Chip in the Tip ultra-compact cameras for endoscopic applications

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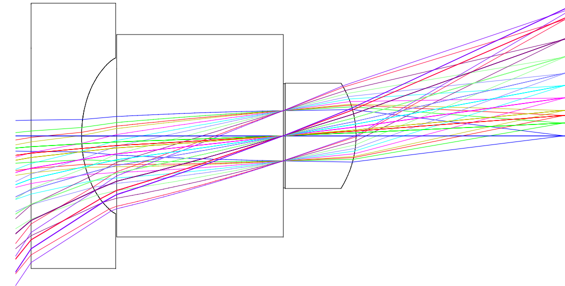
Chip in the Tip – Motivation

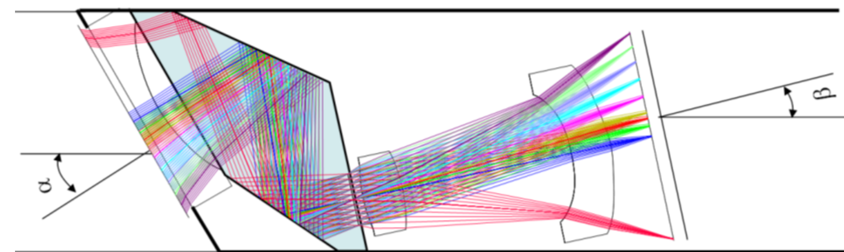
Miniaturized Video Endoscope

- best possible resolution
- Image Akquision and Processing Capacity in the endoscope Head
- Wire or Wireless Connection to the Environment
- compact Designs, round
- flexible Layouts and Assembly
- cheap Manufacturing
- fast Prototyping
- Stable or disposable Systems

Straight View, 110 ° FOV



Objective + Imager



30 ° View, 70 ° FOV

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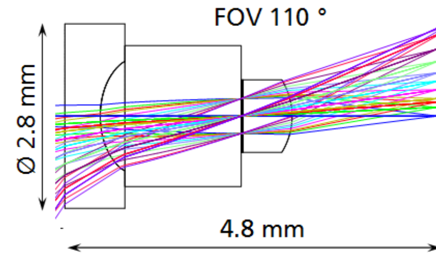
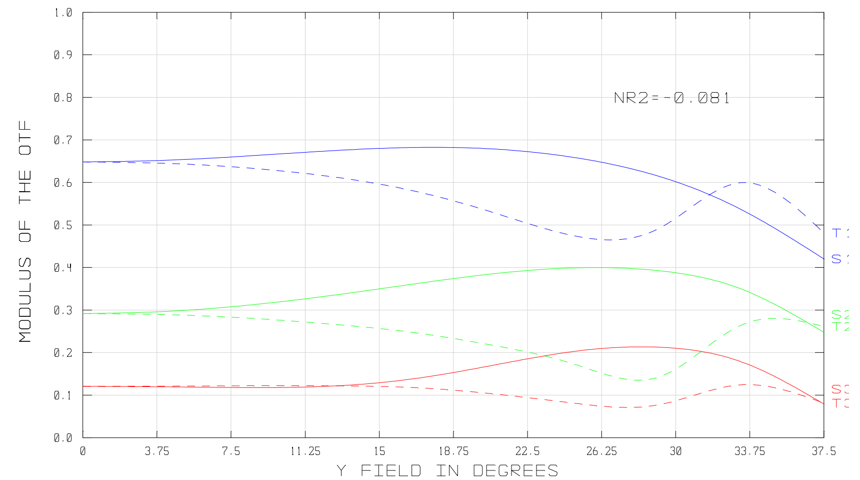
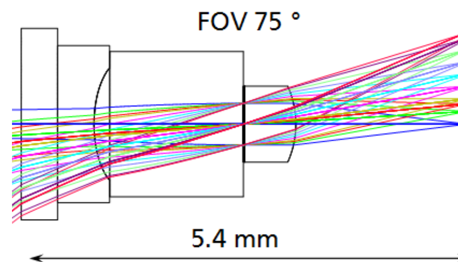
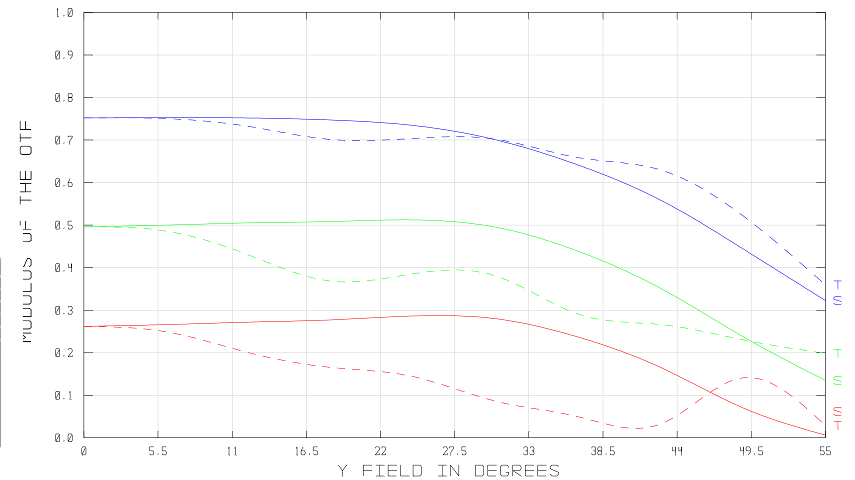
Chip in the Tip – Optical Designs

- Straight View
- 2.8 µm Pixel
- Nyquist 178 LP / mm
- FOV 75 ° and 110 °
- F-Number 4.6
- Object Distance 8 mm
- Front Plano-Asphere
- GRIN Lens with back side Aperture
- Back Sphere









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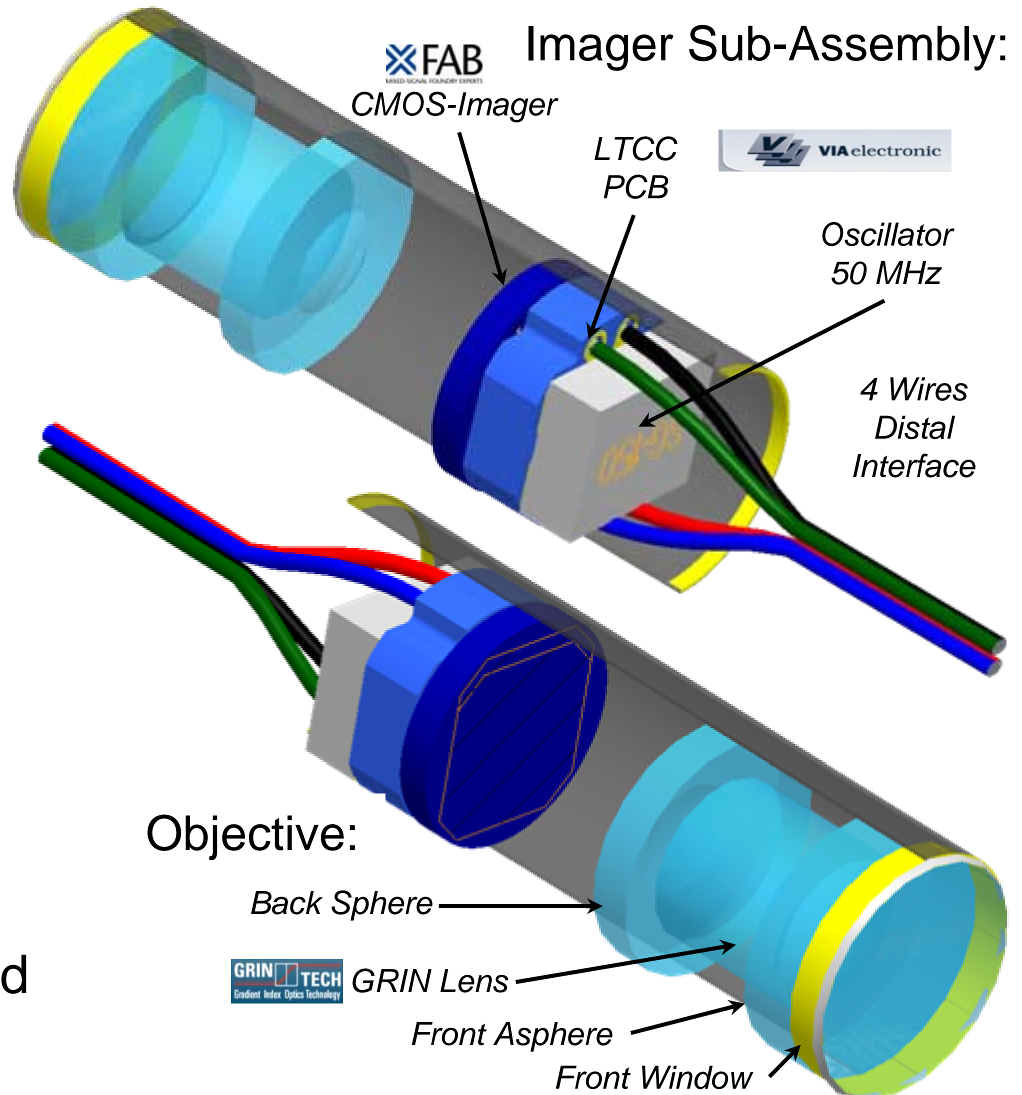
Chip in the Tip – Optomechanical Design

- Stainless Steel Tube Ø 3 mm
- Objective Ø 2.8 mm
  - SPDT / Injection moulded Lenses
  - Back Sphere: Drop-on-Demand possible
- stacked Objective
- Imager Anisotropic Conductive Adhesive mounted on LTCC Printed Circuit Board
- LTCC PCB carries Clock
- Imager connected during Assembly & actively aligned
- external Illumination



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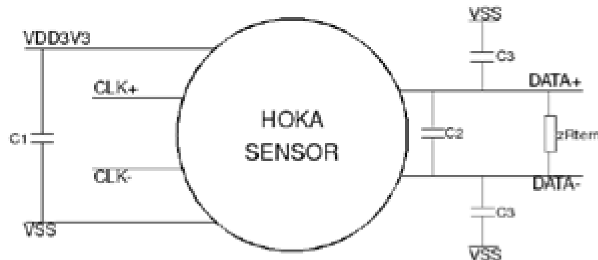
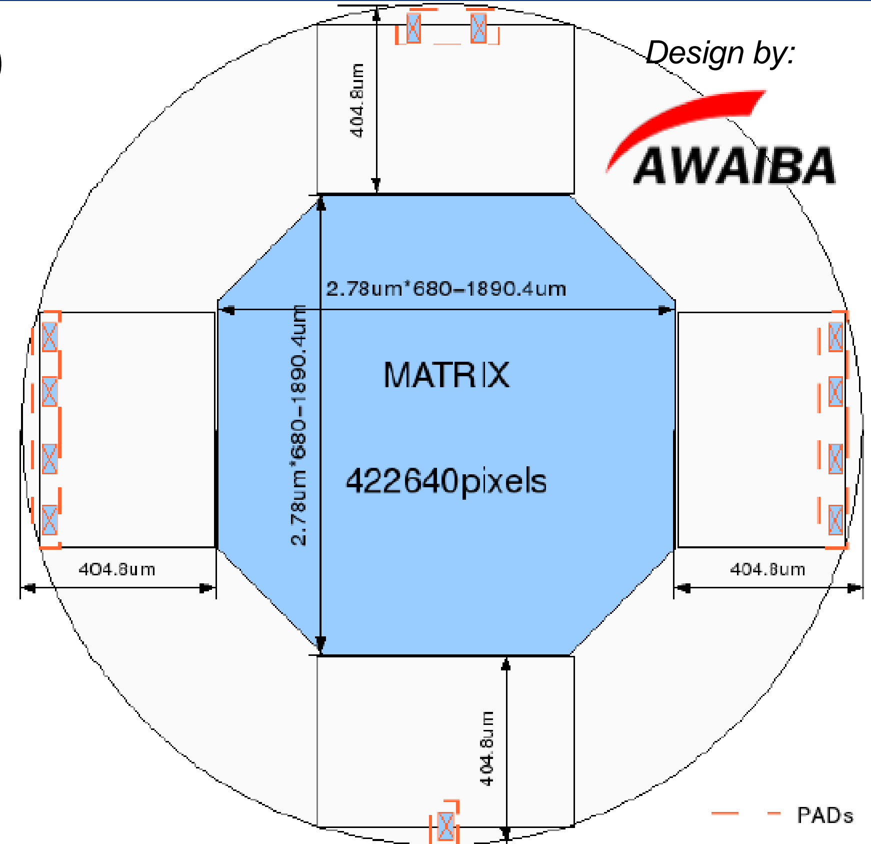
VGA CMOS-Imager – Specifications

- >VGA(640×480) Resolution - 680x680
- Pixel Size 2.78 µm
- Image Circle Ø 2.1 mm
- Outer Ø 2.7 mm
- 50 Frames per Second
- On-Chip Pre-Processing
- 6 Connectors





...because the world is analog.

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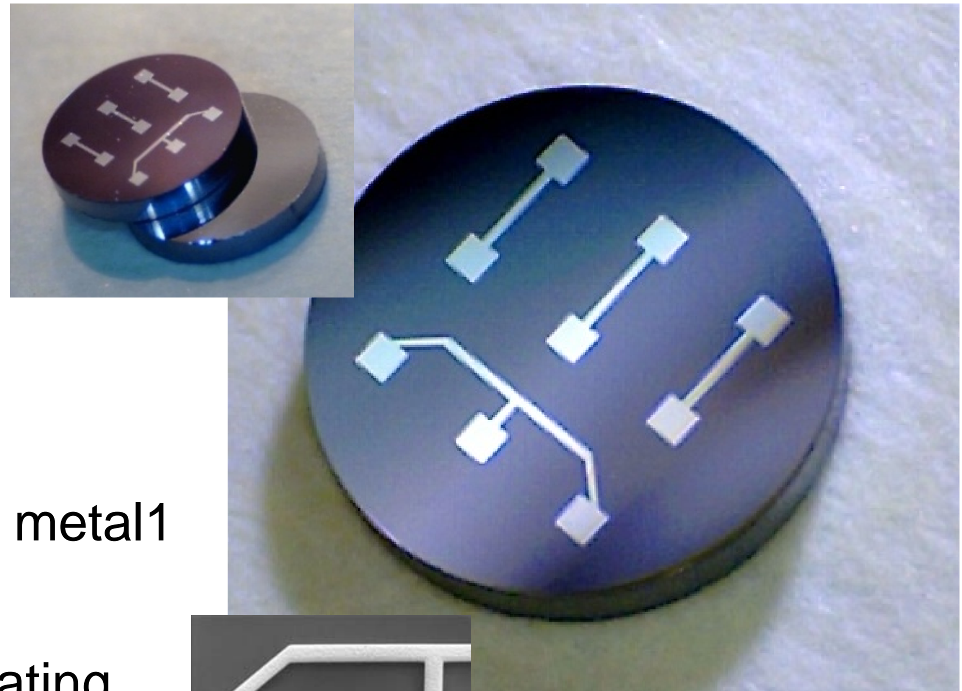
VGA CMOS-Imager – Through Silicon Via and FreeForm Dicing

- FreeForm Dicing - FFD
  - fully flexible chip shape
  - no unfunctional Si left
- Through Silicon Via - TSV
  - for 400 µm wafers
  - TSV lands on 60x60 µm² metal1 areas in CMOS Backend
  - Via filling by Cu electroplating
  - Backside pads and routing



Backside Al-Routing on FFD Imager Chip

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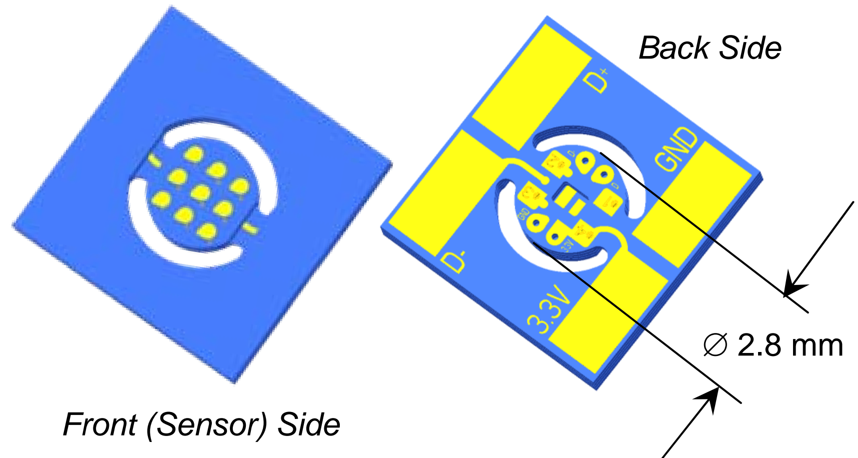
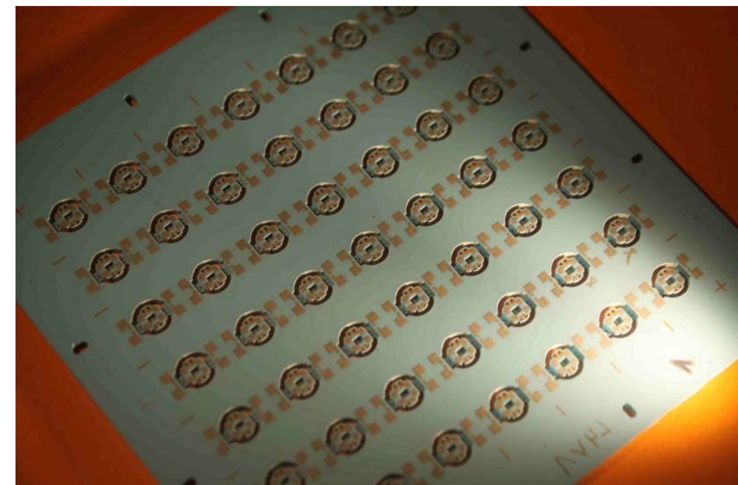
Ceramic Carrier – LTCC PCB

- Round LTCC Carrier
  - ∅ 2.8 mm, 0.8 mm thick
  - 4 Layers DP951
  - Rerouting Front (Sensor) -> Back (Interface) with Oscillator SG-150 (20..50 MHz) and C-Integration
  - Out: Data +/-, 3.3 V, GND
- 4“ Multi-PCB Coupon
  - 49 PCB per Coupon
  - Pre-singulated by cutting / lasering
  - Final Singulation after Reflow by Breaking





LTCC Coupon 4“

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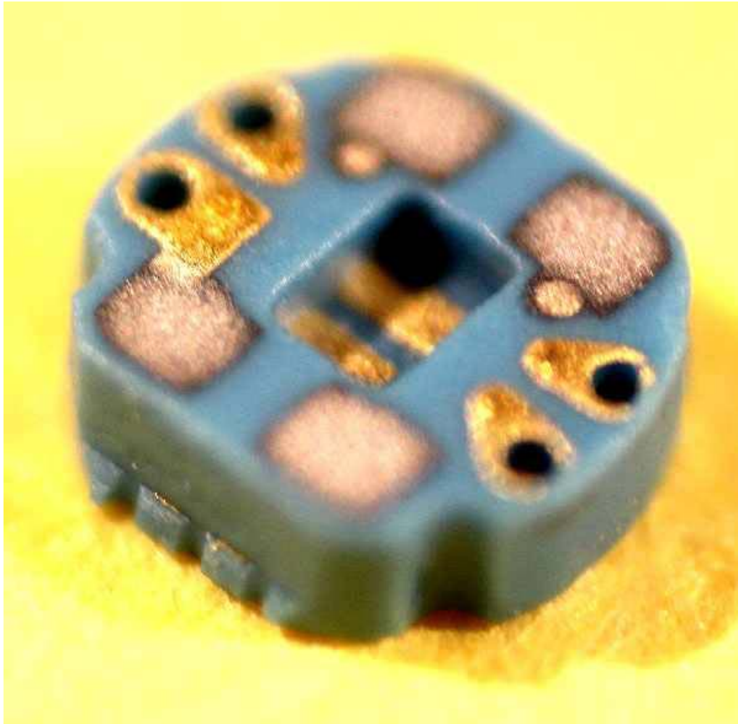
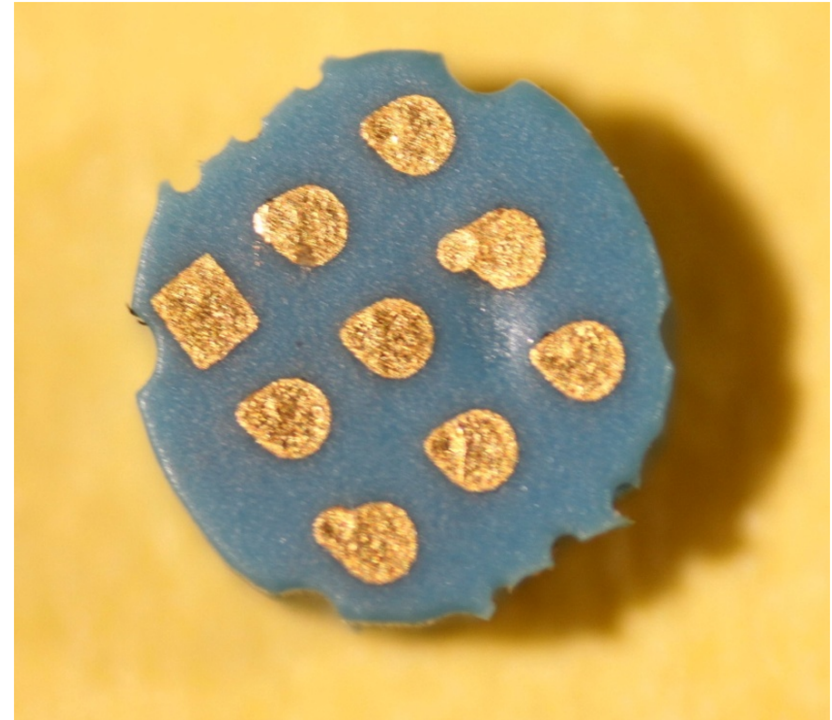
Ceramic Carrier – LTCC PCB



Back (Component and Interface) Side



Front (Sensor) Side

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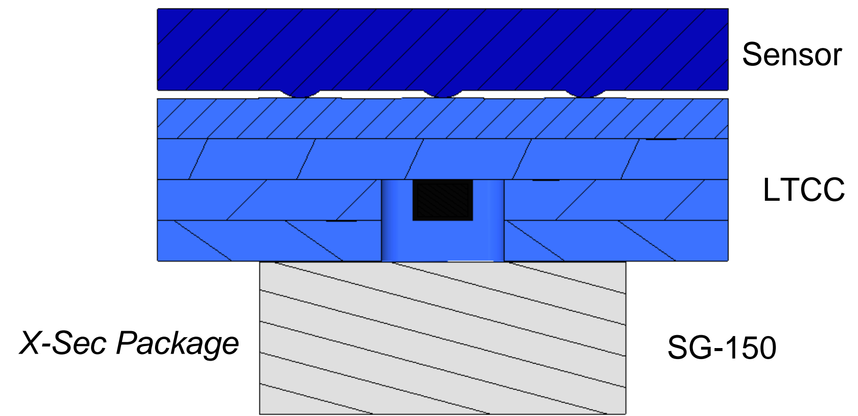
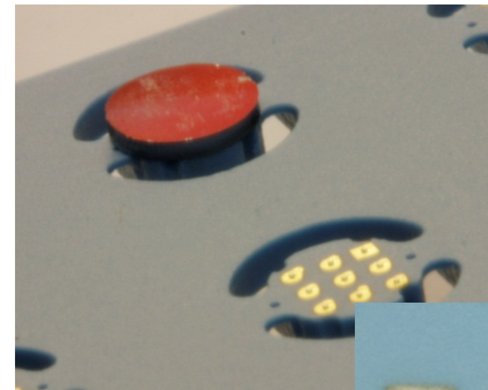
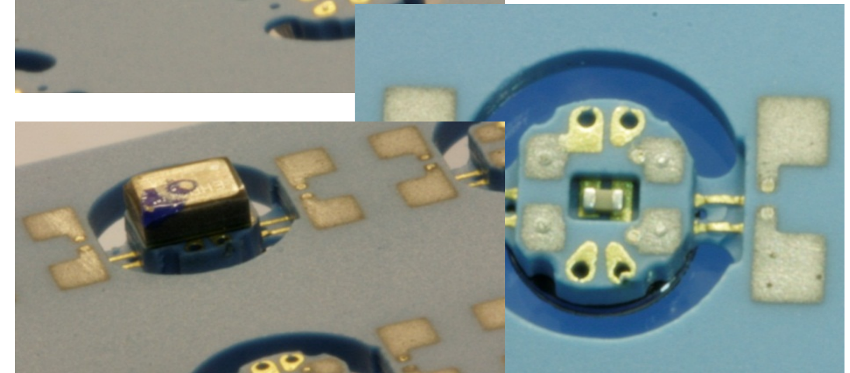
LTCC PCB Packaging

- Two Stage Flip-Chip
  - Sensor: Solder Bumps 200 µm, 80Au20Sn on LTCC
  - 370°C / 100°C Sensor / LTCC Reflow
  - Components. Solder Bumps 400 µm SAC305
  - 240°C / 100°C Oscillator, C / LTCC
  - Reflow by FiconTec BL2000

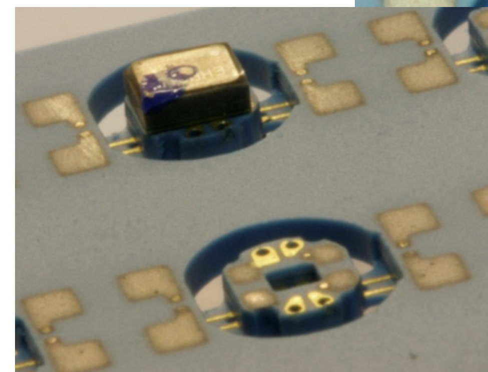




Reflow Sensor



Reflow Capacity



Reflow Oscillator

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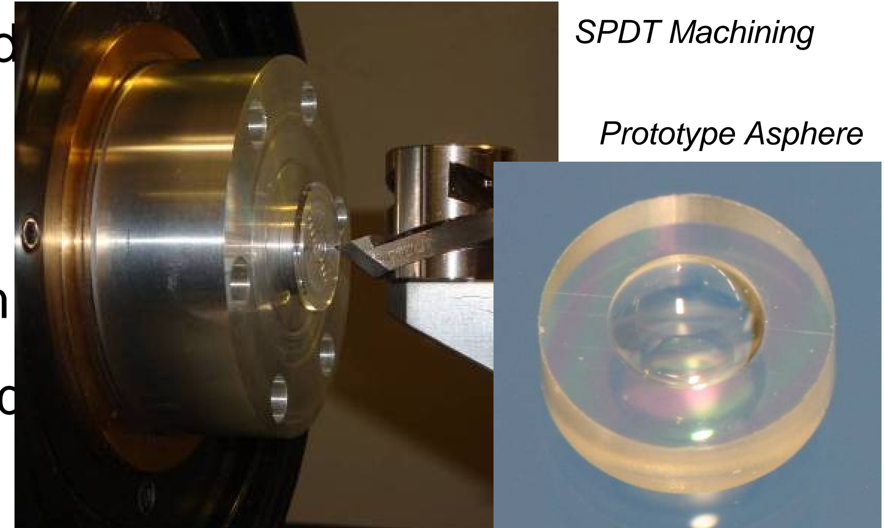
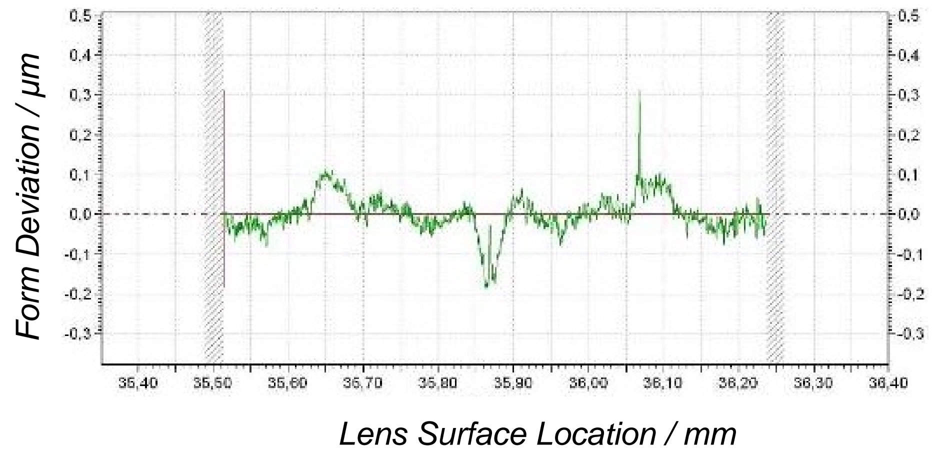
Optics Manufacturing – Prototype Lenses SPDT

- Single Point Diamond Turning for Rapid Prototyping in Polymer
  - Material: ZEONEX
  - PV: <300 nm, rms ca. 50 nm
- Single Point Diamond Turning for Mould Manufacturing
  - Mould Material: electro-plated NiP
  - Ultrasonic Sound enhanced SPDT -> Stainless Steel Moulds
  - Replication by Injection Moulding





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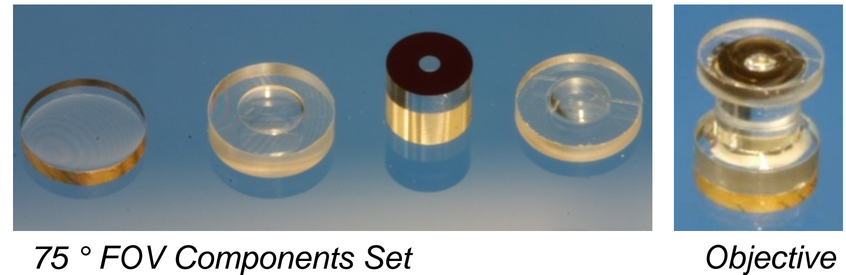
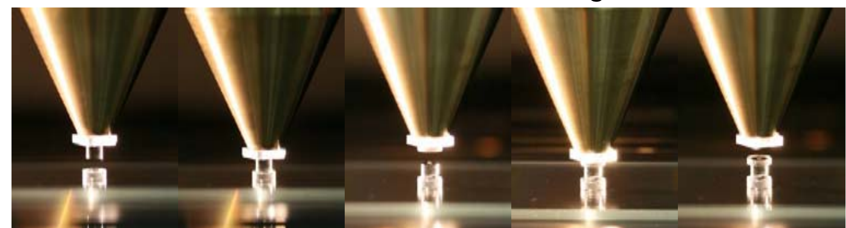
Optics Assembly – Automated Pick&Place for Stacking

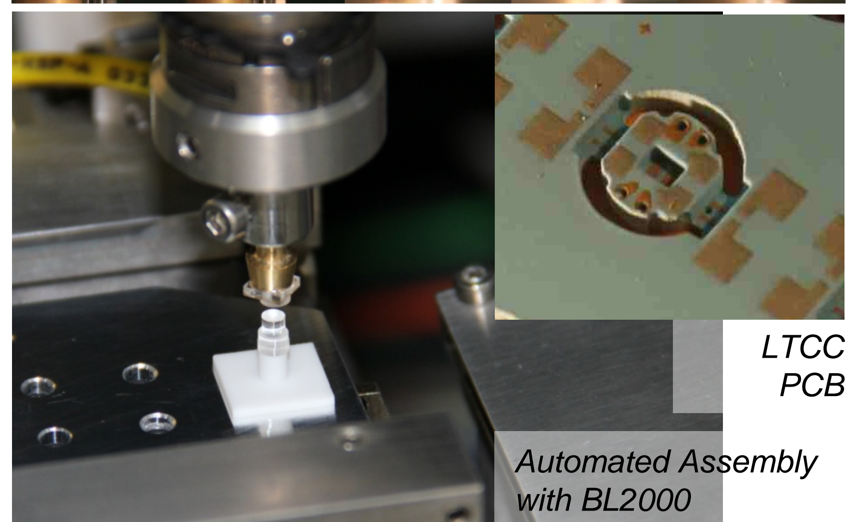
- Objective Stacking
  - passive Concentric Alignment
  - Decenter < 10 µm
  - Tip / Tilt < 1‘
- active Alignment (Tip/Tilt/ Focus) Objective <-> Imager-Assembly
  - Imager pre-Assembly on LTCC
  - Handling / Connector frame on LTCC
  - Singulation @ predetermined break point
- automated in FlipChip Bonder BL2000 (ficonTEC)



75 ° FOV Components Set *Objective*

Stacking





LTCC PCB

Automated Assembly with BL2000

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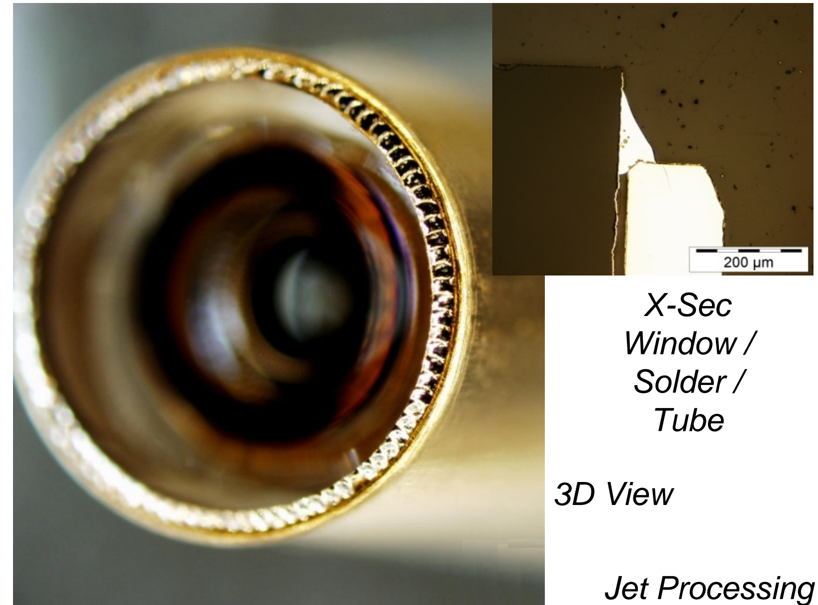
Optics Assembly – Front Window Soldering

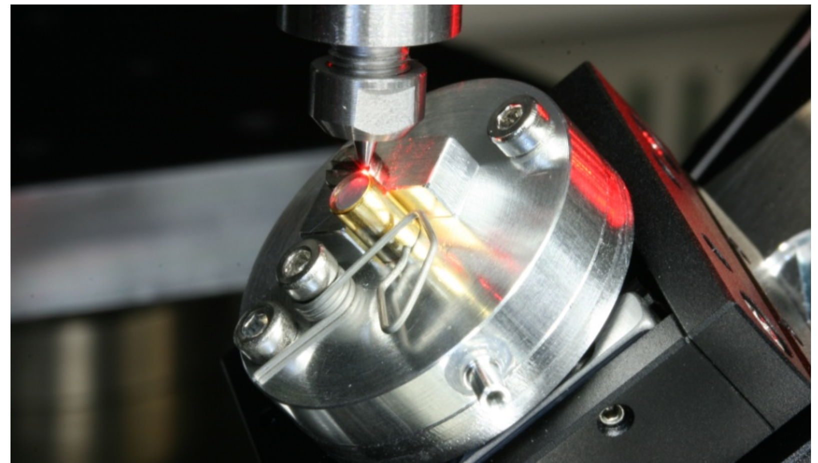
- Long term stable soldered Front Window
- Solderjet Bumping[1] – overlapping discrete Solder Droplets
- liquid Solder Application, no flux, local thermal Impact
- 300 µm Ø Spheres AuSn used
- Time ca. 1 min (Bumping Frequency 1 Hz, 10 Hz possible)
- Autoclave Cycles 5x @ 134 °C, 98 % rel. Humidity, 5 min
- Hermeticity before and after Autoclave Cycles: $4e^{-9}$ mbar*l*s^{-1}



X-Sec Window / Solder / Tube

3D View

Jet Processing



[1]: Patented: DE102007002436 & WO03/006197

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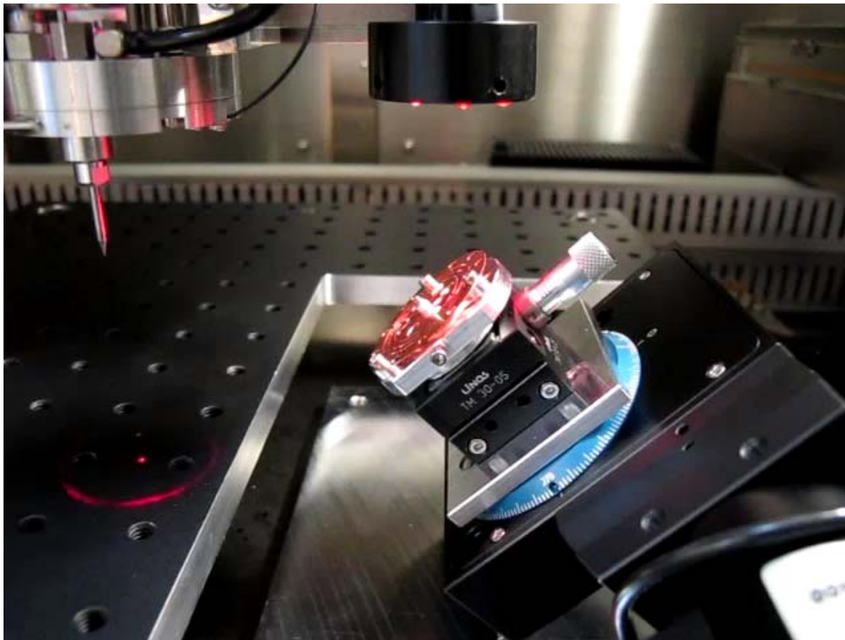
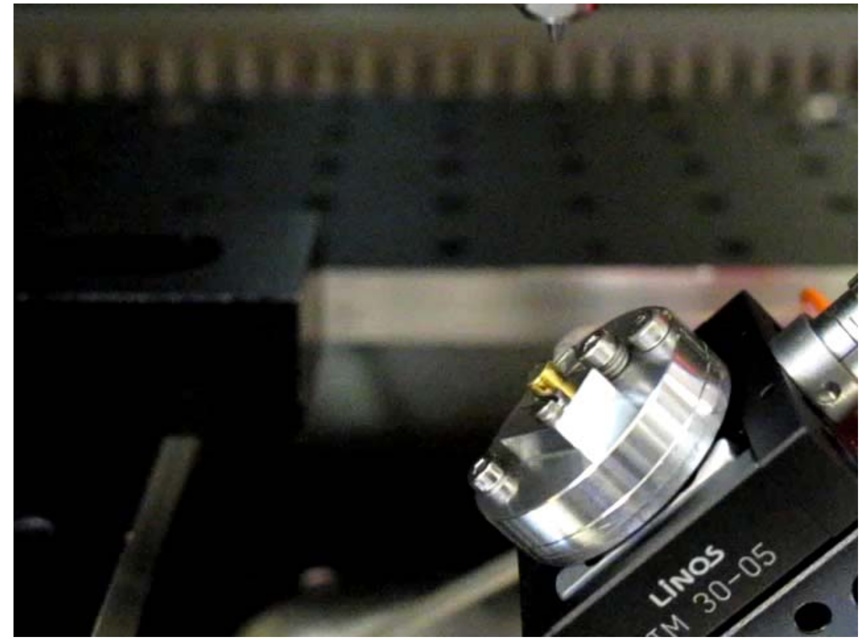
Front Window Soldering





First Step: Fixation

Second Step: Hermetic Sealing

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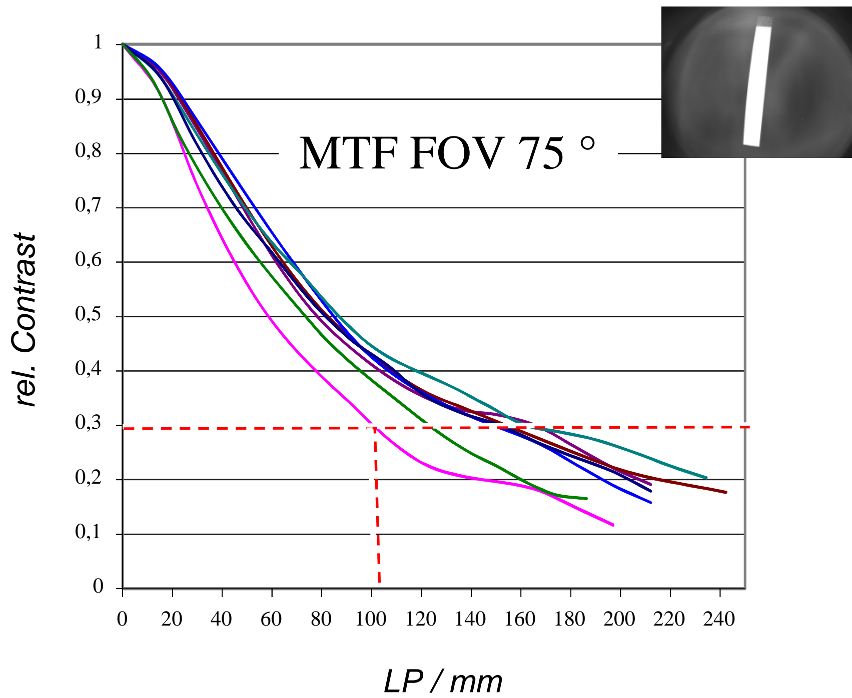
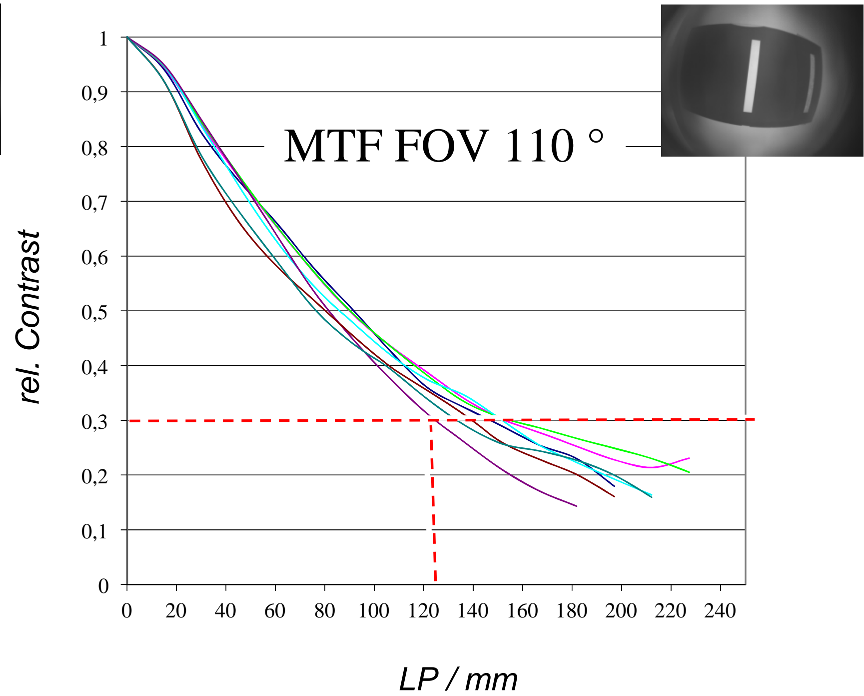
Optics Evaluation – Modulation Transfer Function





- Method: Slanted Edge*, Goal$_{\text{(Nyquist/2)}}$: 90 LP / mm @ 30 % contrast
- FOV 75 °: > 100 LP / mm @ 30 % contrast
- FOV 110 °: > 100 LP / mm @ 30 % contrast

*: ISO/TC42N 4230 (1997), Electronic Still Picture Imaging. Spatial Frequency Response (SFR) Measurements

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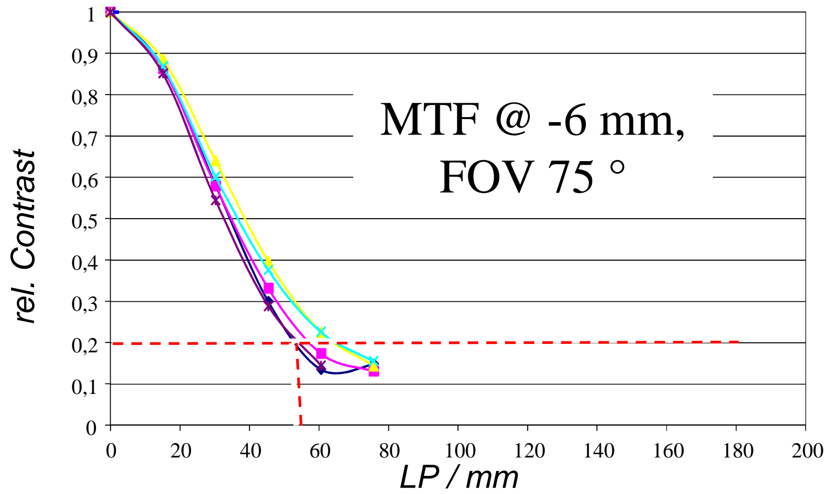
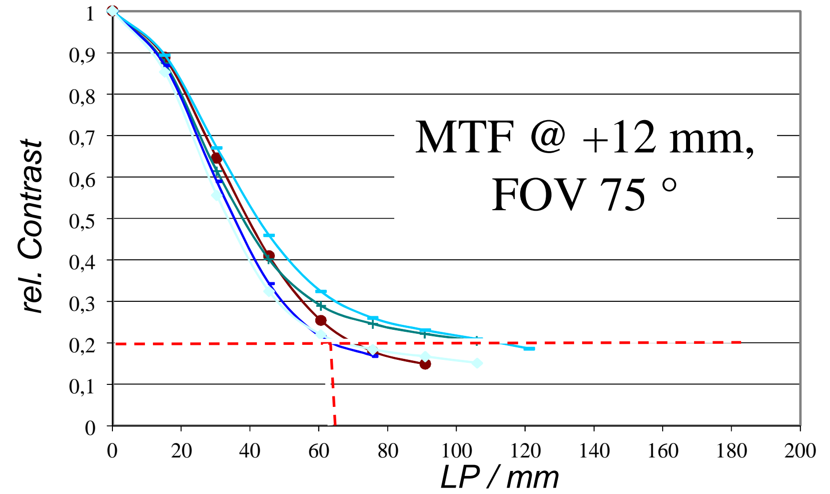
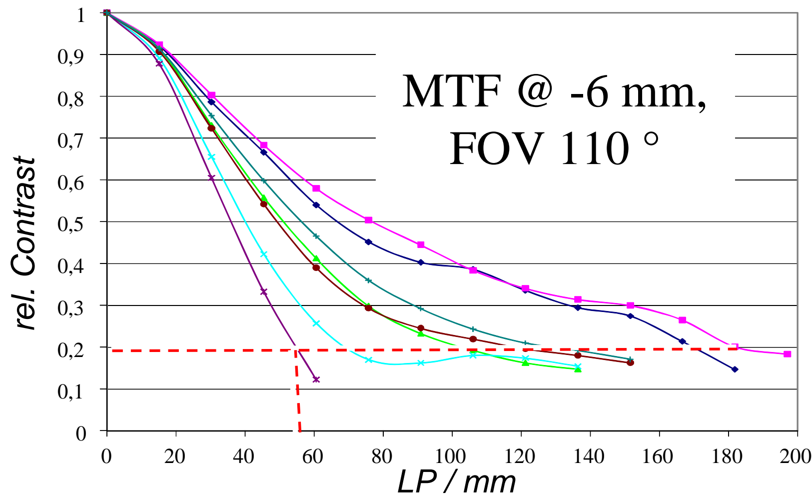
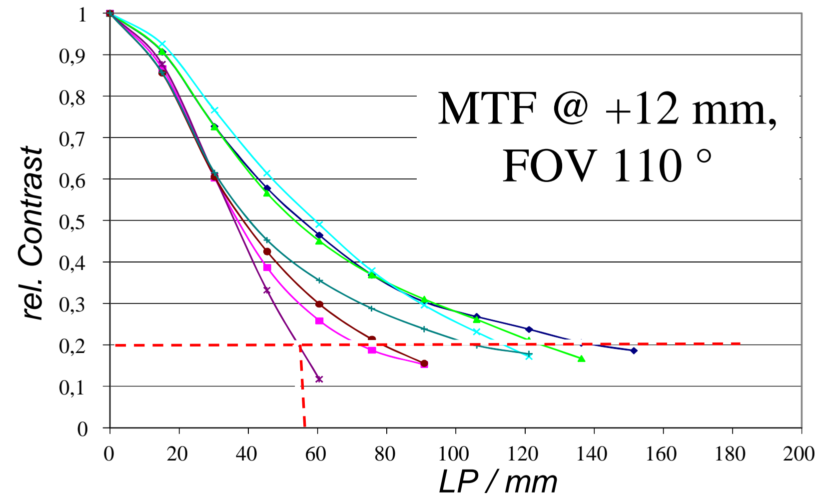
Optics Evaluation – Depth of Fokus





distal ⬅ Goal: 60 LP / mm @ 20 % contrast ➡ proximal





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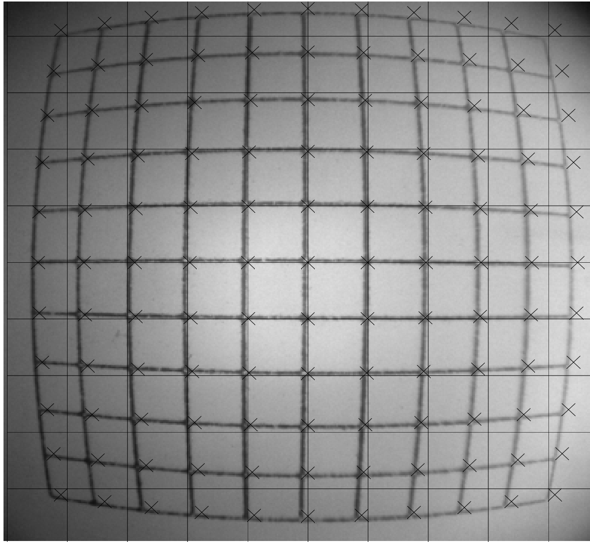
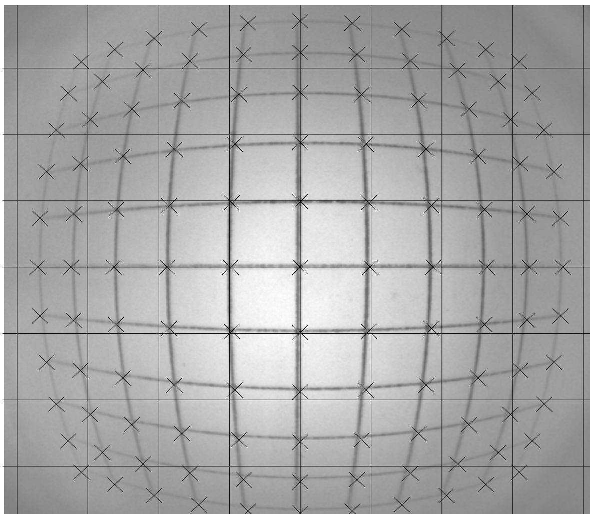
Optics Evaluation – Distortion



FOV 75 °

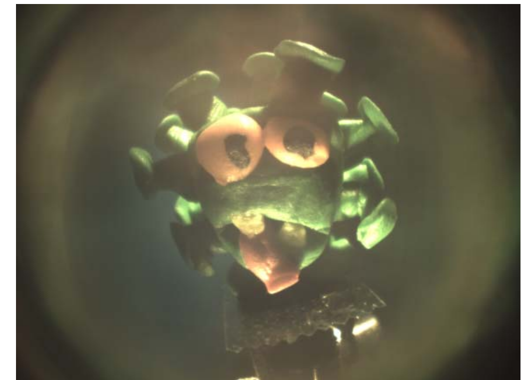
- -18 % max.

scary „real life“ object



FOV 110 °

- -40 % max.



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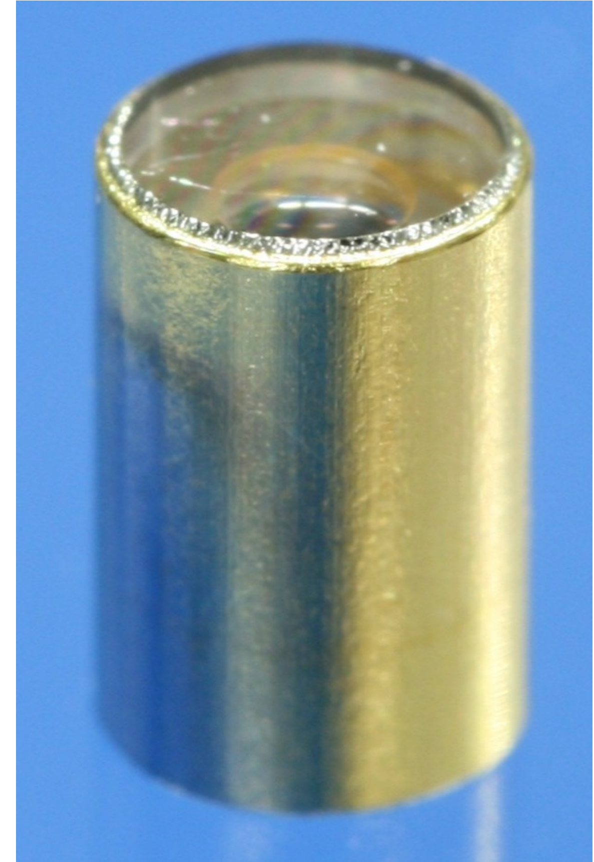
Summary

- SPDT manufactured Prototype Lenses
- Central GRINS lens for stacking
- FFD round CMOS-Sensor with TSV
- Pick& Place for simplified Assembly
- long term stable soldered Front Window
- automated mid-Volume Production

Flexible Integration



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