

## Executive Summary of Proposal:

### Single-shot, Isotropic and Miniaturized Differential Interference Contrast (SIM-DIC) Microscopy Based on Computational Flat-Optics

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In our daily life, we care about our health and the environment on the earth. In the healthcare and biomedical technologies, we need to image the biological samples, including cells, tissue slices and many others; in many areas on this planet and in many working spaces, people and other living creatures are facing challenging problems such as air pollutions (due to PM<sub>2.5</sub> dust micro/nanoparticles), microplastics in the sea and others. It is important to image those tiny samples with optical microscopy, and to track their movements in real time and in three dimensions.

However, most of those matters are transparent in the visible spectrum, being hard to be seen in most microscopies based on the optical absorption variances. There are existing techniques such as differential interference contrast (DIC) microscopy to record the refractive index change and the associated phase difference for imaging purpose. DIC features the merits of high spatial resolutions, outstanding contrast, optical sectioning capability, cost effectiveness, and pseudo-3D relief type of image. However, the conventional system is bulky (use 4f system) and can only obtain the information in one dimension, not the others, which is known as problem of “orientation sensitivity”.

In this proposal, we will use the flat-optical elements, i.e. metasurfaces, to innovate the traditional DIC microscope and develop the *single-shot, isotropic and miniaturized* DIC (SIM-DIC) microscopy. Our single-layer metasurface is made of millions of *deeply subwavelength, thin* (~300 nm) and *COMS-compatible* Si nanostructures and can perform the multiple functionalities including the focusing phase, the polarization multiplexing, and the edge detection (i.e. the first-order derivative mathematic operations). Moreover, our system is a *2f* compact system and has the powerful capabilities of mapping the full and isotropic contours of moving transparent microparticles and bio-samples in three dimensions. Most importantly, it can be designed into a simple and flexible module as an add-on portable device for our daily consumer electronics such as cellphones and others.

Beyond those technological values, the proposed project will lead the innovation of conventional photonic technologies via fusing the emerging platforms such as computational flat-optics. Our designed important system is highly integrated, low-cost, portable, flat and multifunctional for various high-end applications, including bio-imaging microscopy, wearable healthcare devices, environmental monitoring (of air pollution, microplastic pollution and etc.) and others.