SkinBall – A Photonic Instrument for Skin Monitoring

Innovation Project within the INTERREG-V-A Program "ROCKET Reloaded"

Vitaly Rymanov*, Joanna K. Bendyna**, and Andreas Stöhr*
*Microwave Photonics GmbH, Essener Str. 5, 46047 Oberhausen, Germany
**Mintres BV, De Nieuwe Erven 8, 5431 NT Cuijk, The Netherlands

Executive Summary

The SkinBall project focuses on health care and will develop a mobile millimeter-wave (mm-wave) spectroscopy instrument to enable mobile skin monitoring. It is foreseen that the instrument will be used by registered doctors for in-vivo screening, being beneficial for two reasons: 1st to reduce a number of unnecessary biopsies and 2nd to support early skin-cancer detection. It will also support in-vitro monitoring, e.g., applied by skin-cancer surgeons in specified clinics.

Table of Contents

Microwave Photonics GmbH
Essener Str. 5
46047 Oberhausen, Germany
info@microwave-photonics.com
www.microwave-photonics.com

Mintres BV
De Nieuwe Erven 8
5431 NT Cuijk, The Netherlands
info@mintres.com
www.mintres.com

Introduction

In the recent past, a considerable interest has been shown in detecting and managing various types of cancer by means of non-ionizing electromagnetic waves. Applied research into this area has shown that cancer modifies the water content of the skin, which has a direct impact on the skin's permittivity [1]. For that reason, the microwave range (in particular from 300 MHz - 10 GHz) has been exploited for imaging breast cancer [2] and lung cancer [3]. In comparison to microwaves, millimeter waves (30-300 GHz) exhibit shorter wavelengths and thus penetrate only a few millimeters or waves into the human body [4], making them highly efficient for sensing pathological variations in different skin layers in which skin tumors primarily occur [5]. Additional biomedical applications include non-invasive-dental-caries detection, blood-glucose monitoring, corneal-hydration assessment, wound-healing monitoring, and vital-sign observation [1]. Even though the concepts are very promising, more accurate, more reliable, and more stable mm-wave monitoring systems still have to be developed. This also includes the development of a high-accuracy skin-monitoring instrument.

SkinBall Project

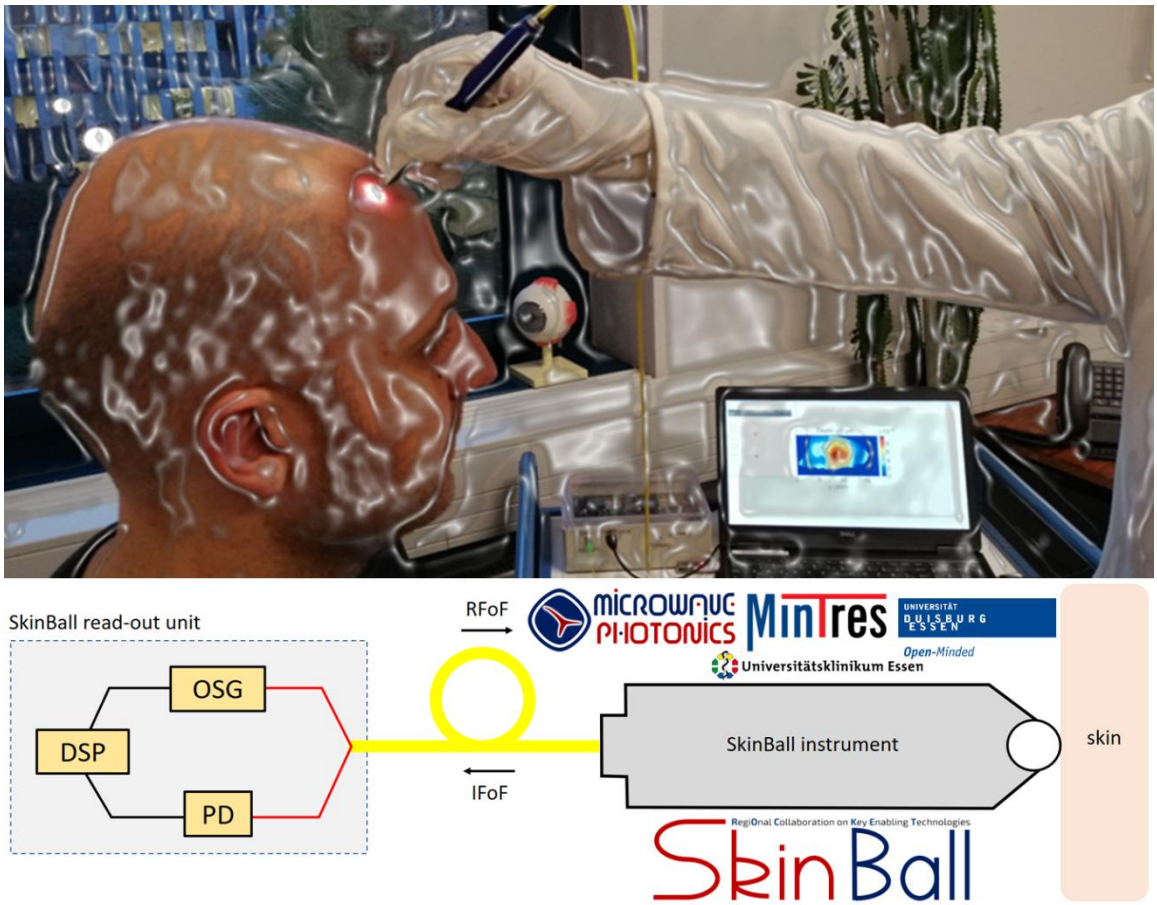
The SkinBall project will develop such a mobile mm-wave spectroscopy-imaging (MMWSI) system based upon advanced photonic technologies and an innovative mm-wave spectroscopy-system concept. The SkinBall MMWSI system will be used to monitor the permittivity of the human skin in vivo and in vitro. The technological challenge is to develop a mobile and high-resolution MMWSI system that could operate over an extremely wide bandwidth (>50 GHz) and provides sufficient contrast for reliable skin-tumor detection and analysis.

In general, photonics is the best-known technology for providing low-phase-noise reference signals (see Nobel Prize for T. W. Hänsch et al. in Physics 2005) and for providing ultra-broadband mm-wave generators and detectors. These two features are fundamental prerequisites for a successful development of a stable MMWSI system. Therefore, for the first time, SkinBall will develop a mobile photonic MMWSI system for enabling in-vivo and in-vitro skin monitoring (see figure below). If successful, the SkinBall MMWSI system will support skin-tumor detection, potentially reducing the number of unnecessary biopsies and it may also assist surgeons by providing precise data on the tumor's size and depth.

For achieving a high image contrast and for providing precise spectroscopic data of the skin's permittivity, a high-power (>1 mW) photonic mm-wave source operating from 30-100 GHz is required.

Microwave Photonics GmbH
Essener Str. 5
46047 Oberhausen, Germany
info@microwave-photonics.com
www.microwave-photonics.com

Mintres BV
De Nieuwe Erven 8
5431 NT Cuijk, The Netherlands
info@mintres.com
www.mintres.com



Practitioner examining a patient's skin using the lightweight, mobile, and fiber-coupled mm-wave spectroscopy instrument to be developed in SkinBall: Re-enacted scene for visualizing the project's key objective (top) and illustration of the SkinBall system (bottom) consisting of the SkinBall instrument and readout unit (digital signal processing (DSP), optical signal generator (OSP), photodetector (PD)). The instrument is connected via lightweight optical fiber (RF signal over fiber (RFoF), IF signal over fiber (IFoF)) to the readout unit.

However, for enabling mobile in-vivo skin monitoring, the power consumption of the photonic mm-wave source as well as the power consumption of the mm-wave receiver must be low. To achieve this, SkinBall will exploit free-space mm-wave power combining by using a photodetector array with photodiodes, which only require some milliamperes of DC supply. There will be no power-hungry amplifier used in the mobile SkinBall instrument. In addition, SkinBall proposes an innovative dual-frequency-spectroscopy system setup. This will allow to use zero-bias mm-wave Schottky detectors for determining the complex permittivity of the skin by simple envelope detection.

Microwave Photonics GmbH
Essener Str. 5
46047 Oberhausen, Germany
info@microwave-photonics.com
www.microwave-photonics.com

Mintres BV
De Nieuwe Erven 8
5431 NT Cuijk, The Netherlands
info@mintres.com
www.mintres.com

Project Partners

For realizing the above innovations, the SkinBall partners Microwave Photonics GmbH and Mintres BV will join their forces. For high-power operation, Mintres BV will integrate a photonic InP chip provided by ZHO/Optoelectronics on a CVD diamond carrier (chip-on-carrier, CoC) for thermal Joule-heating management in the high-power source. Mintres BV will provide the photonic CoC to Microwave Photonics GmbH where it will be packaged with optical fiber. The University Hospital Essen in Germany will provide skin samples to the project partners and will also provide an expert evaluation of the measured spectroscopic and image data.

Conclusion

In summary, the focus of the SkinBall project is the development of a photonics-based mm-wave spectroscopy instrument for mobile skin-cancer identification and screening. For this, the project proposes a number of innovations with respect to photonic processes, modules, and systems. The project also addresses smart materials and new process development for fabricating hybrid integrated chiplets.

Acknowledgment

The authors acknowledge financial support by the European Union and the INTERREG partners within the SkinBall project (http://rocket-innovations.eu/rocket/projekt-rocket-reloaded/skinball/) in the framework of the European INTERREG-V-A program "ROCKET Reloaded" (http://rocket-innovations.eu/rocket/projekt-rocket-reloaded/).

References

[1] A. Mirbeik-Sabzevari and N. Tavassolian, "Tumor Detection Using Millimeter-Wave Technology," in IEEE Microwave Magazine, vol. 20, no. 8, pp. 30-43, 2019.

[2] N. K. Nikolova, "Microwave Imaging for Breast Cancer," in IEEE Microwave Magazine, vol. 12, no. 7, pp. 78-94, 2011.

[3] A. Zamani, S. A. Rezaeieh, and A. M. Abbosh, "Lung cancer detection using frequency-domain microwave imaging," in Electronics Letters, vol. 51, no. 10, pp. 740-741, 2015.

[4] A. Mirbeik-Sabzevari and N. Tavassolian, "Ultrawideband, Stable Normal and Cancer Skin Tissue Phantoms for Millimeter-Wave Skin Cancer Imaging," in IEEE Transactions on Biomedical Engineering, vol. 66, no. 1, pp. 176-186, 2019.

[5] A. Uong and L. I. Zon, "Melanocytes in development and cancer," in Journal of Cellular Physiology, vol. 222, no. 1, pp. 38-41, 2010.

Microwave Photonics GmbH
Essener Str. 5
46047 Oberhausen, Germany
info@microwave-photonics.com
www.microwave-photonics.com

Mintres BV
De Nieuwe Erven 8
5431 NT Cuijk, The Netherlands
info@mintres.com
www.mintres.com