

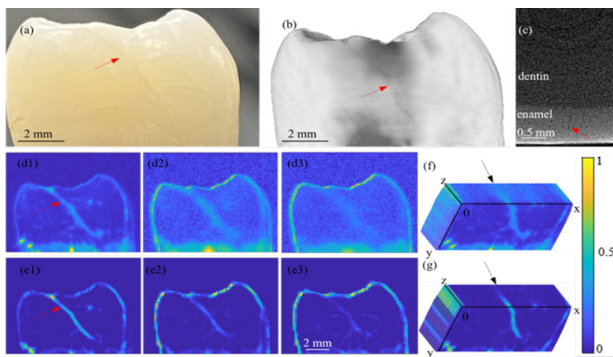
5th World Congress on
DENTISTRY AND MAXILLOFACIAL SURGERY
September 18-19, 2023 | Rome, Italy

Received Date: 06-04-2023 | Accepted Date: 06-07-2023 | Published Date: 10-20-2023

Three-dimensional thermophotonic super-resolution and multispectral truncated-correlation photothermal coherence tomography imaging methods for detection of dental subsurface defects and early-stage bacterial demineralization caries

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This talk will present a method to overcome the physics of lateral thermal diffusion in photothermal infrared-photon-mediated (thermophotonic) dynamic tomographic imaging that has greatly limited the use of thermal imaging (thermography), specifically, its application to dental diagnostic imaging to date. The method was developed using a spatial second derivative algorithm, combined with a modified spatiotemporal gradient adaptive filter, an experimentally developed photothermal point spread function (PPSF) for optimized diffusive image restoration (Richardson-Lucy deconvolution). When implemented through enhanced truncation-correlation photothermal coherence tomography (eTC-PCT) [1], the PPSF-mediated deconvolution corrects diffusion spread by reversing the effect of spatial convolution. A combination of these operations was applied to the conventional eTC-PCT images, and the results show that it restores the image resolution very close to the pre-diffusion optical resolution enhanced by thermal conversion immune to optical scattering. This is a breakthrough since traditional limitations caused by lateral and axial heat diffusion were overcome. A first study of highly optically scattering biological tissues such as human dental enamel shows that the unique combination of thermophotonic optical-grade restoration methods and rapid camera CCD or CMOS full pixel array image processing [2] reveals the true spatial extent of a hairline dental enamel crack, resolves finely patterned anatomical structures of a mouse brain in-vivo and ex-vivo, and monitors cancerous tumor growth in-vivo in a mouse thigh after cancer cell injection [3]. A multispectral (MS) eTC-PCT imaging modality will also be presented for the detection of bacterial-induced dental caries [4]. Compared with conventional TC-PCT [5], MS eTC-PCT was found to provide superior contrast and increased depth information about the state of defects in teeth. The experimental results were validated using micro-computed tomography (μ CT). These are distinct advantages for dental imaging over conventional optical methods which cannot operate subsurface due to the high light scattering nature of soft and hard tissues, while X-rays exhibit lower contrast to early demineralization and compromised safety due to ionizing radiation.



a) A photograph of a tooth with a crack shown by the red arrow. (b) Reconstructed MicroCT image. (c) MicroCT slice of the tooth showing the depth of the crack in (b). (d1-d3) Conventional eTC-PCT images at delay times 0 ms, 200 ms, and 400 ms, respectively. (e1-e3) eTC-PCT images in (d1-d3) after applying super-resolution algorithms. Angled cross-section of the 3D volume from conventional eTC-PCT images (f) and filtered eTC-PCT images (g).

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Recent publications

1. Tavakolian P, Sivagurunathan K, Mandelis A (2017) Enhanced truncated-correlation photothermal coherence tomography with application to deep subsurface defect imaging and 3-dimensional reconstructions. *Journal of Applied Physics* 122: 023103.
2. Kaiplavil S, Mandelis A (2014) Truncated-correlation photothermal coherence tomography for deep subsurface analysis. *Nature Photonics* 8: 635-642.
3. Tavakolian P, Rointan S, Mandelis A (2020) Non-invasive in-vivo 3-D imaging of small animals using spatially filtered enhanced truncated-correlation photothermal coherence tomography. *Scientific reports* 10: 1-10.

Biography

Andreas Mandelis has established the fields of diffusion waves and thermophotonics and has made seminal contributions to photoacoustic and photothermal sciences and technologies. He is the Director of the University of Toronto's Institute for Advanced Non-Destructive and Non-Invasive Diagnostic Technologies (IANDIT) and the Director of the Center for Advanced Diffusion-Wave and Photoacoustic Technologies (CADIPT). His current research interests are advanced instrumentation and metrology development for non-destructive and non-invasive imaging at the industrial – biodiagnostics-in-healthcare interface.

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