The LUCA Project

Laser and Ultrasound Co-Analyzer for Thyroid Nodules

2016-2020

The Project

Thyroid cancer is a major health issue with about 500,000 new cases diagnosed each year. Unfortunately, the current methods for assessing the malignancy of a nodule (ultrasound followed by fine needle aspiration biopsy) lack specificity and sensitivity, which often leads to non-diagnostic or false positive results and, consequently, to a high number of unnecessary surgeries.

The LUCA project therefore will bring to the clinic a state-of-the-art low-cost device for thyroid nodule screening to increase the sensitivity and specificity of thyroid cancer diagnosis by adding direct physiological and hemodynamic information to the screening process.

The Technology

The LUCA project has developed a versatile device that combines diffuse correlation spectroscopy (DCS) and time-resolved spectroscopy (TRS) with medical ultrasound.

Ultrasound

LUCA builds on medical sonography which is the current standard for thyroid cancer screening. It delivers anatomical information required for a first diagnosis of a pathological situation, gives guidance for placing the optical probe in the region of interest, and provides fundamental information on the geometry of the tissue necessary to improve the accuracy and precision of the optical data analysis.

Diffuse Correlation Spectroscopy (DCS)

DCS uses a continuous wave lase source and exploits the decay of the speckle intensity auto-correlation function due to light scattering by moving particles (i.e. red blood cells) to measure microvascular blood flow of a tissue.

Time-Resolved Spectroscopy (TRS)

TRS sends short laser pulses (approx. 10 ps) at multiple wavelengths and studies their deformation after having traveled through the tissue. This allows determining tissue optical properties such as absorption and scattering and to retrieve tissue component concentrations such as blood oxygenation, collagen, water and lipid concentrations.

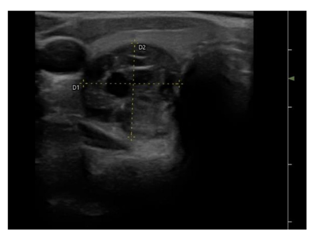

Figure 1. US

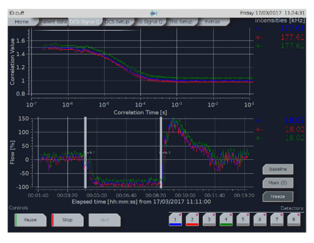

Figure 2. DCS

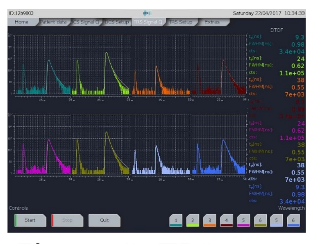

Figure 3. TRS

The LUCA Device

The LUCA device is a cost-effective novel solution developed by an international, multi-disciplinary consortium of clinical endocrinologists, radiologists, physicists, engineers and industry players that combines ultrasound and near-infrared diffuse optical technologies in a single device and a hand-held probe for multimodal data acquisition.

The combination of TRS and DCS allows retrieving complementary information about hemodynamics, composition and structure of the measured tissue, enhancing the sensitivity to biomarkers important to discriminate between benign and malignant nodules.

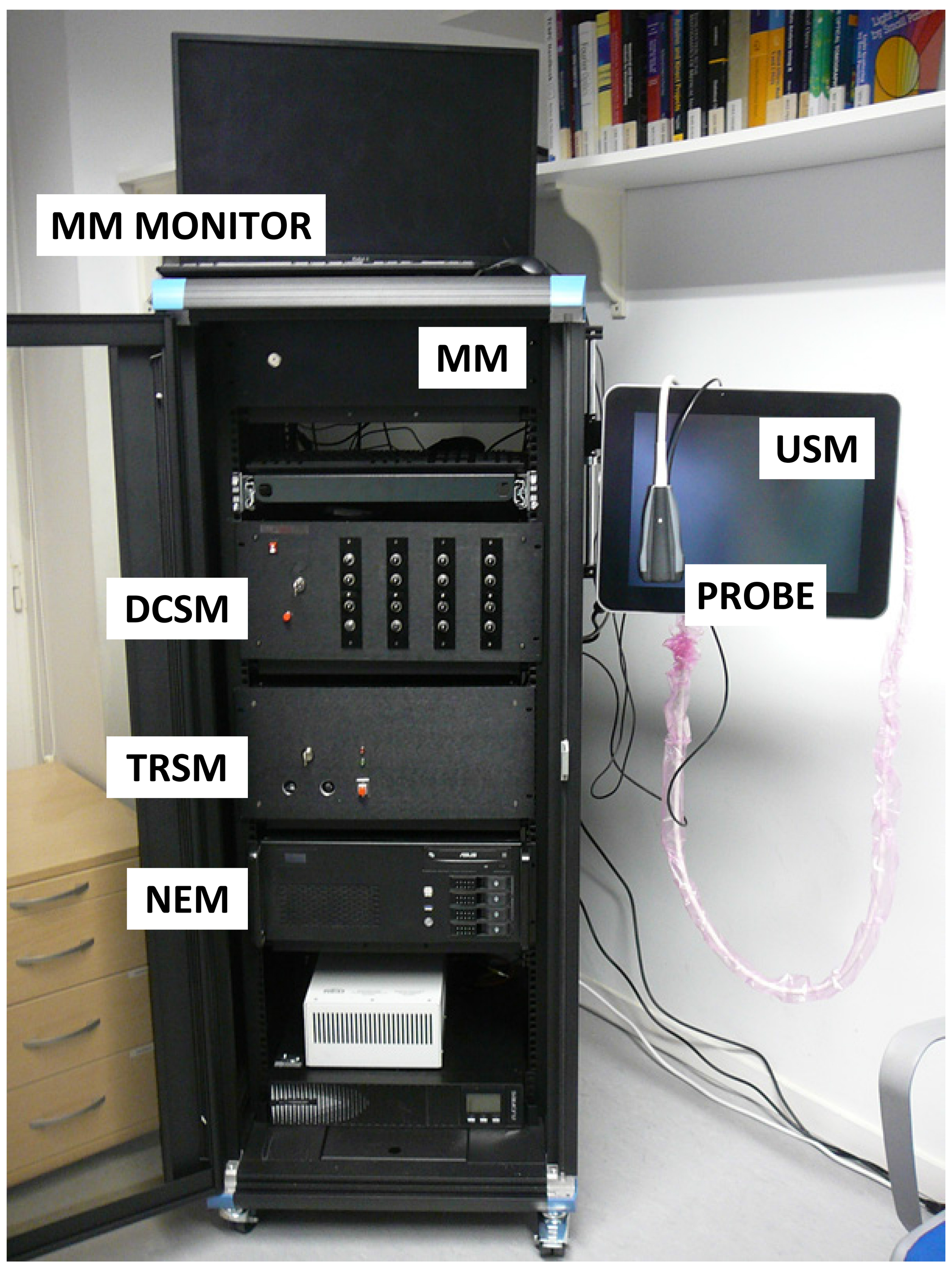

Figure 4. LUCA demonstrator

The Modules

The LUCA device consists of four modules governed by a main control module and a multi-modal probe:

Main Module (MM)

The optical main module is the principal control unit and handles the communications with all other modules through USB and network (TCP/IP) connections and TTL signals.

Diffuse Correlation Spectroscopy Module (DCSM)

The DCSM is characterized by a custom fiber coupled laser system (785 nm, 70 mW) and a 16-channel detection system based on custom-made autocorrelators.

Time-Resolved Spectroscopy Module (TRSM)

The 8-wavelength (635- 1050 nm) TRSM is based on eight fiber coupled edge emitting diodes, Silicon Photon-multipliers (SiPM) detectors, and a time-correlated single photon counting system based on a Time-to-Digital Converter.

Ultrasound Module (USM)

The USM is based on EXAPad, a commercial ultrasound system by IMV Imaging. The software and graphical interface have been modified to communicate with the other modules and run the combined optical-ultrasound measurements.

Multi-modal Optica-US Probe

The LUCA probe produced by VERMON combines a standard US transducer commonly used for thyroid ultrasound and a case allowing the insertion of the optical fibers necessary for the DCS and TRS modules.

NIRFAST Evaluation Module (NEM)

The LUCA post-processing unit consists of a custom assembled computer with a data analysis software based on Near Infrared Fluorescence and Spectral Tomography (NIRFAST).

Clinical Validation

The **first in vivo measurements** on healthy volunteers included variability and repeatability tests with excellent results demonstrating very low single measurement variability, variability between different measurements and between different days for both DCS and TRS. Additionally, an arm cuff occlusion challenge was carried out which proved the capability of the LUCA device in detecting temporal hemodynamic changes.

The **clinical study** runs from July 2019 to July 2020 at IDIBAPS/Hospital Clínic Barcelona. It will include a total of 70 subjects: 15 healthy controls, 25 patients with a single benign nodule, 15 patient with a single malignant nodule, and 15 with multi-nodular goiters.

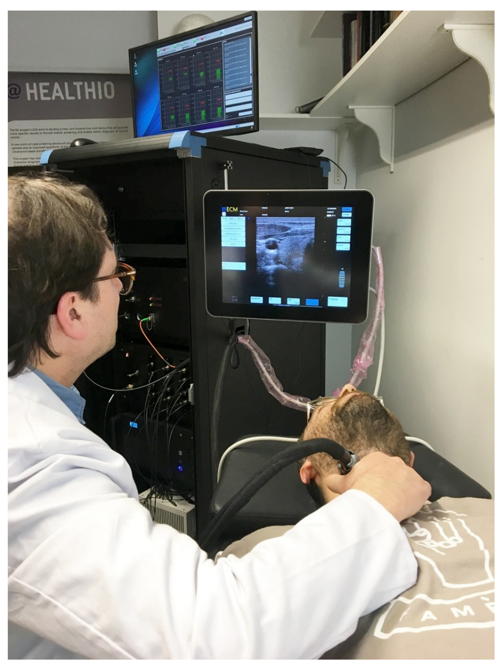

Figure 5. In vivo measurements

Conclusion and Outlook

Completed in 2019, the LUCA device is a multi-modal system capable of operating TRS and DCS simultaneously with US. First results indicate an improved specificity and sensitivity for thyroid nodule diagnosis.

The multi-modal LUCA approach lends itself to applications in other fields like breast, head and neck oncology, rheumatology, pediatric neurology and nephrology, and clinical veterinarian medicine.

The LUCA project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 688303 and is an initiative of the Photonics Public Private Partnership.

Contact

@LUCA_H2020
luca-project.eu
kkrischak@eibir.org (Project Office)

Read more

1. L. Cortese, et al. "The LUCA device: laser and ultrasound co-analyzer for thyroid nodules " in Proc. SPIE 11074, Diffuse Optical Spectroscopy and Imaging VII, 1107410 (2019).
2. L. Cortese, et al. "The LUCA device: a multi-modal system combining diffuse optics and ultrasound imaging for thyroid nodules diagnosis", in preparation.
3. C. Lindner, et al., "Diffuse Optical Characterization of the Healthy Human Thyroid Tissue and Two Pathological Case Studies," PLOS ONE 11, e0147851 (2016).
4. S. Konugolu Venkata Sekar, et al., "Diffuse optical characterization of collagen absorption from 500 to 1700 nm," Journal of Biomedical Optics 22, 015006 (2017).
5. S. Konugolu Venkata Sekar, et al., "Broadband (550-1350 nm) diffuse optical characterization of thyroid chromophores," Scientific Reports 8, 1–8 (2018).
6. S. Wojtkiewicz, et al., "Cloud-based nirfast server for tissue parameters recovery: laser and ultrasound co-analyser of thyroid nodules," Proc. SPIE 11074, Diffuse Optical Spectroscopy and Imaging VII, 110740L (2019).
7. M. Renna, et al., "Eight-Wavelength, Dual Detection Channel Instrument for Near-Infrared Time-Resolved Diffuse Optical Spectroscopy," IEEE Journal of Selected Topics in Quantum Electronics 25, 1–11 (2019).

ICFO The Institute of Photonic Sciences · POLITECNICO MILANO 1863 · IDIBAPS · HemoPhotonics · imv imaging · Vermon · UNIVERSITY OF BIRMINGHAM · EUROPEAN INSTITUTE FOR BIOMEDICAL IMAGING RESEARCH · PHOTONICS21 PHOTONICS PUBLIC PRIVATE PARTNERSHIP