

Extended Abstract

ChipScope Symposium: Novel Approaches for a Chip-Sized Optical Microscope [†]

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Abstract: In the Chipscope project funded by the EU, a completely new strategy towards optical microscopy is explored by a team of researchers from different European institutions. In this workshop, the different researchers of the project will explain the last advances obtained in the project, presenting the microscopes, how light emission is produced, and the detection principles and simulations.

Keywords: LED; microscopy; shadow imaging; nano-illumination

In the Chipscope project funded by the EU, a completely new strategy towards optical microscopy is explored by a team of researchers from different European institutions. In classical optical microscopy, the analyzed sample area is illuminated simultaneously, collecting the light which is scattered from each point with an area-selective detector, e.g., the human eye or the sensor of a camera. In the Chipscope idea, instead, a structured light source with tiny, individually addressable elements is used. As depicted in Figure 1, the specimen is located on top of this light source, in close vicinity. Whenever single emitters are activated, the light propagation depends on the spatial structure of the sample, very similar to what is known as shadow imaging in the macroscopic world. To obtain an image, the overall amount of light which is transmitted through the sample region is sensed by a detector, activating one light element at a time and thereby scanning across the sample space. If the light elements have sizes in the nanometer regime and the sample is in close contact with them, the optical near field is of relevance and super-resolution imaging may become possible with a chip-based setup.

To realize this alternative idea, a bunch of innovative technology is required. Several partners in the ChipScope project bring in expertise in the according research fields. The structured light source is realized by tiny light-emitting diodes (LEDs), which are developed at the University of Technology in Braunschweig, Germany. Due to their superior characteristics in comparison to other lighting systems, e.g. the classical light bulb or Halogen-based emitters, LEDs have conquered the market for

general lighting applications in the past decades. However, to the present point, no structured LED arrays with individually addressable pixels down to the sub- μm regime are commercially available. This task belongs to the responsibility of TU Braunschweig within the frame of the ChipScope project. The LEDs are based on gallium nitride (GaN), a semiconductor material that is commonly used for blue and white LEDs. Controlled structuring of such LEDs down to the sub- μm regime is extremely challenging. It is conducted by photo- and electron-beam lithography, where structures in the semiconductor are defined with high precision by optical shadow masks or focused electron beams.

As a further component, highly sensitive light detectors are required for the microscope prototype. The University of Barcelona has a high level of know-how and develops so-called single-photon avalanche detectors (SPADs), which can detect very low light intensities down to single photons. First tests with those detectors integrated into a prototype of the ChipScope microscope have already been conducted and shown promising results. Moreover, a way to bring specimens into close vicinity of the structured light source is vital for proper microscope operation. An established technology to realize this utilizes microfluidic channels, where a fine system of channels is integrated into a polymer matrix. Using tiny pumps, a liquid is driven through this system and carries the specimen along to the target position. This part of the microscope assembly is contributed by the Austrian Institute of Technology AIT. Further partners in the ChipScope project comprise a team of the Medical University of Vienna, the University of Rome Tor Vergata, the Maximilian Ludwigs University in Munich and the FSRM, Switzerland.

The ChipScope project, funded in the framework of the EU's Horizon 2020 program, was launched in 2017 and will run until the end of 2020. Up to now, a lot of progress has already been achieved in the different subtopics involved in the project, including a prototype of the proposed microscope. The different aspects of the technology will be discussed in this workshop, providing a detailed overview of what can be achieved today.

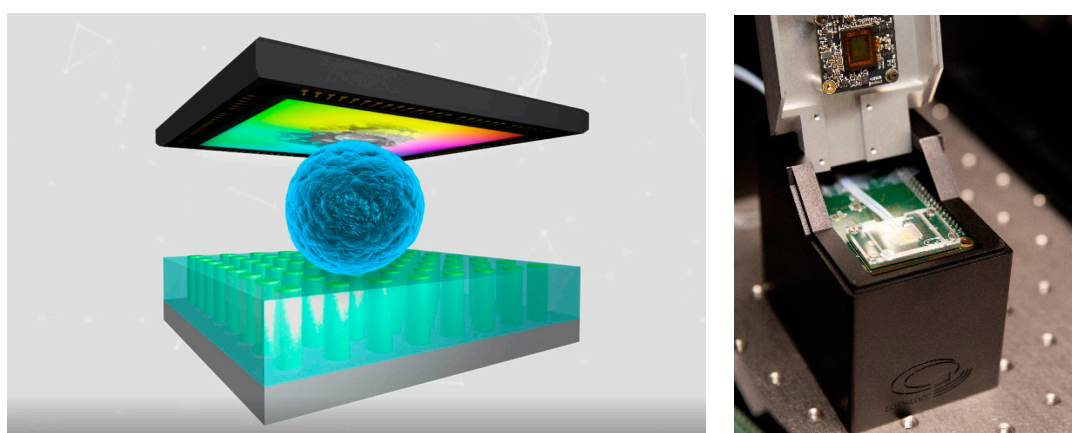


Figure 1. (left) A model of the ChipScope microscope: the specimen lying on the nanoLED surface is scanned, and the shadow image is recorded. (right) Current Chipscope microscope integrating microfluidics to observe the sample.

Supplementary Materials: Video of the project is available online at <https://www.youtube.com/watch?v=pePTwFz1x8s>. The project website is www.chipscope.eu.

Author Contributions: A.D. is the coordinator of the Chipscope project and responsible of microscope integration; S.B. works on the LED fabrication and characterization; K.K.-K. has performed the electro-optical simulations of LEDs; K.T. and V.G. are working on the single molecule detection on portable microscopes; S.S. is the team leader for the integration of microfluidics in the microscope. All authors have read and agreed to the published version of the manuscript.

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