A multimodal imaging system hosting an innovative photonic module to improve breast cancer diagnosis: the SOLUS project

L. Di Sieno[1], A. Dalla Mora[1], E. Ferocino[1], A. Pifferi[1], A. Tosi[2], E. Conca[2], V. Sesta[2], A. Giudice[3], A. Ruggeri[3], S. Tisa[3], A Flocke[4], B. Rosinski[5], J.-M. Dinten[6], M. Perriollat[6], D. Savery[7], H. Sportouche[7] S. Arridge[8], A. Farina[9], P. Panizza[10], E. Venturini[10], P. Gordebeke[11], P. Zolda[11], P. Taroni[1]

[1]Politecnico di Milano - Dipartimento di Fisica, Milano (Italy); [2]Politecnico di Milano - Dipartimento di Elettronica, Informazione e Bioingegneria, Milano (Italy); [3]Micro Photon Devices Srl, Bolzano (Italy); [4]iC-Haus, Bodenheim (Germany); [5]Vermon SA, Tours (France); [6]CEA-LETI, Grenoble, France; [7]Supersonic Imagine, S.A., Aix en Provence (France); [8]University College London, Department of Computer Science, London (UK); [9]Consiglio Nazionale delle Ricerche, Istituto di Fotonica e Nanotecnologie, Milano (Italy); [10]Scientific Institute (IRCCS) Ospedale S. Raffaele-Breast Imaging Unit, Milano (Italy); [11]European Institute for Biomedical Imaging Research, Vienna (Austria)

Breast cancer is the most common cancer in women and early diagnosis is fundamental to maximize survival rate and patient's quality life. For this reason, the availability of cost-effective and non-invasive diagnostics tools with high sensitivity and specificity is a real clinical need. The SOLUS project [1] aims to develop an innovative multimodal tomographic breast imaging system making use of 3 different non-invasive diagnostic techniques to improve the specificity of breast cancer diagnosis. Specifically, the SOLUS system will combine: i) ultrasound imaging (US) to assess the presence of lesions and provide *a-priori* information for the optical tomographic reconstruction; ii) shear wave elastography (SWE) which provides a quantitative measurement of the tissue stiffness; iii) time domain (TD) diffuse optical tomography that, through the measurements of the optical properties of tissue (i.e. absorption and reduced scattering), improves the discrimination of cancerous lesions (often characterized by high blood, water and collagen content, and a relatively low quantity of lipids [2]).
The multimodal tomographic system relies on combining a commercial instrument for US and SWE (Aixplorer by SuperSonic Imagine S.A.) with state-of-the-art TD diffuse optics, so that a single probe can perform imaging in the three modalities. To this extent, a new photonic module is being developed. It exploits the so-called "small source-detector approach" coupled to high-dynamic range (HDR) range fast-gated (FG) acquisition [3] to significantly improve light harvesting and spatial resolution. Each photonic module (see Figure 1) hosts: i) 8 pulsed lasers in the range between 635 and 1064 nm (to sample the different constituents of the breast tissue); ii) a large-area single-photon FG digital SiPM to enable HDR acquisition of the photons that probed deeper within tissue; iii) the acquisition electronics to record the time-of-flight distribution of re-emitted photons. Eight of those photonic modules (divided in 2 groups of 4 modules each) are arranged around the US transducer of the SOLUS probe, thus allowing multiple view acquisition and tomographic reconstruction. The module is also a stand-alone device for multiple wavelength TD diffuse optical imaging/spectroscopy with a wide range of potential applications (from medical imaging, to athlete training monitoring to non-destructive assessment of fruit quality).
In the first 18 months of the project, all the main components of the photonic module were conceived, developed and validated in laboratory settings. Currently, the realization and characterization of the single photonic module is ongoing together with the development of the final probe, that aims at providing high multi-modal imaging performance and be ergonomic and easy-to-use for the radiologist. The development and testing of a highly automated software for image processing and optical tomographic reconstruction is in progress, also exploiting the anatomical information obtained by US. Multi-parametric analysis of data provided by the three techniques is being developed. Once the final multimodal system is ready, the clinical validation will start to test the system usability and investigate whether the SOLUS system is capable of providing high specificity and to improve the non-invasive *in-depth* characterization of breast lesions.

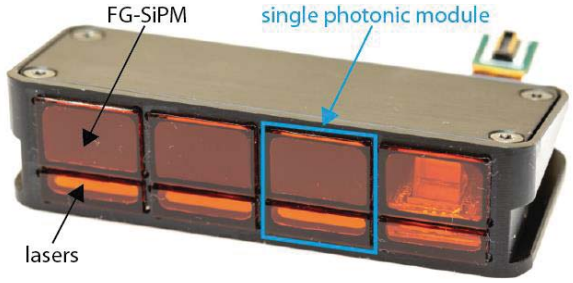

Figure 1. Photo of a set of 4 photonic modules, each one composed of a FG-SiPM (with timing electronics) and 8 lasers.

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Reference

1. "SOLUS project," http://www.solus-project.eu/.
2. G. Quarto et al, Biomed. Opt. Express **5**, 3684–98 (2014).
3. A. Dalla Mora et al, IEEE Sel. Top. Quantum Electron. **16**, 1023–1030 (2010).