

# UC Irvine

## UC Irvine Previously Published Works

### Title

A LED based spatial frequency domain imaging system for optimization of photodynamic therapy of Basal Cell Carcinoma (BCC)

### Permalink

<https://escholarship.org/uc/item/9qr2c0nb>

### Authors

Saager, Rolf B  
Cuccia, David J  
Saggese, Steven  
et al.

### Publication Date

2010-12-01

### DOI

10.1364/fio.2010.ftus2

### Copyright Information

This work is made available under the terms of a Creative Commons Attribution License, available at <https://creativecommons.org/licenses/by/4.0/>

Peer reviewed

# A LED based spatial frequency domain imaging system for optimization of photodynamic therapy of Basal Cell Carcinoma (BCC)

Rolf B Saager<sup>1</sup>, David J Cuccia<sup>2</sup>, Steven Saggese<sup>2</sup>, Kristen M Kelly<sup>1</sup> and Anthony J Durkin<sup>1</sup>

<sup>1</sup>The Beckman Laser Institute, University of California – Irvine, Irvine, CA 92617

<sup>2</sup>Modulated Imaging, Inc., Irvine, CA 92617

rsaager@uci.edu

A LED based spatial frequency domain imaging (SFDI) system has been developed to provide personalized photodynamic therapy for BCC. We present the instrument design, validation of performance and initial characterization of wide-field properties of BCC.

©2010 Optical Society of America

OCIS codes: (170.5280) Photon Migration; (170.7050) Turbid Media; (170.6935) Tissue characterization

## 1. Introduction

PDT offers the potential for enhanced treatment of BCC skin cancer without the detriments associated with current treatment methods: healthy tissue loss, scarring. In spite of this, PDT has still not achieved the consistent performance required to gain widespread clinical acceptance for treatment of skin cancer. One particular limitation is a lack of reliable quantitative tools to perform *in vivo* dosimetry that monitors the treatment light dose during PDT [1]. Even when dosimetry is used, lesion-to-lesion variability leads to treatment plans that are not optimum [2,3]. Our hypothesis is that by using an imaging system that can characterize the tissue and photosensitizer optical properties, we can use that information to spatially and temporally optimize the light irradiance for personalized treatment, thus improving outcomes.

## 2. Instrument Development

In this presentation we limit our discussion to the design and development of a new LED based spatial frequency domain imaging (SFDI) system, performance characterization of the system and optical characterization of a series of *in-vivo* BCC. SFDI is a novel non-contact optical imaging technology under development at the Beckman Laser Institute [4]. SFDI has the unique capability of spatially resolving optical absorption and scattering parameters, allowing wide-field quantitative mapping of tissue optical properties and chromophore concentrations. While compatible with temporally-modulated photon migration methods, SFDI uses spatially-modulated illumination for imaging of tissue constituents.

The SFDI system that we have designed for this application includes 5 programmable illumination sources: 5 LEDs centered at 460, 525, 630, 730 and 850 nm. All illumination sources are delivered to a digital micromirror device (DMD), allowing for projection of spatial patterns having 8-bit gray scale and with 40 micron spatial resolution at the projection image plane. A 16-bit camera is used to collect light from the tissue with a spatial resolution of 30 microns at the image plane. The remitted image from the tissue differs from the illumination pattern due to the optical property characteristics of the sample. Typically, sine-wave illumination patterns are used. The demodulation of these spatially-modulated waves characterizes the sample modulation transfer function (MTF), which embodies the optical property information. The DMD, CCD and LEDs are synchronized with a computer, enabling acquisition of a series of patterns at various spatial frequencies. A TiO<sub>2</sub>-based silicone reflectance standard is used to calibrate the source intensity and to correct for spatial non-uniformities in both the illumination and imaging systems.

## 3. Methods and Results

3.1 The performance of the SFDI measurement modality of this system were compared to existing bench-top SFDI instruments and validated through measurements of tissue simulating phantoms of known optical properties. The signal to noise and light throughput of this system were markedly improved over that of the benchtop instruments, resulting in nearly a 10x reduction in acquisition time under the same settings and measurement parameters. In the context of a clinical setting, this results in measurement sequence acquisition times of 5-10 seconds.

3.2 Homogeneous turbid phantoms of known optical properties were used to validate the system stability and accuracy. A series of 10 phantom measurements were taken sequentially to characterize the stability of the LED based

projection and accuracy of the calculated optical properties via SFDI in relation to the known values. From these measurements, the reflectance values measured from the phantoms varied less than 0.1% for each LED illumination source at the single pixel level. The calculated optical properties exhibited a 1% variance as a result and matched the known optical properties of the phantom to within the accuracy of the multi-distance frequency domain technique that was used to independently verify these properties. As a result of this investigation, we have concluded that under controlled, homogeneous sample conditions, the instrument is capable of determining absorption and reduced scattering values to 1% accuracy and this instrument measurement modality operates under shot-noise limited conditions.

3.3 For the initial stage of this investigation, clinical imaging of BCC lesions was performed at five discrete wavelengths utilizing SFDI techniques. Sinusoidal intensity patterns with 6 distinct spatial frequencies were projected onto the tissue, ranging from 0-0.5 mm<sup>-1</sup>. In some cases, images were taken prior to the initial biopsy which was later confirmed as BCC, while others were imaged prior to treatment. Figure 1 shows an example of optical and physiological property images of a confirmed BCC contrasted from standard clinical photography. From this example, the spatial variance of the reduced scattering in figure 1(b) is +/- 30% the average value, reinforcing the motivation for mapping optical properties prior to PDT to ensure sufficient light dosimetry throughout a highly optically heterogeneous tissue. Figure 1(b) shows the superficial StO<sub>2</sub> distribution surrounding the lesion. The 5 selected wavelengths were selected to optimally characterize, additional physiologic parameters, such as melanin distribution, and oxy/deoxy-hemoglobin concentration. It has also been noted that the biopsy site within the lesion can perturb the optical properties of the underlying tissue, even after several weeks of healing. This is often presented as a 10-20% drop in scattering values relative to the surrounding tissue.

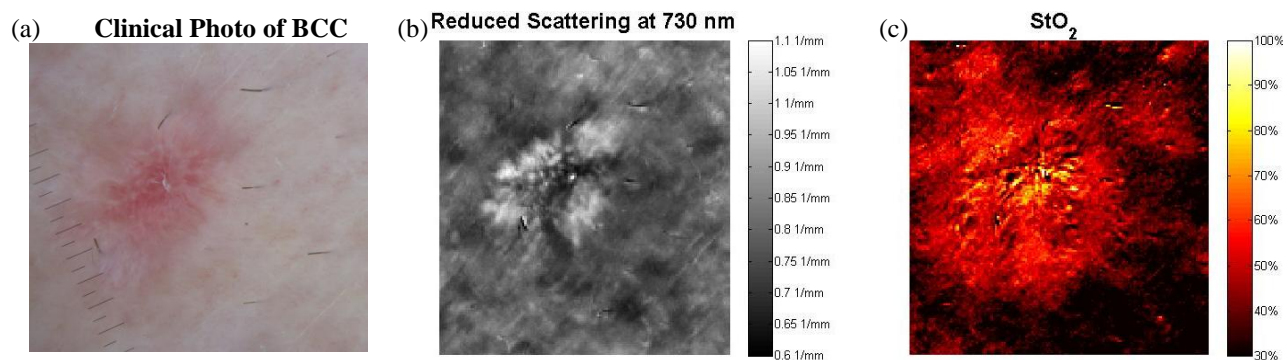


Figure 1. Example BCC lesion: (a) Clinical photo of lesion taken with cross-polarized illumination, (b) scattering properties of that same lesion at 730nm, and (c) calculated oxygenation map of that lesion and surrounding tissue.

#### 4. References

1. M.S. Patterson, et. al. "In vivo tests of the concept of photodynamic threshold dose in normal rat liver photosensitized by aluminum chlorosulphonated phthalocyanine," *Photochem Photobiol*, Vol 51, 343-349, 1990
2. A. Johansson, et.al., "In vivo measurement of parameters of dosimetric importance during interstitial photodynamic therapy of thick skin tumors," *Journal of Biomedical Optics* 11(3), May/June 2006.
3. W.J. Cottrell, et. al. "System for providing simultaneous PDT delivery and dual spectroscopic monitoring in clinical basal cell carcinoma," *Optical Methods for Tumor Treatment and Detection: Mechanisms and Techniques in Photodynamic Therapy XV*, edited by David Kessel, Proc. of SPIE, Vol.6139, 2006
4. D. J. Cuccia, F. Bevilacqua, A. J. Durkin, F. R. Ayers, and B. J. Tromberg, "Quantitation and mapping of tissue optical properties using modulated imaging," *Journal of Biomedical Optics* 14(2), 024012 (2009).