Glaucoma – Advanced, LAbel-free High resolution Automated OCT Diagnostics

GALAHAD

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

The emission from an NKT visible supercontinuum source showing the wide bandwidth available. GALAHAD will use similar sources in the near-IR.

GALAHAD project newsletter #2

Feb 2018

Welcome to the second GALAHAD project newsletter!

GALAHAD is already a year old, and we have made good progress towards our project goals. In this newsletter we present:

- New spectrometer designs from Ibsen
- Retinal layer segmentation algorithms from UPV
- An overview of glaucoma screening from Glostrup Hospital (Region H)
- A new scientific poster and video: see below!

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

GALAHAD at Photonics West

A poster from the GALAHAD team at Westfälische Wilhelms-Univ. Münster (WWU) was presented at Photonics West: *"Developmental approach towards high resolution optical coherence tomography for glaucoma diagnostics,"* S. Ketelhut, B. Kemper, J. Schnekenburger.

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SPIE. PHOTONICS WEST BIOS

- 27-Jan to 01-Feb-2018
- San Francisco, USA
- https://spie.org/conferences-and-exhibitions/photonics-west/bios

GALAHAD video online!!

A short intro video outlining the objectives and concepts of the GALAHAD project is now online on the website. It includes some comments on the project vision from Dr. Andrew Robertson (G&H) and more details of the technical (hardware and software) challenges which will need to be overcome in the next two years.

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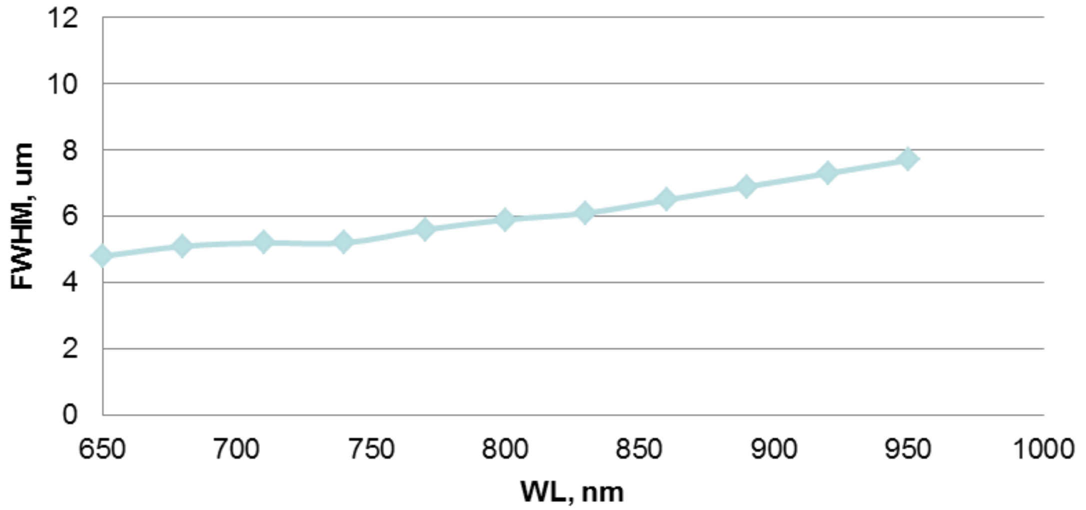
Gooch & Housego · optos · Universitat Politècnica de València · DTU · Gloucestershire Hospitals NHS Foundation Trust · Region H Rigshospitalet · NKT Photonics · Westfälische Wilhelms-Universität Münster · VIVID Components · Ibsen photonics

Spectrometer designs

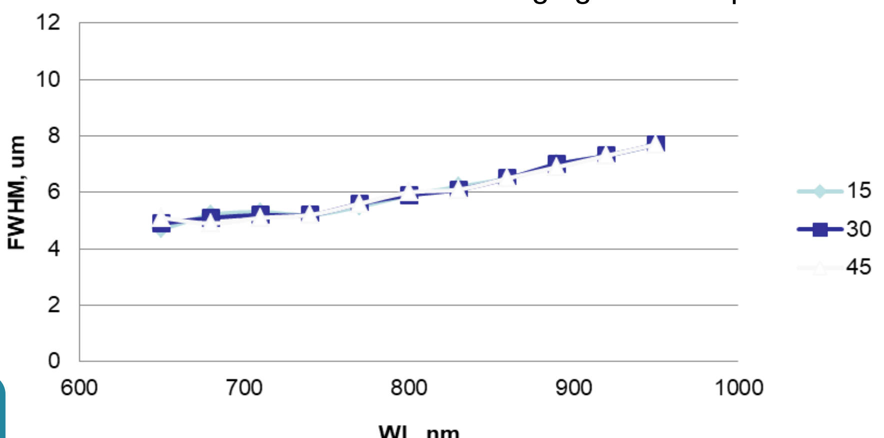
Within the GALAHAD project, Ibsen has designed a new spectrometer for ultra-high resolution OCT with a broad wavelength range (650-950 nm) and a diffraction-limited resolution better than 0.07 nm. An ultra-wide bandwidth of 300 nm and ultra-high resolution are required to reach the axial resolution of 1 µm and maximum depth of 2 mm in the final target OCT system. The spectrometer is based on the well-known lens-grating-lens geometry utilising a collimation lens, a transmission diffraction grating and a focus lens group consisting of two achromatic custom designed lenses.

Optical resolution: The diffraction-limited optical resolution in the detector plane is shown below. As can be seen the resolution (FWHM) is lower than the threshold of 10 µm (pixel size) for all wavelengths.



Diffraction-limited optical resolution of the spectrometer (FWHM) showing that the design meets the required resolution across the wavelength band.

Thermal analysis: A change in the environmental temperature can affect the performance of the spectrometer. There are three primary factors to consider: glass refractive index change, glass expansion and expansion of the mounting material. The optical design has been made in such a way as to minimise the effect of changing the temperature. As can be seen the optical (FWHM) resolution looks almost identical for all temperatures. In the GALAHAD project spectrometers built to these specifications are planned as part of the project demonstration.



Graph showing the optical resolution (FWHM) of the designed spectrometer at 15 °C, 30 °C and 45 °C.

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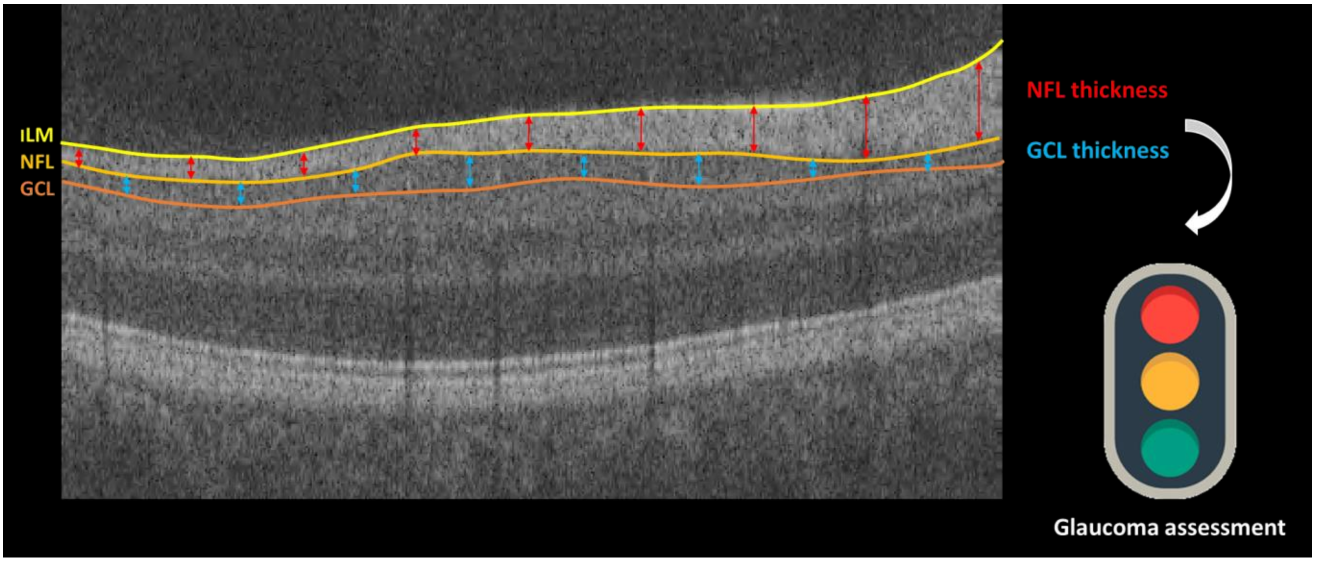
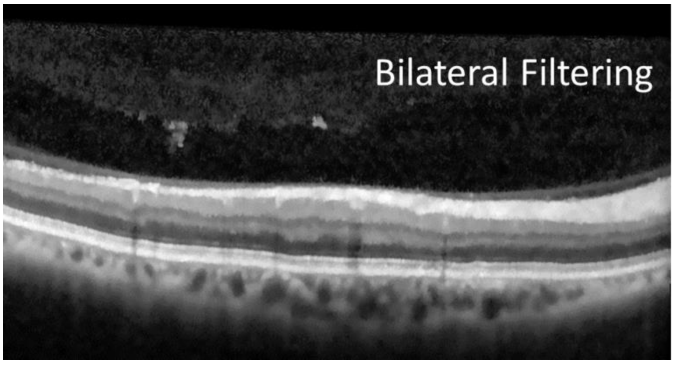
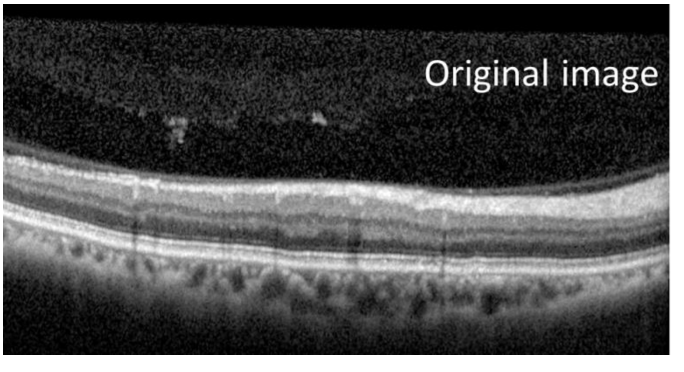
Overview of algorithm development

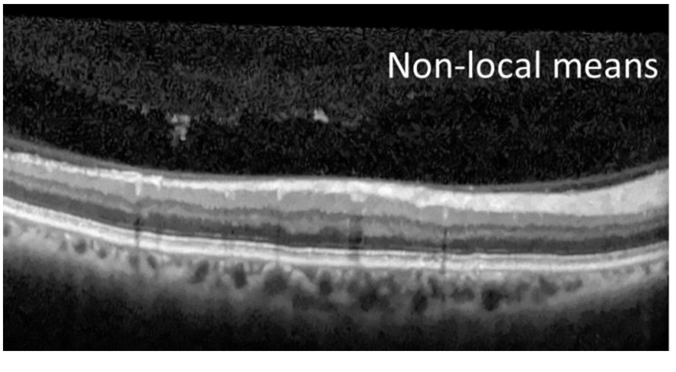
In GALAHAD, UPV is working on automatic retinal layer segmentation algorithms. The key current methods under development are focused on **detecting the nerve fiber layer (NFL) and the ganglion cell layer (GCL)**. Both these layers are highly significant for glaucoma diagnosis. Images from different OCT devices (Topcon and Spectralis) are being used to validate the performance of the segmentation methods.



An OCT image provided by GHNT (acquired with a Topcon device). Three retinal layers are marked: ILM (internal limiting membrane), NFL (nerve fibre layer) and the GCL (ganglion cell layer). UPV is working on an algorithm which can automatically identify these layers using a segmentation process. By measuring the NFL and GCL thicknesses and comparing with a database of existing images GALAHAD hopes to make progress towards an automated process for glaucoma diagnosis.







As part of this work, several noise reduction techniques were tested with the aim of simplifying the segmentation task and improving the results, and this work will continue in the coming months.

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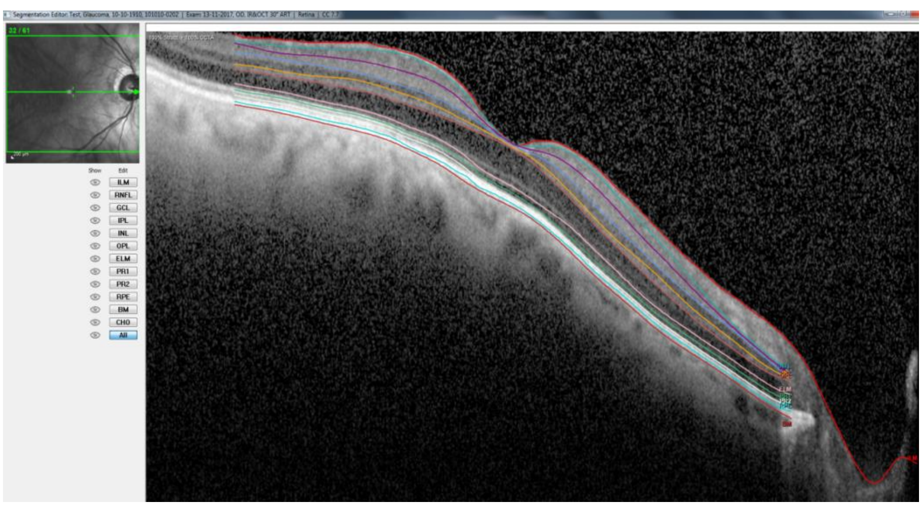
Working towards effective glaucoma screening

Is there a fast, easy and affordable way of finding people who are on their way to going blind from glaucoma, so that the disease can be arrested before it is too late? And if such a method were available, would it be cost-effective, manageable on a large scale and ready for Europe-wide implementation? These questions have been debated for decades. The answer, so far, has been a resounding, "No." Instead, health care providers have relied on opportunistic screening strategies, such as checking for glaucoma when people complain about age-related reading problems, or when they go to the ophthalmologist for a spectacle prescription, when they are prompted to see an ophthalmologist by the finding of glaucoma in a relative *etc.*

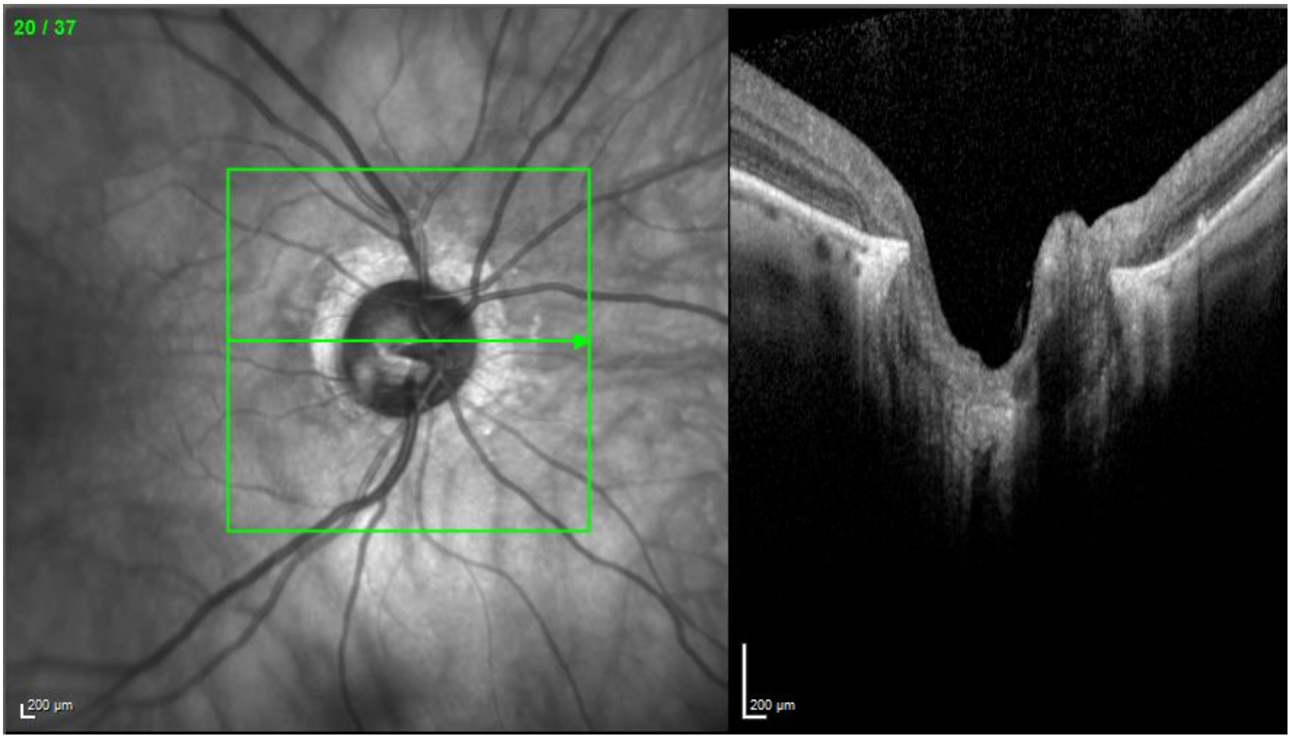
Ophthalmologists know that the current state of affairs is far from ideal. Take the history, for example, of the 56-year old engineer who presented at the local ophthalmologist's office with complaints of having difficulty finding the pencils on his table. The patient was found to have large irreparable visual field defects bordering on tunnel vision. This patient represents a tragic and all-too-common case which should and could have been caught much earlier, had he had a routine eye examination. This particular, very advanced case of glaucoma would have been easy to find, perhaps as much as a decade before. It therefore represents a clear target for screening. Patients who undergo opportunistic screening in routine clinical practice often represent the opposite end of the spectrum, being borderline cases that are difficult to distinguish from healthy subjects; and there are many of them. Therefore, we need faster, more reliable and more convenient tests for glaucoma.



State-of-the-art segmentation of an OCT scan through the human retina.

The coloured lines indicate the approximate boundaries of a series of different layers in the complex structure of the retina. As discussed on the previous page, the thickness, shape and characteristics of these layers is thought to be a potentially useful indication of the presence of glaucoma (as well as other serious eye diseases).

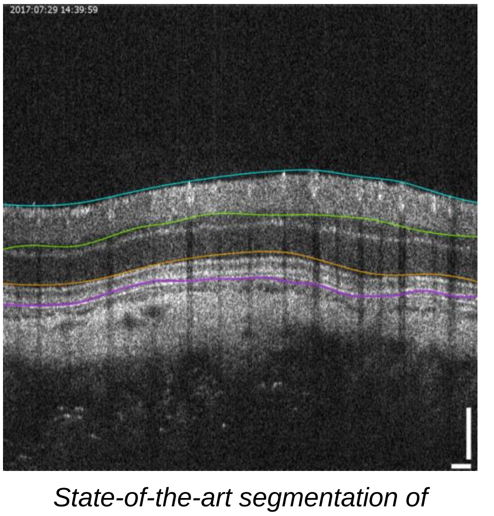
Glaucoma affects vision by inducing visual field defects that go hand in hand with structural defects in the retina and the optic nerve head. They show up as focal or diffuse thinning of specific layers of the retina. We know that they can be found by optical coherence tomography (OCT) a smart non-invasive modern imaging technique. The crucial question is "Can it be done cost-effectively?" Is OCT-based glaucoma screening ready for wide-scale implementation? Or should the OCT instruments and the data analysis methods be improved before we try, once more, to make a case for systematic glaucoma screening? The GALAHAD project is working towards this latter objective, namely to lift the technology to a higher level of practical utility and diagnostic precision, so that a stronger case for glaucoma screening can be made.



OCT scan through the optic nerve head in a patient with glaucoma..

The structural defects in eyes with glaucoma, which appear to precede the visual field defects, make OCT a strong diagnostic tool in principle, but the number of patients without glaucoma is very high, compared with the number of people who have undiagnosed glaucoma. The GALAHAD investigators are currently examining the literature and calculating the statistics to describe the premises for switching from visual field testing to OCT-based structural mapping as the first line of glaucoma screening. This will set the stage for GALAHAD's engineers to calculate the specifications for a new OCT device that will do the job. There are plenty of new component types and data sets to work with. Add some smart system design and an interactive prototype testing strategy and a new clinical tool has been born.

GALAHAD is also training computers to identify the patterns of tissue damage that are characteristic of normal eyes and eyes with glaucoma (see above). Software programmers are training new algorithms to segment images into layers and to do so with a finer tool for compensating for the effects of disease. GALAHAD will demonstrate two ultra high-resolution polarisation-sensitive OCT prototypes which will be ready and tested in a pre-clinical setting on rodents (see right) with hereditary glaucoma-like disease.



State-of-the-art segmentation of an OCT scan from a rat retina

The Rigshospitalet in Copenhagen is the largest center for eye care and eye research in Denmark. Its Department of Ophthalmology is active in scientific studies of a broad range of vision-threatening conditions.

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