SUBTRACTION MICROSCOPY AND SUPER-RESOLUTION IN THE MID-INFRARED

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ABSTRACT: Mid-infrared (MIR) confocal micro-spectroscopy (λ>2.5 μm) is a label-free microscopy relying on vibrational absorption to generate chemically contrasted images. However, the MIR spatial resolution in the far-field remains diffraction-limited with point-spread functions (PSF) that are not narrower than ca. $\lambda/1.3$ (FWHM) with state-of-the-art reflective objectives. The resolution remains therefore very poor in comparison to most visible and near-infrared microscopies.

Remarkably, by introducing a central solid immersion lens (c-SIL), and imaging the specimen backside and immersed in air or water, we recently verified that for a linear-polarized Gaussian beam the PSF is reduced to a FWHM of ca. $\lambda/2$ along the axis normal to the polarization [1]. Furthermore, we are able to reconstruct dense (albeit sparse) specimens with a spatial resolution of $\lambda/2.6$ using crossed-polarized MIR images and a new algorithm developed around a particle swarm optimization (PSO) that explicitly takes advantage of the super-resolving sparsity arguments proposed by A. Szameit et al. [2]. This represents a more than two-fold improvement over the state-of-the-art.

To complement the approach above, we are exploring optical beam patterning to optically enhance the MIR spatial resolution by subtraction microscopy [3]. The method is well-known with visible light but unexplored in the MIR. A silicon phase plate was thus fabricated and the formation of a so-called half-moon beam verified with the c-SIL. Moreover, to avoid intensity artefact whilst maximizing the spatial resolution, we developed a new subtraction algorithm where the Gaussian image is first filtered in the spatial-domain with an PSO optimized kernel. The new method is applicable to various beam patterns and at any wavelengths and can over-perform earlier subtraction schemes exploiting Gaussian and doughnut beams.

In this contribution, we will summarize our recent MIR microscopy work and detail the reconstruction and subtraction procedures which are expected to equally apply and perform in MIR as well as in the ubiquitous visible microscopy.

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