GALAHAD project newsletter #4

Feb 2019

GALAHAD is a research project supported by the European Commission through Horizon 2020 under Grant Agreement 732613.

Welcome to the fourth GALAHAD project newsletter!

In this newsletter we present:

- A new supercontinuum noise model for OCT imaging from DTU and NKT
- An update on GALAHAD system integration from Optos
- Numerical dispersion cancellation in OCT by DTU and NKT
- Comments on ethical requirements of GALAHAD data from Glos. Hospitals NHS Trust

More info is available on the website (www.galahad-project.eu).

Supercontinuum noise and OCT

The extremely broad bandwidths offered by supercontinuum sources make them extremely interesting for OCT applications, but many researchers have questioned to what extent this advantage might be counteracted by the intrinsic source noise. GALAHAD partners DTU and NKT, in collaboration with the University of Kent (UK), have performed a theoretical and practical investigation of the pulse-to-pulse fluctuations of the supercontinuum source on the spectral domain noise in OCT imaging.

An NKT SuperK Extreme supercontinuum source

Supercontinuum sources have complex noise properties, and the impact on OCT images is quite different to what many OCT users expect from superluminescent diodes or other conventional light sources. The usual theoretical expression for OCT noise (derived for a thermal light source) is not suitable for supercontinuum sources. A new, measurement-based OCT noise model that predicts the noise without any assumptions on the type of light source was proposed by the team, and they showed that the predicted noise is in excellent agreement with measured values. The spectral correlation evaluated for the photo-detected signal when using a supercontinuum determines the shape of the OCT noise floor, which must be taken into account when characterizing the sensitivity roll-off.

M. Jensen, I.B. Gonzalo, R.D. Engelsholm, M. Maria, N.M. Israelsen, A. Podoleanu & O. Bang, *"Noise of supercontinuum sources in spectral domain optical coherence tomography,"* J. Opt. Soc. Am. B **36**, p. A154-A160 (2019).

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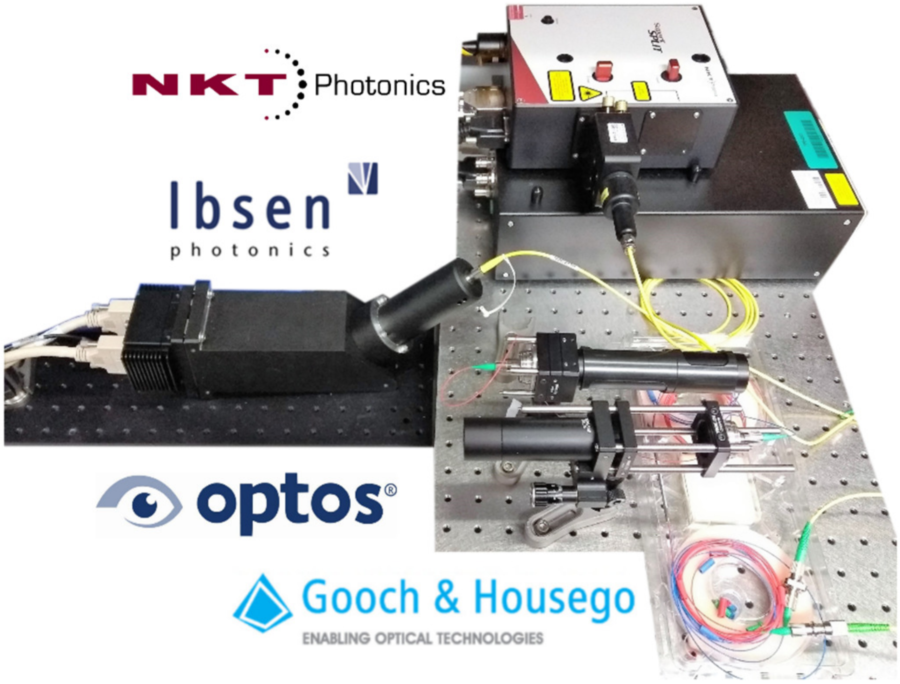
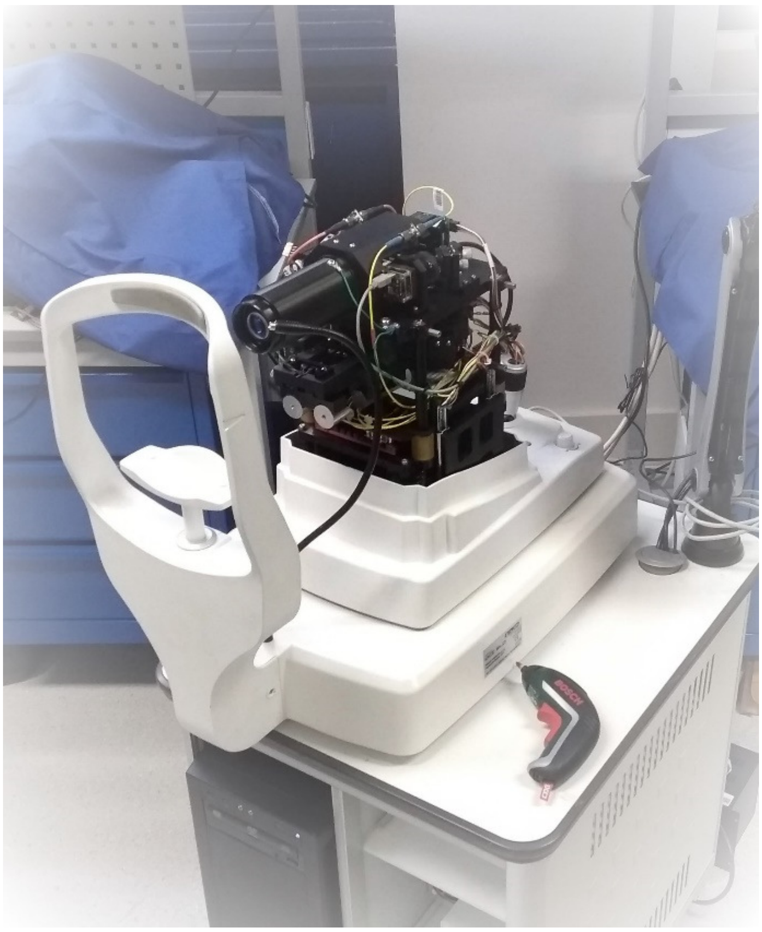
GALAHAD system integration

Optos has been working with the component manufacturers in the GALAHAD consortium to integrate the light source, spectrometer and fibre interferometer into a high resolution, polarisation sensitive optical coherence tomography (PS-OCT) system. The first stage of this process was to test the components together on an optical table. These initial trials were very successful, showing resolution close to the theoretical limit. Dispersion compensation algorithms developed by DTU were used to achieve the best resolution (see page 3).



Testing of components using an interferometer built on an optical table at Optos.



Integration of GALAHAD components into a retinal imaging device and adaptation for rodent imaging.

Work to integrate the GALAHAD components into a retinal imaging device is now underway at Optos (Dunfermline, UK). This includes upgrades and modifications to the existing device software to include the additional spectrometer required for PS-OCT in the laboratory prototype system which is being developed in GALAHAD. The integrated OCT system is also being adapted to suit the optical requirements for imaging rodent retinas, since human trials are beyond the scope of the project. This requires changes to the sample arm of the interferometer, which must be matched in the reference arm to ensure the resolution is not degraded. The lens design must also be modified from the standard Optos systems in order to image the much smaller rodent eye.

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GALAHAD

DTU

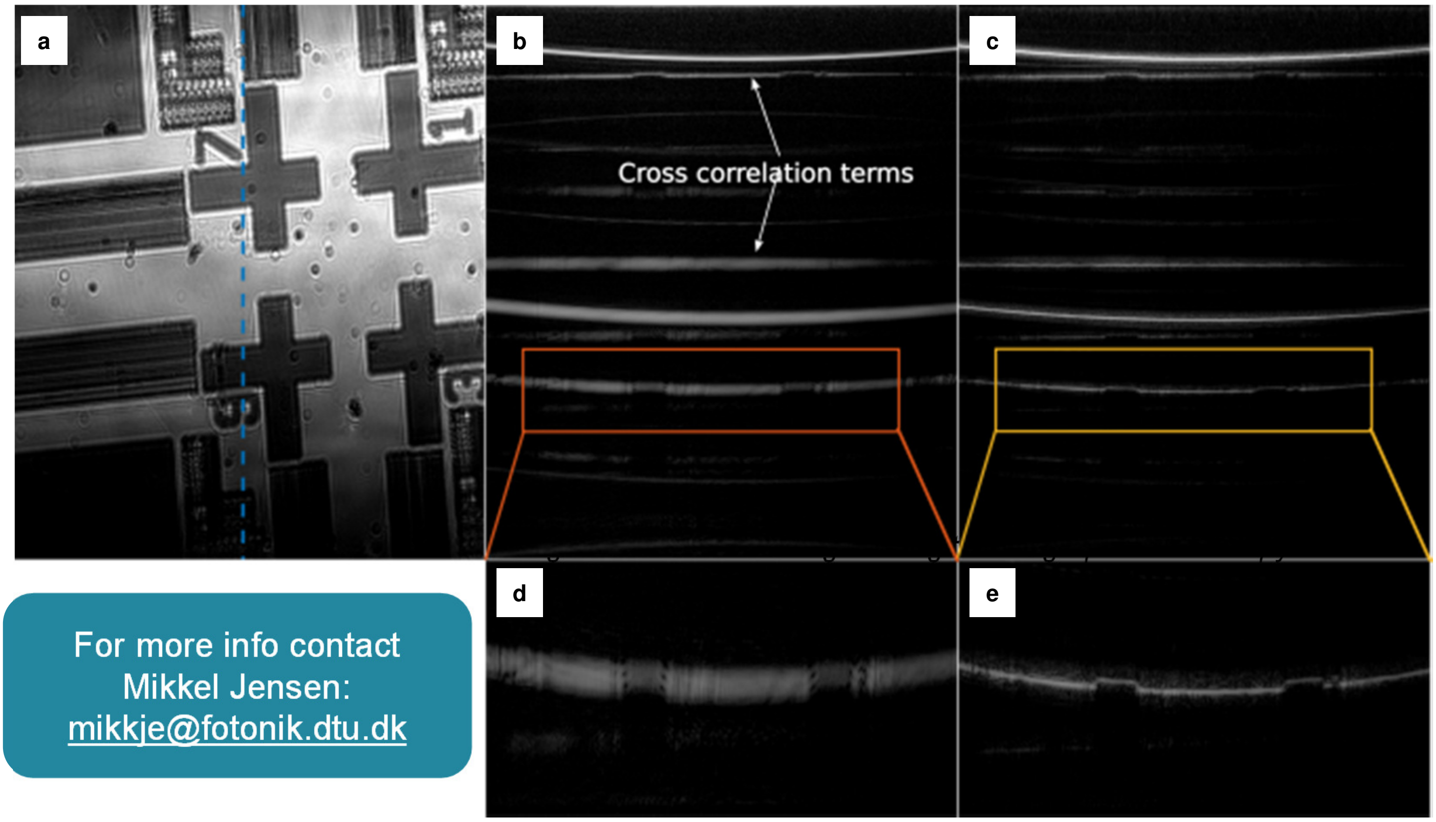
NKT Photonics

Numerical dispersion cancellation in OCT

In ultra-high resolution (UHR-) OCT the group velocity dispersion (GVD) must be corrected for in order to approach the theoretical resolution limit. A new approach promises not only compensation, but complete annihilation of even order dispersion effects, at all sample depths. This approach usually requires an experimentally demanding ‘balanced detection’ configuration using two detectors. GALAHAD researchers from DTU and NKT, in collaboration with University of Kent (UK), have demonstrated intensity correlation (IC) OCT using a conventional spectral domain (SD) UHR-OCT system with a single detector. IC-SD-OCT configurations exhibit cross term ghost images and a reduced axial range, half of that of conventional SD-OCT. The team showed that both shortcomings could be removed by applying a generic artefact reduction algorithm and using analytic interferograms.

In summary the study demonstrated for the first time that purely numerical intensity correlation may be used for all-depth dispersion cancellation of several interfaces, without the use of two expensive detectors as in the hardware based systems. This valuable insight will be an important part of the GALAHAD imaging system. In their recent Scientific Reports paper (see below) the team demonstrated the superiority of IC-SD-OCT compared with conventional SD-OCT by imaging spatial structures behind a strongly dispersive silicon wafer.

M. Jensen, N.M. Israelsen, M. Maria, T. Feuchter, A. Podoleanu, O. Bang, *“All-depth dispersion cancellation in spectral domain optical coherence tomography using numerical intensity correlation,”* Scientific Reports **8**, p. 9170 (2018).



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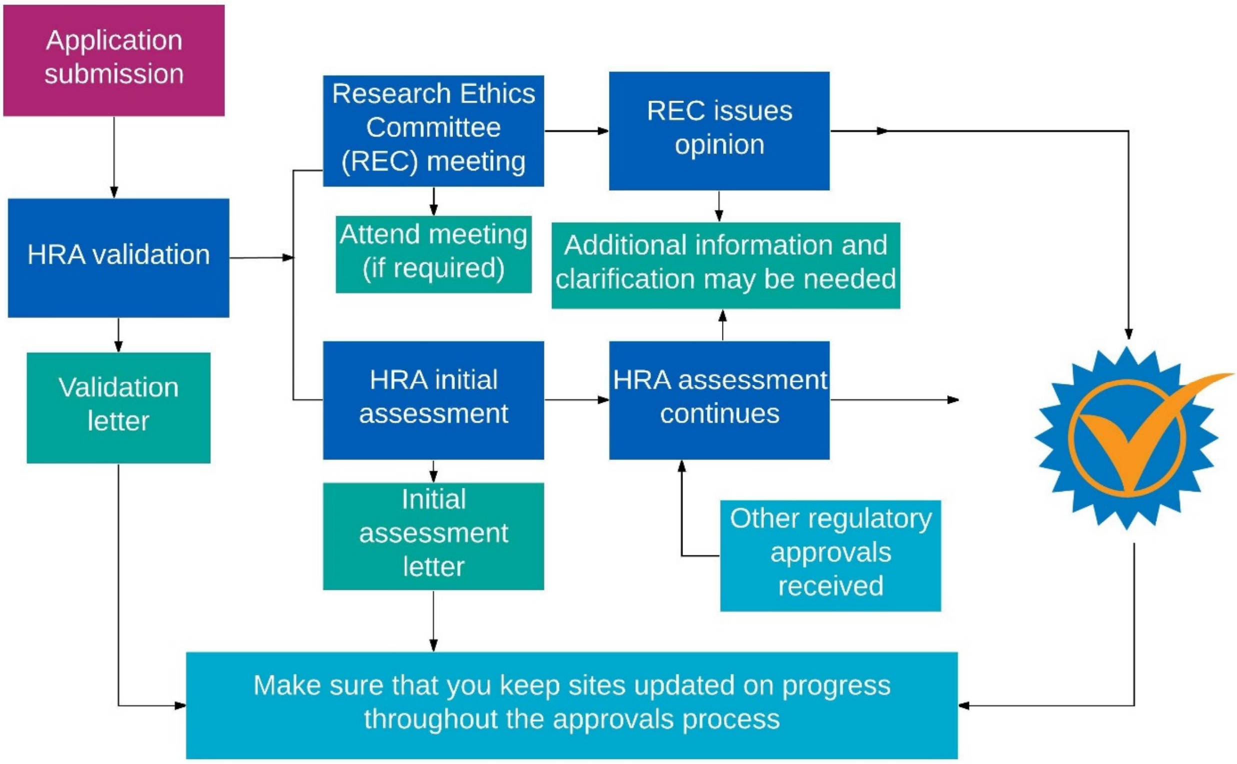
OCT images of a silicon wafer with surface structure placed beneath an ordinary silicon wafer. (a) Shows a top view of the surface structure, (b) shows a B-scan along the dashed blue line with conventional DC applied, and (c) shows the same B-scan using ICA-SD-OCT. (d) and (e) show a zoom of the structure from (b) and (c), respectively, highlighting the superior level of detail of ICA-SD-OCT.

Ethical requirements in GALAHAD

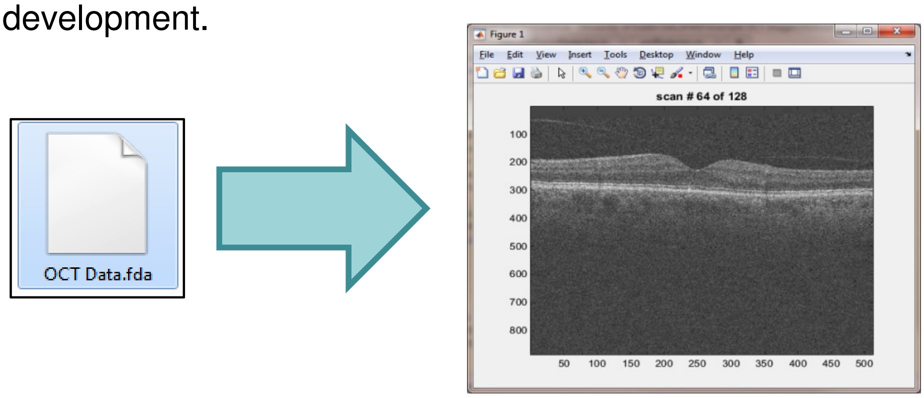
In order to access and process patient data for research, ethical approval is needed. This requires the completion of an online form and creation of a protocol for submission to a Research Ethics Committee. The protocol details what will happen to the data, how it will be kept anonymous and who will have access. Anonymisation of the data is essential since consent for use for research purposes was not obtained prior to the OCT procedures.

Research ethics committees meet approximately monthly and approvals processes can take up to six weeks. GHNT was able to use its new fast-tracking service for the GALAHAD application since it only related to existing anonymous data. New data collection requires consent forms and patient information sheets which all have to be independently reviewed.



HRA ethics approval flowchart (https://www.hra.nhs.uk/approvals-amendments/what-approvals-do-i-need/hra-approval/)

The ethics application to access anonymous data at GHNT was submitted in Feb-2018 and granted in Mar-2018. Twelve sample patients (six with glaucoma) were selected to examine the data extraction techniques and begin initial extraction. Programs have been developed to speed up the automatic anonymisation of data, redacting the personally identifiable fields. The proprietary, binary .fda files have been reverse engineered to extract the OCT image data, which has been sent to UPV (Valencia, Spain) for machine learning algorithm development.



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