

STRONG
MAR

Strengthening Maritime Technology
Research Center

Winter School on
Underwater Sensing Science
Programme



The STRONGMAR project is funded by the European Commission under the H2020 EU Framework Programme for Research and Innovation (H2020-TWINN-2015, 692427).



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20 to 24 March 2017
Aberdeen
Scotland, United Kingdom

Topics

- Fibre sensors
- Holography
- Raman spectroscopy
- LIBS
- Sonar imaging

Activities

- Lectures
- Lab demonstrations
- Research lab visits
- Industry visits

ORGANIZER



FUNDING



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<http://www.strongmar.eu/site/underwater-sensing-science-53>

TABLE OF CONTENTS

1 – WELCOME	4
2 – VENUES	5
2.1 – University of Aberdeen	5
2.2 – Oceanlab	7
2.3 – Teledyne Bowtech	8
3 – PROGRAMME	9
3.1 – Schedule	9
3.2 – Lectures	9
3.3 – Lab demonstrations	11
3.4 – Research lab visits	12
3.5 – Industry visits	12
4 – SPEAKERS	13
5 – SOCIAL PROGRAMME	16
5.1 – School dinner	16
5.2 – Visit to whisky distillery	16
6 – PARTICIPANTS	17
6.1 – Speakers and trainers	17
6.2 – Participants	17

1 – WELCOME

Dear all participants, welcome to another Winter School in the **STRONGMAR** series.

The aim of **STRONGMAR** is to create solid and productive links in the global field of marine science and technology between INESC TEC and established leading research institutions in Europe, that are capable of enhancing the scientific and technological capacity of INESC TEC and linked institutions, thereby helping raising research profile of its and its recognition as a European maritime research center of excellence.

The training strategy of the **STRONGMAR** project is based on technical presentations and demonstrations covering multidisciplinary aspects of marine science and technology, followed by sessions focused on specific fields of expertise, allowing researchers to improve their knowledge and preparing them for the research and implementation challenges in the harsh sea environment. This training strategy targets not only theoretical training but also practical aspects with hands-on laboratory demonstrations, enabling direct application of the knowledge acquired and improvement of understanding of the actual requirements of the stakeholders, allowing attendees to design solutions with higher economic potential.

Interchange and interaction among different fields of expertise is fundamental to address the ocean challenges, due to the multidisciplinary nature of the application area. Cross-fertilization among fields of expertise is also key to stimulate the design of better specific solutions.

This winter school (**Underwater Sensing Science**) will cover the following broad topics: Holography (both analogue and digital), Laser Induced Breakdown Spectroscopy (LIBS), Raman Spectroscopy, Fibre Optic Sensing and Sonar Imaging. The respective technologies and their applications underwater, in deep and shallow seas, will be presented. Visits to some local Aberdeen research labs and industries are also planned.

The **STRONGMAR** team.

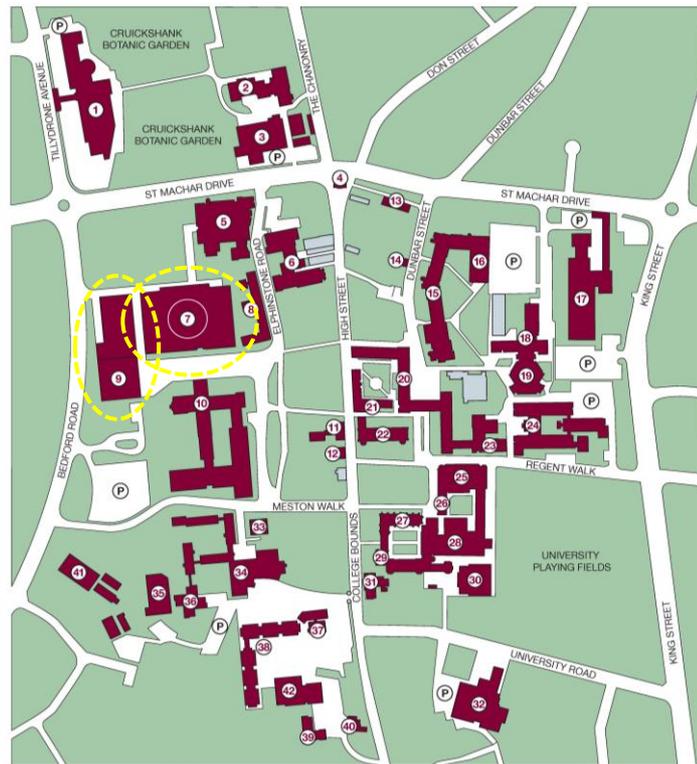
2 – VENUES

The winter school programme comprises lectures, lab demonstrations, research lab visits, industry visits and social events. Lectures and lab demonstrations will take place at the **Old Aberdeen Campus** of the **University of Aberdeen** (Aberdeen); research lab visits will take place at the campus of the **Robert Gordon University** (Aberdeen) and the **Oceanlab** (Newburgh); industry visits will take place at **Oceanering** (Dyce, Aberdeen) and **Teledyne Bowtech** (Dyce, Aberdeen).

2.1 – University of Aberdeen

The core activities of the winter school programme will take place at the **Old Aberdeen Campus** of the University of Aberdeen. Lectures will take place at the meeting room 1 of **The Sir Duncan Rice Library** (number ⑨ at the figure below) and lab demonstrations will take place at the **Fraser Noble Building** (number ⑦ at the figure below).

Old Aberdeen Campus



Map of the Old Aberdeen Campus of the University of Aberdeen (a PDF version is available [here](#)).

Address: University of Aberdeen, Old Aberdeen Campus, King's College, Aberdeen AB24 3FX, UK
Coordinates: 57.1652° N, 2.1056° W
Maps: [University of Aberdeen](#) | [Google Maps](#)
Website: www.abdn.ac.uk



The Sir Duncan Rice Library

The Sir Duncan Rice Library is a 21st century space for learning and research. It was officially opened on 24th September 2012 by Her Majesty Queen Elizabeth accompanied by the Duke of Edinburgh. The Sir Duncan Rice Library houses the largest of the University's modern collections on Floors 1-7 - including Arts, Humanities, Sciences and Social Sciences, and historic collections of rare books, manuscripts and archives in the Special Collections Centre on the Lower Ground Floor.



The building is open to the wider public, as well as students and staff. A wide range of facilities and services are available including:

- a Gallery on the Ground Floor for exhibitions and displays (which all are welcome to visit)
- an Events Area for school visits, and lectures and presentations
- a Microform Room, Multimedia Room, Music Resources Room, the Teaching Resource Collection, Assistive Technology Booths and other facilities
- PCs on every floor

There are also more informal areas including The Hardback Café on the Ground Floor (which is open to all), and the 'Break-out' Room on Floor 7, where students can enjoy panoramic views of the city while reading, working on a laptop, or engaging in quiet conversation.

There are over 1,200 study spaces: from traditional silent study rooms to interactive areas (Co-Labs) for collaborative projects, supported by information technology. The entire building has comprehensive wireless network coverage, and there are also wired network connection sockets to plug in your own laptop throughout.



The building, designed by Danish architects Schmidt Hammer Lassen was conceived to mark the ice and light of the north. The design concept was to provide "a meeting place and a cultural centre for the University and the wider Aberdeen community".

Address: University of Aberdeen, Bedford Road, Aberdeen, AB24 3AA, UK

Coordinates: 57.165445, -2.105843

Maps: [University of Aberdeen](#) | [Google Maps](#)

Website: www.abdn.ac.uk/library/about/main

Fraser Noble Building

The Fraser Noble Building houses the School of Engineering and the Department of Mathematics.

The building was opened as the Natural Philosophy Department in 1963 by Sir G P Thomson, former Professor of Natural Philosophy at Aberdeen who won the Nobel Prize in Physics for the work that he did here in the late 1920s.

In this work he demonstrated that electrons could be diffracted by atoms in the same way that light waves are diffracted by very small objects. This wavelike behaviour of entities formerly thought of as particles was at the very foundation of the new physics of quantum mechanics that was being developed in the 1920s. G P Thomson was the son of J J Thomson, who discovered the existence of electrons in 1897.



The Fraser Noble Building is named in recognition of the valuable services to the University of Sir Fraser Noble MBE, MA, LL.D., FRSE Principal and Vice Chancellor 1976 - 1981.

The building was erected in 1963 and after extensive refurbishment was formally re-opened by Sir Fraser Noble on 16 November 1988.

Address: University of Aberdeen, 1-5 Elphinstone Road, Aberdeen AB24 3EF, UK

Coordinates: 57.165873, -2.104601

Maps: [University of Aberdeen](#) | [Google Maps](#)

2.2 – Oceanlab

The University of Aberdeen's Oceanlab is a field research station of the Institute of Biological & Environmental Sciences (IBES) and the School of Biological Sciences (SBS). It is located in the northeast village of Newburgh 20km north of the main University campus in Old Aberdeen.



Oceanlab, founded in 2001 by Prof. Monty Priede, is located on the former site of the Culterty Field Station founded by Prof. V.C. Wynne Edwards FRS in 1958 on the banks of the Ythan estuary overlooking Forvie National Nature Reserve.

The first building, Oceanlab 1 contains engineering laboratories and hangar space for the design and construction of underwater technology and a suite of environmental commercial testing facilities operated by the Oceanlab Business Unit.

Oceanlab 2, opened in 2009, houses up to 35 persons and specialised laboratories to accommodate examination and sorting of preserved biological specimens, and molecular and biogeochemical analyses.

The Oceanlab Business Unit links customer contracts and test requirements to the expertise and facilities, bringing onshore proving to off shore technology. Industry aware and with a strong customer focus the Unit has undertaken Certificated Testing, Laboratory, and Fieldwork contracts for many of the world's leading manufacturers, energy providers and consultancy companies.

Staff and students based at Oceanlab undertake a wide range of research from coastal to deep-sea science and are heavily involved in international projects are research expeditions to the Atlantic Ocean, Mediterranean Sea, Indian Ocean, Southern Ocean, Arctic Ocean, Pacific Ocean as well as local work in the North Sea and the Ythan Estuary at Newburgh.

Address: Main Street, Newburgh, ELLON, Aberdeenshire, AB41 6AA, UK

Coordinates: 57.325293, -2.001185

Maps: [University of Aberdeen](#) | [Google Maps](#)

Website: www.abdn.ac.uk/oceanlab



2.3 – Teledyne Bowtech

Teledyne Bowtech specialises in the design and manufacture of underwater vision systems including: video inspection systems, underwater cameras, underwater LED lights, xenon emergency relocation strobes, custom moulded cable assemblies, pan and tilts, electrical and fibre-optic connectors, fibre-optic multiplexers and slip rings for use in hazardous areas or subsea.



Address: ABZ Business Park, International Avenue, Dyce, Aberdeen, AB21 0BH, Scotland, UK

Maps: [Google Maps](#)

Website: www.teledynemarine.com/bowtech



3 – PROGRAMME

3.1 – Schedule

	20/03/2017	21/03/2017	22/03/2017	23/03/2017	24/03/2017
09:00 10:30	Introduction to holography Prof. John Watson Aberdeen University campus Sir Duncan Rice Library, Meeting Room 1	Introduction to Raman Spectroscopy Prof. Johannes Kiefer Aberdeen University campus Sir Duncan Rice Library, Meeting Room 1	Introduction to LIBS Prof. Javier Laserna Aberdeen University campus Sir Duncan Rice Library, Meeting Room 1	Sonar Imaging Dr. Jeff Chambers & Dr. Pauline Jepp Aberdeen University campus Sir Duncan Rice Library, Meeting Room 1	Teledyne Bowtech Dr. Brian Hector Aberdeen University campus Sir Duncan Rice Library, Meeting Room 1
10:30 11:00	Coffee break	Coffee break	Coffee break	Coffee break	
11:00 12:30	Applications of holography underwater Dr. Nick Burns Aberdeen University campus Sir Duncan Rice Library, Meeting Room 1	Raman spectroscopy for underwater sensing Prof. Johannes Kiefer Aberdeen University campus Sir Duncan Rice Library, Meeting Room 1	LIBS for deep sea applications Prof. Javier Laserna Aberdeen University campus Sir Duncan Rice Library, Meeting Room 1	Fibre Optical Distributed chemical sensing Mr. Jon Oddvar Hellevang Aberdeen University campus Sir Duncan Rice Library, Meeting Room 1	Visit to Teledyne Bowtech Dyce, Aberdeen
12:30 13:30	Lunch	Lunch	Lunch	Lunch	Lunch
13:30 17:00	Holography Lab demonstrations Prof. John Watson, Dr. Nick Burns & Dr. Thanga Thevar Aberdeen University campus Fraser Noble Building	Visit to RGU Fibre Sensor Labs Dr. Prabhu Radhakrishna Robert Gordon University campus School of Engineering	LIBS Lab demonstration Dr. Thanga Thevar, Prof. John Watson & Dr. Sarwat Ozair Aberdeen University campus Fraser Noble Building	Visit to University of Aberdeen's Oceanlabs Newburgh	Visit to Glen Garioch Oldmeldrum
Evening			School dinner		

Lectures
Lab demonstrations
Research lab visits
Industry visits
Social events

3.2 – Lectures

Monday the 20th of March

Introduction to Holography

Professor John Watson, University of Aberdeen

Prof Watson will introduce the basic concepts of holography and will describe both in-line and off-axis modes of recording. He will discuss this from the point-of-view of analogue recording and replay of holograms on photographic emulsions. This will lead into the concepts of digital holography (which will be described in more detail by Dr Nick Burns). Prof Watson will also talk about the use of holography in imaging and measurement of marine organisms and particles and will describe the

HoloMar system, and its deployment, which was one of the most advanced subsea holographic camera developed. Demonstrations of analogue recording and replay will follow this talk.

Application of holography underwater

Dr. Nick Burns, University of Aberdeen

Dr. Burns Will discuss the design and operation of the digital holographic camera, eHoloCam. He will cover the requirements for recording, storage and reconstruction of digital holograms including a brief introduction to algorithms that may be used in the reconstruction phase. Basic techniques for automated interrogation of digital holograms will then be covered during which automated focusing approaches will be introduced.

Tuesday the 21st of March

Introduction to Raman Spectroscopy & its application in underwater sensing

Professor Johannes Kiefer, University of Bremen

Raman spectroscopy is a very versatile tool for process and environmental monitoring. It utilizes the inelastic scattering of photons off molecules. During this scattering process a molecule-specific amount of energy is transferred to or from the photon. Consequently, the Raman spectrum is a molecular fingerprint. A great feature of Raman scattering is that it simultaneously happens at all molecules irradiated by a laser. Therefore, the spectrum carries information about all the species and their concentration. Hence, Raman spectroscopy is capable of multi-parameter measurements. It is a particularly interesting tool for underwater sensing as its sensitivity to the water background is relatively low.

The first part of the talk will give an introduction to Raman spectroscopy. A brief outline of the interpretation of spectra and the possibilities for measuring species concentrations and temperature will be given. Also modern techniques for data analysis will be covered briefly. The second part of the talk will then focus on applications of Raman spectroscopy to aqueous systems and underwater sensing. Examples will include the detection and quantification of dissolved gases as well as sensing of crude oil components.

Wednesday the 22nd of March

Introduction to LIBS & its application in deep sea measurement

Professor Javier Laserna, University of Malaga

Laser induced breakdown spectroscopy is one of the most active research fields in current analytical chemistry. This talk will present the fundamentals of LIBS from the inception of the ideas leading to a practical measurement principle to the instruments and their evolution. Because of the extreme versatility of this technology, LIBS is of use in a broad front of applications, from laboratory measurements to field monitoring. Several examples of the use of LIBS in current analytical practice will be presented.

After decades of development in laboratories and land operations, chemical analysis of submerged objects is starting to become a reality. While the analysis of water at variable depth has been demonstrated in the past using fluorescence spectroscopy and Raman spectroscopy, determination of the atomic composition of submerged objects is much a more complex task. Technology based on laser-induced breakdown spectroscopy (LIBS) has been recently developed for such sub-sea operations. This talk will discuss the operating parameters of a marine LIBS analyzer. Metals, alloys, rocks, marble, concrete, can be analyzed at a depth of up to 50 m. Deeper waters can be also

analyzed using LIBS. In this case, the instrument, which must remain dry, is enclosed in a pressure chamber and mounted inside the payload of a ROV for secure carriage. Both close-contact LIBS and standoff LIBS approaches can be then implemented.

Thursday the 23rd of March

Underwater sonar imaging

Dr. Jeff Chambers & Dr. Pauline Jepp, Trittech International Ltd

Trittech International Ltd is a high-technology business dedicated to providing the most reliable imaging and ancillary equipment for use in underwater applications. Trittech will present an introduction and overview of modern sonar techniques and technologies including mechanical and multibeam sonars. The differences between the two technologies will be discussed alongside the applications most appropriate for each approach. The presentation will also cover their latest developments in the field of automatic target identification and tracking. Detected targets include manufactured objects such as pipes and marine life such as fish and mammals.

Fibre optical distributed chemical sensing

Mr. Jon Oddvar Hellevang, CMR Norway

Hellevang will focus his talk on optical water monitoring and sensing. He is currently heavily involved in a distributed fibre optical sensing project for detecting water ingress into critical infrastructure. The project is one of four projects funded by the Research Council of Norway in a special “groundbreaking” call targeting new ideas with huge impact potential. Hellevang will give a status mid-way through the project, with ideas for future spin-off. He will also present work done on improving reliability and reducing cost of optical sensor for measuring CO₂ and pH in water. An initiative for large scale integrated fibre optical monitoring of geological storage of CO₂ offshore will be presented. Hellevang will also give an overview of other ongoing subsea sensing projects at CMR.

3.3 – Lab demonstrations

Monday the 20th of March

Laboratory Demonstration on Holography

Laboratory demonstrations will include recording and replay of classical analogue holograms of plankton, recording and replay of digital subsea holograms and display of white light holograms.

Wednesday the 22nd of March

Laboratory Demonstration on LIBS

Laboratory demonstrations will include basic working principles of LIBS that covers the laser, spectrometer, plasma collection optics, and display of results. Following this comparison between entry level spectrometers and high spec spectrometers will be demonstrated. The challenges of doing LIBS underwater will also be considered.

3.4 – Research lab visits

Tuesday the 21st of March

Visit to Robert Gordon University’s Optical Research facility

Technical presentation by research staff followed by tour of facility.

Thursday the 23rd of March

Visit to University of Aberdeen’s Oceanlab

DELOS – Subsea Environmental Monitoring for BP – John Polanski, Electronics Technician

Fix03 – Subsea Networks– Dr Stewart Chalmers, Technical Director

Tour of Oceanlab Subsea Testing Facilities

3.5 – Industry visits

Friday the 24th of March

Visit to Teledyne Bowtech

4 – SPEAKERS

SPEAKER'S BIO



John Watson

John Watson is Emeritus Professor of Optical Engineering at the University of Aberdeen. He has been researching and teaching in optics, optoelectronics, optical engineering and electronics for nearly forty years. His main areas of activity include holography, laser induced spectral analysis and optical image processing. In particular much of his work has centred around the application of holography for subsea imaging of marine plankton. He has published several hundred peer-reviewed papers and three books in related areas. He is a Fellow of the Inst of Physics (UK) and the Institute of

Engineering Technology and is also a Senior Member of IEEE.



Nick Burns

Nick graduated from the University of Aberdeen with a BEng in Electronic and Computer Engineering in July 2005. He followed that with a PhD titled "Automated Analysis System for the Study of Digital Inline Holograms of Aquatic Particles". Nick work in the Engineering department of the University of Aberdeen and undertake course development and course delivery for the Electronics degree programmes. He has also had involvement in various research projects where his role has been in development of holographic systems, optical measurement techniques and

digital control system design. Nick is the principal operator of the eHoloCam underwater holographic camera, which he has redeveloped to be deployed in ocean trenches to a depth of 10 km.



Javier Laserna

Javier Laserna is Professor of Analytical Chemistry at the University of Malaga – Malaga, Spain. He graduated in Chemistry at University of Granada and received his PhD from the University of Málaga. He did postdoctoral work with Jim Winefordner at University of Florida for two years from 1986 to 1989.

Prof. Laserna's current research interests include the use of lasers in chemical analysis, laser-induced plasma spectroscopy; time-of-flight mass spectrometry; secondary ionization mass spectrometry; surface analysis using laser ablation with optical and ion detection, imaging techniques; laser remote chemical analysis; instrumental solutions for chemical analysis in the industry; fieldable analytical instrumentation; analysis of energetic materials; development of sensors for CBNRE threats; lasers for cultural heritage; underwater LIBS; and materials analysis. By the end of 1990's, he succeeded in demonstrating large-scale optics standoff laser induced breakdown spectroscopy for analysis of distant objects. Later this technique has been used in the analysis of explosives and in space exploration.

He has given numerous invited plenary and keynote talks in international meetings. Currently he is associate editor of the journal Applied Spectroscopy and member of the advisory board of Spectrochimica Acta -Part B Atomic Spectroscopy and Reviews in Analytical Chemistry. Prof. Laserna was awarded with the RSEQ National Award for Research in Analytical Chemistry in 2009 and the SEA National Award for his research career in applied spectroscopy in 2010.



Johannes Kiefer

Johannes Kiefer is Chair Professor and Head of the division Technische Thermodynamik at the University of Bremen, Germany. In addition, he is an Honorary Professor at the University of Aberdeen, Scotland, and he holds a guest professorship of the Erlangen Graduate School in Advanced Optical Technologies (SAOT) at the University Erlangen-Nuremberg, Germany. Johannes holds undergraduate and PhD degrees in chemical engineering from the University of Erlangen-Nuremberg, Germany. From 2010 to 2014, he was a lecturer and senior lecturer in Chemical Engineering at the University of Aberdeen. Moreover, he is a frequent visiting scientist at Lund University, Sweden and at the Sandia National labs Livermore, USA. His research interests are the areas of developing and applying spectroscopic techniques for the characterization of advanced materials and processes.



Prabhu Radhakrishna

Dr. Radhakrishna Prabhu has a bachelor's degree in Electrical Engineering, master's degree in Opto-electronics & Laser Technology and PhD in Optical Instrumentation. After completing PhD, he worked as Research Fellow for nearly 10 years at University of Twente, The Netherlands and Robert Gordon University (RGU), UK. He also worked as a part-time lecturer at RGU from 2007 to 2011, prior to joining as a full-time lecturer. He has more than 20 years of research experience and generated strong research record in areas including optical instrumentation, sensing, surface engineering & nanocoatings, clean technology, optical materials & electronic instrumentation. He has authored more than 90 publications in scientific journals, conferences, symposia and books. He also has 4 patents related to optical security and biosensing. His research has led to many research collaborations both nationally and internationally including USA, Europe, Brazil, Malaysia and India. Furthermore, he has delivered invited/key-note talks at international conferences and have been the technical chair for two international conferences. He is one of the technical chairs for the MTS IEEE OCEANS'17 conference, Aberdeen, during June 2017.



Jon Oddvar Hellevang

Jon Oddvar Hellevang received his MSc degree in electronics and telecommunication from the Norwegian University of Science and Technology (NTNU) in Trondheim Norway in 2003, where he specialized in photonics technologies. Hellevang worked with subsea control system at FMC Technologies in Kongsberg from 2004-2006. Since the autumn 2016, he has worked as a scientist at Christian Michelsen Research (CMR) in Bergen Norway. Hellevang primary interest and working area is within measurement science. Main expertise and field of work is fibre optical sensing. As a scientist at CMR, he has also been active in strengthening the research, development and innovation in the Norwegian GCE Subsea cluster, having status as Global Centre of Expertise.



Jeff Chambers

Jeff Chambers joined Tritech in 2006 and was promoted to the position of Engineering Director in February 2013. Jeff has over 30 years' engineering experience, having previously held the role of Technical Director with military electronics manufacturer Oxley Developments, before joining System Technologies (now Tritech) in 2005 as Engineering Manager. Jeff has a Ph.D. from the University of Cambridge in the development of thin-film structures for use in electronic displays and holds a B.Eng. (Hons) in Electrical and Electronic Engineering. Jeff is responsible for the development of Tritech's technology strategy and leading the engineering team in new product development.



Pauline Jepp

Pauline Jepp is a Senior Software Engineer and has been with Tritech since 2010. She is the lead designer and programmer for the SeaTec software suite and has worked on the RAMS® project and other multibeam software solutions. Pauline has a PhD in Computer Science with a focus on Computer Graphics and Artificial Intelligence. She uses her experience of analysing data spaces for features and agent movement characteristics to continually improve SeaTec's target identification and classification system. In her capacity, Pauline also works closely with customers on tailoring applications for their specific requirements.



Thanga Thevar

Thanga is a senior lecturer in School of Engineering, University of Aberdeen. He graduated from the same University with a first class honours in electrical engineering followed by a PhD in laser engineering. His main research areas include laser design and development, laser induced breakdown spectroscopy (LIBS), and non-destructive testing. He worked in the US laser industry for close to 10 years before moving into academia. In addition, he spent some time in NASA Langley Research Centre on sabbatical. While in the industry, he was involved in design and development of specialized solid-state lasers for military and research applications. He was also involved in developing laser based systems for non-destructive testing. Current research involves developing LIBS systems for subsea applications. Thanga has more than 25 publications in journals and international conferences. He holds a patent in laser design.

5 – SOCIAL PROGRAMME

5.1 – School dinner

The school dinner will be in Howies Restaurant, Aberdeen on the evening of 22nd March. The restaurant is located in the city's Chapel Street, off Union Street. It serves traditional Scottish food that we hope the participants will enjoy!

Please be there at 6:30 pm for 7:00 start. The address is as follows:

50 Chapel St, Aberdeen AB10 1SN (<http://www.howies.uk.com/chapel-street-aberdeen>)



5.2 – Visit to whisky distillery

The last event of the winter school will be a visit to a local whisky distillery.



6 – PARTICIPANTS

6.1 – Speakers and trainers

Nº	Name	Institution	E-mail
1	John Watson	University of Aberdeen	j.watson@abdn.ac.uk
2	Thanga Thevar	University of Aberdeen	t.thevar@abdn.ac.uk
3	Nick Burns	University of Aberdeen	n.m.burns@abdn.ac.uk
4	Sarwat Ozair	University of Aberdeen	Sarwat.ozair@abdn.ac.uk
5	Johannes Kiefer	University of Bremen	jkiefer@uni-bremen.de
6	Javier Laserna	University of Malaga	laserna@uma.es
7	Radhakrishna Prabhu	Robert Gordon University	r.prabhu@rgu.ac.uk
8	Jon Oddvar Hellevang	Christian Michelsen Research	jon.oddvar.hellevang@cmr.no
9	Jeff Chambers	Tritech International Ltd.	Jeff-Chambers@tritech.co.uk
10	Pauline Jepp	Tritech International Ltd.	Pauline-Jepp@tritech.co.uk

6.2 – Participants

Nº	Name	Institution	E-mail
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14	Manuel Marques	INESC TEC CAP	manuel.j.marques@inesctec.pt
15	Maurício Guedes	INESC TEC CRAS	mauricio.o.quedes@inesctec.pt
16	Miguel Ferreira	INESC TEC CAP	miguel.s.ferreira@inesctec.pt
17	Paulo Marques	INESC TEC CAP	psmarques@inesctec.pt
18	Pedro Jorge	INESC TEC CAP	pjorge@inesctec.pt
19	Rui Martins	INESC TEC CAP	rui.c.martins@inesctec.pt
20	Rui Oliveira	INESC TEC CAP	rlvo@inesctec.pt
21	Vítor Amorim	INESC TEC CAP	vitor.a.amorim@inesctec.pt

CAP (Centre for Applied Photonics), **CRAS** (Centre for Robotics and Autonomous Systems), **CSIG** (Centre for Information Systems and Computer Graphics).