Optical nanoscopy based on photonic integrated circuits

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Present optical nanoscopy uses a complex microscope setup to illuminate and a simple glass slide to hold the sample[1]. We propose to invert this arrangement by using a complex but mass-fabricated photonic integrated chip (PIC) to hold and illuminate the sample while keeping the microscope simple and affordable to acquire super-resolved images. Here, we report structured illumination microscopy (SIM) using a photonic chip. Our approach is to decouple illumination and collection optics, whereby photonic chips generate, deliver and steer the laser illumination pattern required for SIM. The sample is kept directly on top of a waveguide chip and is illuminated by the evanescent field of the waveguide. To generate the structured illumination fringes, the waveguide is split into two parts generating two counter-propagating guided modes that interfere and create a standing evanescent field pattern. For conventional 2D-SIM, 3 phase steps and 3 angles are required. In chip-based SIM, phase steps are obtained by slightly varying the path length in one of the waveguide arms and 3 angles are obtained by using 3 pairs of waveguide arms at 120º with respect to each other.

Importantly, we show experimentally that chip-based SIM can overcome the 2× resolution enhancement (*λ/4N.A.*) set by the objective launch in conventional linear SIM. The fringe spacing for conventional SIM is limited by the diffraction limit of the objective lens. Opposed to that, fringes formed by the waveguide are limited by the effective refractive index (n_{eff}) of the guided mode. By employing high refractive index material, such as silicon nitride and tantalum pentoxide, the n_{eff} of the guided mode can be made larger (e.g. 1.7) than the *N.A.* of commonly used oil immersion objective lens (1.4). The resolution of chip-based SIM thus is given by $\lambda/2(N.A+ n_{eff})$. Using a detection *N.A.* of 1.2 and emission wavelength (λ_{em}) at 680 nm the resolution enhancement of 2.3× was obtained (Fig. 1c). Compared to plasmonic SIM[2] that uses a metal-dielectric interface, the proposed chip-based SIM use only dielectric materials enabling light guidance to practically unlimited length. We believe chip-based optical nanoscopy would enable widespread availability of affordable multi-modality optical nanoscopes by retrofitting any standard fluorescence microscope. The fibre-compatibility of PIC enables light delivery with high-speed telecom devices enhancing the imaging speed.

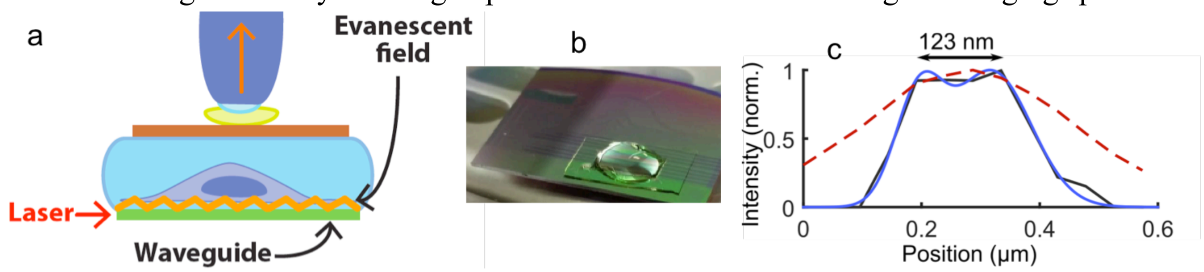

Fig.1a) Schematic diagram of chip-based nanoscopy, b) optical waveguide with a PDMS chamber; c) Two 100 nm beads with a distance of 123 nm were clearly separated using chip-based SIM (λ_{em} = 680 nm & detection N.A. 1.2) indicating resolution enhancement of 2.3×.

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2. Feifei Wei, Dylan Lu, Hao Shen, Weiwei Wan, Joseph Louis Ponsetto, Eric Huang, and Zhaowei Liu, "Wide Field Super-Resolution Surface Imaging through Plasmonic Structured Illumination Microscopy", *Nano Letters* 2014 *14* (8), 4634-4639