PROJECT FINAL REPORT

"Final publishable summary report"

"Use and dissemination of foreground"

Grant Agreement number:	**201880**
Project acronym:	**FUN OCT**
Project title:	**Functional optical coherence tomography**
Funding Scheme:	**Collaborative Project (Small or medium-scale focused research project)**
Period covered:	**from** 1 April 2008 **to** 30 September 2012

Name, title and organisation of the scientific representative of the project's coordinator:

Peter E. Andersen, Research Prof., Technical Univ. of Denmark

Tel: **+45 4677 4555**

Fax: **+45 4677 4565**

E-mail: **peta@fotonik.dtu.dk**

Project website address: **www.funoct.eu**

Final publishable summary report

Background

Recent advances in medical procedures provide promising potential for effective treatment of numerous life-threatening diseases and impairing diseases affecting the aging population. Full exploitation of this potential, however, is inherently linked to performing early and specific diagnosis. In areas such as cancer screening and ophthalmology, current clinical practice calls for the development of techniques to diagnose disease in its early stages, when treatment is most effective and significant irreversible damage can either be prevented or postponed. *Cross-sectional in vivo imaging* provides a valuable clinical tool for the diagnosis, staging, and management of diseases. Emerging imaging methods are increasingly providing information on the physiology and molecular characteristics of lesions. Hence, the objective is to derive a multi-parametric biologic phenotype for diseases, e.g. tumours, based on imaging technology enabling precise guiding of treatment on an individual basis.

Non-invasive imaging is of fundamental and increasing importance in the daily disease management. Although physical examination and laboratory tests remain key methods for treatment planning and disease management, imaging increasingly represents a key objective metric in the diagnosis, and it is generally used multiple times during the course of a disease and also for monitoring of treatment efficacy. Imaging processes in biological tissue, i.e., functional information, is also increasingly applied in drug development processes and, thus, aid in developing new therapies.

Novel functional imaging platform

Optical coherence tomography (OCT) is an emerging non-invasive, optical diagnostic imaging modality that enables *in vivo* cross-sectional tomographic, 3-D visualization of internal microstructure and functional information in biological systems. OCT achieves axial image resolution of 1 to 5 micrometers with penetration depth of a few millimetres. Recent developments in light sources and systems have enabled OCT to perform *non-invasive optical biopsy* with performance approaching the level of that achieved with histopathology. Because OCT penetration is limited to a few mm into scattering tissue it is of importance to devise suitable delivery probes, e.g. endoscopes, to reach inner body parts. In this way, limited penetration is not hindering the unique ability of OCT for detection of pathologies arising in the vicinity of surfaces, i.e., minute epithelial pathological changes.

Functional OCT provides depth resolved physiologic, metabolic and molecular information from the tissue being imaged through polarisation sensitive OCT (PS OCT), Doppler OCT (DOCT), spectroscopic OCT (SOCT) and optophysiology. However, there is a *strong need* for increasing imaging speed, improving system technology and advancing delivery systems to successfully bring these potential imaging modalities into clinics. Optical coherence microscopy (OCM) combines OCT with a system of high numerical aperture in order to obtain transverse resolutions comparable to confocal microscopy but with increased depth of penetration.

Multiphoton tomography (MT) has become a well established optical imaging technique since its first exploitation more than a decade ago. MT is based on the detection of multiphoton excited fluorescence emitted by endogenous or exogenous fluorescent compounds. It allows thin optical sectioning from tissues at resolution surpassing that of OCT, but at less penetration depth. One key aspect of this proposal is the combination of OCT/OCM and MT for pre-clinical and clinical application expected to provide unprecedented capabilities in early cancer diagnostics.

The *proposed novel medical imaging platform* comprises high-speed, high-resolution, depth-resolved, functional OCT and the integration of OCT/OCM with MT, hence, providing localised tissue function imaging. Albeit limited to mm-range penetration, this powerful platform may provide

early diagnosis of numerous cancerous lesions and other diseases, such as retinal diseases, originating from minute pathological epithelial changes at the cellular level. It should be emphasised that the novel imaging technique complements existing technology to the benefit of patients through improved or even new diagnostics.

Aim, objectives and main targets

Aim

The over-all aim of FUN OCT is to expand the non-invasive optical biopsy capability of optical coherence tomography (OCT) and combination of OCT with multiphoton tomography (MT) to develop novel functional capabilities hereby enabling 'morphofunctional' performance, i.e., the fusion of anatomic and functional imaging at the cellular resolution level. These methodologies will enable unprecedented non-invasive detection of depth resolved physiological, metabolic as well as molecular specific tissue information, i.e., forming a novel, powerful medical imaging platform. The hypothesis is that the combination of cellular resolution, real time imaging of morphology and *depth resolved tissue function* could enable a major step forward in early cancer diagnosis and in the early detection of retinal pathologies that are worldwide leading causes of blindness.

Objective

The main objective of FUN OCT is to expand state-of-the-art OCT medical imaging capabilities to include depth resolved functional information, i.e., forming a novel, powerful medical imaging platform, and to demonstrate its general feasibility in selected clinical applications that can contribute to the enhancement of quality of life and living conditions of the European aging population. The creation of this medical imaging platform is realised through the development of optical ultra-broad bandwidth and ultrahigh speed tuneable light sources, optical, electronic, hard/soft-ware designs for functional OCT, delivery systems for the envisaged medical applications, and contrast agents to further enhance OCT tomogram contrast. These developments enable unique, three-dimensional, real time in situ functional imaging providing unprecedented depth resolved functional tissue information that is essential to significantly improve early cancer diagnosis as well as detection of retinal pathologies such as age-related macular degeneration (AMD) and glaucoma that are worldwide leading causes for blindness.

Impact

The outcome contributes directly to improving and to maintaining the quality of life and living conditions of the European aging population through early diagnosis of cancer and of retinal pathologies as well as more efficient therapy monitoring. Moreover, the new imaging modality may in the long term act as a screening device to investigate the prevalence of cancer as a function of geographic (regional) or gender related parameters. Finally, the diagnosis of other age-related diseases in a variety of medical fields, such as cardiology, neurology, gynaecology, and gastroenterology, may also benefit from this novel diagnostic platform provided by FUN OCT.

Main achievements

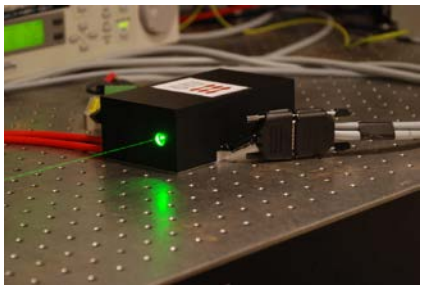
Light source technology

LMU has demonstrated the first Megahertz OCT imaging of the anterior segment. The system used a newly developed 1310nm FDML laser for a dramatically improved ranging depth. Key enabling element was a so called chirped fiber Bragg grating in the laser, this grating has been specifically developed for application in OCT lasers. The laser achieves a sweep repetition rate of more than 1.6MHz. To handle such rapid wavelength tuning a ultra-high data rate detection system has been developed, a proper signal conditioning solution was implemented and raw data pre-processing algorithms have been evaluated. The system is 53x faster than the fastest commercial instrument and more than ~8x faster than the fastest single spot ophthalmic imaging results of the anterior segment. For the first time, a dense, isotropically sampled OCT data set of the entire anterior segment acquired in 0.8s enabled a full volumetric reconstruction.

DTU developed a broadband FDML laser operating at 1060 nm with a sweep repetition rate of 350 kHz. With bandwidth up to 100 nm and spectral shaping it enables an axial resolution down to 6.5 µm in tissue. It was successfully applied at MUW-A for high-speed polarization-sensitive OCT imaging. Furthermore, DTU investigated the impact of water absorption in the human eye on retinal OCT imaging in the 1060 nm band. They implemented a numerical model that provides detailed design rules for new broadband swept sources and may be used for general performance analysis of OCT systems.

FL developed a highly integrated Ti:Sapphire laser with a compact module size footprint and exceptional stability while still maintaining ultra-short pulse output of 8.7fs and 170nm spectral width. The performance data of this source may make it the ideal choice for numerous ultra-high resolution OCT imaging setups where 800nm centre wavelength, high output power and wide spectral bandwidth is required.

DTU has made advances in developing a novel, compact, high-power laser source that may replace existing bulky and expensive pump sources for Ti:S lasers, for example, pumping the compact CORE produced by FL. Current performance exceeds 1.5 W (2.1 W has been measured) at 531 nm with good beam quality and excellent power stability. The footprint must be decreased further. Potentially the source may run without water cooling. In 2011, together with FL, it was demonstrated that size *and* cost of pump lasers for Ti:S lasers are reduced whilst maintaining performance.



Delivery probes

Two novel retinal imaging platforms for polarisation sensitive (PS) and Doppler OCT were successfully built. Optimal adjustment of the beam with respect to the investigated eye was achieved.

Furthermore, flexible OCT probes for endoscopic imaging were built and tested. A circumferentially scanning endoscope uses a 1.7 mm diameter motor for rotating a micro prism. For bronchoscopy a forward scanning probe was successfully demonstrated. The 3 mm probe has at 4.5 mm working distance 1.5 mm field of view.

A combined hand-held scanner for multiphoton tomography (MT) with large field OCT was demonstrated. The compact scan head which is fiber-coupled to the femtosecond laser gives a new degree of freedom for MT. By tracked motion of the scanner over the OCT images with a field-of-view of several centimetres are possible.

Functional OCT imaging platform

LMU developed a Fourier Domain Mode Locked Laser source operating at 1300 nm for PS-OCT. An additional buffer stage was developed that boosts imaging speed by factors of 2, 4, or 8. The source and buffer stage were shipped to MUW where they were implemented into a fibre optic polarisation sensitive OCT interferometer. This new interferometer type, developed at MUW, is based on polarisation maintaining fibres and requires only a single measurement per measurement location to retrieve intensity and birefringence data. A final version of the PS-OCT scan engine, equipped with an x-y galvo scanner for 3D imaging, was assembled at MUW, tested, and the performance was characterised. It was then successfully used to image human skin and anterior eye chamber. 2D and 3D data sets of various locations of human skin were measured. From the measured data sets, 2D and 3D images of intensity, retardation, optic axis orientation, and depolarization were obtained. Based on the knowledge gained at MUW, a similar PS-OCT system was built at BMO.

A new patient interface for retinal imaging was developed and successfully tested with an 840 nm spectral domain PS-OCT system. Based on these results, a 1050 nm retinal PS-OCT scanner was

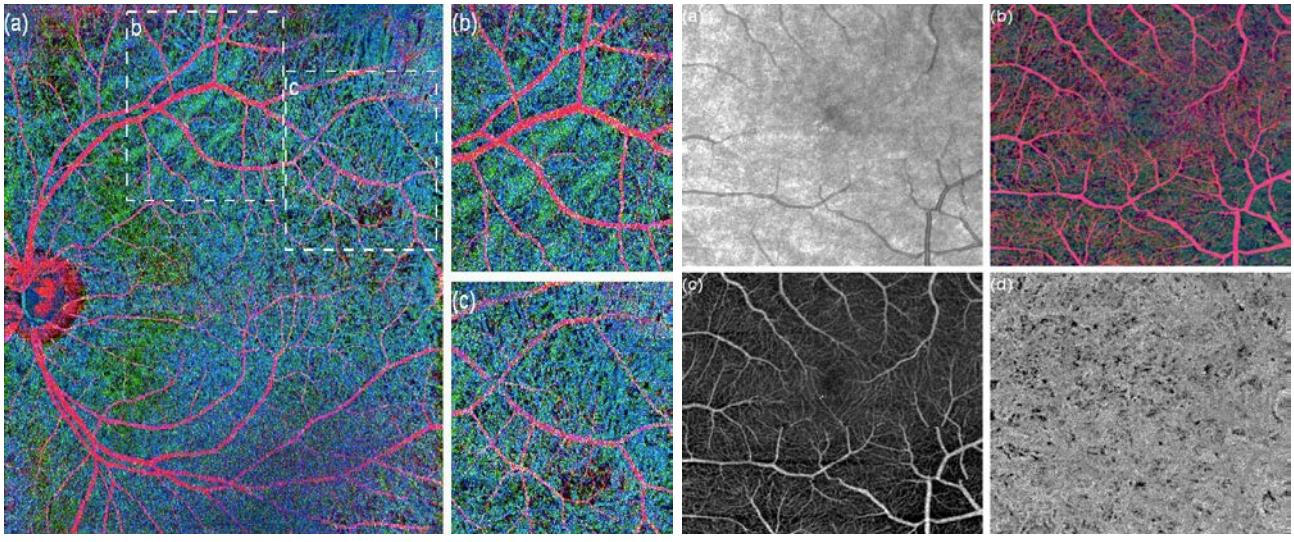
built. It is based on polarization maintaining single mode fibres and requires only a single measurement per measurement location to retrieve intensity and birefringence data. The PS-OCT retinal scanner was tested with a commercial swept source and an FDML source developed by DTU. Imaging speeds of 100 kA-scans/s and 350 kA-scans/s, respectively, were achieved with the two sources. 2D and 3D images from the retina of healthy subjects and patients with various diseases were successfully acquired, demonstrating the capability of the system to measure backscattered intensity, birefringence, and depolarization simultaneously. The superior penetration depth of 1050 nm OCT, down to choroid and sclera, could be demonstrated and allowed to segment the choroidal thickness based entirely on polarization effects.

New software was developed to measure and image depolarisation. Based on this method, segmentation algorithms to identify retinal layers and lesions based on intrinsic, tissue specific contrast were developed and successfully tested in healthy subjects and patients with age related macular degeneration and diabetic retinopathy. Preliminary tests demonstrated good reproducibility of quantification of lesions like drusen and atrophies in age related macular degeneration.

Preclinical application of both a high-speed retinal DOCT-angiography platform operating with a swept source at 1060nm as well as an extended focus dermatology DOCT platform operating at 1300nm has been demonstrated.

The retinal DOCT angiography employed a high speed swept source FDML laser from LMU with 1.67MHz scan rate. Such high speed allowed for the first time completely non-invasive wide field angiographic retinal-imaging over 50deg. The gold standard fluorescence angiography needs to administer contrast agents with possible advert side effects for the patients. This prevents also the screening of large populations. DOCT angiography on the other side is easy to implement in single beam retinal OCT platforms and is easy to operate. Thus it would potentially help to diagnose major retinal diseases already at an early state before the onset of pathologic alteration with loss of vision. A large benefit of cutting down health costs can be therefore anticipated.

The result of wide field 3D DOCT angiography is shown in Fig. 1 below. The colour encodes depth. Figure 2 is a zoomed region of Fig.1 demonstrating the capability to resolve even the smallest capillaries in the parafoveal region.



LEFT: Color coded en-face mean projection of the retinal and choroidal vasculature. (a) ~48° depth-resolved angiogram. (b) and (c) zoom showing large choroidal vessels and fine vasculature.

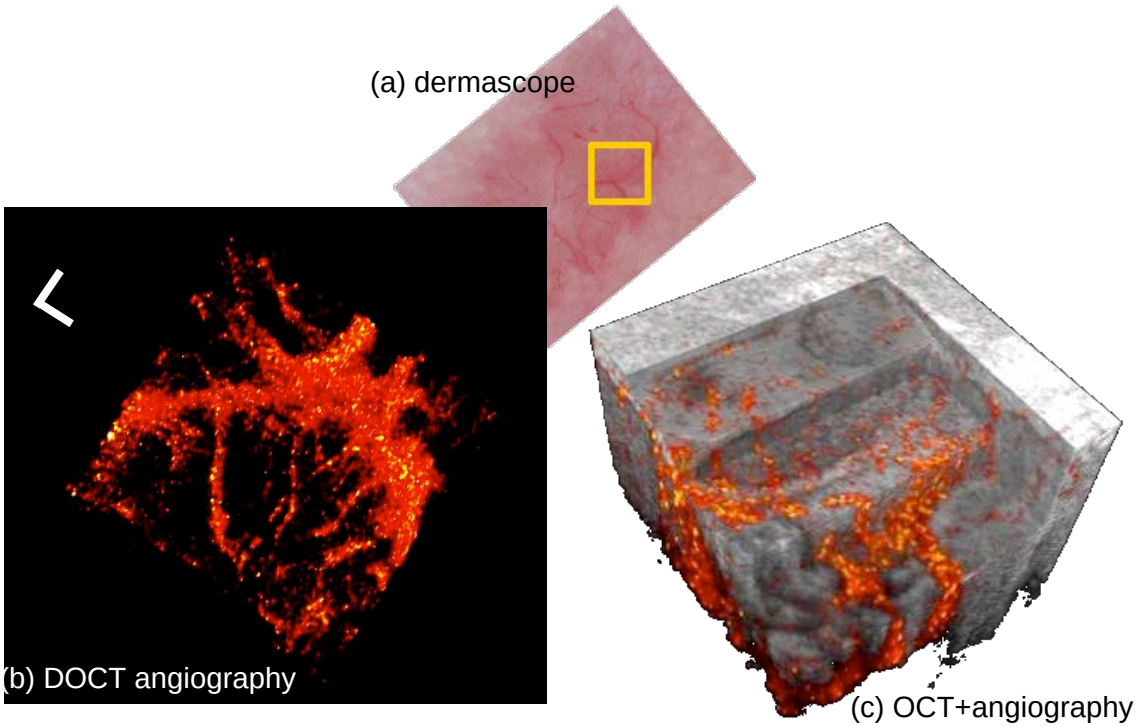
RIGHT: FOV~12° centered at the fovea (a) Pseudo-SLO fundus obtained by en-face mean projection of the intensity data set. (b) Color coded en-face mean projection of the retinal and choroidal vasculature. (c) retinal vasculature. (d) choroidal vasculature.

In case of dermatologic DOCT at 1300nm first patient measurements have been performed revealing characteristic vascular structures for different skin diseases. The vascular pattern of

basal cell carcinoma has been for the first time measured in human beings in-vivo and in-situ. A chaotic vascular structure is visible with large vessels close to the skin surface.

The figure below shows a case of basal cell carcinoma. It shows the dermascope image that is usually used by the dermatologists for diagnosis. It does neither provide in-depth structure information nor information on the actual blood supply in deeper structures. This is provided by the OCT and DOCT angiography image. The advantage of the dermascope image is the larger field of view and the possibility to locate the OCT volume with respect to the lesion site.

There is hope that with the combined knowledge of vascular as well as tissue structure a better diagnosis of skin diseases will be possible. This could in case of skin cancer help for better guidance of the dermatologists for skin biopsies and for determining the tumour boundaries. Furthermore the treatment monitoring would greatly benefit by having additional information on the important tissue perfusion.



BCC on the forehead. a: Dermascopy image with square indicating the OCT FOV of 2mmx2mm. b: DOCT 3D angiography seen from above by taking the intensity differences; White scale bars indicate 250µm. c: OCT volume in grey levels with DOCT angiography in red hot LUT as overlay for better appreciation of vascular structure with respect to tissue.

Functional imaging combining OCT and photoacoustic tomography

The main objectives of this part package were the extraction of functional information from spectroscopic optical coherence tomography (SOCT) and photoacoustic tomography (PAT) using endogenous or exogenous chromophores as well as the development of novel contrast agents for functional OCT and PAT, including nanoparticle-based agents that can act as ligands to specific molecules or proteins.

In order to achieve these objectives, we designed and built a PAT system, including data acquisition hardware and software. Existing OCT systems were modified and used for SOCT studies. Preliminary testing of the PAT system in phantoms has begun, and phantom imaging was completed for SOCT studies as well.

In collaboration with Paul Beard and Edward Zhang (University College London, UK) we combined OCT and PAT for proof-of-principle measurements. The system employs an integrated, all optical

detection scheme for both modalities in backward mode utilizing a shared 2D optical scanner with a field-of-view of ~13 x 13 mm^2. The photoacoustic waves were detected using a Fabry-Pérot polymer film ultrasound sensor placed on the surface of the skin. The sensor is transparent in the spectral range 590-1200 nm. This permits the photoacoustic excitation beam (670-680 nm) and the OCT probe beam (1050 nm) to be transmitted through the sensor head and into the underlying tissue thus providing a backward mode imaging configuration. The respective OCT and PAT axial resolutions were 8 and 20 µm and the lateral resolutions were 18 and 50-100 µm. The system provides greater penetration depth than previous combined PA/OCT devices due to the longer wavelength of the OCT beam (1050 nm rather than 829-870 nm) and by operating in the tomographic rather than the optical resolution mode of photoacoustic imaging.

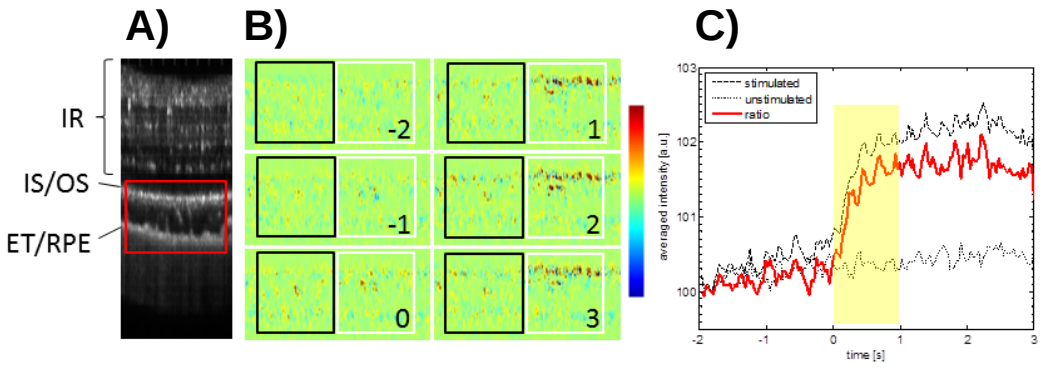
Nanoparticle based contrast agents (gold nanorods) were developed and are currently being tested for SOCT and PAT. The main results achieved were the concept and design development and implementation as well as preliminary testing in phantoms. Furthermore, an approach to conjugating antibodies to the surface of these gold nanorods that will allow for targeted imaging is under investigation.

Collaboration with the department of dermatology at the Medical University of Vienna for in-vivo, human PA/OCT studies is planned and we are currently seeking ethics committee approval for these studies. We will look at healthy blood oxygenation via spectroscopic PAT imaging, and study neovascularization in human subjects with skin cancer. These studies will also be performed in mouse models of skin cancer. The long-term potential impacts of these studies and the application of PA/OCT in dermatology are better delineation of tumor regions and earlier diagnosis of metastasis, which may lead to earlier intervention opportunities and better treatment outcomes.

Opto-physiology

After accomplishing first successful in vivo 800nm and 1060nm optophysiological studies in nomal subjects, the potential of ultrahigh speed FDML laser – only available at LMU – were tested. A-scan rates up to 1.6 million depth scans per second were used and the potential for in vivo human optophysiology enabling motion artifact free imaging was investigated. 1060nm based in vivo optophysiologic studies could successfully be conducted in a cost-effective glaucoma animal model (tree shrew). These results represent the first in vivo optophysiologic measurements that could be reproduced in several measurements of several animals.

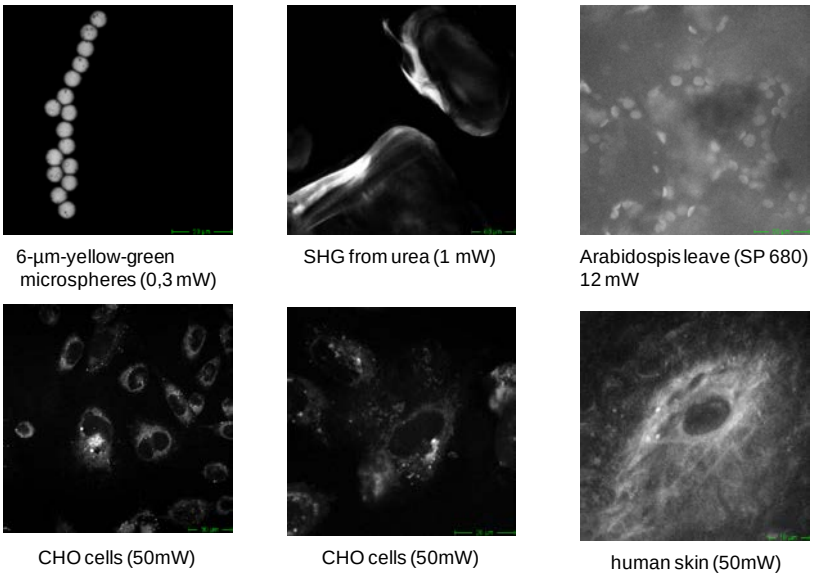
Finally, state-of-the-art ultrahigh resolution OCT microscope based on SD OCT was developed to reproduce in vitro optophysiologic studies published in 2006 in PNAS based on TD OCT.



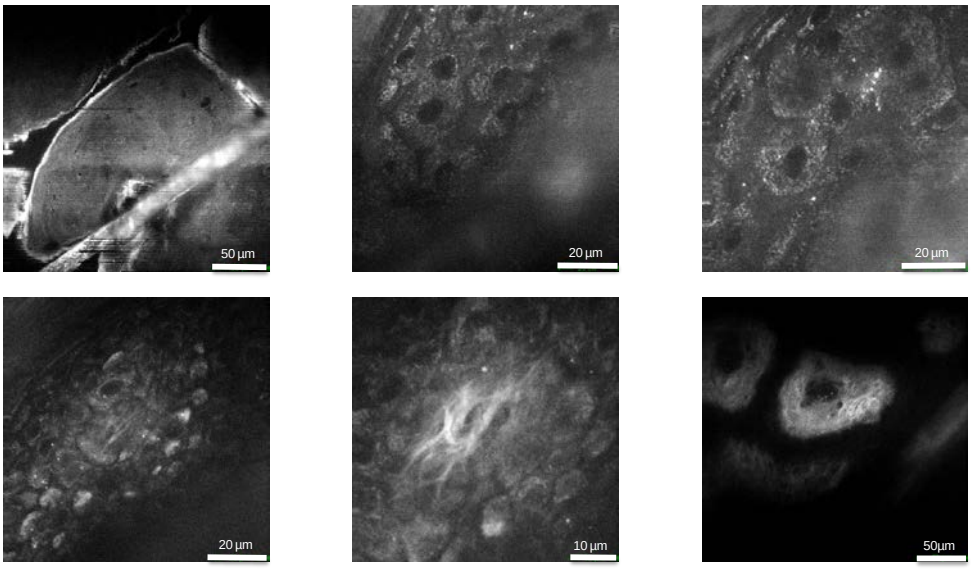
Retinal stimulation experiment in an tree shrew animal model.
A) Tomogram visualizing all major retinal layers: IR – inner retina with nerve fiber layer, inner and outer plexiform and nuclear layers; IS/OS – junction between photoreceptor inner and outer segments; ET/RPE – photoreceptor end tips / retina lpigment epithelium. The red box indicates the area shown in B).
B) Processed tomograms at different time points relative to the stimulus (times are indicated in seconds). Black square indicates unstimulated, white square indicates stimulated area.C) The area averaged intensity change; onset and duration of the stimulus is indicated by the yellow box.

Multiphoton tomography

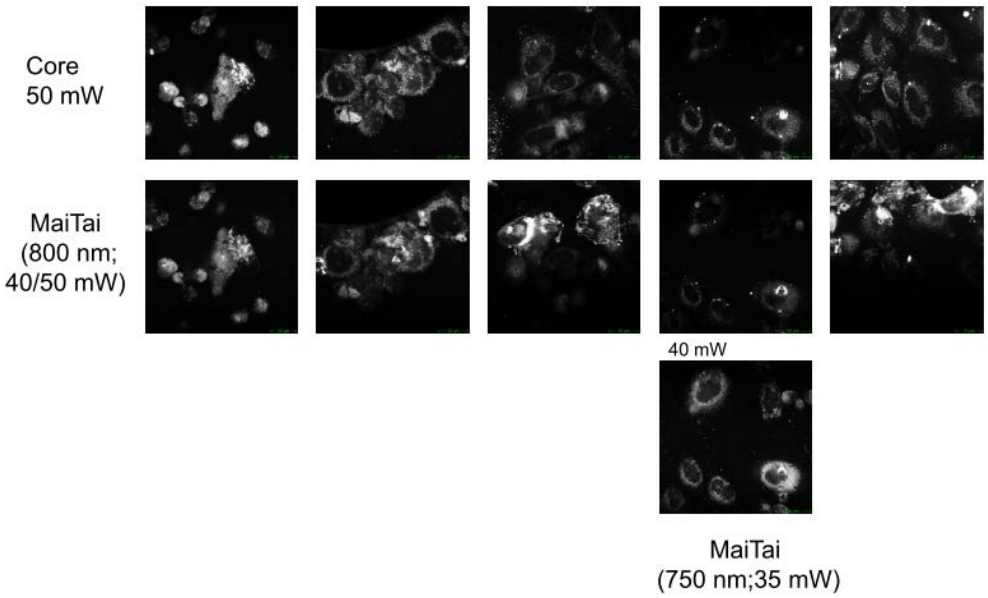
The key result concerns testing the new integral core laser for multiphoton imaging. To illustrate the multiphoton imaging capabilities, images of different samples like 6 µm fluorescent spheres, urea crystals (which generate second harmonic generation light), leaves, Chinese hamster ovary (CHO) cells, and skin are shown (see figure). The figure demonstrates the good suitability of the new laser for multiphoton imaging. Further examples for multiphoton imaging of different skin layers are shown (separate figure). Comparison of imaging CHO samples with the Core laser and a 100-fs-Ti:sa laser (MaiTai Spectra Physics) is shown also. In contrast to the core laser which has a repetition rate of 340 MHz, the MaiTai has a repetition rate of 80 MHz. The comparison suggests a lower phototoxicity of the core laser compared to the MaiTai at equal average mean powers.



Examples for multiphoton imaging of different samples with the new Core fs- laser.



Further examples of multiphoton images of skin from different skin layers.



Comparison of new Core laser and MaiTai for imaging of CHO cells.

The consortium

The consortium comprises six leading research groups and two SME-sized companies spanning complementary expertise in the fields of laser sources, OCT, MT and beam delivery system technology. Moreover, the consortium made use of its existing relations to clinical collaborators in order to achieve proof-of-principle validation of the imaging modalities.

The consortium members are

- Technical University of Denmark, Denmark (DTU, co-ordinator)
- Universität zu Lübeck, Germany (BMO)
- Ludwig-Maximilians-Universität München, Germany (LMU)
- Medizinische Universität Wien, Austria (MUW)
- Femtolasers Produktions GmbH, Austria (FL)
- JenLab GmbH, Germany (JL)

Web site and project logo

Web site: www.funoct.eu

Use and dissemination of foreground

Section A – Dissemination strategy overview

After FUN OCT, dissemination of results is mainly defined by publishing in leading scientific journals and through the attendance of consortium members at leading international conferences, including but not limited to, European Conference on Biomedical Optics (ECBO), Photonics Europe, Conference on Lasers and Electrooptics (CLEO), ARVO, and Photonics West. Results will be made public observing FUN OCT IP. Peer-reviewed journals with a high impact factor, such as Appl. Phys. Lett., Phys. Rev. Lett., Optics Letters, Optics Express, Biomedical Optics Express, Science, Nature Photonics, Nature Medicine, Journal of Biomedical Optics, Physics in Medicine and Biology will primarily be targeted. Publications and press releases targeting the general public, young scientists, and even high-school students are also envisioned as have been done during the project. The FUN OCT that allows effective dissemination of findings and it will be maintained beyond the project end date.

During FUN OCT press releases were distributed and also some of the FUN OCT results were highlighted for a broader readership. Most notably, in 2012, one of the key results (Doppler OCT of skin cancerous lesions, see also Publishable Summary) was highlighted in The Economist (The Economist, October 6th, 2012, “Deep Skin”). Please refer to D9.4 for the complete list including other national/international news media.

FUN OCT dissemination
Dissemination of scientific project results followed the two main strategies commonly used for this kind of research projects: Publication in peer reviewed scientific journals and presentation at major international conferences.

1. Publication in peer reviewed scientific journals:
A total of 87 scientific papers were published in peer reviewed journals. Depending on content and developmental stage of the technology/results to be published, manuscripts were submitted to technical/engineering journals with a focus on optical sciences (42 manuscripts), to translational journals with a focus on biomedical optics (27 manuscripts), and to clinical journals covering a variety of clinical applications like ophthalmology, dermatology, etc. (18 manuscripts). To provide access to our results for a large audience, the majority of papers (55 of 87 or ~ 63%) were published as open access.

2. Conference presentations:
Results of the project were presented in more than 130 conference contributions at major international conferences on optical technology, biomedical optics and clinical topics. Among the major conference series where FUN OCT results were regularly presented were Biomedical Optics *BiOS*/Photonics West (San Francisco), European Conferences on Biomedical Optics *ECBO* (Munich), Association for Research in Vision and Ophthalmology *ARVO* (Fort Lauderdale) and several other conferences in Europe, North America and Asia. A total of 26 invited talks comprising results of FUN OCT were presented.

3. Others:
In addition to scientific papers and conference presentations, results of the project were reported in specialized magazines like *Optics and Photonics News*, *BioOptics World*, and in online portals like *SPIE Newsroom* and *OCT News*.

After press releases by Optical Society of America and Medical University of Vienna, the project results on imaging of skin cancer by Doppler OCT recently achieved wide attention in both, specialized and general media. International and Austrian newspapers reported on the results in English and German language.

Section A table (public)

TEMPLATE A: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS IN CHRONOLOGICAL ORDER										
NO.	**Title**	**Main author**	**Title of the periodical or the series**	**Number, date or frequency**	Publisher	**Place of publication**	**Year of publication**	**Relevant pages**	**Permanent identifiers (if available)**	**Is/Will open access provided to this publication?**
01	K-space linear Fourier domain mode locked laser and applications for optical coherence tomography	Christoph M. Eigenwillig, Benjamin R. Biedermann, Gesa Palte, and Robert Huber	Opt. Express	16	The Optical Society of America (OSA)	Washing-ton, DC	2008	8916-8937	http://dx.doi.org/10.1364/OE.16.008916	yes
02	Real time en face Fourier-domain optical coherence tomography with direct hardware frequency demodulation	B.R. Biedermann, W. Wieser, C.M. Eigenwillig, G. Palte, D.C. Adler, V.J. Srinivasan, J.G. Fujimoto, R. Huber	Opt. Lett.	33(21)	The Optical Society of America (OSA)	Washing-ton, DC	2008	2556-2558	http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2743229/pdf/nihms136896.pdf	yes
03	Raman-pumped Fourier-domain mode-locked laser: analysis of operation and application for optical coherence tomography	T. Klein, W. Wieser, B.R. Biedermann, C.M. Eigenwillig, G. Palte, R. Huber	Opt. Lett.	33(23)	The Optical Society of America (OSA)	Washing-ton, DC	2008	2815-2817	http://dx.doi.org/10.1364/OL.33.002815	no
04	Dispersion encoded full range frequency domain optical coherence tomography	B. Hofer, B. Považay, B. Hermann, A. Unterhuber, G. Matz, W. Drexler	Opt. Express	17(1)	The Optical Society of America (OSA)	Washing-ton, DC	2009	7-24	http://dx.doi.org/10.1364/OE.17.000007	yes

05	Impact of enhanced resolution, speed and penetration on three-dimensional retinal optical coherence tomography	B. Považay, B. Hofer, C. Torti, B. Hermann, A.R. Tumlinson, M. Esmaeelpour, C.A. Egan, A.C. Bird, W. Drexler	Opt. Express	17(5)	The Optical Society of America (OSA)	Washing-ton, DC	2009	4134-4150	http://dx.doi.org/10.1364/OE.17.004134	yes
06	Three-dimensional polarization sensitive OCT imaging and interactive display of the human retina	E. Götzinger, M. Pircher, B. Baumann, C. Ahlers, W. Geitzenauer, U. Schmidt-Erfurth, C.K. Hitzenberger	Opt. Express	17(5)	The Optical Society of America (OSA)	Washing-ton, DC	2009	4151-4165	http://dx.doi.org/10.1364/OE.17.004151	yes
07	Ultra-high-speed volumetric tomography of human retinal blood flow	T. Schmoll, C. Kolbitsch, R.A. Leitgeb	Opt. Express	17(5)	The Optical Society of America (OSA)	Washing-ton, DC	2009	4166-4176	http://dx.doi.org/10.1364/OE.17.004166	yes
08	Subharmonic Fourier domain mode locking	C.M. Eigenwillig, W. Wieser, B.R. Biedermann, R. Huber	Opt. Letters	34(6)	The Optical Society of America (OSA)	Washing-ton, DC	2009	725-727	http://dx.doi.org/10.1364/OL.34.000725	no
09	Wide-field optical coherence tomography of the choroid in vivo	B. Považay, B. Hermann, B. Hofer, V. Kajic, E. Simpson, T. Bridgford, W. Drexler	Invest. Ophthalmol. Vis. Sci.	50(4)	Biomedi-cal Imaging Group, School of Opto-metry and Vision Sciences, Cardiff University	Cardiff, U.K.	2009	1856-1863	http://dx.doi.org/10.1167/iovs.08-2869	yes

10	Spectroscopic measurements with dispersion encoded full range frequency domain optical coherence tomography in single- and multilayered non-scattering phantoms	B. Hermann, B. Hofer, C. Meier C, W. Drexler	Opt. Express	17(26)	Optical Society of America	Washington, DC, USA	2009	24162-24174	http://dx.doi.org/10.1364/OE.17.024162	yes
11	Adaptive optics optical coherence tomography at 120,000 depth scans/s for non-invasive cellular phenotyping of the living human retina	C. Torti, B. Považay, B. Hofer, A. Unterhuber, J. Carroll, P.K. Ahnelt, W. Drexler	Opt. Express	17(22)	Optical Society of America	Washington, DC, USA	2009	19382-19400	http://dx.doi.org/10.1364/OE.17.019382	yes
12	Comparison of UHR-OCT versus Stratus-OCT for definition of early retinal changes after intravitreal Bevacizumab (Avastin) application in patients with AMD	F. Zeiler, B. Považay, C. Glittenberg, B. Hermann, S. Hagen, S. Lie, W. Drexler, S. Binder	Spektrum der Augen-heilkunde	23(1)	SPRINGER	NEW YORK, USA	2009	30-35	http://dx.doi.org/10.1007/s00717-009-0313-1	no
13	Three- and four-dimensional visualization of cell migration using optical coherence tomography	S.M. Rey, B. Považay, B. Hofer, A. Unterhuber, B. Hermann, A. Harwood, W. Drexler	J Bio-photonics	2(6-7)	WILEY-VCH Verlag GmbH & Co. KGaA	Weinheim, Germany	2009	370-379	http://dx.doi.org/10.1002/jbio.200910027	yes

14	Techniques for extraction of depth-resolved in vivo human retinal intrinsic optical signals with optical coherence tomography	A.R. Tumlinson, B. Hermann, B. Hofer, B. Považay, T.H. Margrain, A.M. Binns, W. Drexler	Jpn. J. Ophthalmol.	53(4)	SPRINGER TOKYO	Tokyo, Japan	2009	315-326	http://dx.doi.org/10.1007/s10384-009-0684-5	no
15	High-resolution ocular imaging: combining advanced optics and microtechnology	M.F. Cordeiro, R. Nickells, W. Drexler, T. Borrás, R. Ritch	Opht-halmic Surg Lasers Imaging	40	SLACK INC	THOROFARE, USA	2009	480-488	http://dx.doi.org/10.3928/15428877-20090901-07	no
16	Clinical optical coherence tomography combined with multiphoton tomography of patients with skin diseases	K. König, M. Speicher, R. Bückle, J. Reckfort, G. McKenzie, J. Welzel, M.J. Koehler, P. Elsner, M. Kaatz	J. Bio-photonics	2(6-7)	WILEY-BLACK-WELL	Malden, USA	2009	389-397	http://dx.doi.org/10.1002/jbio.200910013	no
17	Dispersion, coherence and noise of Fourier domain mode locked lasers	B.R. Biedermann, W. Wieser, C. M. Eigenwillig, T. Klein, Robert Huber	Opt. Express	17(12)	Optical Society of America	Washington, DC	2009	9947-9961	http://dx.doi.org/10.1364/OE.17.009947	yes
18	Nonlinear optical frequency conversion of an amplified Fourier Domain Mode Locked (FDML) laser	R. Leonhardt, B.R. Biedermann, W. Wieser, R. Huber	Opt. Express	17(19)	Optical Society of America	Washington, DC, USA	2009	16801-16808	http://dx.doi.org/10.1364/OE.17.016801	yes
19	A 75 MHz Light Source for Femtosecond Stimulated Raman Microscopy	E. Ploetz, B. Marx, T. Klein, R. Huber, P. Gilch	Opt. Express	17(21)	Optical Society of America	Washington, DC, USA	2009	18612-18620	http://dx.doi.org/10.1364/OE.17.018612	yes

20	Wavelength swept amplified spontaneous emission source	C.M. Eigenwillig, B.R. Biedermann, W. Wieser, R. Huber	Opt. Express	17(21)	Optical Society of America	Washington, DC, USA	2009	18794-18807	http://dx.doi.org/10.1364/OE.17.018794	yes
21	Ultra-rapid dispersion measurement in optical fibers	W. Wieser, B.R. Biedermann, T. Klein, C.M. Eigenwillig, R. Huber	Opt. Express	17(25)	Optical Society of America	Washington, DC, USA	2009	22871-22878	http://dx.doi.org/10.1364/OE.17.022871	yes
22	A theoretical description of Fourier domain mode locked lasers	C. Jirauschek, B. Biedermann, R. Huber	Opt. Express	17(26)	Optical Society of America	Washington, DC, USA	2009	24013-24019	http://dx.doi.org/10.1364/OE.17.024013	yes
23	Recent developments in Fourier Domain Mode Locked lasers for optical coherence tomography: Imaging at 1310 nm vs. 1550 nm wavelength	B.R. Biedermann, W. Wieser, C.M. Eigenwillig, R. Huber	J. Bio-photonics	2(6-7)	WILEY-V C H VERLAG GMBH	Weinheim, Germany	2009	357-363	http://dx.doi.org/10.1002/jbio.200910028	no
24	Polarization maintaining fiber based ultra-high resolution spectral domain polarization sensitive optical coherence tomography	E. Götzinger, B. Baumann, M. Pircher, C.K. Hitzenberger	Opt. Express	17(25)	Optical Society of America	Washington, DC, USA	2009	22704-22717	http://dx.doi.org/10.1364/OE.17.022704	yes
25	Histogram-based filtering for quantitative 3D retinal angiography	C. Kolbitsch, T. Schmoll, R.A. Leitgeb	J. Bio-photonics	2(6-7)	WILEY-V C H VERLAG GMBH	Weinheim, Germany	2009	416-425	http://dx.doi.org/10.1002/jbio.200910026	no

26	Single-camera polarization-sensitive spectral domain OCT by spatial frequency encoding	T. Schmoll, E. Götzinger, M. Pircher, C.K. Hitzenberger, R.A. Leitgeb	Opt. Lett.	35(2)	Optical Society of America	Washington, DC, USA	2009	241-243	http://dx.doi.org/10.1364/OL.35.000241	no
27	Imaging of the retinal pigment epithelium in age-related macular degeneration using polarization sensitive optical coherence tomography	C. Ahlers, E. Götzinger, M. Pircher, I. Golbaz, F. Prager, C. Schütze, B. Baumann, C.K. Hitzenberger, U. Schmidt-Erfurth	Invest. Ophthal-mol. Vis. Sci.	51(4)	ASSOC RESEARCH VISION OPHTHALMOLOGY INC	Rockville, USA	2009	2149-2157	http://dx.doi.org/10.1167/iovs.09-3817	yes
28	Optical coherence tomography with online visualization of more than seven rendered volumes per second	J. Probst, D. Hillmann, E. Lankenau, C. Winter, S. Oelckers, P. Koch, and G. Hüttmann	J. Biomed. Opt.	15(2)	SPIE (**The International Society for Optics and Photonics**)	Bellingham, Washington, and Cardiff, Wales, U.K.	2010	026014	http://dx.doi.org/10.1117/1.3314898	no
29	Slit-lamp-adapted fourier-domain OCT for anterior and posterior segments: preliminary results and comparison to time-domain OCT	M. Mueller, C. Schulz-Wackerbarth, P. Steven, E. Lankenau, T. Bonin, H. Mueller, A. Brueggemann, R. Birngruber, S. Grisanti, and G. Hüttmann	Curr. Eye Res.	35(8)	Informa Healthcare	New York, NY	2010	722-732	http://dx.doi.org/10.3109/02713683.2010.481069	no

30	Optical coherence tomography allows for the reliable identification of laryngeal epithelial dysplasia and for precise biopsy: A clinicopathological study of 61 patients undergoing microlaryngoscopy	T. Just, E. Lankenau, F. Prall, G. Hüttmann, H. W. Pau, and K. Sommer	Laryngo-scope	120(10)	Wiley-Blackwell	Oxford, UK; Hoboken, NJ	2010	1964-1970	http://dx.doi.org/10.1002/lary.21057	no
31	In vivo Fourier-domain full-field OCT of the human retina with 1.5 million A-lines/s	T. Bonin, G. Franke, M. Hagen-Eggert, P. Koch, and G. Huttmann	Opt. Lett.	35(20)	The Optical Society of America (OSA)	Washing-ton, DC	2010	3432-3434	http://dx.doi.org/10.1364/OL.35.003432	no
32	Segmentation and quantification of retinal lesions in age-related macular degeneration using polarization-sensitive optical coherence tomography	B. Baumann, E. Götzinger, M. Pircher, H. Sattmann, C. Schütze, F. Schlanitz, C. Ahlers, U. Schmidt-Erfurth, C.K. Hitzenberger	J. Biomed. Opt.	15(6)	SPIE (The International Society for Optics and Photonics)	Bellingham, Washington, and Cardiff, Wales, U.K.	2010	061704	http://dx.doi.org/10.1117/1.3499420	yes
33	Stable absolute flow estimation with Doppler OCT based on virtual circumpapillary scans	Amardeep S. G. Singh, Christoph Kolbitsch, Tilman Schmoll, and Rainer A. Leitgeb	Biomed. Opt. Express	1(4)	The Optical Society of America (OSA)	Washing-ton, DC	2010	1047-1059	http://dx.doi.org/10.1364/BOE.1.001047	yes

34	High sensitivity phase mapping with parallel Fourier domain optical coherence tomography at 512 000 A-scan/s	Branislav Grajciar, Yves Lehareinger, Adolf F. Fercher, and Rainer A. Leitgeb	Opt. Express	18(21)	The Optical Society of America (OSA)	Washing-ton, DC	2010	21841-21850	http://dx.doi.org/10.1364/OE.18.021841	yes
35	In vivo functional retinal optical coherence tomography	Tilman Schmoll, Christoph Kolbitsch, Rainer A.Leitgeb	J. Biomed. Opt.	15(4)	SPIE (The International Society for Optics and Photonics)	Bellingham, Washington, and Cardiff, Wales, U.K.	2010	041513	http://dx.doi.org/10.1117/1.3463008	yes
36	Scan-free optical correlation techniques: history and applications to optical coherence tomography	Luc Froehly and Rainer Leitgeb	J. Opt.	12(8)	Institute of Physics (IOP) Publishing Ltd.	Bristol, U.K., Philadelphia, USA	2010	084001	http://dx.doi.org/10.1088/2040-8978/12/8/084001	no
37	Fourier domain mode-locked swept source at 1050 nm based on a tapered amplifier	S. Marschall, T. Klein, W. Wieser, B. R. Biedermann, K. Hsu, K. P. Hansen, B. Sumpf, K. Hasler, G. Erbert, O. B. Jensen, C. Pedersen, R. Huber, P. E. Andersen	Opt. Express	18(15)	The Optical Society of America (OSA)	Washing-ton, DC	2010	15820-15831	http://dx.doi.org/10.1364/OE.18.015820	yes

38	Multi-Megahertz OCT: High quality 3D imaging at 20 million A-scans and 4.5 GVoxels per second	W. Wieser, B. R. Biedermann, T. Klein, C. M. Eigenwillig, and R. Huber	Opt. Express	18(14)	The Optical Society of America (OSA)	Washing-ton, DC	2010	14685-14704	http://dx.doi.org/10.1364/OE.18.014685	yes
39	Wavelength swept amplified spontaneous emission source for high speed retinal optical coherence tomography at 1060 nm	C. M. Eigenwillig, T. Klein, W. Wieser, B. R. Biedermann, and R. Huber	J. Bio-photonics	4(7-8)	Wiley-Blackwell	Oxford, UK; Hoboken, NJ	2010	552-558	http://dx.doi.org/10.1002/jbio.201000104	no
40	Direct measurement of the instantaneous linewidth of rapidly wavelength-swept lasers	B. R. Biedermann, W. Wieser, C. M. Eigenwillig, T. Klein, and R. Huber	Opt. Lett.	35(22)	The Optical Society of America (OSA)	Washing-ton, DC	2010	3733-3735	http://dx.doi.org/10.1364/OL.35.003733	no
41	Three-Dimensional 1060-nm OCT: Choroidal Thickness Maps in Normal Subjects and Improved Posterior Segment Visualization in Cataract Patients	M. Esmaeelpour, B. Povazay, B. Hermann, B. Hofer, V. Kajic, K. Kapoor, N.J.L. Sheen, R.V. North, W. Drexler	Invest. Ophthal-mol. Vis. Sci. (IOVS)	51(10)	Association for Research in Vision and Ophthalmology (ARVO)	Stanford, USA	2010	5260-5266	http://dx.doi.org/10.1167/iovs.10-5196	yes
42	Robust segmentation of intraretinal layers in the normal human fovea using a novel statistical model based on texture and shape analysis	V. Kajic, B. Povazay, B. Hermann, B. Hofer, D. Marshall, P.L. Rosin, W. Drexler	Opt. Express	18(14)	The Optical Society of America (OSA)	Washing-ton, DC	2010	14730-14744	http://dx.doi.org/10.1364/OE.18.014730	yes

43	Highly reproducible swept-source, dispersion-encoded full-range biometry and imaging of the mouse eye	L. Wang, B. Hofer, Y. Chen, J.A. Guggenheim, W. Drexler, B. Povazay	J. Biomed. Opt.	15(4)	SPIE (The International Society for Optics and Photonics)	Bellingham, Washington, and Cardiff, Wales, U.K.	2010	046004	http://dx.doi.org/10.1117/1.3463480	no
44	Multispectral in vivo three-dimensional optical coherence tomography of human skin	A. Alex, B. Povazay, B Hofer, S. Popov, C. Glittenberg, S. Binder, W. Drexler	J. Biomed. Opt.	15(2)	SPIE (The International Society for Optics and Photonics)	Bellingham, Washington, and Cardiff, Wales, U.K.	2010	026025	http://dx.doi.org/10.1117/1.3400665	no
45	In Vivo, In Situ Imaging of Microneedle Insertion into the Skin of Human Volunteers Using Optical Coherence Tomography	S. Coulman, J. Birchall, A. Alex, M. Pearton, B. Hofer, C. O'Mahony, W. Drexler, B. Povazay	Pharma-ceutical Research	28(1)	American Association of Pharmaceutical Scientists (AAPS); Springer	Arlington, VA, USA; Heidelberg – New York	2011	66-81	http://dx.doi.org/10.1007/s11095-010-0167-x	no
46	Artefact reduction for cell migration visualization using spectral domain optical coherence tomography	B. Hofer, B. Povazay, B. Hermann, S.M. Rey, V. Kajic, A. Tumlinson, K. Powell, G. Matz, W. Drexler	J. Biophotonics	4(5)	Wiley-VCH	Weinheim	2011	355-367	http://dx.doi.org/10.1002/jbio.201000109	yes

47	Visualization of microvasculature by dual-beam phase-resolved Doppler optical coherence tomography	S. Zotter, M. Pircher, T. Torzicky, M. Bonesi, E. Götzinger, R.A. Leitgeb, C.K. Hitzenberger	Opt. Express	19(2)	The Optical Society of America (OSA)	Washing-ton, DC	2011	1217-1227	http://dx.doi.org/10.1364/OE.19.001217	yes
48	Retinal optical coherence tomography: past, present and the future	W. Geitzenauer, C.K. Hitzenberger, U.M. Schmidt-Erfurth	Br. J. Ophthal-mol.	95(2)	British Medical Journal (BMJ)	London, UK	2011	171-177	http://dx.doi.org/10.1136/bjo.2010.182170	no
49	Megahertz OCT for ultrawide-field retinal imaging with a 1050nm Fourier domain mode-locked laser	T. Klein, W. Wieser, C. M. Eigenwillig, B. R. Biedermann, and R. Huber	Opt. Express	19(4)	The Optical Society of America (OSA)	Washing-ton, DC	2011	3044-3062	http://dx.doi.org/10.1364/OE.19.003044	yes
50	Frequency-doubled DBR-tapered diode laser for direct pumping of Ti:sapphire lasers generating sub-20 fs pulses	Müller, O. B. Jensen, A. Unterhuber, T. Le, A. Stingl, K.-H. Hasler, B. Sumpf, G. Erbert, P. E. Andersen, and P. M. Petersen	Opt. Express	19(13)	Optical Society of America	Washington, DC, USA	2011	12156-12163	http://dx.doi.org/10.1364/OE.19.012156	yes
51	Extended coherence length Fourier domain mode locked lasers at 1310 nm	D.C. Adler, W. Wieser, F. Trepanier, J.M. Schmitt, and R.A. Huber	Opt. Express	19(21)	Optical Society of America	Washington, DC, USA	2011	20930-20939	http://dx.doi.org/10.1364/OE.19.020930	yes

52	Extended focus high-speed swept source OCT with self-reconstructive illumination	C. Blatter, B. Grajciar, C.M. Eigenwillig, W. Wieser, B.R. Biedermann, R. Huber, and R.A. Leitgeb	Opt. Express	19(13)	Optical Society of America	Washington, DC, USA	2011	12141-12155	http://dx.doi.org/10.1364/OE.19.012141	yes
53	Instantaneous lineshape analysis of Fourier domain mode-locked lasers	S. Todor, B. Biedermann, W. Wieser, R. Huber, and C. Jirauschek	Opt. Express	19(9)	Optical Society of America	Washington, DC, USA	2011	8802-8807	http://dx.doi.org/10.1364/OE.19.008802	yes
54	Speckle noise reduction in high speed polarization sensitive spectral domain optical coherence tomography	E. Götzinger, M. Pircher, B. Baumann, T. Schmoll, H. Sattmann, R.A. Leitgeb, C.K. Hitzenberger	Opt. Express	19(15)	Optical Society of America	Washington, DC	2011	14568-14584	http://dx.doi.org/10.1364/OE.19.014568	yes
55	Polarization Sensitive Optical Coherence Tomography in the Human Eye	M. Pircher, C.K. Hitzenberger, U. Schmidt-Erfurth	Prog. Ret. Eye Res.	30(6)	PERGA-MON-ELSEVIER SCIENCE LTD	Oxford, England	2011	431-451	http://www.sciencedirect.com/science/article/pii/S1350946211000395	yes
56	Heritability of ocular component dimensions in mice phenotyped using depth-enhanced swept source optical coherence tomography	L. Wang, Ling, B. Povazay, Y.P. Chen, B. Hofer, W. Drexler, J.A. Guggenheim	Exp. Eye Res.	93(4)	ACADEMIC PRESS LTD-ELSEVIER SCIENCE LTD	London, England	2011	25-33	http://dx.doi.org/10.1016/j.exer.2011.06.008	no

57	Multimodal photoacoustic and optical coherence tomography scanner using an all optical detection scheme for 3D morphological skin imaging	E. Zhang, B. Povazay, J. Laufer, A. Alex, B. Hofer, B. Pedley, C. Glittenberg, C. Treeby, B. Cox, P. Beard, W. Drexler	Biomed. Opt. Express	2(8)	Optical Society of America	Washington, DC	2011	2202-2215	http://dx.doi.org/10.1364/BOE.2.002202	yes
58	Selective breeding for susceptibility to myopia reveals a gene-environment interaction	Y.P. Chen, P.M. Hocking, L. Wang, B. Povazay, A. Prashar, C.H. To, J.T. Erichsen, M. Feldkaemper, B. Hofer, W. Drexler, F. Schaeffel, J.A. Guggenheim	Invest. Ophthal-mol. Vis.	52(7)	ASSOC RESEARCH VISION OPHTHALMOLOGY INC	Rockville, USA	2011	4003-4011	http://dx.doi.org/10.1167/iovs.10-7044	yes
59	Mapping choroidal and retinal thickness variation in Type 2 diabetes using 3D-1060nm-OCT	M. Esmaeelpour, B. Povazay, B. Hermann, B. Hofer, V. Kajic, S. Hale, R.V. North, W. Drexler, N.J. Sheen	Invest. Ophthal-mol. Vis. Sci.	52(8)	ASSOC RESEARCH VISION OPHTHALMOLOGY INC	Rockville, USA	2011	5311-5316	http://dx.doi.org/10.1167/iovs.10-6875	yes
60	Pre-treatment choroidal thickness is not predictive of susceptibility to form-deprivation myopia in chickens	J.A. Guggenheim, Y.P. Chen, E. Yip, H. Hayet, V. Druel, L. Wang, J.T. Erichsen, A.R. Tumlinson, B. Povazay, W. Drexler, P.M. Hocking	Ophthal-mic Physiol. Opt.	31(5)	WILEY-BLACK-WELL	Malden, USA	2011	516-528	http://dx.doi.org/10.1111/j.1475-1313.2011.00827.x	no

61	In vivo response of GsdmA3Dfl/+ mice to topically applied anti-psoriatic agents: effects on epidermal thickness, as determined by optical coherence tomography and H&E staining	M.H. Zulfakar, A. Alex, B. Povazay, W. Drexler, C.P. Thomas, R.M. Porter, C.M. Heard	Exp. Dermatol.	20(3)	John Wiley & Sons A/S.	Malden, USA	2011	269-272	http://dx.doi.org/10.1111/j.1600-0625.2010.01233.x	yes
62	High-resolution phase mapping with parallel Fourier domain optical coherence microscopy for dispersion contrast imaging	B. Grajciar, M. Herdin, C. Blatter, M. Groeschl and R. A. Leitgeb	Photonics Letters of Poland	3(4)	Photonics Society of Poland	Warsaw, Poland	2011	135-137	http://dx.doi.org/10.4302/plp.2011.4.03	yes
63	Extended focus high-speed swept source OCT with self-reconstructive illumination	C. Blatter, B. Grajciar, C. M. Eigenwillig, W. Wieser, B. R. Biedermann, R. Huber, and R. A. Leitgeb	Optics Express	19(13)	Optical Society of America	Washington, DC, USA	2011	12141-12155	http://dx.doi.org/10.1364/OE.19.012141	yes
64	Imaging of the parafoveal capillary network and its integrity analysis using fractal dimension	T. Schmoll, A. S. G. Singh, C. Blatter, S. Schriefl, C. Ahlers, U. Schmidt-Erfurth, and R. A. Leitgeb	Biomedical Optics Express	2(5)	Optical Society of America	Washington, DC, USA	2011	1159-1168	http://dx.doi.org/10.1364/BOE.2.001159	yes
65	Segmentation of Doppler optical coherence tomography signatures using a support-vector machine	Singh, A.S.G., T. Schmoll, and R.A. Leitgeb	Biomed. Opt. Express	2(5)	Optical Society of America	Washington, DC, USA	2011	1328-1339	http://dx.doi.org/10.1364/BOE.2.001328	yes

66	Holoscopy - holographic optical coherence tomography	D. Hillmann, C. Lührs, T. Bonin, P. Koch, and G. Hüttmann	Optics Letters	36(13)	Optical Society of America	Washington, DC, USA	2011	2390-2392	http://dx.doi.org/10.1364/OL.36.002390	no
67	Comparison of broadband and ultrabroadband pulses at MHz and GHz pulse-repetition rates for nonlinear femtosecond-laser scanning microscopy	H. Studier, H.G. Breunig, K. König	J. Bio-photonics	4(1-2)	WILEY-VCH Verlag GmbH & Co. KG	Weinheim, Germany	2011	1-8	http://dx.doi.org/10.1002/jbio.201000010	no
68	Investigation of the impact of water absorption on retinal OCT imaging in the 1060 nm range	S. Marschall, C. Pedersen, and P. E. Andersen	Biomed. Opt. Express	3(7)	Optical Society of America	Washington, DC, USA	2012	1620-1631	http://dx.doi.org/10.1364/BOE.3.001620	yes
69	Ultrahigh-speed non-invasive widefield angiography	C. Blatter, T. Klein, B. Grajciar, T. Schmoll, W. Wieser, R. Andre, R. Huber, R.A. Leitgeb	J. Biomed. Opt.	17(7)	SPIE-	Bellingham, USA	2012		http://dx.doi.org/10.1117/1.JBO.17.7.070505	yes
70	Chromatic polarization effects of swept waveforms in FDML lasers and fiber spools	W. Wieser, G. Palte, C.M. Eigenwillig, B.R. Biedermann, T. Pfeiffer, and R. Huber	Opt. Express	20(9)	Optical Society of America	Washington, DC, USA	2012	9819-9832	http://dx.doi.org/10.1364/OE.20.009819	yes
71	Balance of physical effects causing stationary operation of Fourier domain mode-locked lasers	S. Todor, B. Biedermann, R. Huber, and C. Jirauschek	JOSA B	29(4)	Optical Society of America	Washington, DC, USA	2012	656-664	http://dx.doi.org/10.1364/JOSAB.29.000656	no

72	Automated measurement of choroidal thickness in the human eye by polarization sensitive optical coherence tomography	T. Torzicky, M. Pircher, S. Zotter, M. Bonesi, E. Götzinger, C.K. Hitzenberger	Opt. Express	20(7)	Optical Society of America	Washington, DC, USA	2012	7564-7574	http://dx.doi.org/10.1364/OE.20.007564	yes
73	High speed retinal imaging with PS-OCT at 1040nm	T. Torzicky, M. Pircher, S. Zotter, M. Bonesi, E. Götzinger, C.K. Hitzenberger	Optom. Vis. Sci.	89(5)	American Academy of Optometry	Orlando. FL, USA	2012	585-592	http://journals.lww.com/optvissci/Abstract/2012/05000/High_Speed_Retinal_Imaging_with.9.aspx	no
74	Polarization sensitive optical coherence tomography of melanin provides intrinsic contrast based on depolarization	B. Baumann, S.O. Baumann, T. Konegger, M. Pircher, E. Götzinger, F. Schlanitz, C. Schütze, H. Sattmann, M. Litschauer, U. Schmidt-Erfurth, C.K. Hitzenberger	Biomed. Opt. Express	3(7)	Optical Society of America	Washington, DC, USA	2012	1670-1683	http://dx.doi.org/10.1364/BOE.3.001670	yes
75	High-speed polarization sensitive optical coherence tomography scan engine based on Fourier domain mode locked laser	M. Bonesi, H. Sattmann, T. Torzicky, S. Zotter, B. Baumann, M. Pircher, E. Götzinger, C. Eigenwillig, W. Wieser, R. Huber, C.K. Hitzenberger	Biomed. Opt. Express	3(11)	Optical Society of America	Washington, DC, USA	2012	2978-3000	http://dx.doi.org/10.1364/BOE.3.002987	yes

76	Automated choroidal segmentation of 1060 nm OCT in healthy and pathologic eyes using a statistical model	V. Kajic, M. Esmaeelpour, B. Povazay, D. Marshall, P.L. Rosin, W. Drexler	Biomed. Opt. Express	3(1)	Optical Society of America	Washington, DC, USA	2012	86-103	http://dx.doi.org/10.1364/BOE.3.000086	yes
77	Three-dimensional multiphoton/optical coherence tomography for diagnostic applications in dermatology	A. Alex, J. Weingast, M. Weinigel, M. Kellner-Höfer, R. Nemecek, M. Binder, H. Pehamberger, K. König, W.Drexler	J. Bio-photonics		WILEY-VCH Verlag GmbH & Co. KG	Weinheim, Germany	2012		**http://dx.doi.org/10.1002/jbio.201200085**	no
78	Retinal polarization sensitive optical coherence tomography at 1060 nm with 350 kHz A-scan rate using an FDML laser	T. Torzicky, S. Marschall, M. Pircher , B. Baumann, M. Bonesi S. Zotter, E. Götzinger, W. Trasischker, T. Klein, W. Wieser, B. Biedermann, R. Huber, P. Andersen, C.K. Hitzenberger	J. Biomed. Opt.				2012			no
79	Common approach for compensation of axial motion artifacts in swept-source OCT and dispersion in Fourier-domain OCT	D. Hillmann, T. Bonin, C. Lührs, G. Franke, M. Hagen-Eggert, P. Koch, and G. Hüttmann	Optics Express	20(23)	Optical Society of America	Washington, DC, USA	2012	6761-6776	http://dx.doi.org/10.1364/OE.20.025357	yes

80	Efficient Holoscopy image reconstruction	D. Hillmann, G. Franke, C. Lührs, P. Koch, and G. Hüttmann	Optics Express	20(19)	Optical Society of America	Washington, DC, USA	2012	21247-21263	http://dx.doi.org/10.1364/OE.20.021247	yes
81	In situ structural and microangiographic assessment of human skin lesions with high-speed OCT	C. Blatter, J. Weingast, A. Alex, B. Grajciar, W. Wieser, W. Drexler, R. Huber, and R. A. Leitgeb	Biomedical Optics Express	3(10)	Optical Society of America	Washington, DC, USA	2012	2636-2646	http://dx.doi.org/10.1364/BOE.3.002636	yes
82	Intrasweep phase-sensitive optical coherence tomography for noncontact optical photoacoustic imaging	C. Blatter, B. Grajciar, P. Zou, W. Wieser, A. J. Verhoef, R. Huber, and R. A. Leitgeb	Optics Letters	37(21)	The Optical Society		2012	4368-4370	http://dx.doi.org/10.1364/OL.37.004368	no
83	Lateral shearing digital holographic imaging of small biological specimens	A. S. G. Singh, A. Anand, R. A. Leitgeb, and B. Javidi	Optics Express	20(21)	Optical Society of America	Washington, DC, USA	2012	23617-23622	http://dx.doi.org/10.1364/OE.20.023617	yes
84	In-line reference-delayed digital holography using a low-coherence light source	A. S. G. Singh, T. Schmoll, B. Javidi and R. A. Leitgeb	Optics Letters	37(13)	Optical Society of America	Washington, DC, USA	2012	2631-2633	http://dx.doi.org/10.1364/OL.37.002631	no
85	Heart-beat-phase-coherent Doppler optical coherence tomography for measuring pulsatile ocular blood flow	T. Schmoll and R. A. Leitgeb	Journal of Biophotonics		WILEY-VCH Verlag GmbH & Co. KG	Weinheim, Deutschland	2012		http://dx.doi.org/10.1002/jbio.201200029	no
86	Precise Thickness Measurements of Bowman's Layer, Epithelium, and Tear Film	T. Schmoll, A. Unterhuber, C. Kolbitsch, T. Le, A. Stingl and R. Leitgeb	Optometry and Vision Science	89(5)	American Academy of Opto-metry		2012	E795-E802	http://dx.doi.org/10.1097/OPX.0b013e3182504346	no

87	Extended coherence length megahertz FDML and its application for anterior segment imaging	Wolfgang Wieser, Thomas Klein, Desmond C. Adler, Francois Trépanier, Christoph M. Eigenwillig, Sebastian Karpf, Joseph M. Schmitt, and Robert Huber	Biomedical Optics Express	3(10)	Optical Society of America	Washington, DC, USA	2012	2647-2657	http://dx.doi.org/10.1364/BOE.3.002636	yes

Section B (confidential)

Partners benefits and Exploitation Plans – DTU

	Description
Knowledge gained through the FUN OCT project?	• Swept-sources, FDML sources • Two-photon tomography • Clinical applications of OCT in combination with functional extensions • Application for our compact green laser in Ti:sapphire pumping and related applications
Technology gained through the FUN OCT project?	• FDML sources • Green pump laser technology refined for Ti:sapphire application
Technology/Knowledge gained through FUN OCT that is used in your business/products or in your research? • please specify how/what	• Green pump laser technology
Has FUN OCT provided any insights/further research/development for the company/institution? • if so what?	• Green pump laser; • FUN OCT has opened a potential route to market for this proprietary technology
Has FUN OCT allowed you to enter new market sectors? • If so expand? • Please specify any new products that are resulting from FUN OCT	
Has FUN OCT allowed you to enter new research areas? • If so expand?	• Potentially the green laser will allow DTU to engage in other aspects of ultrafast lasers
What are your future plans for the technology/knowledge gained through FUN OCT?	Use the green laser for pumping Ti:sapphire in collaboration with SMEs FL and JL
Please indicate any new employees that have been recruited as a result of FUN OCT	N/A

Exploitation

Following the encouraging results obtained in the later stages of FUN OCT; the green laser successfully pumping a Ti:S and the resulting promising MT application (see publishable summary), the consortium launched a follow-up proposal OPTBIO within the call “HEALTH 2013.0-1: Boosting the translation of health research projects' results into innovative applications for health.” This new consortium comprises DTU, MUW, JL and FL from the present consortium, whilst adding a business developer as the fifth partner (constraint of a maximum of five partners in the targeted call).

A key element is that the effort undertaken in OPTBIO enables innovative imaging performance whilst drastically reducing cost and size of the system; hence, OPTBIO strongly improves market opportunities for the participating SMEs and it even opens entirely new market segments for the SMEs. Moreover, by introducing a virtual company concept**,** OPTBIO represents a uniform R&D plan as well as market access strategy aiming at attracting additional investments and industrial partners for the development beyond the initial project duration, thereby enabling addressing new market segments. Thus, OPTBIO technology can be transferred to or licensed to partners and companies outside the consortium beyond the EC initial investment (project duration).

Partners benefits and Exploitation Plans – BMO

	Description
Knowledge gained through the FUN OCT project?	Extensive knowledge in functional extension of OCT (PS-, Doppler, and absorption contrast)
Technology gained through the FUN OCT project?	Technology for swept-source OCT and Fourier domain mode-locking lasers
Technology/Knowledge gained through FUN OCT that is used in your business/products or in your research? • please specify how/what	Technology for swept-source OCT and Fourier domain mode-locking lasers
Has FUN OCT provided any insights/further research/development for the company/institution? • if so what?	Yes, FUN OCT started the development of new OCT probes and FF-OCT / holoscopy. Funding for new projects was acquired.
Has FUN OCT allowed you to enter new market sectors? • If so expand? • Please specify any new products that are resulting from FUN OCT	N.A.
Has FUN OCT allowed you to enter new research areas? • If so expand?	Yes we started research on digital holography and holographic OCT (holoscopy)
What are your future plans for the technology/knowledge gained through FUN OCT?	Commercialization of the developed probe technology with endoscope manufactures
Please indicate any new employees that have been recruited as a result of FUN OCT	No.

Partners benefits and Exploitation Plans – LMU

	Description
Knowledge gained through the FUN OCT project?	Good image quality is possible at OCT scan rates in excess of MHz. Ultrawidefield imaging of the human retinal with a dense isotropic sampling pattern offers many advantages for improved diagnosis.
Technology gained through the FUN OCT project?	Operational experimental MHz OCT system at 1300nm. Operational experimental MHz OCT system at 1050nm for retinal ultrawidefield imaging.
Technology/Knowledge gained through FUN OCT that is used in your business/products or in your research? • please specify how/what	
Has FUN OCT provided any insights/further research/development for the company/institution? • if so what?	
Has FUN OCT allowed you to enter new market sectors? • If so expand? • Please specify any new products that are resulting from FUN OCT	
Has FUN OCT allowed you to enter new research areas? • If so expand?	
What are your future plans for the technology/knowledge gained through FUN OCT?	
Please indicate any new employees that have been recruited as a result of FUN OCT	

Partners benefits and Exploitation Plans – MUW-A

	Description
Knowledge gained through the FUN OCT project?	Retinal lesions associated with the RPE can be segmented by PS-OCT. Fiber optic PS-OCT with a single input state is possible with the use of PM fibers.
Technology gained through the FUN OCT project?	FDML laser technology at 1300 and 1050 nm. Buffer stage for 1300 nm FDML laser.
Technology/Knowledge gained through FUN OCT that is used in your business/products or in your research? • please specify how/what	Segmentation of retinal layers and lesions by PS-OCT is used in several ongoing clinical studys. E.g., segmentation of RPE, choroid, drusen, geographic atrophies.
Has FUN OCT provided any insights/further research/development for the company/institution? • if so what?	
Has FUN OCT allowed you to enter new market sectors? • If so expand? • Please specify any new products that are resulting from FUN OCT	na
Has FUN OCT allowed you to enter new research areas? • If so expand?	Small animal imaging: retinal PS-OCT in mouse and rat models of retinal diseases (glaucoma and AMD models)
What are your future plans for the technology/knowledge gained through FUN OCT?	Further use of retinal layers and lesion segmentation in clinical research.
Please indicate any new employees that have been recruited as a result of FUN OCT	na

Partners benefits and Exploitation Plans – MUW-B

	Description
Knowledge gained through the FUN OCT project?	
Technology gained through the FUN OCT project?	- High speed Laser technology
Technology/Knowledge gained through FUN OCT that is used in your business/products or in your research? • please specify how/what	-High speed Laser technology: this enabled key applications in dermatology and ophthalmology for highly sensitive visualization of vascular structures in skin as well as in the retina. Especially in the retina it is for the first time possible to perform wide field vascular imaging without any need for contrast agent administration, i.e. fully non-invasive.
Has FUN OCT provided any insights/further research/development for the company/institution? • if so what?	FUN-OCT allowed developing the methodology, and technology for both clinical Doppler OCT imaging as well as dermatologic imaging.
Has FUN OCT allowed you to enter new market sectors? • If so expand? • Please specify any new products that are resulting from FUN OCT	
Has FUN OCT allowed you to enter new research areas? • If so expand?	The speed of developed laser technology as well as the implemented high speed data acquisition hard- and software opened novel future directions for all optical photoacoustic sensing. Furthermore in the search for high resolution retinal imaging we combined principles of holography with optical coherence tomography. This stimulated research for digital control of focusing and aberration correction, that will be pursued in future research projects.
What are your future plans for the technology/knowledge gained through FUN OCT?	Start further clinical studies together with clinical collaborators in ophthalmology and dermatology based on the valuable knowledge about tissue blood flow. Exploit new imaging methodologies that are opened by the new laser technology available.
Please indicate any new employees that have been recruited as a result of FUN-OCT	

Partners benefits and Exploitation Plans – FL

	Description
Knowledge gained through the FUN OCT project?	This project gave FL the opportunity to decisively expand knowledge in technical advancements and market development for OCT, MPT and fast swept light sources.
Technology gained through the FUN OCT project?	Building very light, small and ultra-broadband Ti:S lasers with low pump threshold Extra-cavity dispersive mirrors that enable sub 20 fs laser pulses for MPT Development of very low loss dispersive mirrors that supports compact ultra-broadband Ti:S lasers equipped with small and cost-effective pump lasers.
Technology/Knowledge gained through FUN OCT that is used in your business/**products** or in your research? • please specify how/what	The novel low loss dispersive mirrors and the compact cavity design are applied to a new product (Integral CORE) that sets new standards in compactness of ultra-broadband Ti:S lasers.
Has FUN OCT provided any insights/further research/**development** for the company/institution? • if so what?	Pumping Ti:S lasers with low cost frequency doubled diode lasers is very appealing and remains a main topic for further R&D.
Has FUN OCT allowed you to enter **new market** sectors? • If so expand? • Please specify any new products that are resulting from FUN OCT	New market: OEM laser provider for biomedical photonic equipment manufacturers New products: - Integral CORE: smallest sub 10 fs laser of the world (http://www.femtolasers.com/fileadmin/documents/Leaflets/INTEGRAL_core.pdf) - Integral ELEMENT: versatile high power turn-key sub 10 fs laser for scientific applications (http://www.femtolasers.com/fileadmin/documents/Leaflets/INTEGRAL_element.pdf)
Has FUN OCT allowed you to enter **new research** areas? • If so expand?	Yes: Diode pumping of ultrafast lasers.
What are your **future plans** for the technology/knowledge gained through FUN OCT?	a) Improving methodology/technology to efficiently manufacture compact ultrafast lasers in high numbers (important for cost and spreading of biomedical imaging devices) b) Making the novel laser conforming to IEC requirements for a diagnostic and therapeutic laser device c) further developing diode pumped ultrafast lasers for the sake of cost and device maintenance
Please indicate any new employees that have been recruited as a result of FUN OCT	1 sales manager, 2 sales assistance, 3 laser engineers

Partners benefits and Exploitation Plans – JL

	Description
Knowledge gained through the FUN OCT project?	-Applicability of optical coherence microscopy (OCM) for multimodal imaging system -Test of new compact laser for imaging
Technology gained through the FUN OCT project?	
Technology/Knowledge gained through FUN OCT that is used in your business/products or in your research? • please specify how/what	Further test necessary for application of compact low-cost laser for imaging
Has FUN OCT provided any insights/further research/development for the company/institution? • if so what?	
Has FUN OCT allowed you to enter new market sectors? • If so expand? • Please specify any new products that are resulting from FUN OCT	Future less expensive systems could be attractive for broader community than current systems
Has FUN OCT allowed you to enter new research areas? • If so expand?	
What are your future plans for the technology/knowledge gained through FUN OCT?	Use new compact fs laser for imaging and replace bulky state-of the-art lasers
Please indicate any new employees that have been recruited as a result of FUN OCT	

Exploitation

For JENLAB the main exploitable result was the successfully application of the new compact low-cost fs laser for multiphoton imaging during the extension period of FUNOCT. JENLAB plans to offer a multiphoton imaging system which is uses a version of the FL core laser. Using this new laser, high quality multiphoton images of the distribution of skin fluorophores and collaged can be recorded at significant lower cost and volume than with currently used lasers provided by a US company. JenLab expects to be able significantly reduce production costs since the laser costs comprise more than one third of the whole imaging systems. This goes along with a reduction of volume, power consumption, noise and weight of the system. The cheaper more compact version will be more attractive for hospitals and research institutes for in vivo skin imaging and research. Currently, a widespread use of the clinical multiphoton imaging technique is hindered by the high price and technical complexity compared to current widespread low-tech procedures (i.e. visual inspection with naked eye or magnification glass). The price reduction will help to promote multiphoton imaging for early skin cancer diagnosis.

After successful completion of further tests as well as a successfully certification of the laser for medical imaging which will be perused in a future European project application (OPTBIO), JenLab expects to be able to offer a medical multiphoton imaging system at significantly reduced costs. With a realistic price reduction of several 10000 € JenLab expects to sell 10 systems during the 3-5 years after introduction of the imaging system. This will in turn also increase the awareness level inside the medical and cosmetic community which will further also promote selling in the later future.

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.			
Type of IP Rights: Patents, Trademarks, Registered designs, Utility models, etc.	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
Patent	A 1717/2011	MULTIFUNCTIONAL LASER DEVICE	Femtolasers Produktions GmbH
Patent	DE 10 2011 018 603	Verfahren zur optischen Tomographie	Medizinisches Laserzentrum Lübeck GmbH, Thorlabs GmbH, Universität zu Lübeck
Patent	WO2012034563 (A1)	Laser system with wavelength converter	Technical University of Denmark

TEMPLATE B2: OVERVIEW TABLE WITH EXPLOITABLE FOREGROUND					
Exploitable Foreground (description)	**Exploitable product(s) or measure(s)**	**Sector(s) of application**	**Timetable, commercial use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved**
Novel utra-compact and ultra-broadband Ti:S laser	Light source for ultrahigh-resolution & high-speed OCT. Light source for MPT & multimodal imaging.	1. biomedical imaging 2. industrial inspection 3. security screening	2012	Patent is applied	Beneficiary 8 (owner)
1. New OCT Probes	Endoscopy	1. Medical 2. Industrial inspection	2013 2013	A patent is planned for 2013	University Lübeck Germany
2. Handheld MT	Medical diagnosis	1. Medical	2013		University Lübeck Germany, Jenlab
WO2012034563 (A1)	Green pump laser	1. biomedical imaging 2. industrial inspection 3. security screening	2013/14	Additional patents underway	DTU (owner) can exploit in collaboration with JL and FL

Novel utra-compact and ultra-broadband Ti:S laser*:*

Its purpose

- A light source that is 5 times smaller, 5 times lighter at a half price of high-end Ti:S lasers used for high-speed and high-resolution OCT at 800 nm.

How the foreground might be exploited, when and by whom

- Product launch was beginning of 2012. It is the smallest sub 20 fs laser in the world commercially available. The novel laser has been elected as Prism Award Finalist (for the so-called “Photonics Oscar”) at the Photonics West Show 2013 in the Category of Life Sciences and Biophotonics.

IPR exploitable measures taken or intended

- Patent pending.

Further research necessary, if any

- At the moment three further development goals are defined crucial aiming at: A) speeding up the product manufacturing procedure of the novel ultra-compact laser (or targeting a mass production technology for dispersive mirror based ultra-broadband Ti:S lasers) B) developing a diode-laser based light source with partner DTU that replaces state-of-the-art expensive solid-state pump lasers, and C) developing a prototype that complies with compulsory CE-labeling (Particular requirements for basic safety and essential performance of surgical, cosmetic, therapeutic and diagnostic laser equipment). All further developments aim at a novel ultrafast laser that is low-cost, available in high numbers and readily applicable to medical applications.

Potential/expected impact (quantify where possible)

- The novel ultrafast laser is going to enable a revolutionary platform for biomedical applications like Multi-Photon Microscopy, OCT or gene therapy. It allows significant cost and size reduction which is indispensible for the acceptance of a new technology on the market. Other applications that gain benefit will be
  - Terahertz pulsed imaging (quality inspection, medical imaging)
  - THz spectroscopy (Security Screening & Detection)
  - OCT in non-medical applications (Non-destructive Testing)
  - Two-photon Polymerisation (Photonic crystals, Biomedical applications, Rapid prototyping)

- Expected sales of the novel ultra-compact and ultrafast laser

	Y 2012	Y 2013	Y 2014	Y 2015
MPT	0	5	25	50
OCT	3	15	25	75
THz	0	4	15	50
2-PP	0	1	5	25
Sum	3	25	70	200

Report on societal implications

A General Information *(completed automatically when **Grant Agreement number** is entered.*

Grant Agreement Number:	201880
Title of Project:	Functional Optical Coherence Tomography
Name and Title of Coordinator:	Peter E. Andersen, Research Prof.

B Ethics

1. Did you have ethicists or others with specific experience of ethical issues involved in the project?	**O** **X**	**Yes** **No**
2. Please indicate whether your project involved any of the following issues (tick box) :	***YES***	
INFORMED CONSENT		
• Did the project involve children?		
• Did the project involve patients or persons not able to give consent?		
• Did the project involve adult healthy volunteers?	X	
• Did the project involve Human Genetic Material?		
• Did the project involve Human biological samples?		
• Did the project involve Human data collection?		
RESEARCH ON HUMAN EMBRYO/FOETUS		
• Did the project involve Human Embryos?		
• Did the project involve Human Foetal Tissue / Cells?		
• Did the project involve Human Embryonic Stem Cells?		
PRIVACY		
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)		
• Did the project involve tracking the location or observation of people?		
RESEARCH ON ANIMALS		
• Did the project involve research on animals?		
• Were those animals transgenic small laboratory animals?		
• Were those animals transgenic farm animals?		
• Were those animals cloning farm animals?		
• Were those animals non-human primates?		
RESEARCH INVOLVING DEVELOPING COUNTRIES		
• Use of local resources (genetic, animal, plant etc)		
• Benefit to local community (capacity building ie access to healthcare, education etc)		
DUAL USE		
• Research having potential military / terrorist application		

C Workforce Statistics

3 Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator		1
Work package leader		8
Experienced researcher (i.e. PhD holders)	1	14

PhD Students	2	8
Other	1	4

4 How many additional researchers (in companies and universities) were recruited specifically for this project?	
Of which, indicate the number of men:	11
Of which, indicate the number of women:	2

D Gender Aspects

5	**Did you carry out specific Gender Equality Actions under the project** ?	X ○	Yes No

6 Which of the following actions did you carry out and how effective were they?

		Not at all effective				Very effective
X	Design and implement an equal opportunity policy	○	X	○	○	○
❑	Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑	Organise conferences and workshops on gender	○	○	○	○	○
❑	Actions to improve work-life balance	○	○	○	○	○
X	Other:	Each institution had their own policy/strategy.				

7 Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

X No

E Synergies with Science Education

8 Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

○ Yes- please specify

X No

9 Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

○ Yes- please specify

X No

F Interdisciplinarity

10 Which disciplines (see list below) are involved in your project?

○ Main discipline[1]: 1.2

○ Associated discipline: 2.2 ○ Associated discipline:

G Engaging with Civil society and policy makers

11a	**Did your project engage with societal actors beyond the research community?** *(if 'No', go to Question 14)*	○ X	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

○ No

○ Yes- in determining what research should be performed

○ Yes - in implementing the research

[1] Insert number from list below (Frascati Manual)

○ Yes, in communicating /disseminating / using the results of the project		
11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○ ○	Yes No

12 Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- ○ Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture		Energy		Human rights	
Audiovisual and Media		Enlargement		Information Society	
Budget		Enterprise		Institutional affairs	
Competition		Environment		Internal Market	
Consumers		External Relations		Justice, freedom and security	
Culture		External Trade		Public Health	
Customs		Fisheries and Maritime Affairs		Regional Policy	
Development Economic and Monetary Affairs		Food Safety		Research and Innovation	
		Foreign and Security Policy		Space	
Education, Training, Youth		Fraud		Taxation	
Employment and Social Affairs		Humanitarian aid		Transport	

13c If Yes, at which level?

- ○ Local / regional levels
- ○ National level
- ○ European level
- ○ International level

H Use and dissemination

14 How many Articles were published/accepted for publication in peer-reviewed journals?	**87**
To how many of these is open access[2] provided?	**55**
How many of these are published in open access journals?	**53**
How many of these are published in open repositories?	**2**
To how many of these is open access not provided?	**32**
Please check all applicable reasons for not providing open access:	
X publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available X no suitable open access journal available ❑ no funds available to publish in an open access journal X lack of time and resources X lack of information on open access ❑ other: …….	

15 How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		**3**
16 Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**0**
	Registered design	**0**
	Other	**0**
17 How many spin-off companies were created / are planned as a direct result of the project?		**1**
Indicate the approximate number of additional jobs in these companies:		**3-5**

18 Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

X	Increase in employment, or	X	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify	❑	

19 For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:*
Difficult to estimate / not possible to quantify	X

[2] Open Access is defined as free of charge access for anyone via the internet.

I Media and Communication to the general public

20 As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes X No

21 As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes X No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

X	Press Release	X	Coverage in specialist press
❑	Media briefing	X	Coverage in general (non-specialist) press
❑	TV coverage / report	X	Coverage in national press
❑	Radio coverage / report	X	Coverage in international press
X	Brochures /posters / flyers	❑	Website for the general public / internet
❑	DVD /Film /Multimedia	❑	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	❑	English
X	Other language(s)		

***Question F-10*:** Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)
3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)
3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES
4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)
4.2 Veterinary medicine

5. SOCIAL SCIENCES
5.1 Psychology
5.2 Economics
5.3 Educational sciences (education and training and other allied subjects)
5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES
6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)
6.2 Languages and literature (ancient and modern)
6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group] .