

[Invited Lecture]

## Multi-parameter Analysis and Optimization of 1D Galvanometer-based Laser Scanning with Applications in Optical Coherence Tomography

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### Abstract

One-decade contributions on galvanometer scanning (GS) related to high-end biomedical imaging applications using Optical Coherence Tomography (OCT) are presented. The focus is placed on one-dimensional (1D) laser scanning involving all GS parameters, constructive (i.e., inertia torque, elastic and damping coefficients) and functional (i.e., scan frequency and speed, scan amplitude/Field-of-View (FOV), and duty cycle). The steps of the research have been as follows: (i) The three most common input signals of GSs are explored: sinusoidal, sawtooth, and triangular. The latter is demonstrated to provide the smallest possible distortions and therefore, the largest duty cycle/time efficiency of the scanning process. A trade-off between scan frequency and amplitude (therefore FOV) is reached [V.-F. Duma, et al., *Appl. Opt.* 50, 5735-5749 (2011)].

(ii) A modeling of the scanning process is made considering the theoretical duty cycle  $\eta_t$  (of the input signal) of sawtooth scanning functions (for which a triangular signal is the  $\eta_t$  equals 50% case). The effective duty cycle  $\eta$  (of the output signal/angular position of the galvomirror, placed on the rotor of the GS motor) is deduced, for three different cases of  $\eta_t$ , from 50% to 90%. The latter value refers to the shortest flyback of the GS. A saturation of the device is demonstrated, with a maximum  $\eta$  reached for  $\eta_t$  around 75%. The modeling functions are validated with OCT imaging. An algorithm for mosaic OCT is obtained using them, to obtain real-time imaging, with no post-processing of images [V.-F. Duma, et al., *Appl. Opt.* 54, 5495-5507 (2015)].

(iii) Pre-shaped linear plus parabolic input signals of GSs are demonstrated to be optimal (to provide the highest possible  $\eta$ ), in contrast to the literature, where linear plus sinusoidal signals have been considered best [V.-F. Duma, *Opt. Eng.* 49, 103001 (2010)].

Two-dimensional (2D) dual axis GS optimization can also be obtained using the above results [V.-F. Duma, *Appl. Math. Modelling* 67, 456-476 (2019)]. Micro-Electro-Mechanical Systems (MEMS)-based handheld probes have also been achieved for OCT [A. Cogliati, et al., *Opt. Express* 24, 13365-13374 (2016)]. A range of recent OCT biomedical applications is pointed out, to show the relevance and impact of the technique.

## Short Bio

Virgil-Florin Duma is Professor at the *Aurel Vlaicu* University of Arad, as well as head and founder of the 3OM Research Group (<http://3om-group-optomechatronics.ro/>), for which he has secured funds in excess of 2M Euro in the last decade. He received his PhD cum laude in 2001, from the Polytechnic University of Timisoara (UPT), where he graduated in Fine Mechanics and Optics in 1991, valedictorian. He was a Fulbright Senior Research Fellow at The Institute of Optics, University of Rochester, NY, USA (2009-2010), where he is Visiting Scientist. He is also Honorary Professor at the University of Kent, UK and Adjunct Professor at UPT, at the latter as PhD Advisor. Prof. Duma defended his Habilitation Thesis in 2013 at the Polytechnic University of Bucharest. He is author of over 40 publications in journals indexed in Web of Science (with a total impact factor higher than 70) and of over 100 papers in conference proceedings in WOS, 15 books & book chapters, and has 1 patent awarded and 2 patents pending. He delivered more than 40 invited presentations at international conferences and universities, including as SPIE Visiting Lecturer. Prof. Duma is reviewer for more than 40 journals indexed in Web of Science, for several funding programs, and chair of several SPIE conferences. He is guest editor of several special issues of journals in WOS ([https://www.researchgate.net/profile/Virgil-Florin\\_Duma](https://www.researchgate.net/profile/Virgil-Florin_Duma)). His main research interests are in Measuring Systems, Optomechatronics, and Biomedical Imaging, the latter with a focus on Optical Coherence Tomography. He is member of OSA, Senior Member of SPIE, and Life Member of the Fulbright Association.