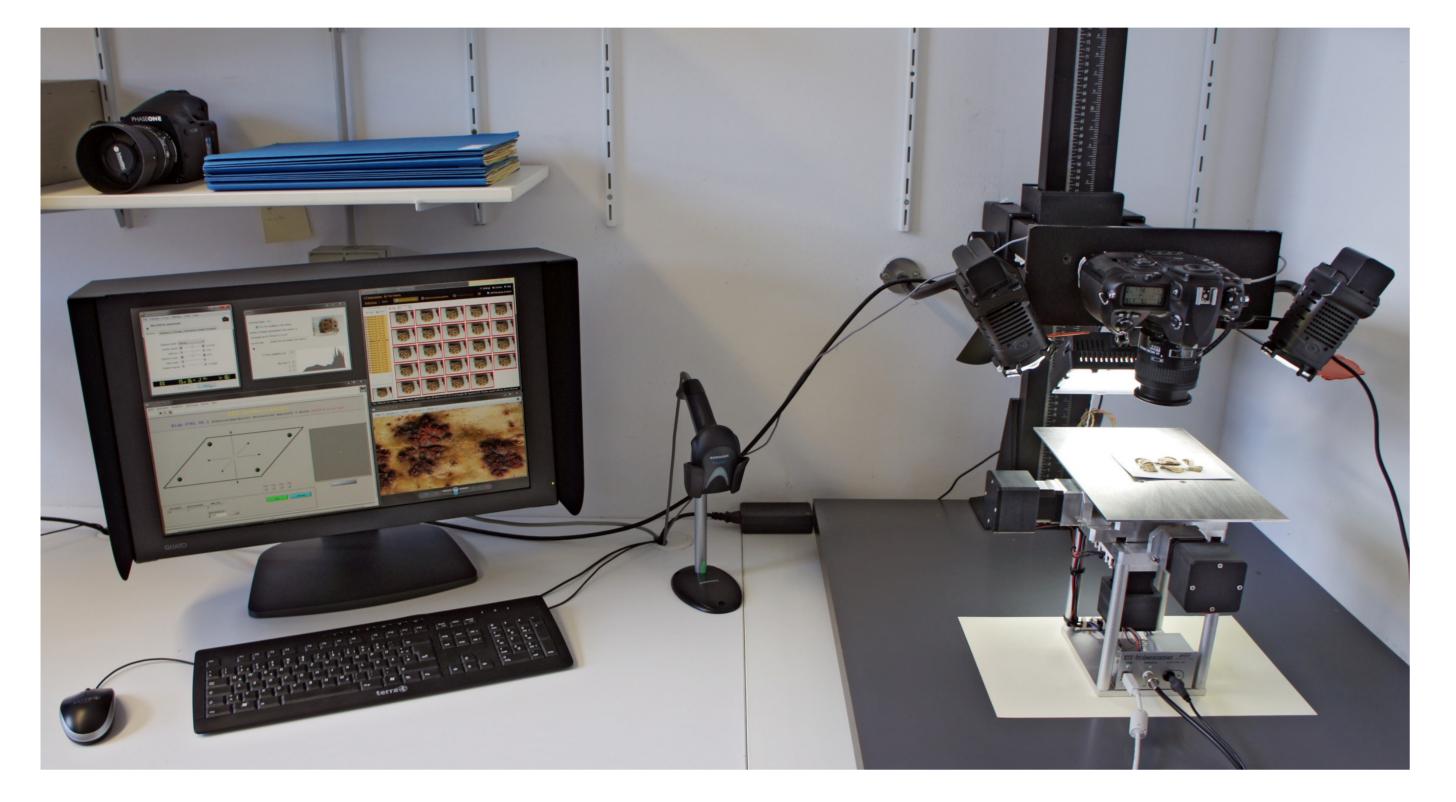# Multi-layered digitization of research-relevant objects using focus stacking technologies and a software-controlled movable table

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High-resolution camera system with software-controlled movable table optimized for three-dimensional macro objects (small fungi) and high depth of field.

Since 2010 the Botanische Staatssammlung München, an institution belonging to the Staatliche Naturwissenschaftliche Sammlungen Bayerns, is running two major third-party funded projects to digitize research-relevant objects of microfungi and lichens. One is done as part of the Global Plants Initiative (GPI), an international collaboration funded by the Andrew W. Mellon Foundation. The other one is funded by the Bundesministerium für Bildung und Forschung (BMBF) in the frame of the GBIF-D Node Fungi & Lichens to mobilize data for GBIF.

Especially in the microfungi visible morphological entities are very small (between 0.1 mm and 10 mm) and with structural details that are often hardly differentiated from the substrate they are growing on. For better visualization a special image-combining workflow has been developed basing upon focus stacking and super-resolution technologies. A software-controlled movable table was constructed to facilitate the easy and precise arrangement of the specimens for the digitization process. The outcome are multi-layered digital images of these mycological objects resulting in high-resolution photographs with extended depth of field.

The object to be digitized is placed on an electric table, called XYZ-Sample-Scanner. The scanner was designed and set up by the Department of Mycology, University of Bayreuth and the Facility for Electronic Infrastructure there. Up to 24 photographs are automatically taken by the accompanying *Elub 0781* software, thereby slightly changing the focus settings after each shot according to predefined parameters. Pixel resolution of a single shot is about 12 MP.
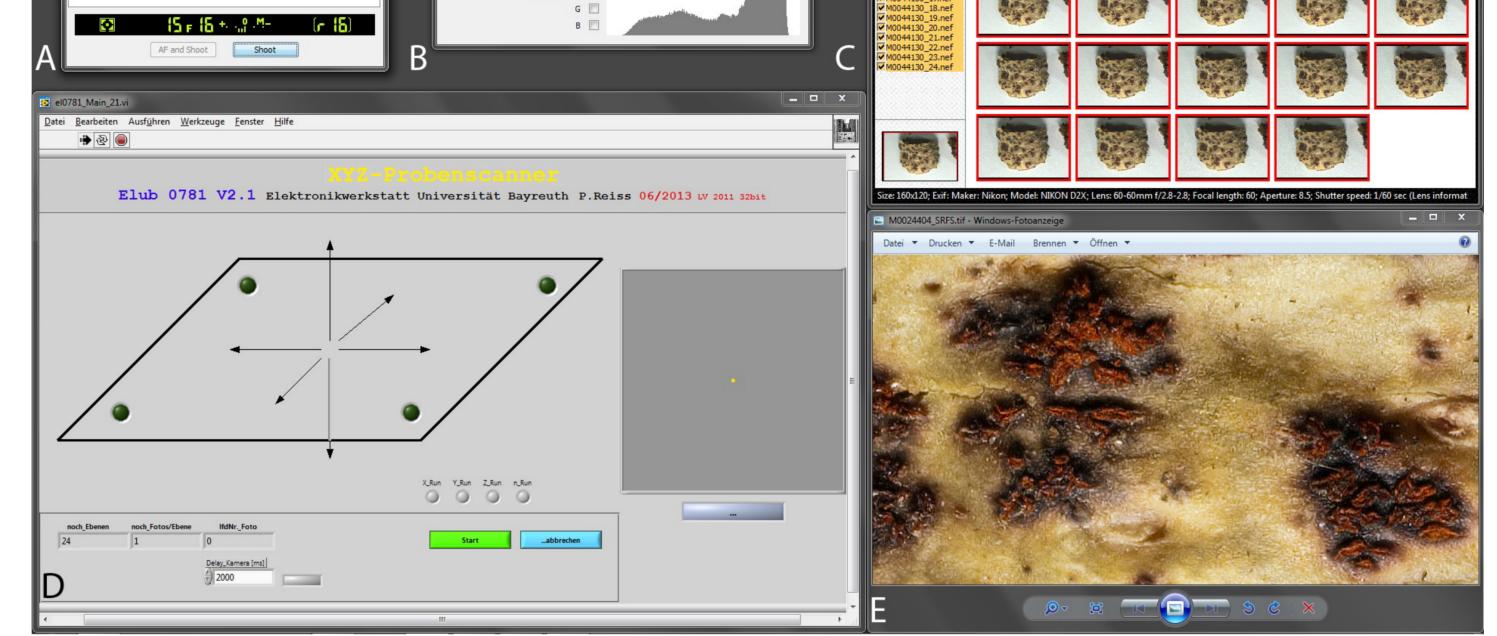
The resulting photographs (RAW files) are combined to one new image (approx. 40 MP) applying super-resolution and focus stacking technologies provided by *Almalence PhotoAcute Studio*. This artificial image contains only that parts of the underlying single shots, which are in focus (focus stacking), and its resolution is enhanced approximately fourfold (super-resolution).

In *Adobe Photoshop*, the final raw image file is color-adjusted, cropped, and exported as TIFF file. The whole procedure with processing and finishing takes about 35 minutes. The image data processing also includes the creation of "zoomable" images using Krpano (www.krpano.com). Until now about 300 objects have been digitized. The digitization workstation is described in the Wiki of the GBIF-D initiative (http://wiki.gbif.de/web/Digitalisierung_an_den_SNSB).

Working environment on PC to take images and apply focus stacking and superresolution.

A. Nikon Camera Control Pro 1.3.0. settings. B. Status display of download processes. C. PhotoAcute Studio 3: Image selection for focus stacking. D. Elub 0781 2.1 control software for the XYZ-Sample-Scanner. E. Final image with super-resolution

Digital images and metadata are managed in the Diversity Workbench (DWB), a framework with 12 independent relational databases (MS SQL; http://www.diversityworkbench.net).

DiversityCollection is devoted to the management of specimens in scientific collections. Images are directly linked with the metadata of a specific specimen.

The images and metadata are accessible via several web portals including those of JSTOR, GBIF and BiNHum. The latter is a portal currently set up by several German Natural History Collections.