Motion-resolved Quantitative Differential Phase Contrast

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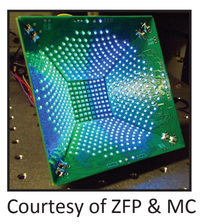
Introduction

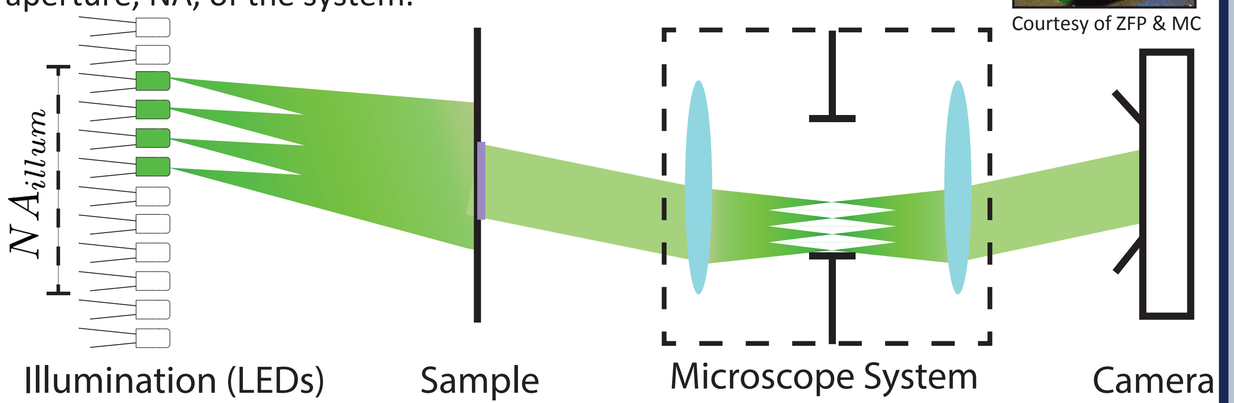
- **Quantitative Differential Phase Contrast (qDPC)**[1] is a **Quantitative Phase Imaging (QPI)**[2] method that recovers the complex transmittance function of a sample through several coded-illumination measurements (multi-shot) and a phase retrieval optimization.
- The **multiple DPC measurements are time multiplexed**, which requires the sample to be stationary during the acquisition, however, typical biological samples are non-stationary and might violate this assumption.
- Similar to **motion-induced blur** during a long exposure, motion occurring between measurements during the multi-shot DPC acquisition will cause spatial distortion and errors in the reconstructed quantitative absorption and phase.

Coded Illumination Microscope

A simple LED array[3] provides a cost-effective hardware solution for **QPI** methods. **qDPC** can be implemented on such a device by acquiring four coded-illumination measurements, where each illumination pattern is a unique semi-circle[1] with radius equal to the numerical aperture, NA, of the system.

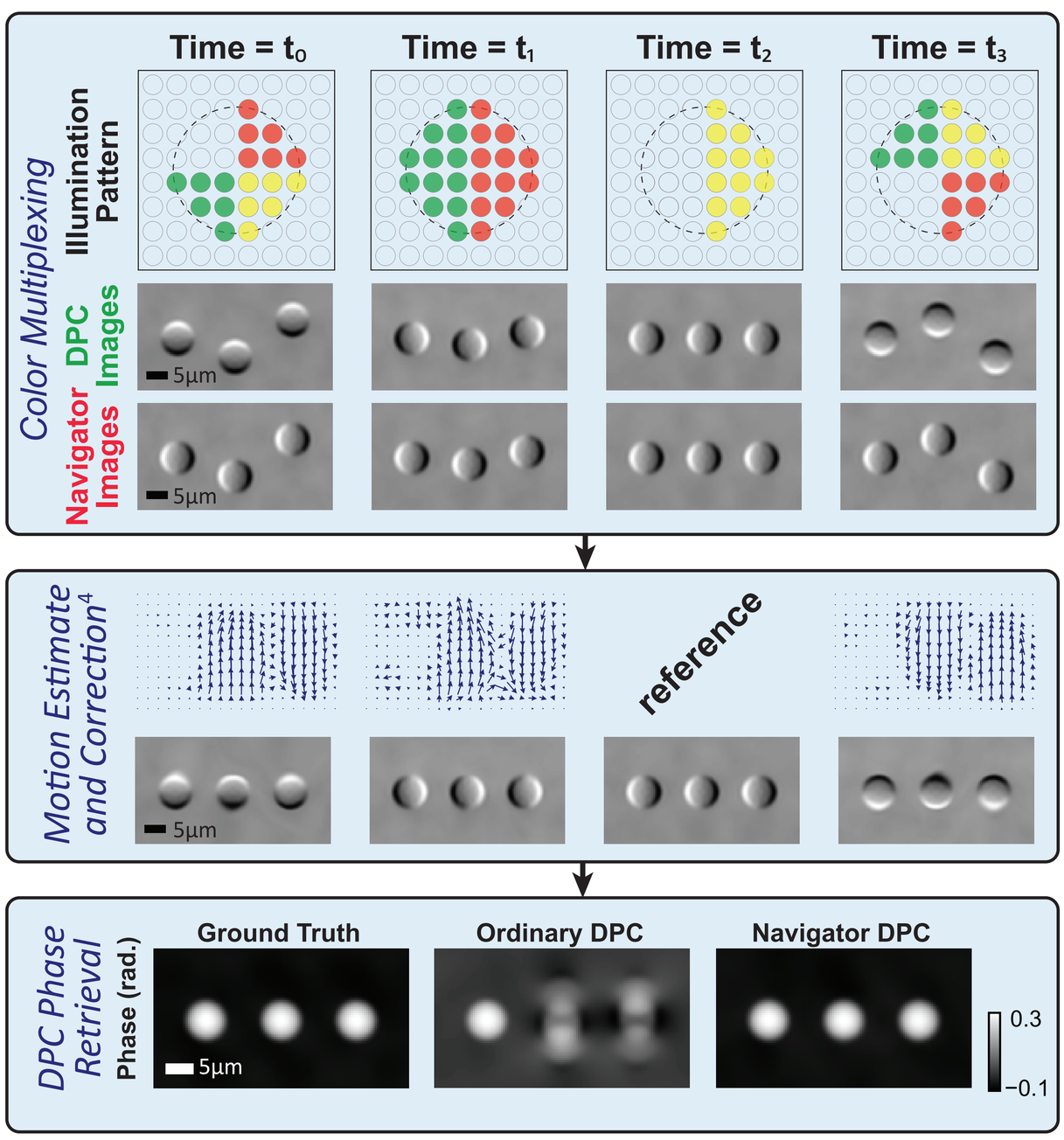


Courtesy of ZFP & MC

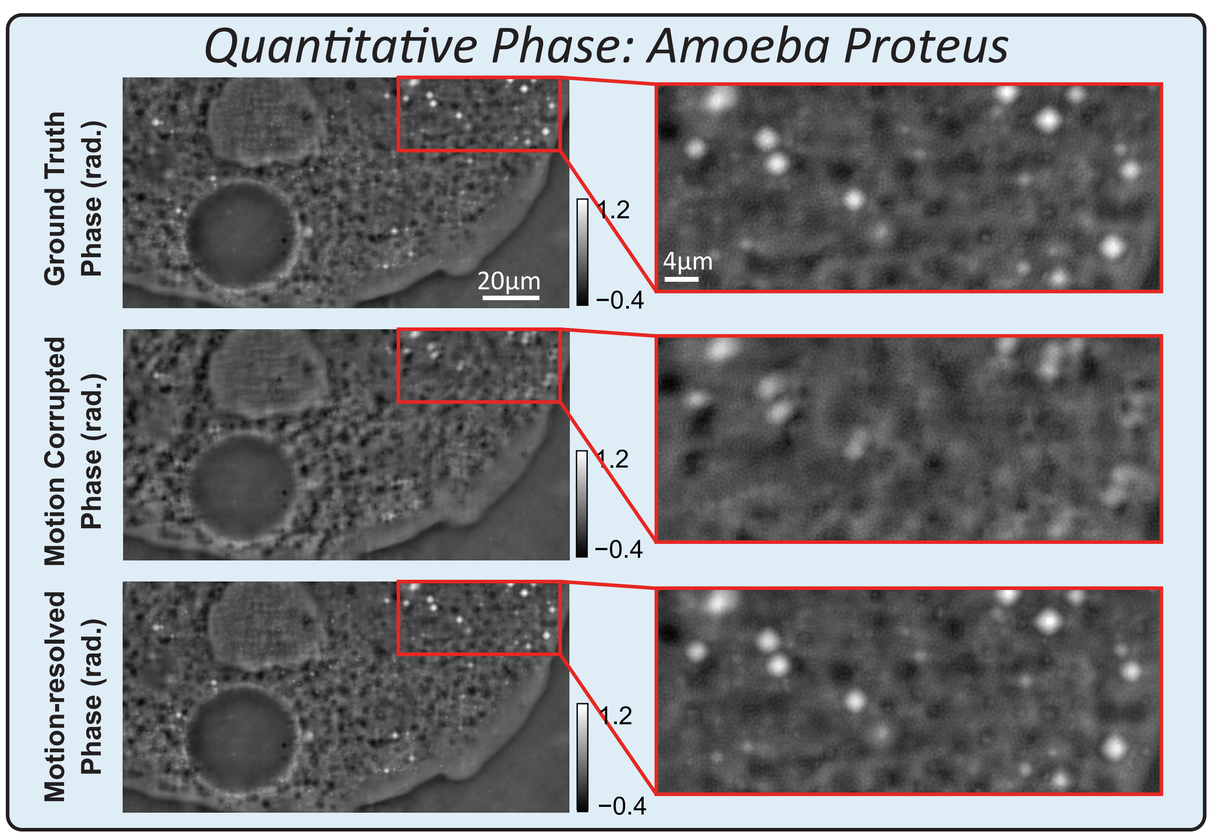


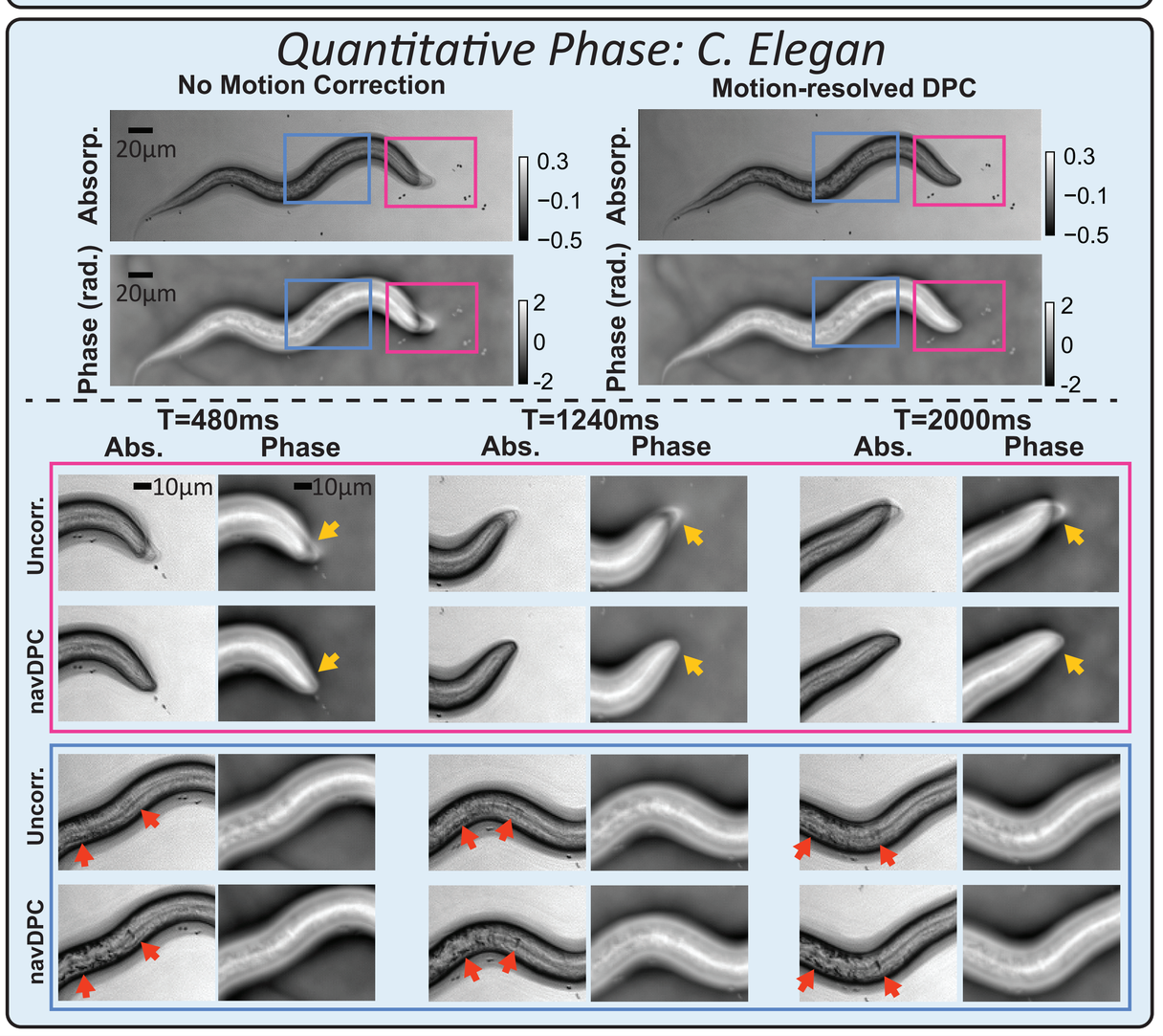
Navigator-based Motion Correction

Coded-illumination measurements cannot be registered with standard techniques due to their **varying spatial-frequency contrast**. Here, we use an additional color-multiplexed measurement with consistent contrast, called the **navigator signal**, to estimate and correct the motion between time points.



Motion-resolved Reconstruction





Conclusion & Discussion

- **Motion-resolved qDPC** can improve the temporal resolution of the original method by a factor of four and can reveal motion dynamics at the frame rate of the camera.
- Our ability to estimate motion depends on the bandwidth and SNR of the navigator signal; because its bandwidth is similar to that of the DPC signals motion estimated in one can be well corrected in the other.
- Further, our method can be applied to **even faster moving samples** by strobing the illumination LEDs during the exposure, this would be equivalent to taking measurements with delays between them.

References

[1] Lei Tian and Laura Waller, "Quantitative differential phase contrast imaging in an LED array microscope," Opt. Express 23, 11394-11403 (2015).
[2] Mir, M., Bhaduri, B., Wang, R., Zhu, R., & Popescu, G. Quantitative phase imaging. Progress in Optics, 57, 133-217. (2012).
[3] Z. Phillips, R. Eckert, and L. Waller, "Quasi-Dome: A Self-Calibrated High-NA LED Illuminator for Fourier Ptychography," in Imaging and Applied Optics (2017).
[4] Avants, B. B., Epstein, C. L., Grossman, M., & Gee, J. C. Symmetric diffeomorphic image registration with cross-correlation: evaluating automated labeling of elderly and neurodegenerative brain. (2008).