

Dual-comb microscopy for scan-less confocal imaging

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Abstract:

Confocal laser microscopy (CLM) is a powerful tool in life science research and industrial inspection because it offers two-dimensional optical sectioning or three-dimensional imaging capability with micrometer depth selectivity. Furthermore, scan-less imaging modality enables rapid image acquisition and high robustness against surrounding external disturbances in CLM. However, the objects to be measured must be reflective, absorptive, scattering, or fluorescent because the image contrast is given by the optical intensity. If a new image contrast can be provided by the optical phase, scan-less CLM can be further applied for transparent non-fluorescent objects or reflective objects with nanometer unevenness by providing information on refractive index, optical thickness, or geometrical shape. Here, we report scan-less confocal dual-comb microscopy offering a phase image in addition to an amplitude image with depth selectivity by using an optical frequency comb as an optical carrier of amplitude and phase with discrete ultra-multichannels. Our technique encodes confocal amplitude and phase images of a sample onto a series of discrete modes in the optical frequency comb with well-defined amplitude and phase to establish a one-to-one correspondence between image pixels and comb modes. The technique then decodes these images from comb modes with amplitude and phase. We demonstrate confocal phase imaging with milliradian phase resolution under micrometer depth selectivity on the millisecond timescale. As a proof of concept, we demonstrate the quantitative phase imaging of standing culture fixed cells and the surface topography of nanometer-scale step structures. Our technique for confocal phase imaging will find applications in three-dimensional visualization of stacked living cells in culture and nanometer surface topography of semiconductor objects.

[1] E. Hase, T. Minamikawa, T. Mizuno, S. Miyamoto, R. Ichikawa, Y.-D. Hsieh, K. Shibuya, K. Sato, Y. Nakajima, A. Asahara, K. Minoshima, Y. Mizutani, T. Iwata, H. Yamamoto, and T. Yasui, "Scan-less confocal phase imaging based on dual-comb microscopy," *Optica*, Vol. 5, Issue 5, pp. 634-643 (2018).

[2] E. Hase, T. Minamikawa, S. Miyamoto, R. Ichikawa, Y.-D. Hsieh, Y. Mizutani, T. Iwata, H. Yamamoto, and T. Yasui, "Scan-less, kilo-pixel, line-field confocal phase imaging with spectrally encoded dual-comb microscopy," *IEEE J. Sel. Top. Quantum Electron.*, Vol. 25, Issue 1, 6801408 (2019).

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