Introduction to Light-Field Imaging II

Dr. Christian Perwaß

Introduction to Light-Field Imaging

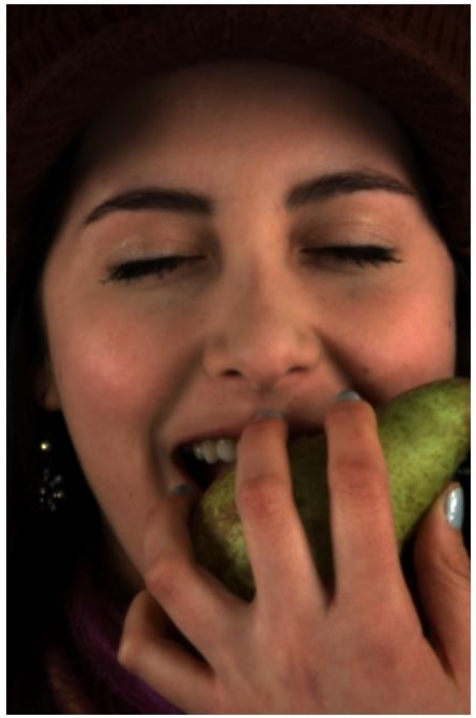
Part 1

1. Introduction
   a) Basic Idea
   b) Available Devices: Raytrix, Lytro, Pelican Imaging, Fraunhofer IOF
2. What is a Light-Field?
   a) Basic optics: Pinhole model
   b) Light Field 1.0 vs. 2.0
   c) Camera Model
3. Towards a real Light Field Camera
   a) Lens optics
   b) Depth of Field
   c) Camera Model
4. Algorithms
   1. Image Synthesis
   2. Depth Estimation
   3. Camera Calibration

Part 2

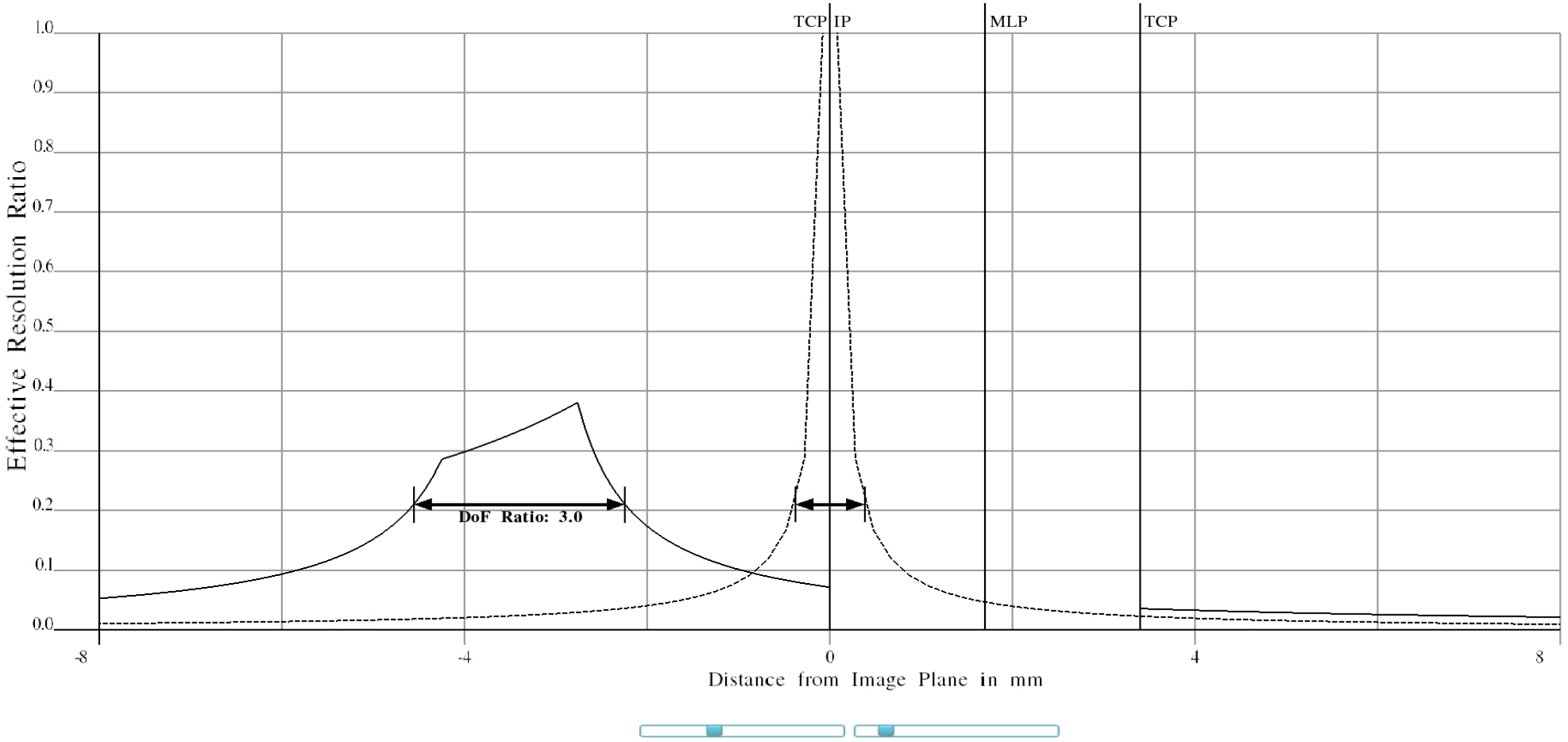
1. Multiple-Focus Light Field Camera
   a) Motivation
   b) Depth of Field
   c) Total Covering
2. Applications
   a) Processing
   b) 3D Quality Inspection
   c) 3D Microscopy
   d) 3D Volumetric Velocimetry
   e) and more…

Multiple Focus Light Field Camera

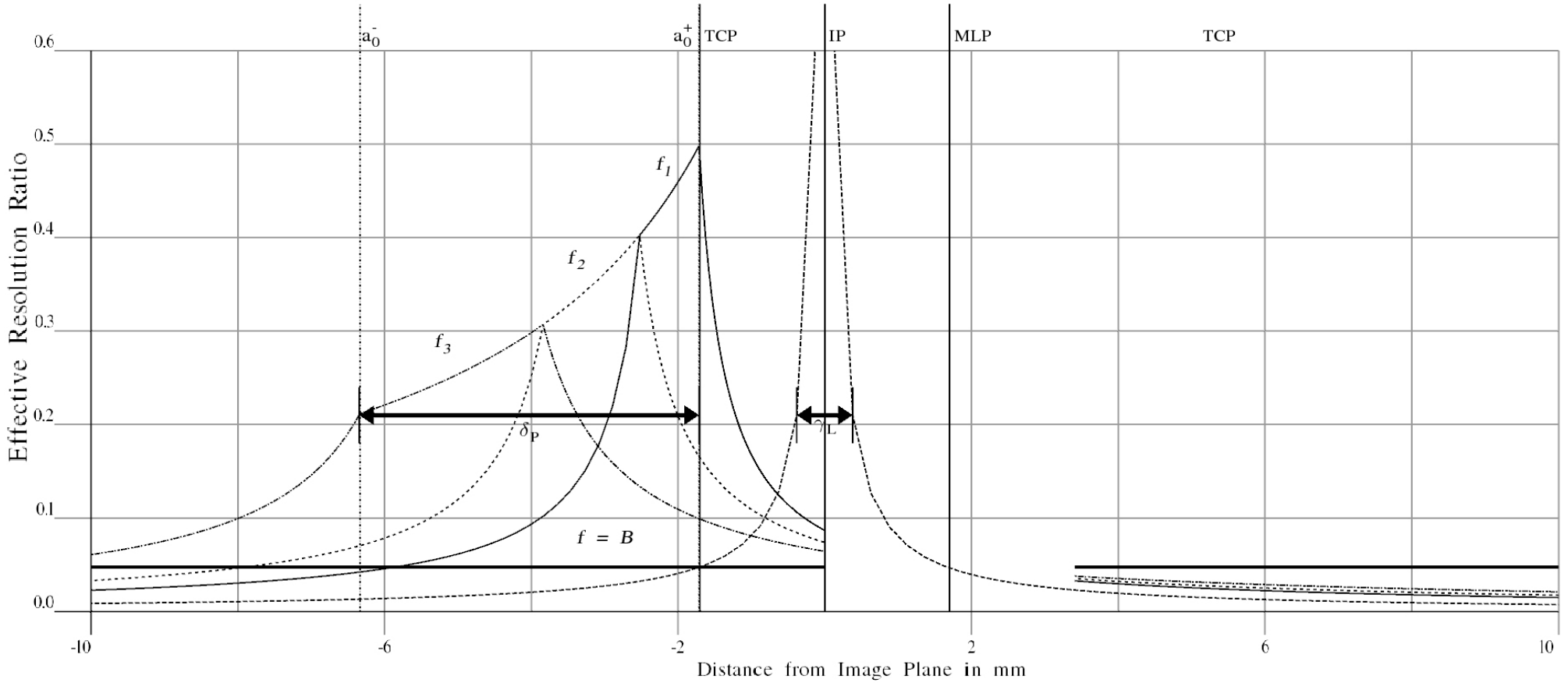


Powered By CluViz 7

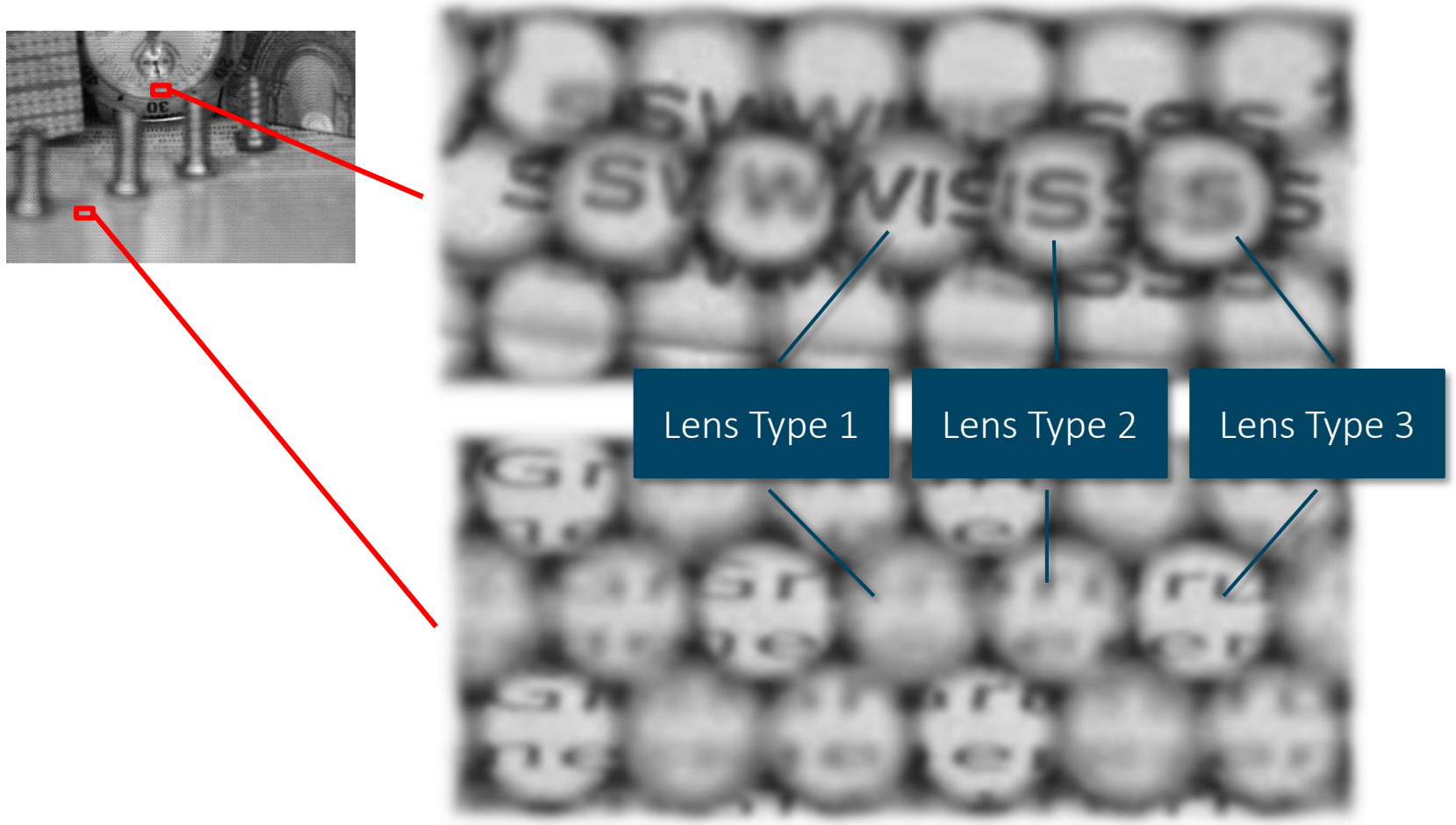
Recap: Light Filed DoF



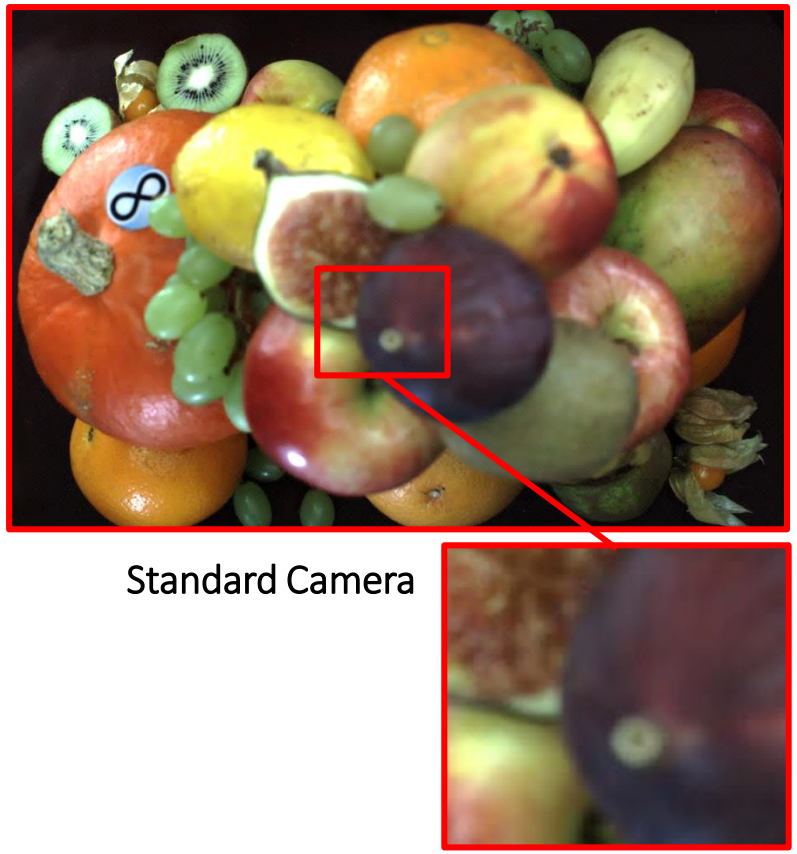
Multiple Focus DoF



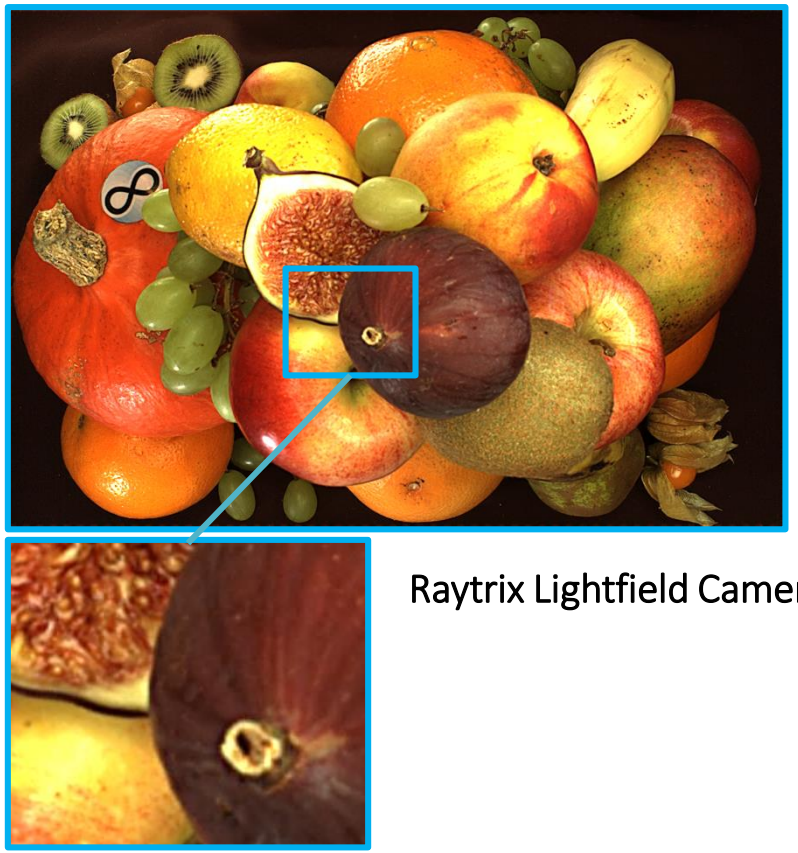
Multiple Focus Raw Image



Extended DoF



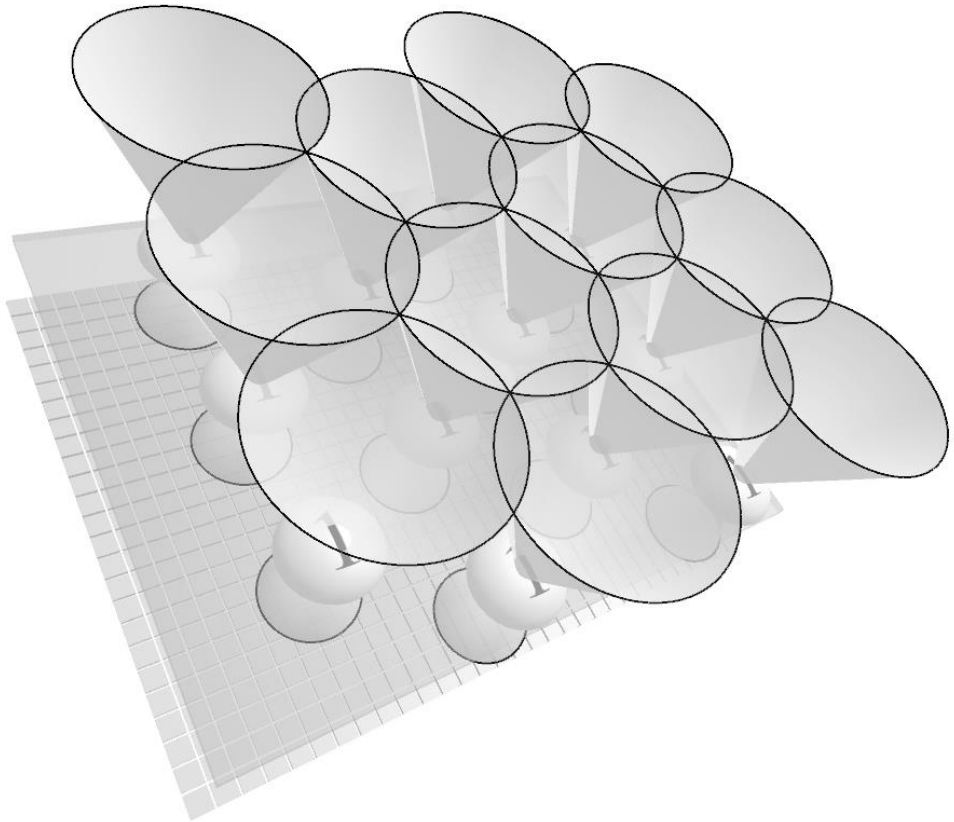
Standard Camera



Raytrix Lightfield Camera

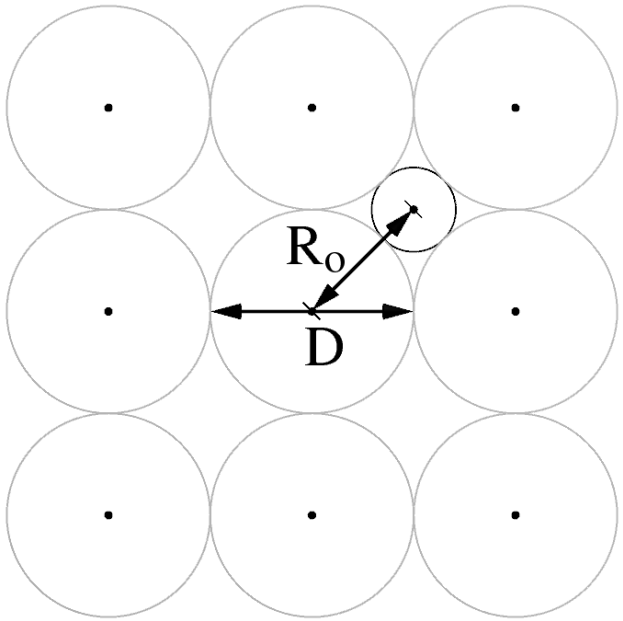
Both images were taken with same 11 megapixel sensor, same lens and same aperture.

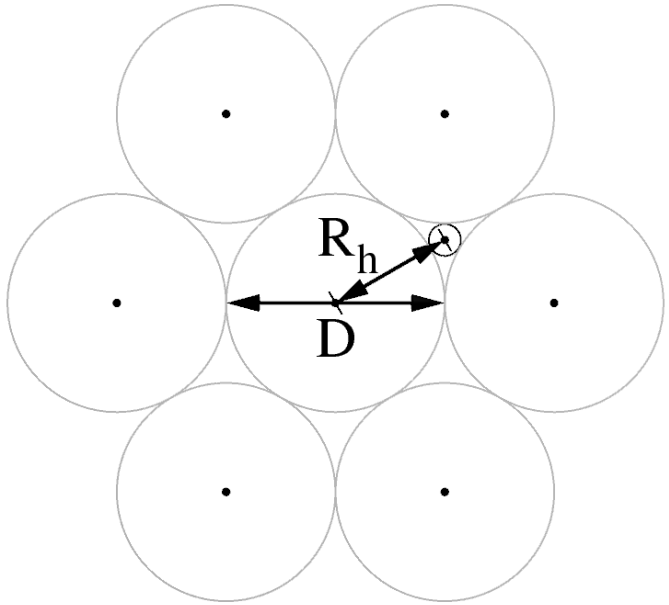
Total Covering



Full MLA Cones Back Cones Front Projection

Orthogonal vs. Hexagonal Setup



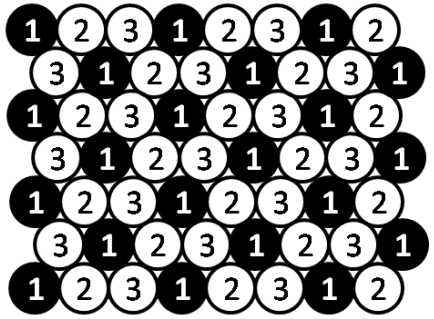


Total covering is achieved at a smaller distance from the MLA with a hexagonal micro lens setup.

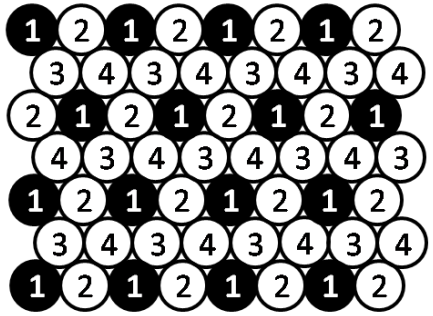
$$R_O = \frac{1}{\sqrt{2}}\, D \approx 0.71\, D$$

$$R_h = \frac{D}{2}\sqrt{1 + (\tan \pi/6)^2} \approx 0.58\, D$$

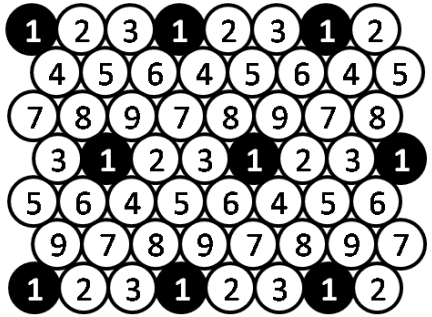
Lens Type Counts



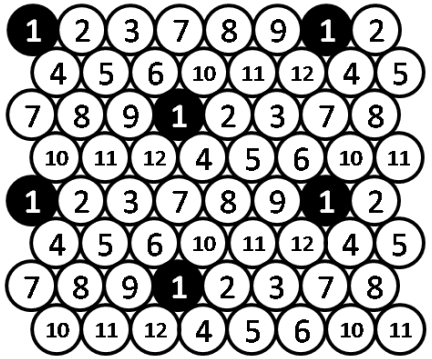
3 Lens Types



4 Lens Types



9 Lens Types



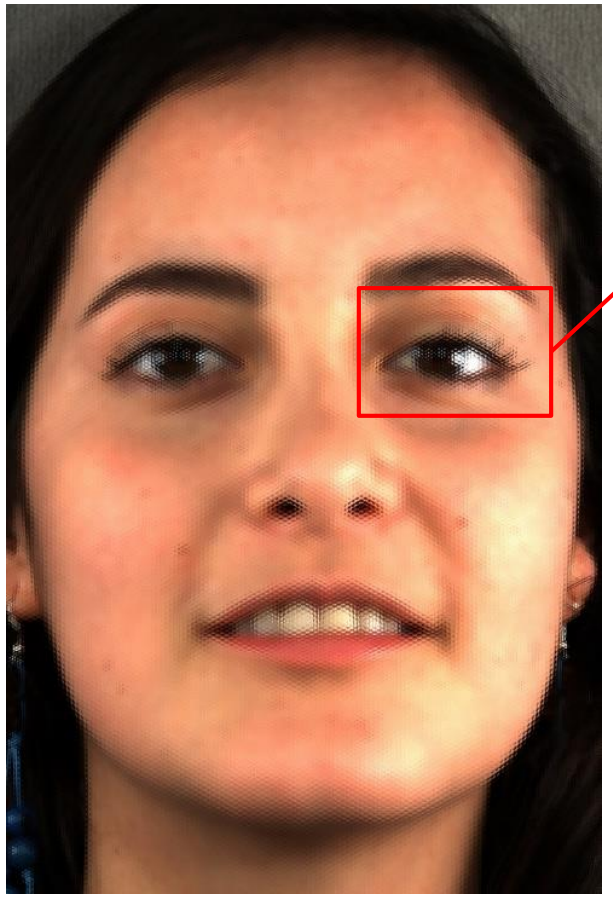
12 Lens Types

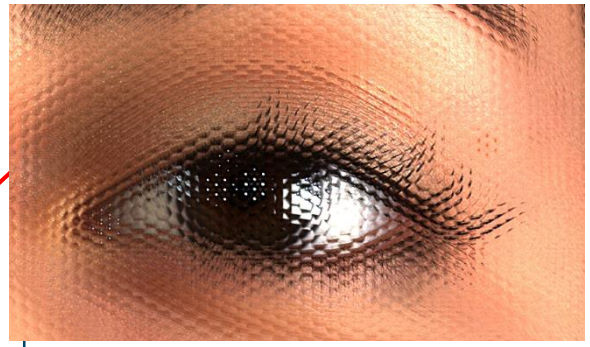
To achieve an uniform distribution of lenses of same type, only certain numbers of different lens types are possible.

- 3 Lens Types TCP at v = 2.0
- 4 Lens Types TCP at v = 2.15
- 9 Lens Types TCP at v = 2.73
- 12 Lens Types TCP at v = 3.0

Application

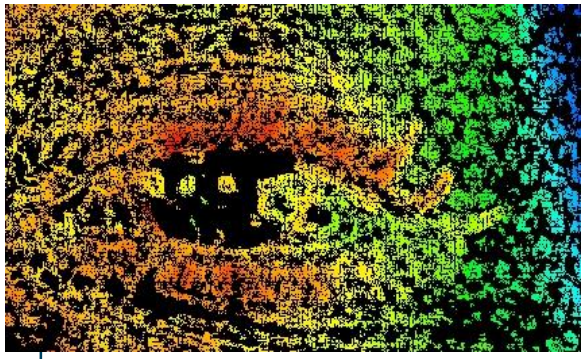
Image Generation



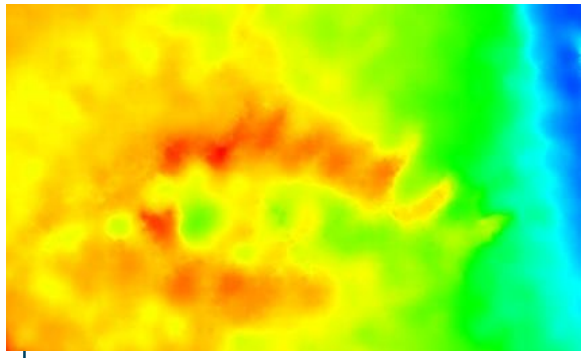


Micro-images show multiple imaging of object parts

Computationally reconstructed image from raw image and depth map

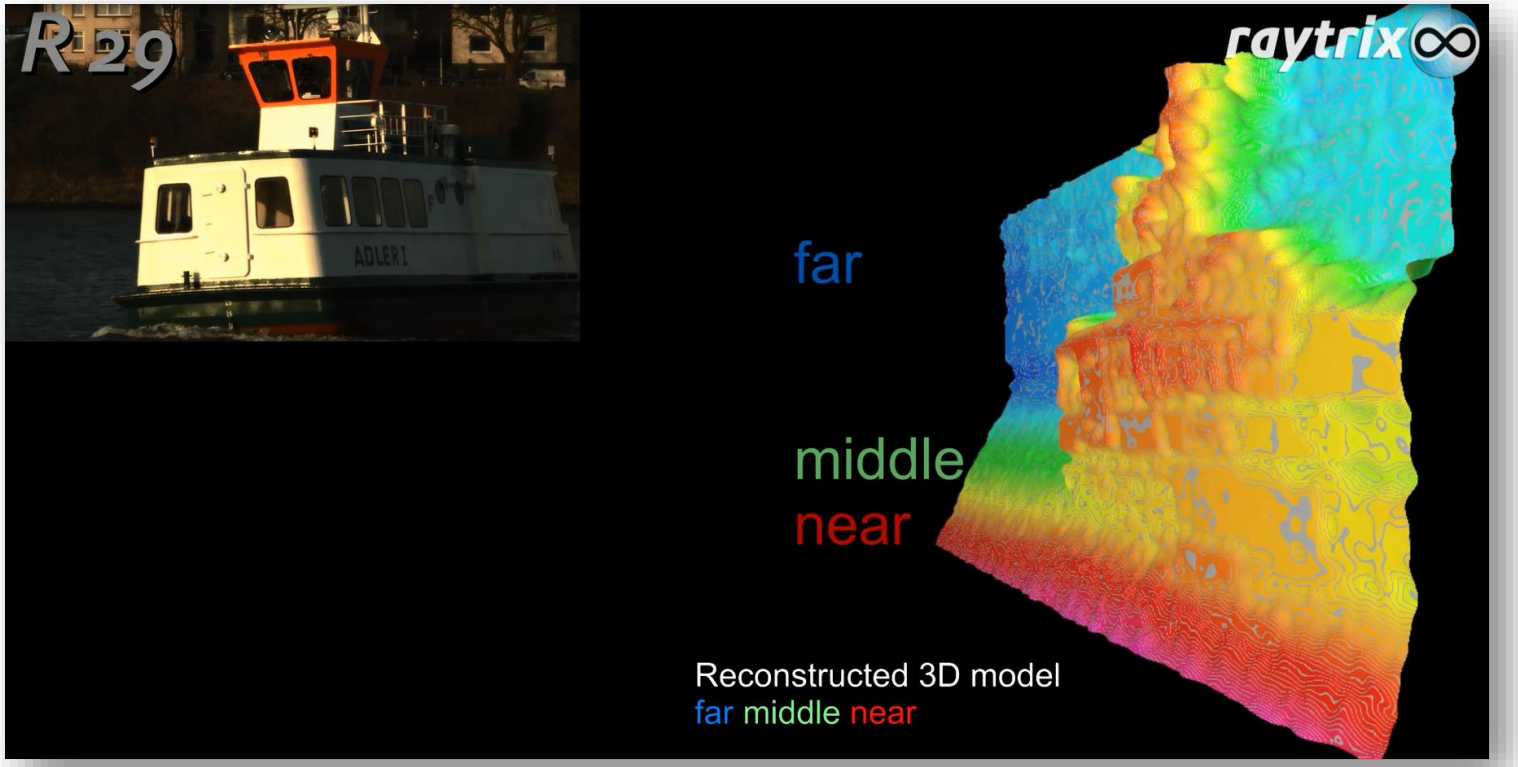


Color-coded depth map for high-contrast areas



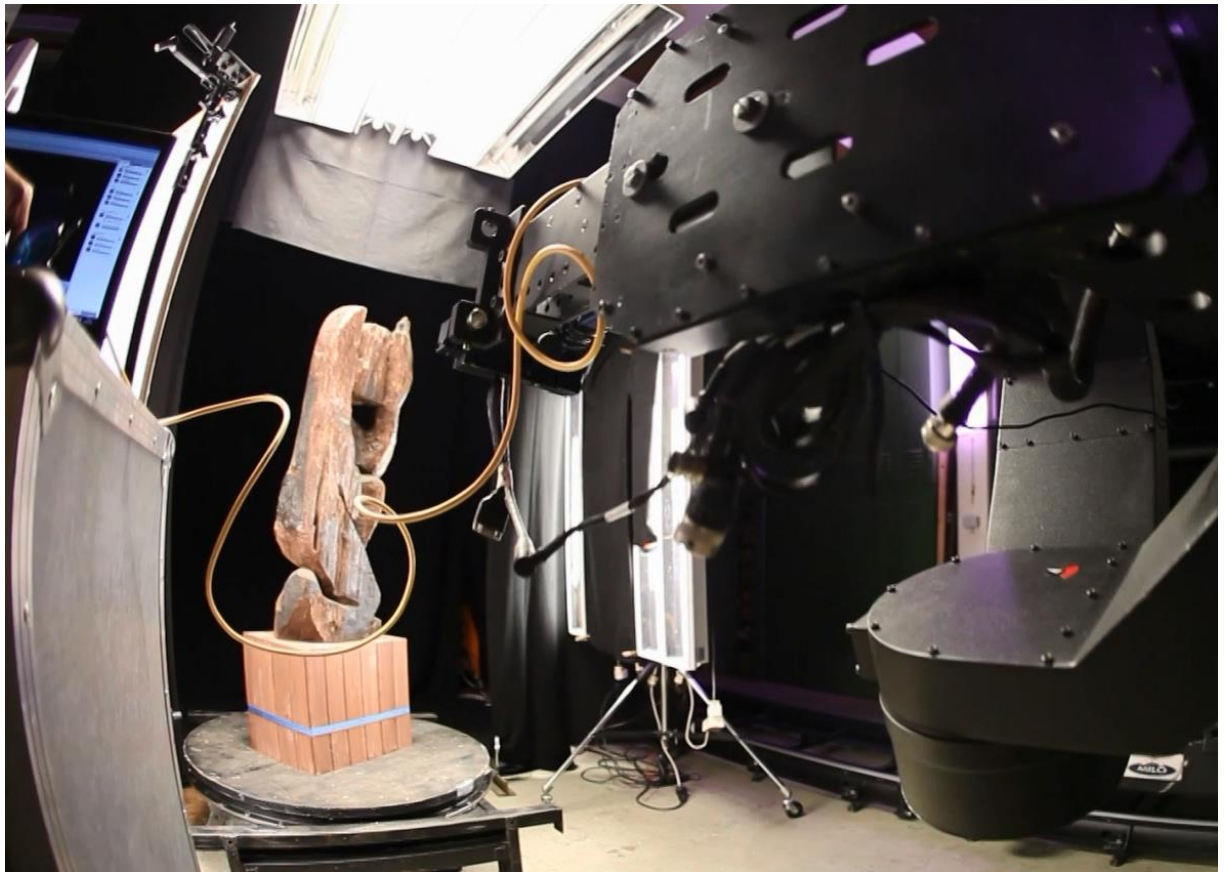
Filled depth map

Capability Overview



Show Video

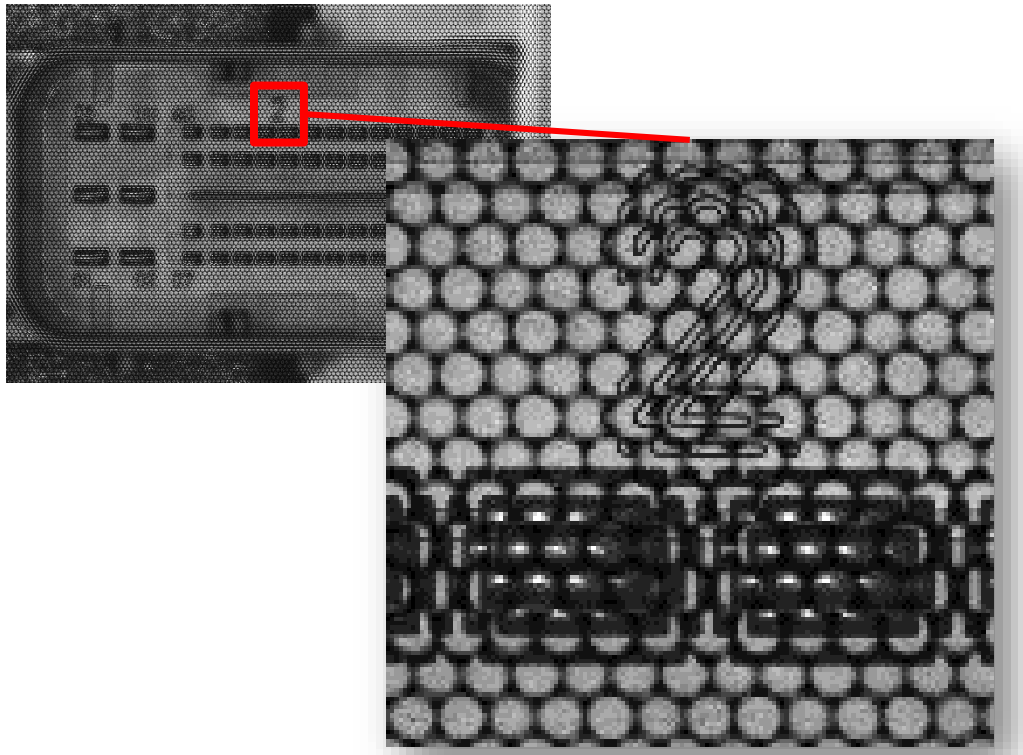
3D Capture



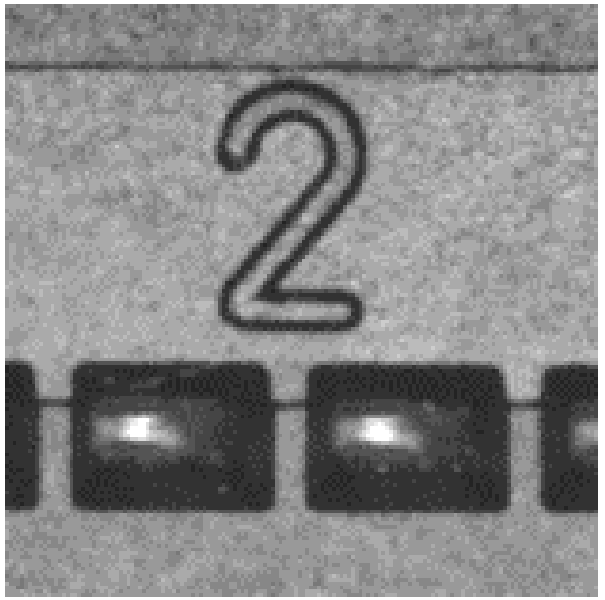
Show Video

Quality Inspection

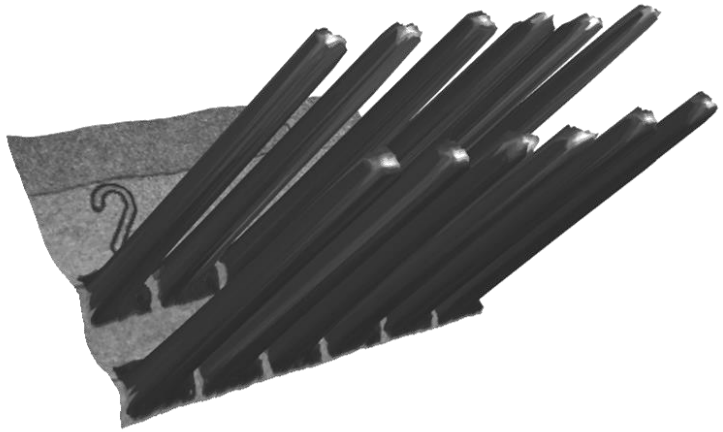
Pin Inspection



Raw light field image is an array of many micro images

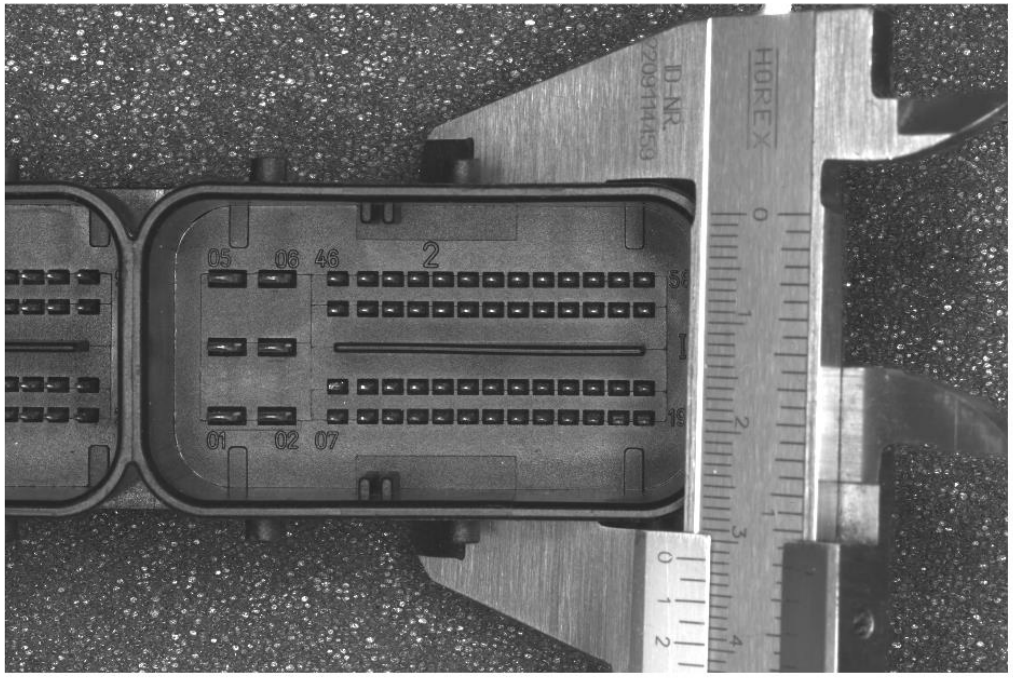


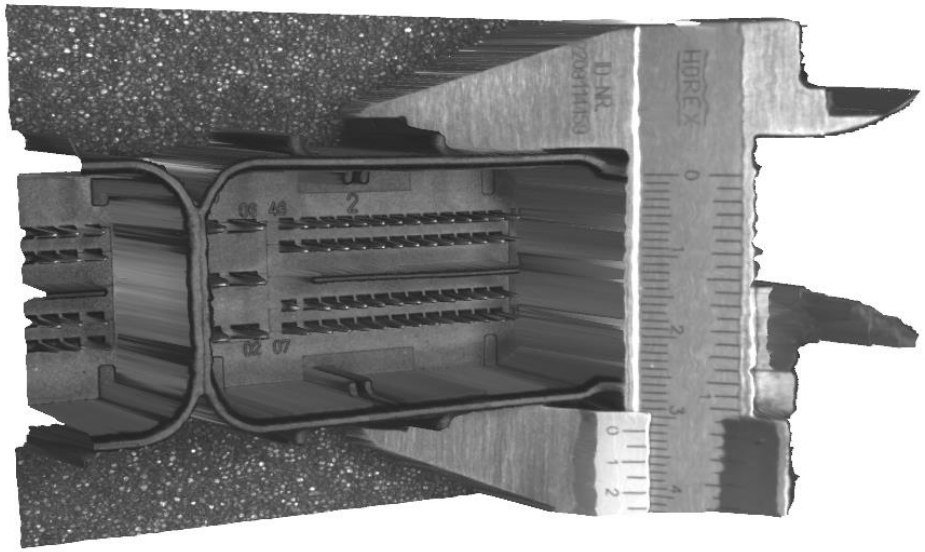
2D Reconstruction



3D Reconstruction

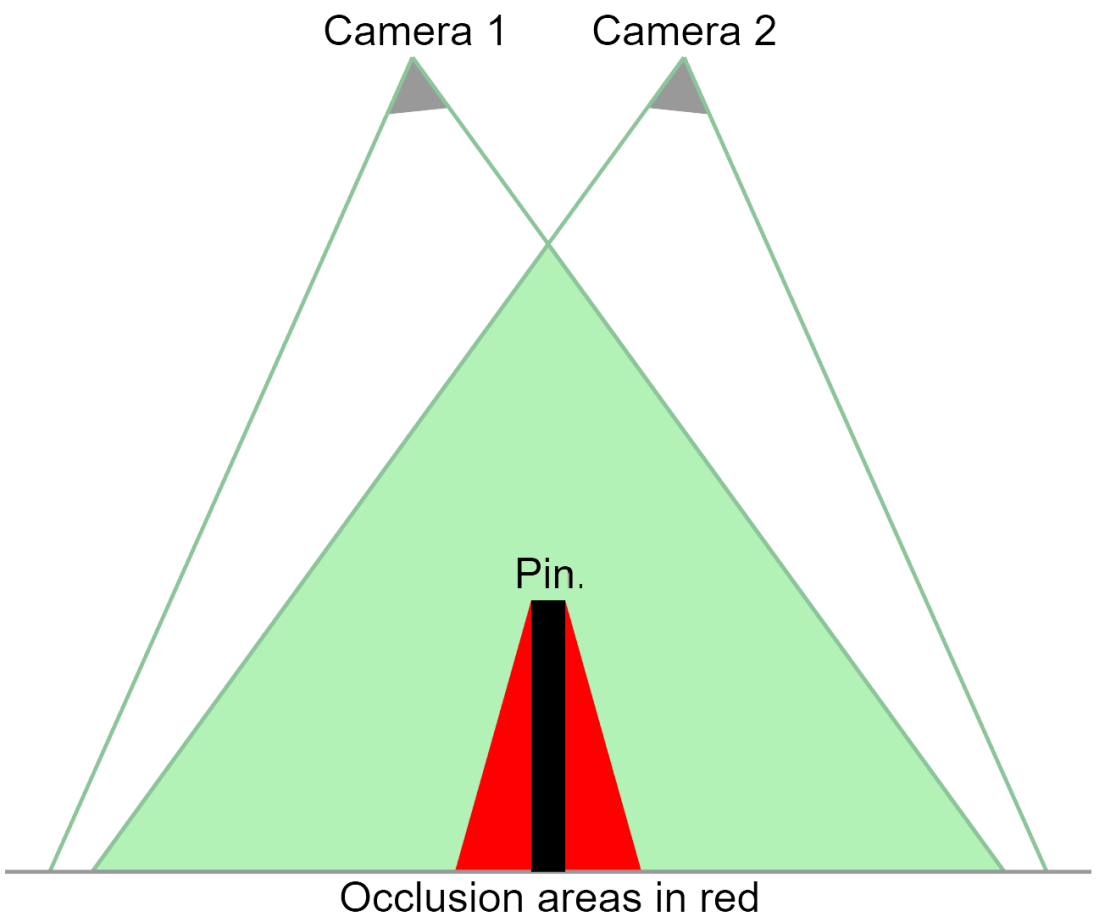
Pin Inspection



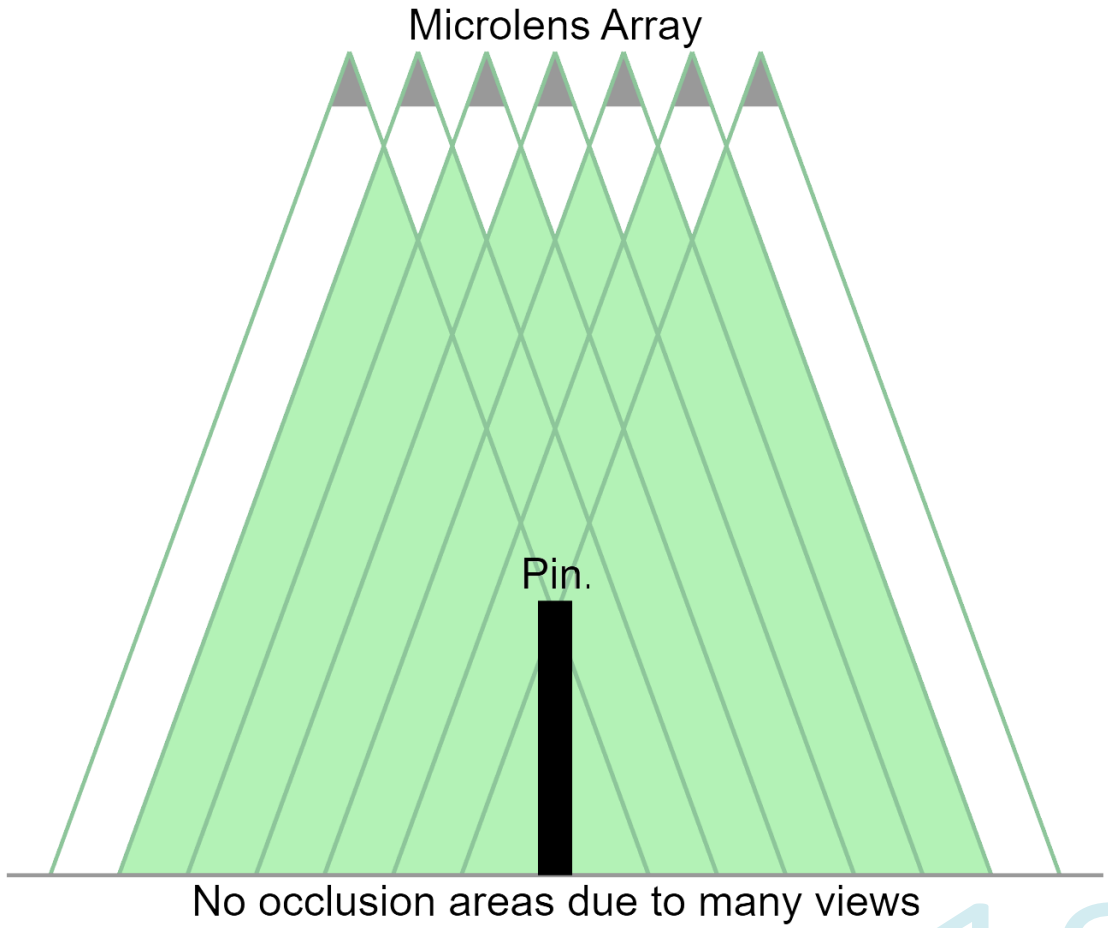


Occlusion

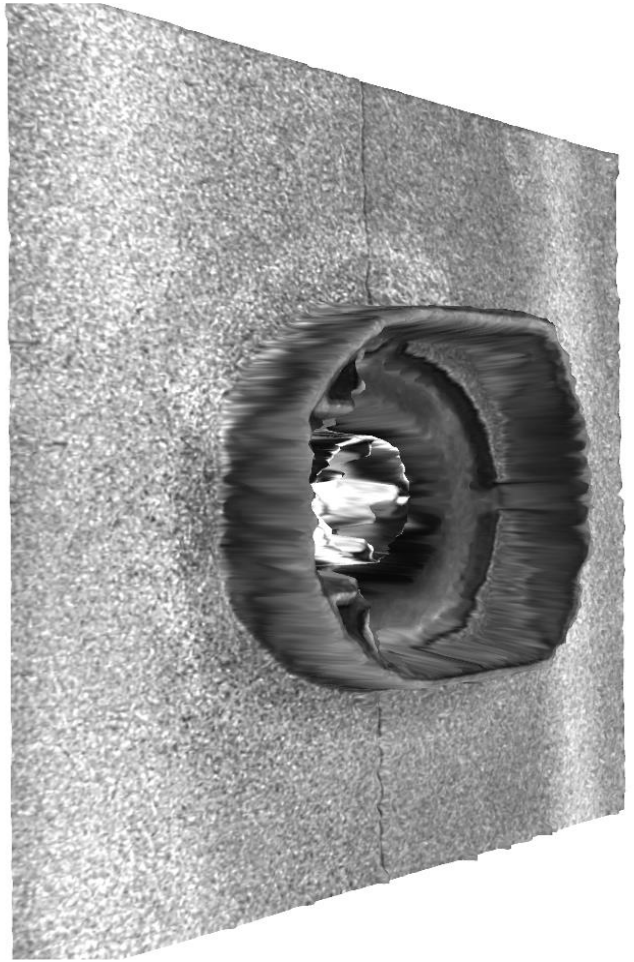
Stereo Camera System reconstructs pin as cone



Light Field Camera reconstructs pin as rectangle

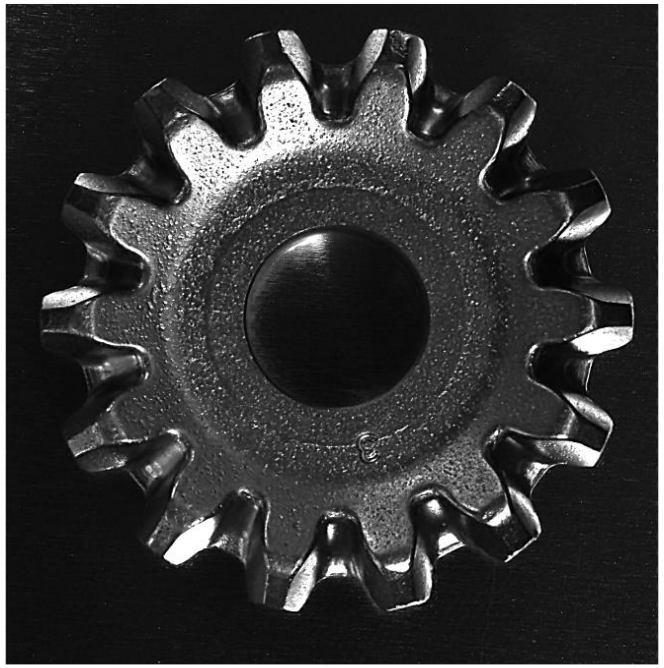


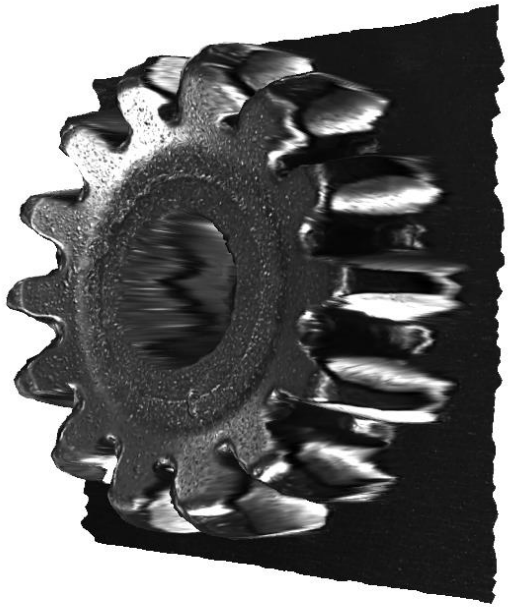
Pin Inspection



Powered By CluViz 7

Inspection





Bottles

Powered By CluViz 7

Light Field Microscopy

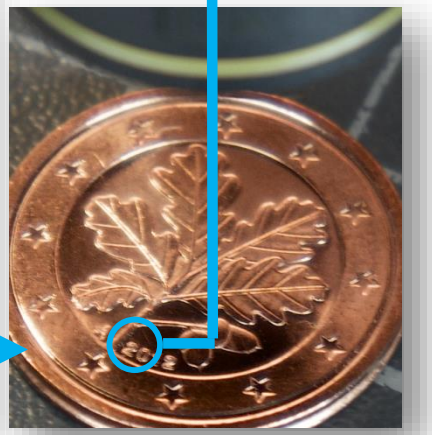
Remarks

- Microscopical optical systems typically have a very high f/# on the image side, e.g. f/16.
- Optical resolution only depends on object side NA.
- Microscopes are basically wide angle optics very close to the object.
- Effect of extended depth of field is particularly pronounced for microscopes.

Basic LF-Microscope Setup

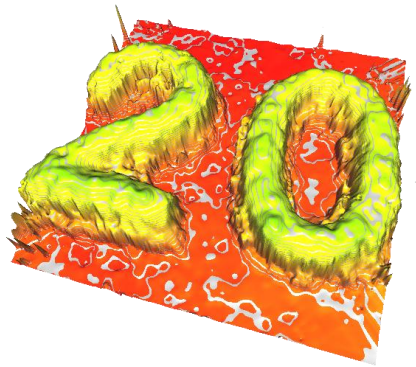
Camera used is R5 with 4MP CMOSIS sensor.

Microscope Setup



FoV ~ 1x1mm

Total Focus

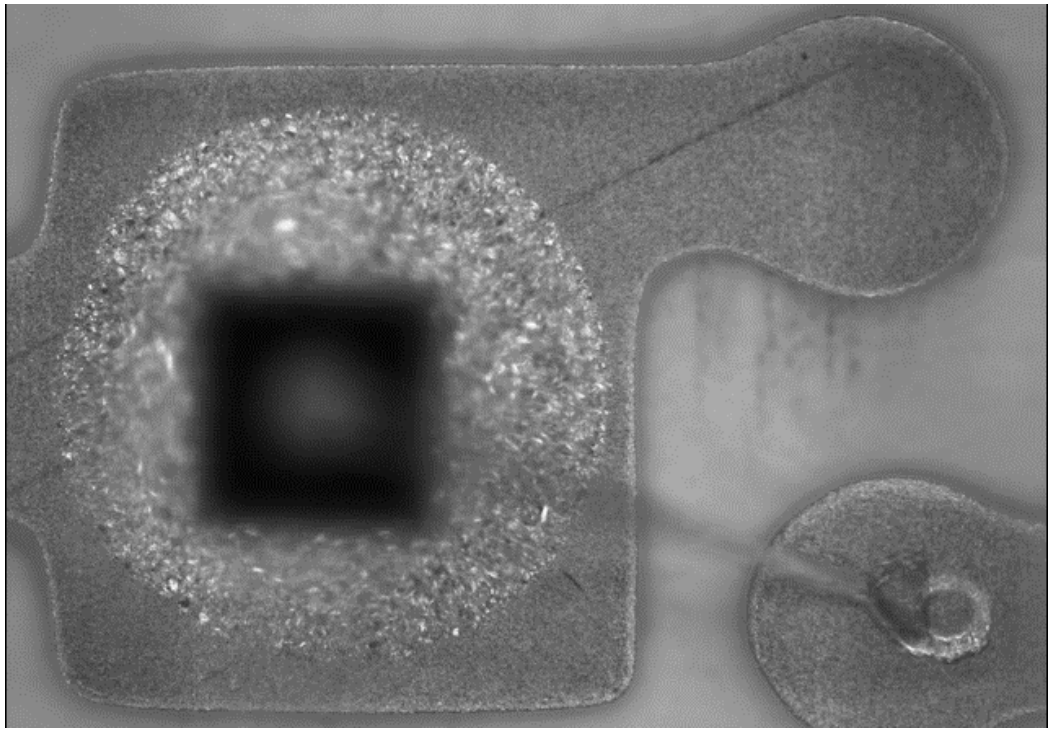


3D Reconstruction

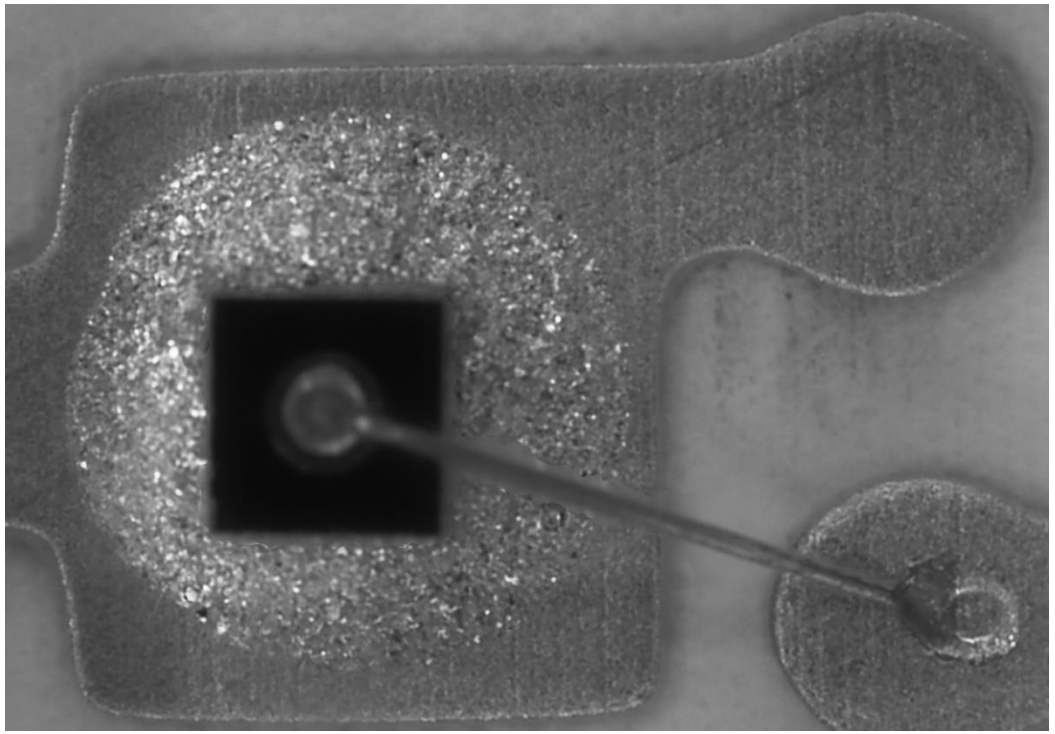
LF-Microscope DoF

10x Microscope

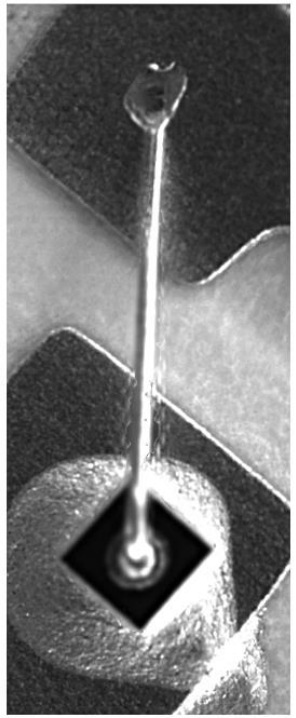
8 Exposures at 20µm depth steps with **2D Camera**

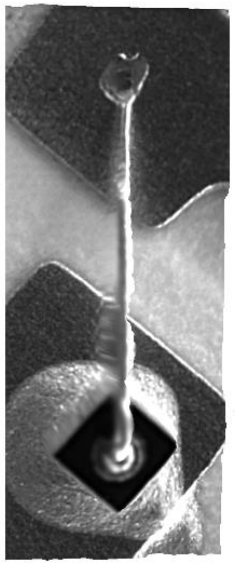


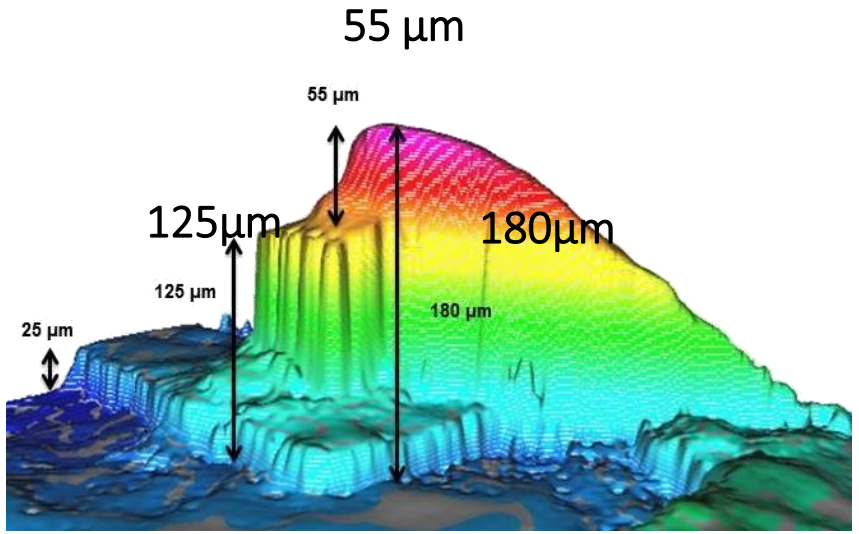
Single exposure with **Light Field Camera**



Bonding Wire

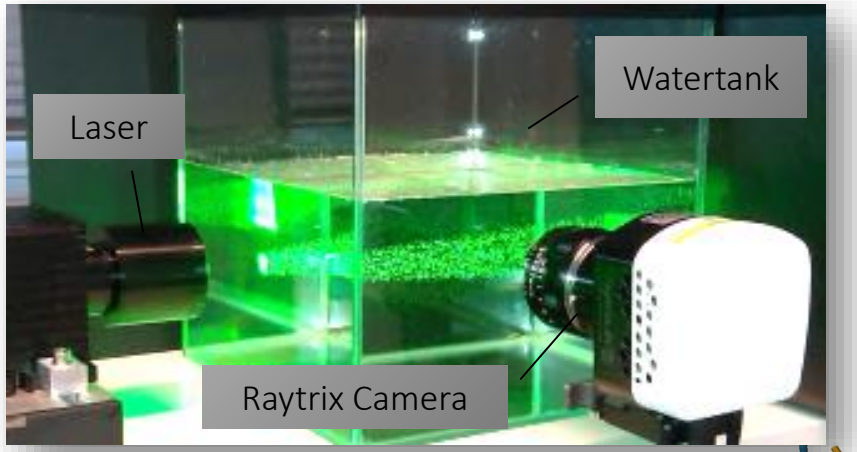






Light Field Volumetric Velocimetry

LF-Volumetric Velocimetry Setup

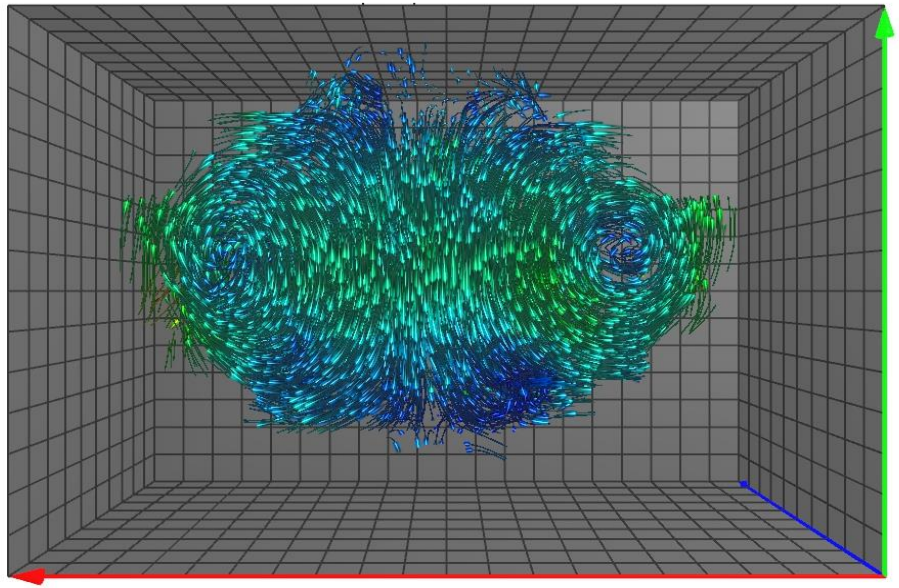


Calculate 3D flow vectors and particle time-histories from lightfield data

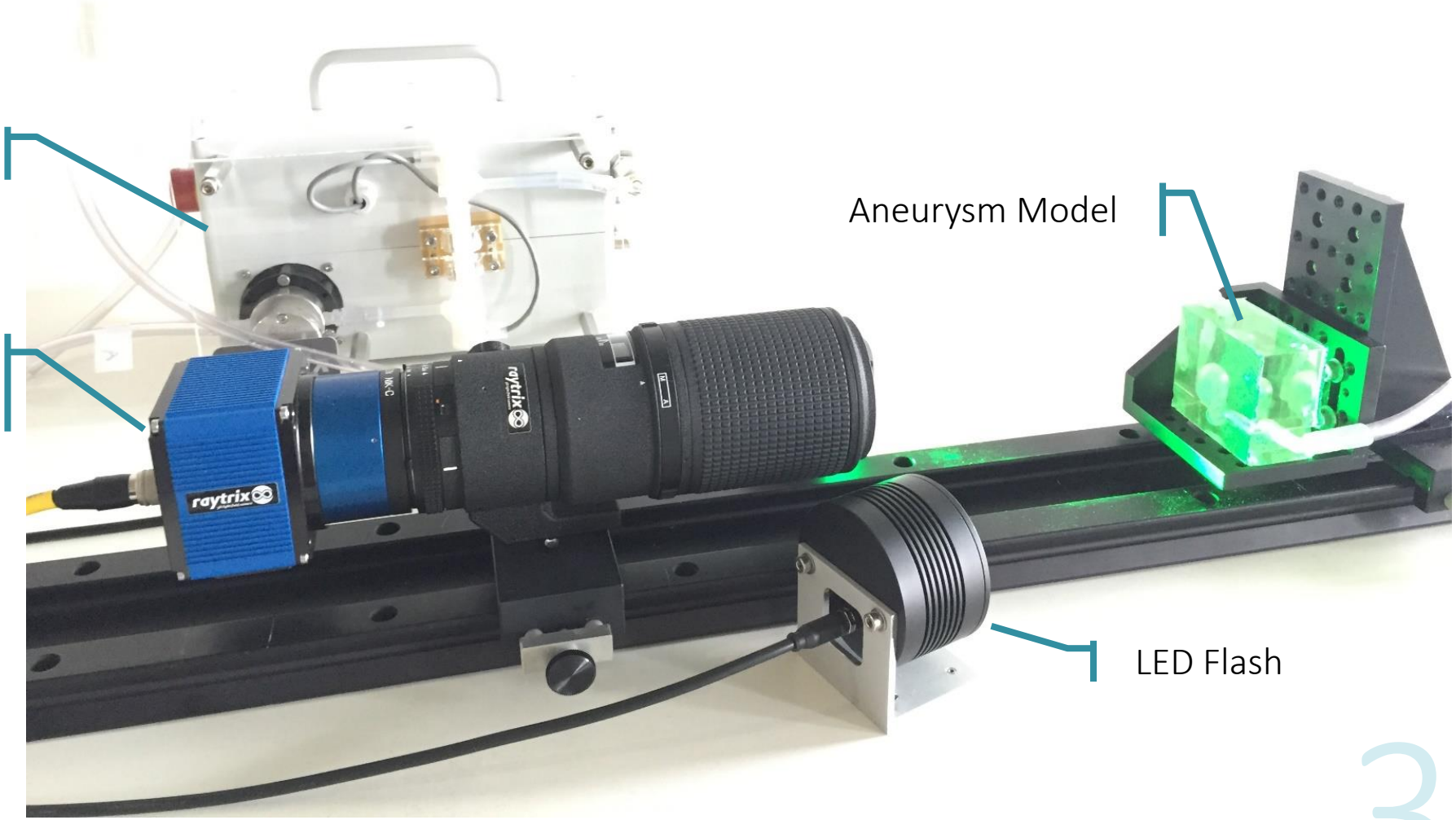
- Measure 3D flow of particles in water.
- Need only **one** lightfield camera.
- Simple calibration with single image.
- No need to synchronize cameras.
- Robust setup.

DANTEC DYNAMICS

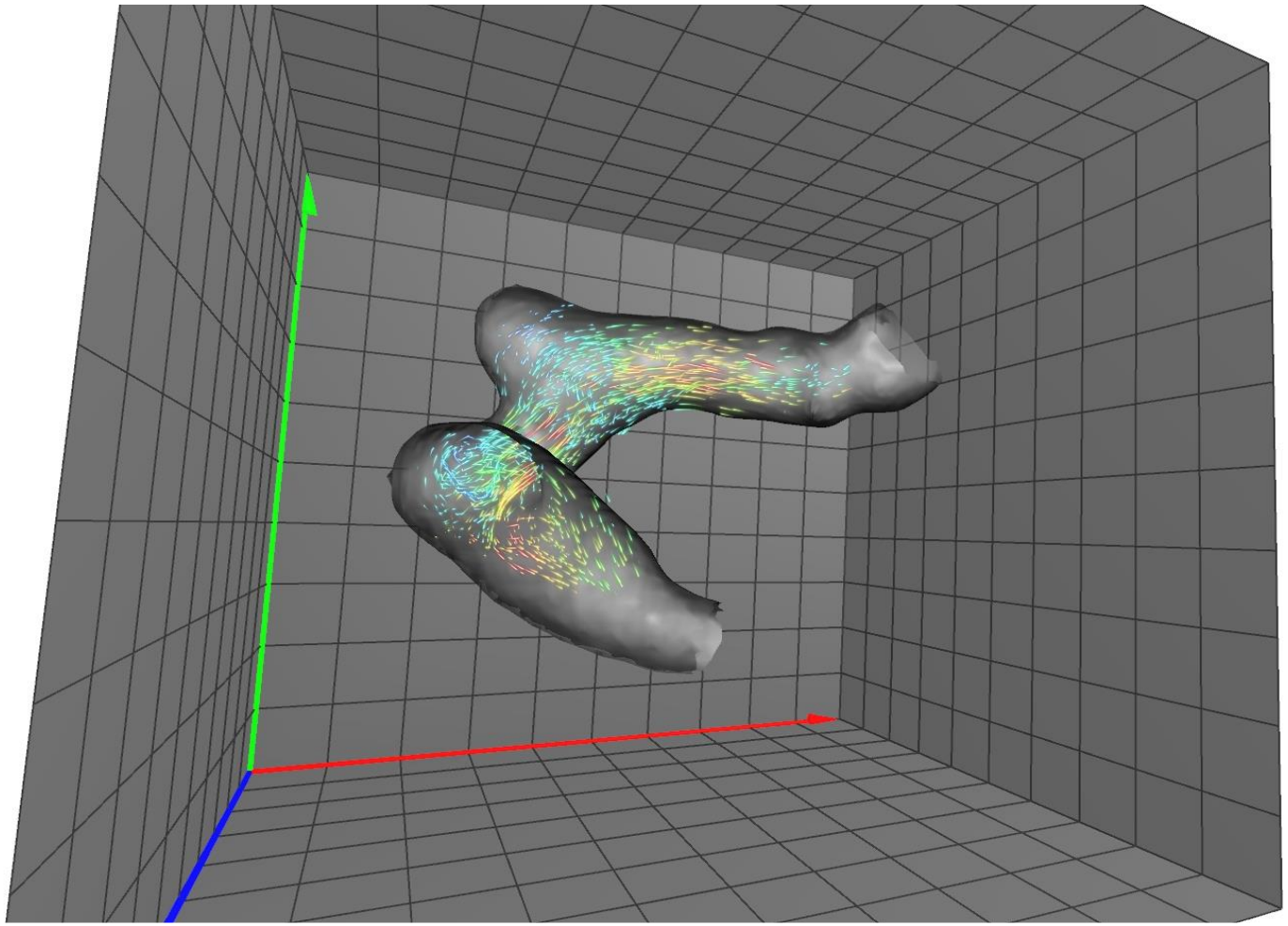
Toroidal Flow



Measuring Flow through Aneurysm Model



Aneurysm Flow

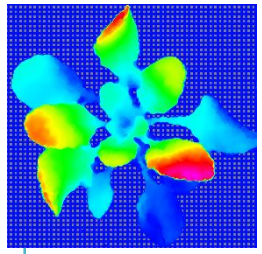


Miscellaneous

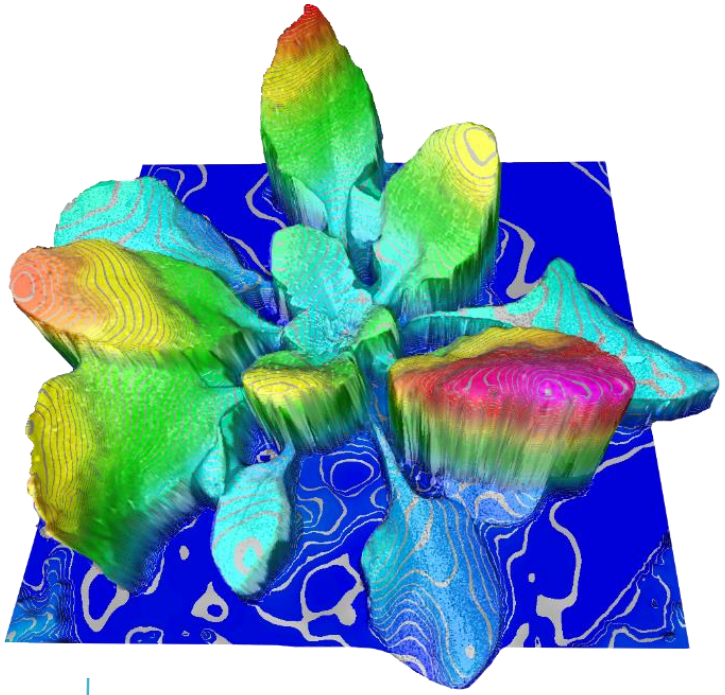
Faces

Phenotyping

2D Image



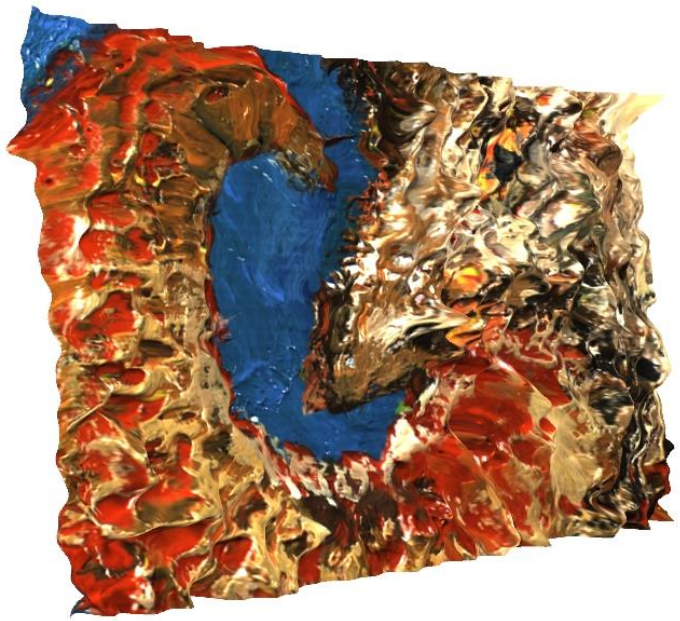
Depth Map

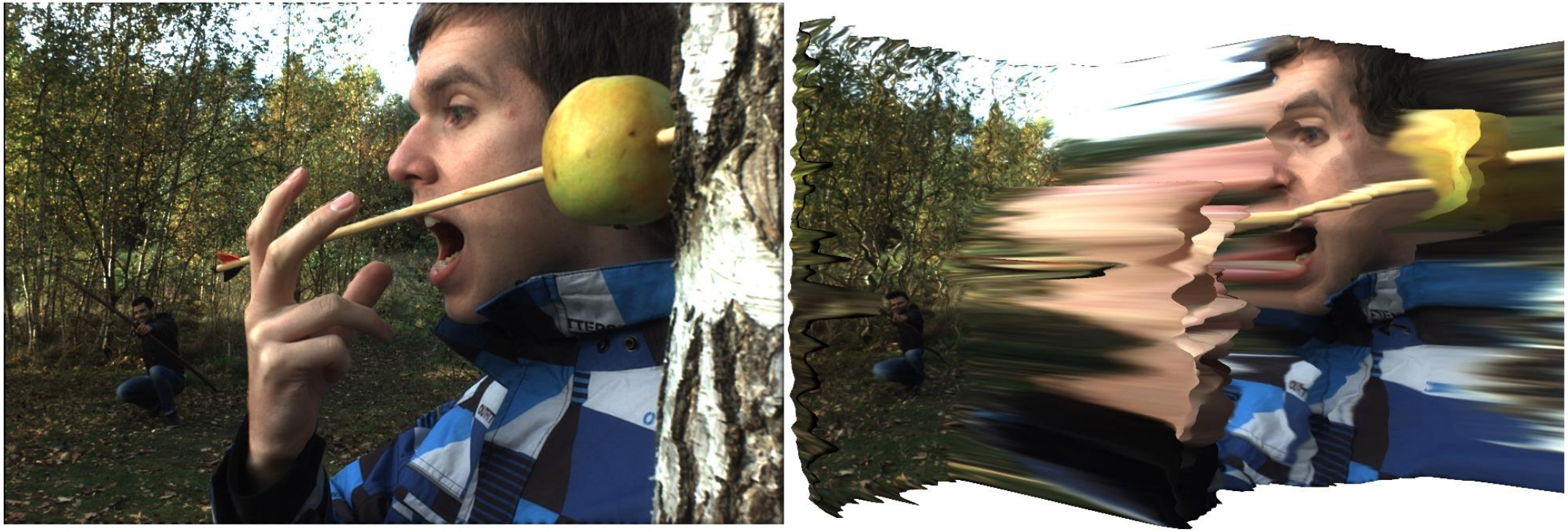


3D View

Raytrix camera with main lens attached and standard lighting. Only a single picture has to be taken to obtain 2D and 3D data.

Oil Painting





Thank you for your attention!