Andrew I. Whitehouse (Managing Director for APL) was seconded to BNFL Instruments Inc at their offices in Santa Fe, New Mexico, USA. Starting with an outline of APL's business strategy in the context of this secondment, the report continues with a summary of the objectives of the secondment together with the work programme which was developed to meet these objectives, the benefits and lessons learned during the secondment, how the acquired knowledge was put to good use by both the secondee and APL, the conclusions and some recommendations are offered for other small companies considering using this scheme. The report concludes with our acknowledgements and a brief list of references to technical presentations given at three international conferences attended during this secondment.

## **Strategy**

The company's mission is *"To be the UK's centre of excellence for the advancement of industrial applications of Laser-Induced Breakdown Spectroscopy and related photonic technologies"*. In order to achieve this, we must continually strive to develop and expand our in-house expertise and capabilities in this field of technology. Accordingly, we must be aware of scientific and technological advancements in this area of technology, in particular the work of the many research groups throughout the USA who are at the forefront of this field. A key area of application of this technology is within the nuclear decommissioning and clean-up industry and hence it is also necessary for us to increase our awareness and understanding of this market area. Our company has a long-standing relationship with BNFL and so when the opportunity arose to team with a BNFL subsidiary company based in the USA (BNFL Instruments Inc.), the possibility existed for us to achieve both of the above objectives. However, it was only with the financial support of the DTI that we were able to send two senior members of staff (Dr Whitehouse and Dr Young) to work with BNFL Instruments Inc by way of a Global Watch Secondment. (Dr Young's secondment was of a much shorter duration and was completed six months ago)

## **Objectives and Work Programme**

Over the last 5 years, Applied Photonics Ltd (APL) has gained considerable experience of deploying its LIBS (Laser-Induced Breakdown Spectroscopy) technology within various industrial environments. During this period, approximately half of the company's business was with the UK nuclear industry. The unique nature of APL's products and services as applied to the remote chemical analysis of radioactive materials, together with the operational experience gained within the UK nuclear industry, have helped to stimulate interest from outside of the UK and the US nuclear industry in particular. APL believes there are significant market opportunities for their LIBS technology within the US Department of Energy (DoE) funded programme of decommissioning and clean-up of redundant nuclear facilities. The cost of this programme has been estimated by the DoE to be in excess of \$200 billion.

Although APL has considerable experience of the UK nuclear industry, it is unfamiliar with the technologies used and the working practices employed by the US nuclear industry, especially in the area of decommissioning. Accordingly, an objective of this secondment was to learn about the way in which the US nuclear decommissioning programme operates and the technologies currently used to remotely analyse radioactive waste materials. Our host company within the US, BNFL Instruments Inc. - a leading

supplier of radiometric instrumentation and services to the US nuclear industry, was ideally placed to help us learn about the US nuclear industry.

The principal objectives of this secondment, as set out in our original application to the DTI, may be summarised as follows:

- Gain knowledge about the US nuclear decommissioning programme and how it functions
- Learn about the technology currently used to analyse and characterise radioactive materials (radiometric instrumentation)
- Learn new business skills in bid preparation, technical presentations, dealing with US organisations and customers, and best practice in quality assurance
- Learn about the work of the various US research groups active in the field of LIBS

The work programme, which was produced during the initial period of the secondment, may be summarised as follows:

#### **Months 1 - 2 (August and September 2002)**

- Introduction to staff at BNFL Instruments Inc (BII), general familiarisation etc
- Establish an office
- Arrange accommodation in Santa Fe
- Develop a work programme and plan for the secondment
- Preparations for LIBS 2002 conference (to be held in Orlando, Florida in Sept. 2002)
- Continue to transfer knowledge as outlined in the work programme in the secondment application
- Present a paper at the LIBS 2002 conference at end of September 2002

#### **Months 3 and 4 (November and December 2002)**

- Work with BII staff as and when required to assist with their proposal writing, technical papers etc. and to learn about radiometric instrumentation as used to characterise radioactive materials
- Help prepare a joint APL / BII technical paper for submission to Waste Management '03 conference (Tucson, Arizona)
- Visit Los Alamos National Laboratory to meet with Dr David Cremers and his LIBS team
- Help prepare a joint APL / BII technical paper for submission to the International High Level Radioactive Waste Management Conference (Las Vegas, Nevada)

#### **Months 5 and 6 (February and March 2003)**

- Continue working with BII at their Santa Fe offices to learn about radiometric instrumentation, Quality Assurance, bid preparation and working with the US nuclear industry
- Attend Waste Management '03 conference in Tucson, Arizona (late February 2003)
- Visit Catalina Scientific Corporation while in Tucson to learn about their Echelle spectrometer systems
- Attend the International High Level Radioactive Waste Management Conference (Las Vegas, Nevada, late March 2003)

#### **Month 7 (July 2003)**

- Continue working with BII at their Santa Fe offices to learn about radiometric instrumentation, Quality Assurance, bid preparation and working with the US nuclear industry
- Visit various LIBS research groups throughout the US

#### **Month 8 (November - December 2003)**

- Continue working with BII at their Santa Fe offices to learn about radiometric instrumentation, Quality Assurance, bid preparation and working with the US nuclear industry

## **Month 9 (April 2004)**

- Further visits to LIBS research groups throughout the US
- Produce Final Report for the DTI

## **Benefits and Lessons Learned**

To help describe the benefits and what has been learned as a result of this secondment, each of the four principal objectives will be considered in turn as follows:

### **The U.S. nuclear decommissioning programme**

By working with BII on bid preparations, technical presentations at conferences and by attending meetings with various organisations currently involved with US nuclear decommissioning work, much was learned about the technical requirements of the industry and the ways in which BII provides its products and services to this market. From an early stage, it became evident that much emphasis is placed on “selling” ones products and services and so considerably more effort is expended on proposal writing and bid preparation than in the UK. It was very interesting to work with a company who have a notable track record of success in this area and hence much was learned from them. The US way of conducting business in nuclear decommissioning seems to be more focussed on teaming with other companies in order to meet the requirements of, for example, a Request for Proposal (RFP) from the US Department of Energy (DoE). The DoE appears to favour a multi-disciplinary and multi-organisation approach to tackling what are often very demanding technical challenges in the nuclear decommissioning arena. The teaming approach to winning contracts is not something we have experience of in the UK and so the lessons learned from BII in this regard are very valuable to us as we would not have had the opportunity to experience this method of working from our operations in the UK. To further increase our exposure to the US nuclear industry, various meetings and technical tours were conducted including:

- A conference and technical meeting in Reno, Nevada, during August 2002 where BII were exhibiting their radiometric instrumentation and services.
- A meeting in Las Vegas with a group from Bechtel (a leading contractor to the US DoE) who are working at the Nevada Test Site
- A technical tour of the Yucca Mountain Waste Repository Project (within the Nevada Test Site)
- A meeting in Albuquerque with SEA Inc. – a company involved with various DoE funded projects including the use of LIBS for monitoring beryllium particulates in air at the DoE Rocky Flats site in Colorado
- A meeting with Nuclear Filter Technology Inc., Golden, Colorado. Discussed with Terry Wickland (Vice President of Product Development / Marketing) issues relating to the containment of various forms of radioactive waste.
- Attendance of the Waste Management conference in Tucson, Arizona in February 2003 - this event proved to be very useful in networking with the major contractors within the US nuclear decommissioning programme.

### **Radiometric instrumentation (BII’s technology and services to the US nuclear industry)**

BII is a leading provider of radiometric instrumentation to the US nuclear industry. Their products and services span a broad spectrum of technologies including gamma spectroscopy, neutron (active and passive) techniques, alpha particle detection and beta radiation detection. The relatively short duration of this secondment did not allow for a complete familiarisation of all of BII’s technology but a good overview of the capabilities of the more regularly used types of radiometric instrumentation was obtained. A good example of this is BII’s RadScan system which is a transportable gamma detection system integrated with a video camera so as to allow real-time detection of “hot-spots” within a radioactive environment. The system operates by monitoring the gamma ray emissions of radioactive materials and superimposing the location of the emitting material with the colour video camera display. This makes it

very easy for an operator to scan across a room or area of plant and produce a recordable video image of the environment together with a colour-coded map of the radioactive materials present within that environment. RadScan is also able to determine the type of radioactive material by recording the spectrum of gamma rays being emitted by the material and conducting an isotopic analysis of the data. There are many parallels between RadScan and APL's LIBS technology and the potential exists for integrating the technologies to produce a system capable of detecting the radioactive materials (RadScan) and also the non-radioactive materials (LIBS) within radioactive waste. The techniques used by RadScan to analyse the gamma ray spectra are analogous to the techniques used within APL's LIBS technology to analyse the atomic and ionic emission spectra derived from a LIBS measurement of a material. By working with BII's software development team, we were able to glean useful information on the preferred methods of system control and spectral analysis.

### **Conducting business with the US nuclear industry**

This has been touched on above but also extends to Quality Assurance procedures, costing of individual work packages and complete work programmes, report writing, and the provision of manpower at a nuclear site. It is now clear to us that conducting business with the US nuclear industry is greatly facilitated by teaming with a US-based company and preferably a company with experience of the industry. To attempt to win contracts with the DoE etc from the UK would, in our view, be extremely difficult. Safety is of paramount importance when conducting work for the US nuclear industry, both on and off nuclear sites. A company with anything less than an excellent safety record is unlikely to be considered as a potential contractor to the DoE. For most projects, appropriate Quality Assurance standards are an essential prerequisite for winning business in this area. APL currently does not have ISO 9000 accreditation whereas BII do (they also have other nuclear-specific QA procedures and accreditation). BII were agreeable for us to learn about their ISO 9000 QA procedures and so the opportunity was used to learn from this in order to update and expand APL's existing QA procedures with a view to applying for ISO 9000 accreditation in the future.

### **US research groups active in the field of LIBS**

Compared to the UK and Europe, there are a significant number of research groups active in LIBS throughout the US. The majority of these groups are known to us and we have met many of the scientists and technologists during our past attendance of international conferences (eg. LIBS 2000 conference held in Pisa, Italy in September 2000 and also LIBS 2002 conference held in Orlando, Florida in September 2002). A brief summary of the visits conducted during this secondment now follows.

1. Visit to Dr David Cremers and his LIBS research group at Los Alamos National Laboratory, New Mexico. After obtaining the necessary permits, a full day was spent with Dr Cremers to see at first hand his laboratories and to be briefed on the current research projects of his team (application of LIBS for a Mars rover vehicle to conduct chemical analysis of the martian planet surface, use of LIBS for analysis of soil to assess carbon sequestration).
2. Catalina Scientific Corporation (Tucson, Arizona). Manufacturer of Echelle spectrographs for use with LIBS. Met Dr Burt Beardsley and spent a full day at their facilities to learn about the capabilities of the spectrograph and also the software used to control the device.
3. Department of Chemistry, University of Florida, Gainesville, Florida. Met with Prof. Jim Winefordner and Dr Ben Smith, toured laboratories and learned more about their current research (use of LIBS to analyse hazardous waste, heavy metal contamination in soil etc)
4. Department of Mechanical Engineering, University of Florida, Gainesville, Florida. Met with Dr David Hahn and colleagues to tour his research facilities and learn more about their current research (use of LIBS for analysing particulate pollution in atmospheric air, detection of heavy-metals in wood).
5. Ocean Optics Inc. (Head Office), Dunedin, Nr Clearwater, Florida. Manufacturers of optical components including optical spectrographs applicable to LIBS. They are very interested in LIBS and have recently been awarded a grant from the US military to develop a highly-portable LIBS

instrument suitable for detecting hazardous materials in the field. A tour of their facilities plus meetings with key research staff and the Sales Director, Dr Leeward Bean.

6. Department of Chemistry and Biochemistry, University of South Carolina, Columbia. Met with Dr Mike Angel and colleagues. Tour of facilities followed by giving a presentation to their research team on APL's work on LIBS.
7. Kaiser-Hill - a meeting with Alec Cameron and colleagues who are responsible for decommissioning plutonium facilities at the DoE's Rocky Flats plant near Denver, Colorado. Specific area of interest was beryllium monitoring (some parts of the plant were used to fabricate components from beryllium metal - a very hazardous material if inhaled in particulate form. A prototype LIBS instrument developed by Science & Engineering Associates Inc. (SEA) has been used at Rocky Flats to monitor beryllium particulates in air. The purpose of the meeting was to learn about their experience of using this technology at Rocky Flats.
8. ADA Technologies - Patrick French (Instruments Program Manager) and colleagues. Based in Littleton, Colorado. Have an interest in LIBS and are actively pursuing development projects in this area including a beryllium monitor for the Rocky Flats site.
9. Savannah River Site (DoE nuclear weapons site), South Carolina. Dr Whitehouse was invited to give a presentation on APL's use of LIBS within the UK nuclear industry. The presentation was arranged through Bill Spencer and Krissy Zeigler of Savannah River Technology Centre. Approximately 20 people attended the presentation including plant managers and senior members of the Technology Centre.
10. Ocean Optics Inc. (R&D and Production), Orlando. The R&D and Production facilities are headed up by Dr Roy Walters. Spent several days working with Roy and his team on the application of their new range of compact, low-cost optical spectrometers for LIBS. Ocean Optics have received a substantial grant from the US Army to develop a portable, back-pack LIBS instrument for use in the field to detect materials of interest to Homeland Security. The contract is for three prototype units to be manufactured.

The knowledge gained and lessons learned from the above have been put to good use within APL. It should be noted, however, that the above is an ongoing process for APL and this secondment has acted essentially as a catalyst to stimulate further dialogue and working relationships with people from many of the organisations we have interacted with, in addition to BII. Relevant aspects of the working practices of BII have been introduced to APL. By way of example, we now put much more effort into our proposal writing and, based on what we have learned from BII, have a more structured approach to calculating the costs and profit margins for our contract work in the UK. Since BII is part of a much larger organisation (the BNFL Group of Companies) but being relatively small itself is still able to relate to the problems and challenges faced by small companies such as APL, we developed a very good working relationship with BII during the secondment. This relationship is set to continue beyond the secondment period.

In summary, the secondment has given Dr Whitehouse and APL a unique opportunity to gain technical and commercial knowledge directly relevant to the business aspirations of the company. Dr Whitehouse has personally benefited greatly from the secondment, in particular the opportunity it has given him to interact with various research groups throughout the US.

### **Applying the Knowledge**

The staged nature of the secondment greatly facilitated the transfer to APL of the commercial skills learned by Dr Whitehouse during the secondment. Where appropriate, APL has adopted the working practices of BII in areas such as proposal generation and Quality Assurance. Teaming with other US companies is seen as being key to winning business in the US. The contacts Dr Whitehouse has made during the term of this secondment has helped to build bridges between APL and companies already

engaged in work of the US DoE and so the staff of APL now feel more confident to seek new business opportunities in the US.

To assist with the transfer of technical knowledge in the LIBS area to APL, Dr Whitehouse has expanded on an initial report produced by Dr Young with the aim of reviewing all the US LIBS research groups known to us, paying particular attention to those visited. The report summarises the research work of each group, provides references to their scientific publications and gives names and contact details of the scientific staff.

The knowledge gained by Dr Whitehouse as a direct result of his visits and interactions with LIBS research groups in the US has helped to focus APL's own R&D efforts and their strategy on commercialisation of their technology. A brief summary of a selection of the main areas of interest to APL is as follows:

1. The LIBS group at Los Alamos National Laboratory (Dr David Cremers et al) are presently focussed on developing LIBS for space applications and carbon sequestration measurements (re: climate change). Their current interests in LIBS does not conflict with those of APL and scope exists for APL to work with the LANL group in the future.
2. Science and Engineering Associates Inc. (SEA) have been active in the LIBS field and could be considered to be a competitor but do not appear to have a high level of in-house expertise in this area (they have previously used the LANL group to conduct much of the scientific work on LIBS). SEA have been bought out by a larger company so that the combined company employs approximately 900 people - this means they no longer qualify for SBIR funding.
3. ADA Technologies Inc do qualify for SBIR funding but have very limited in-house R&D capabilities in LIBS.
4. University of Florida, Gainesville, has two LIBS research groups. Both of these groups are of a very high calibre. The recent research work of Dr David Hahn's group who investigated the use of LIBS for the detection of heavy-metals in wood is of particular interest to APL. In September of this year, APL was approached by the Timber Research and Development Association (TRADA – UK based organisation) who were interested to learn about the feasibility of applying LIBS to the rapid detection of CCA-based preservatives in wood (CCA – chromated copper arsenate). We have since established that, as a result of recent European legislation, CCA-treated wood waste is to be classed as hazardous waste since it contains significant quantities of hexavalent chromium and arsenic – both are known poisons. We subsequently conducted our own experiments which confirmed that LIBS is capable of differentiating CCA-treated wood from untreated wood. In November, APL applied to the DTI for a research and development grant aimed at assessing the feasibility of applying LIBS for rapid, on-line sorting of CCA-treated wood waste. The key factors influencing the feasibility are i) the speed of the measurement must be sufficient to make the sorting process commercially viable and ii) the reliability of identification. Our application to the DTI was successful, and the feasibility study commenced on 1 February 2004.
5. PharmaLaser Inc - a small company that has developed and marketed a LIBS instrument for analysing pharmaceutical products. There does not appear to be a conflict of interest between this company and APL.
6. University of South Carolina - an established LIBS research group with an excellent track record. One of their projects is involved with Woods Hole Oceanographic Institute (WHOI) who have an interest in applying LIBS to the analysis of marine sediments. APL has formed good links with the University group and has made contact with the relevant people in WHOI although a meeting has not yet taken place.
7. Ocean Optics Inc. Due in part to the significant funding obtained via SBIR to develop LIBS technologies for the US Army, this company has unfortunately become a serious competitor to APL.

There are many other examples of where knowledge gained during this secondment has had a significant and positive impact on the research efforts and business of APL. Some of these are of a commercially sensitive nature and so cannot be disclosed in this report.

## **R&D funding opportunities in the US**

During his visits to the various LIBS research groups at US universities and within US small companies, Dr Whitehouse had the opportunity to learn about how small companies in the US can benefit from US Government funding for R&D work. The US Government run a scheme called SBIR (Small Business Innovative Research) which is accessible through the DoE and the DoD and is available to US companies who employ less than 500 people. This scheme is similar to the DTI's R&D Grant scheme (formerly the SMART scheme) although the level of funding available from SBIR is considerably higher. Another important difference is that the R&D funding through SBIR is on a 100% costs basis and so the company does not need to find additional funding to support the research and development project it is conducting. SBIR is split into different phases whereby Phase 1 is for initial feasibility studies lasting typically 6 months or less (funding of up to approx. \$100,000) and Phase 2 is for prototype development projects lasting up to 18 months (funding of up to approx. \$1,000,000). Other similar schemes exist for funding R&D in universities. A good example of SBIR funding is that of Ocean Optics and their project to develop a portable LIBS instrument for the US Army and Homeland Security. The company received nearly \$100,000 for a feasibility study (Phase 1) followed by \$890,000 for the development of three prototype instruments (Phase 2). The company was able to use part of the money (about \$100,000) to fund scientific work at a local University (University of Florida, Gainesville) to investigate spectral correlation techniques applied to LIBS analysis of materials. A significant fraction of the funding was also used to contract a specialist company to manufacture a purpose-designed Q-switched Nd:YAG laser specifically for the project. Ocean Optics' core technology is in optical spectrometers and other novel optical devices - the company has no previous experience of LIBS. The SBIR funding, however, has allowed Ocean Optics to quickly establish itself as a leading provider of LIBS technology. Other US small companies active in the LIBS field have also benefited from SBIR funding including SEA Inc. (more than \$1,000,000), and ADA Technologies Inc. (believed to be at least \$500,000). In view of this, it is difficult to see how small, technology-based companies in the UK can compete with their US counterparts.

## **Conclusions and Recommendations**

All the objectives set out at the commencement of this secondment have been met. Dr Whitehouse has benefited immensely from this secondment in terms of personal development while APL has likewise benefited from gaining valuable technical and commercial know-how relevant to the business aims of the company. Some of the knowledge gained has already been put to good effect within APL, for example, improved proposal writing, better methods of calculating contract costs and profits, technical report writing and presentation skills, QA procedures, future direction of our internal R&D programme etc.

We would have no doubt in recommending to other organisations that they take advantage of the Global Watch Secondment scheme as we are absolutely delighted with the benefits we have gained from this scheme. For very small companies like ours, however, we would offer the following advice:

1. Do not underestimate the short-term negative impact on your business of sending a key member of staff on an extended secondment. We partially overcame this problem by conducting a staged secondment whereby the secondee spends between 1 and 2 months with the host company followed by a similar period of time back in the UK. The negative impact of this is that the cost to the company increases (eg. apartment rent had to be paid whether or not the secondee was in the US, additional flight costs) and the secondee had to endure significant periods of travelling (in our case, total travel one-way was approaching 24 hours).

2. Allow sufficient time to find suitable accommodation (increased security measures in the US as a result of the terrorist attacks of 11 September 2001 have made it much more difficult for foreign nationals to obtain accommodation). It helps significantly if you have a US Social Security number – this can only be obtained after your visa is issued.
3. Obtain a US driver licence as soon as you can - drivers license are used throughout the US as an identity card and hence possessing one is extremely useful. You will need your UK drivers licence and you will need to take a written test. You will also need a US Social Security number before you can apply for a drivers licence.
4. Ensure that you have a detailed work programme before commencing the secondment and that the work programme is endorsed by your host company.
5. Try not to become too depressed about the R&D funding opportunities available to small companies in the US, even if it is very difficult not to be!

## **Acknowledgements**

Our sincere thanks go to Liz Chambers of the DTI who was instrumental in making this secondment a reality. Her friendly and supportive manner throughout all stages of this secondment – from initial application through to preparing the final report – has helped to make this secondment a great success for our company. Our thanks also go to Stuart Fuller, Bill Powrie and Roger Benson of the Small Business Service and also to Craig Wallbank of the DTI, each of whom have provided much-needed advice and constant encouragement throughout all stages of this secondment. We are indebted to our host company, BNFL Instruments Inc., for their generous help and support in providing us with office space and allowing us to become intimately involved with their business throughout this secondment. Last but not least, our thanks go to Rachel Robinson whose tireless efforts to keep track of expenditure, manage the logistics and undertake the administrative tasks needed to maintain the smooth and efficient running of this secondment are gratefully appreciated.

## **References**

1. A I Whitehouse, J Young, C P Evans, *Extreme LIBS*, Presented at: LIBS 2002, September 25 – 28, 2002, Orlando, Florida, USA
2. A I Whitehouse, J Young, C P Evans, A Brown (Applied Photonics Ltd.), J Franco, A Simpson (BNFL Instruments Inc.), *Remote compositional analysis of spent-fuel residues using Laser-Induced Breakdown Spectroscopy*, Presented at: Waste Management 2003 Symposium (WM '03) February 23 – 27, 2003, Tucson, Arizona, USA
3. A I Whitehouse, J Young, C P Evans, A Brown (Applied Photonics Ltd.), J Franco, A Simpson (BNFL Instruments Inc.), *Remote Characterization of HLW using Laser-Induced Breakdown Spectroscopy*, Presented at: 10<sup>th</sup> International High-Level Radioactive Waste Management Conference (IHLRWM), March 30 - April 2, 2003, Las Vegas, Nevada, USA

Dr Andrew I. Whitehouse  
**Managing Director**

For and on behalf of Applied Photonics Ltd

Date: 30 April 2004