SEQUOIA

https://sequoia-project.eu

SEQUOIA Horizon Europe project

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SEQUOIA project

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- *NORBLIS software update*
- *New QOCT set-up at DTU*
- *NCU theoretical studies*

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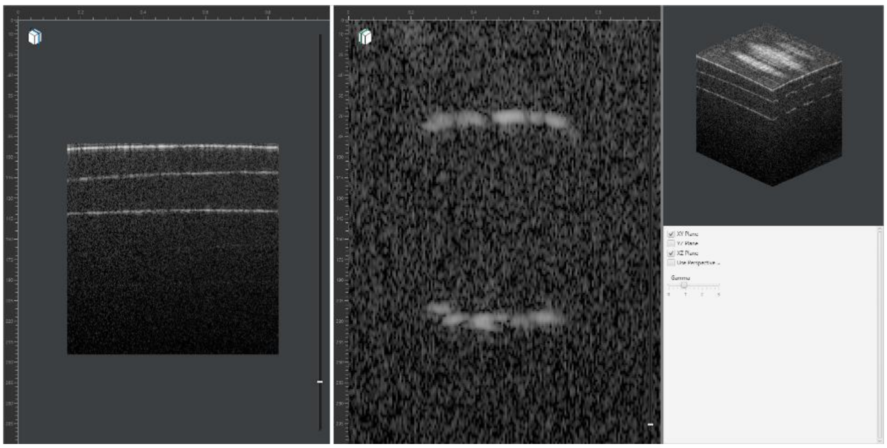
First quantum OCT software platform

As part of the SEQUOIA project, NORBLIS will deliver the first quantum optical coherence tomography (QOCT) software platform. In the early stages of the project, NORBLIS has worked on improving the performance of its existing classical OCT software. This software enables scans to be quickly and automatically developed into an image, greatly improving the user experience.

To achieve this, NORBLIS completely rewrote the processing code and developed its own algorithms for key aspects of the processing pipeline. This will allow for more freedom in the future as key parts can be tailored specifically for SEQUOIA.

The processing is developed with modern computers in mind, and the platform has been designed to make efficient use of cache and parallelism to get the most out of the hardware.



This image shows a partial screenshot from the NORBLIS QOCT software platform which has been developed in SEQUOIA. The user can instantly manipulate and explore representations of 3D voxel data.

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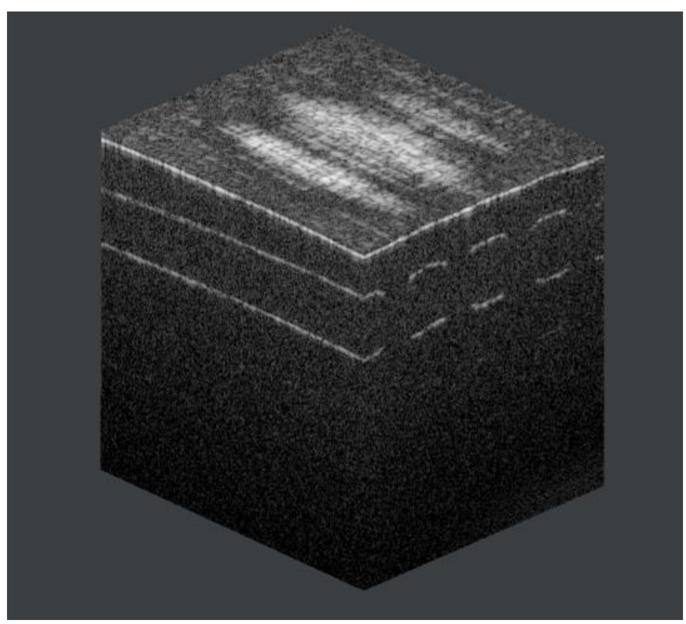
In addition to these processing improvements, NORBLIS has worked on a tool for visualising 3D voxel data. The tool is a graphical user interface (GUI) that can display processed data from different directions. Currently, the user can select any layer for closer inspection and thus gain a deeper understanding of the volume they are working with.

All voxel data is rendered by the GPU in a fully 3D environment. This means that the user can interact with the data and apply filters with almost instantaneous effect. It also makes it possible to add more advanced visualisation aids in future.



NORBLIS is currently working on bringing more features to the tool that will allow for analysing scan data in greater detail; specifically, adding more options for working with a single layer of a volume.

The tool will eventually encompass all key parts of the QOCT software platform, being able to both process and visualise raw scan data, thus creating a unified platform.

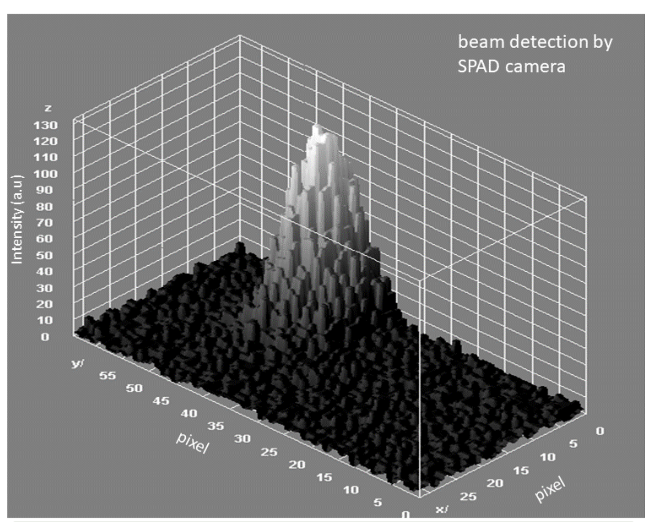
New quantum OCT set-up established at DTU

DTU

The Fiber Sensors & Supercontinuum group in the Technical University of Denmark (DTU) is responsible for developing the experimental set-up for quantum optical coherence tomography (QOCT) using a supercontinuum source and single photon avalanche diode (SPAD) imager supplied by two SEQUOIA project partners, NKTP and MPD respectively. The initial targeted axial resolution of the developed time domain (TD)-QOCT system is 1 μm and a better penetration depth is also targeted by imprinting orbital angular momentum (OAM) onto the sample beam. A schematic of the targeted set-up is shown on the right.

A new Quantum Imaging Lab is being set up by DTU specifically to execute this project. The first six months of SEQUOIA have been spent setting up this lab, which includes purchasing optical tables, different optical and opto-mechanical components, non-linear crystals *etc*. The development phase is now almost over, and a photo of the lab can be found on the left. DTU also participated in several meetings with partners from NCU, PTB and NKTP to finalise the crystal required for the spontaneous parametric down conversion (SPDC).

Presently, DTU is performing preliminary experiments with the test source supplied by NKTP and SPAD imager from MPD. Two experiments are running in parallel. After completing the characterisation of the source, a BBO crystal is being pumped by the source in order to optimise different parameters for generating entangled photon pairs via SPDC. On the other hand, work to test the SPAD imager and getting familiarised with the interface is almost complete.



Effort is now focused on synchronising the camera with the trigger pulse from the source and to optimise the gating, frame rates *etc*. in order to capture photon pairs generated by the pulses with 80 MHz repetition rate. After successful completion of these two test experiments, the fully fledged development of the TD-QOCT set-up will start. A photo of the beam detection operation by the SPAD imager is shown on the right.

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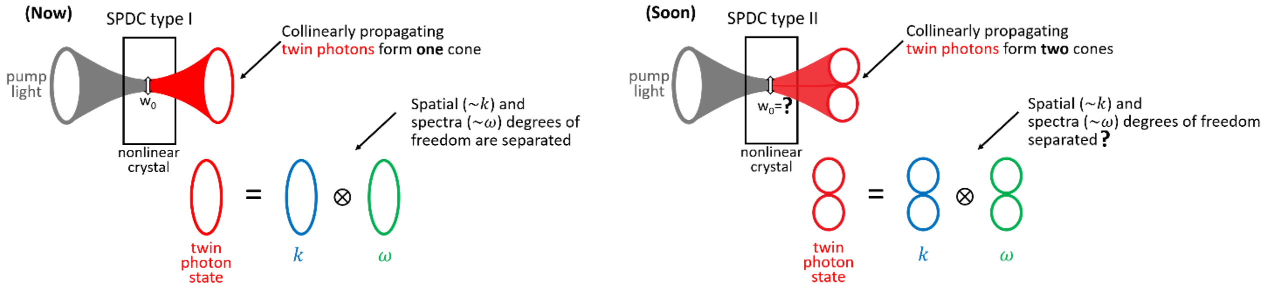
Quantum OCT theory development at NCU

NICOLAUS COPERNICUS UNIVERSITY IN TORUŃ

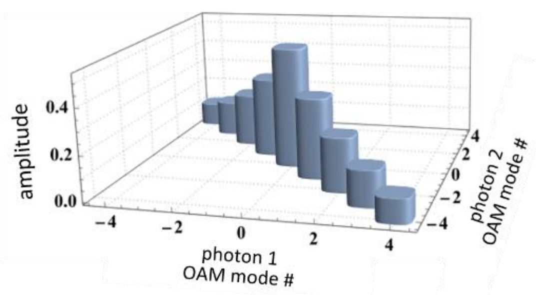
NCU supports SEQUOIA in all things theoretical, leveraging their experience in quantum optics and quantum OCT. Their fundamental analyses and simulations inform the decisions on the experimental side of the project, starting from the type of nonlinear crystal and its optimum configuration for photon entanglement, through the spatial and rotation-related photon characteristics, and finishing at single photon detection techniques for optimum entanglement capture. The team at NCU (Crislane, Piotr and Sylwia) has been very busy developing the first models of SPDC, the process behind the quantum entanglement, and OAM, a rotation-related property of light, in the general context of quality-enhanced quantum OCT imaging.



(Now) The condition for separating spatial and spectral modes in type I SPDC was found to be a small pump beam waist. (Soon) A condition will be found to enable spatial-spectral separation for collinear type II SPDC.

The theoretical study led them to new information on the experimental conditions required to maximise the quality of a quantum OCT signal. This study involved modelling of type I SPDC where the light at the input of the nonlinear crystal (the pump light) is collinear with the generated entangled photons. The goal was to determine the parameters of the experiment enabling separation of the spatial and spectral degrees of freedom of the photon pairs. When coupled, these degrees of freedom could detrimentally affect the detected quantum OCT signal and lead to low-quality images. The team noticed that in order to obtain spatial-spectral decoupling, one needs to make sure that the pump beam waist is small (see above). This finding was broadly discussed and turned out actually to be good news! Tight focussing connected to small beam waists is what SEQUOIA should generally pursue – tight focusing is what increases the production rate of photons crucial for high-quality quantum OCT.

OAM mode distribution for twin photons



Expected OAM mode distribution in the generated photon pairs.

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The initial results of the theoretical work on OAM provided a valuable insight into its use in QOCT contexts. It was determined that the experimental system will need to incorporate an OAM mode sorter enabling separation and analysis of up to five OAM modes for a Gaussian pump beam (see the distribution graph-left). This is related to the widths of the pump and twin photon beams. The optimum width ratio enables the twin photons to be efficiently distributed in five OAM modes. For non-optimum width ratios, although more modes are generated, their amplitudes are too small to significantly contribute to the experiment. In the next step, a study will be carried out to determine the optimum parameters for the type II arrangement, the ultimate configuration for the SEQUOIA project.