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Programmable and Computational Microscopy

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Current developments in modern light microscopy are strongly influenced by the rapid technological progress made in light generation, shaping and detection as well as in the available computational power. The objective of forming a real sharp image on the retina of the microscopist is increasingly replaced by the more general aim of collecting information.
The possibility of adapting the optical properties of an imaging system bears great potential when combined with data processing algorithms that account for the changes made.
In my talk, I will present two examples from the field of light microscopy:
The first is **engineered scanning microscopy**, an imaging platform combining high spatial resolution and penetration depth with the ability to detect additional sample properties: depending on the user's choice, the microscope can be "sensitized" to additional properties, for instance 3D spatial structure or emission color.
The second example is **localization microscopy**, which breaks the classical resolution barrier by recording thousands of images, each showing only a sparse subset of fluorescent molecules that are sufficiently separated in space. The positional data of all molecules together represent a super-resolved image of the sample. I will outline the potential of deep learning for estimating molecule positions and more.

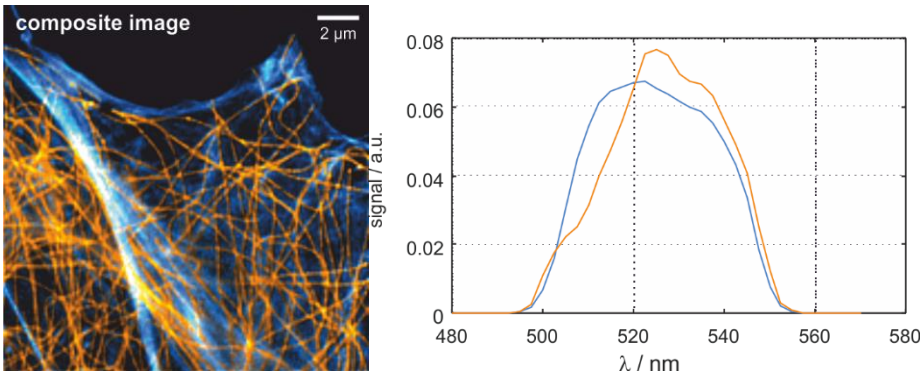

Fig. 1. Left: Actin and tubulin filaments in a HeLa cell. Although appearing blue (actin) and orange in the image, the different proteins are stained with dyes featuring very similar emission spectra (shown on the right). The spatial and spectral information has been acquired with an engineered image scanning microscope that has been programmed to measure colors.

[1] Jesacher, A., M. Ritsch-Marte, and R. Piestun, Three-dimensional information from two-dimensional scans: a scanning microscope with postacquisition refocusing capability. Optica, 2015. 2(3): p. 210-213.

[2] P. Zelger, K. Kaser, B. Rossboth, L. Velas, G. Schütz, and A. Jesacher. Three-dimensional localization microscopy using deep learning. Accepted for *Optics Express,* Nov. 2018.