

LEISTER

High Resolution Mask Welding by Well Collimated Beam from Fiber Laser

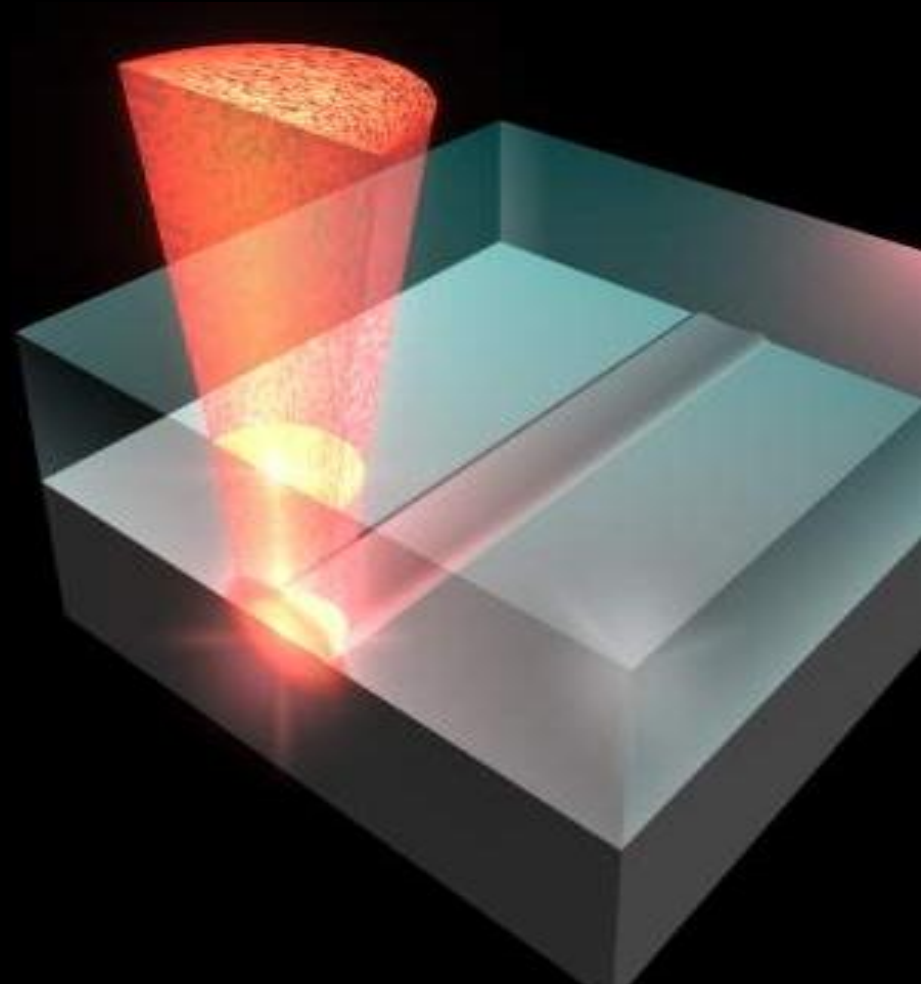
**POLY
BRIGHT**



AKL, Aachen, 9th May 2012
Dr. Ulrich Gubler



- (1) Introduction to mask welding
- (2) Highly-collimated line from fiber laser
- (3) Mask evaluation
- (4) Resolution tests
- (5) Conclusion



Leister group



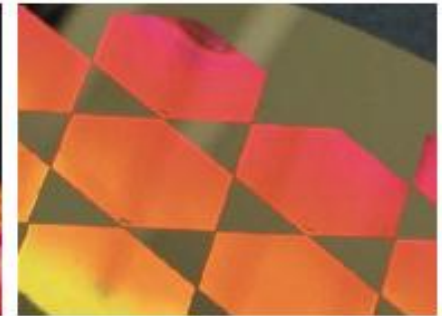
> PLASTIC WELDING



> PROCESS HEAT



> LASERSYSTEMS



> MICROSYSTEMS

- since 1949 tools and machines for welding plastics
- strong technical and application competence
- innovative company culture and wide patent portfolio
- sales und service centers in more than 90 countries
- 98% of turnover in export
- ~500 employees worldwide, ~400 in Switzerland

Business Unit Lasersystems

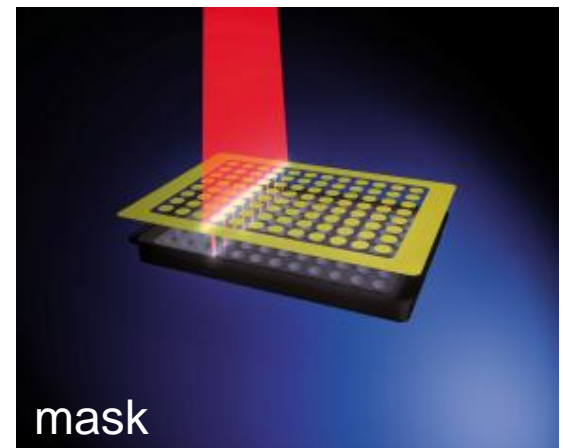
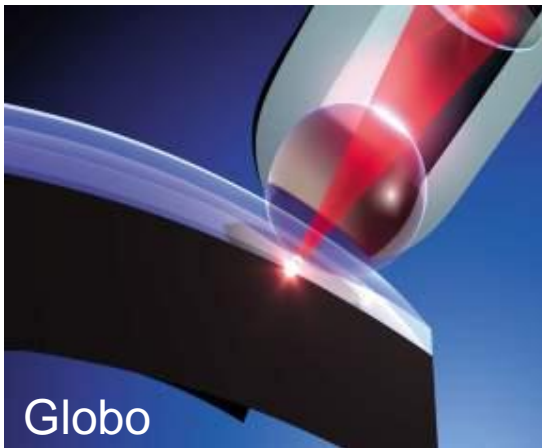
- plastic welding by laser
- first products since 1998
- own sales and application centers in:
 - Sarnen (CH)
 - Chicago (USA)
 - Shanghai (CN)
 - Yokohama (JP)
 - Aachen (D)
- present in additional countries by distributors
- only company offering all standard welding processes



NOVOLAS™
> LASERSYSTEMS



Standard welding processes



(1) Introduction to mask welding

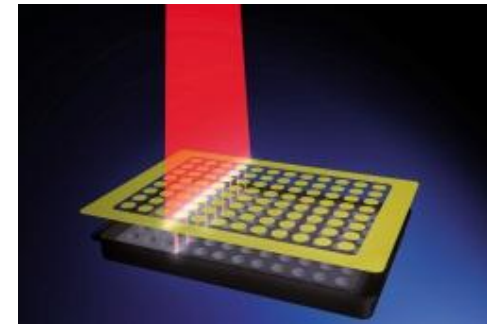
- line-shaped beam sweeps over mask
- mask projects shadow on work piece
- welding only in illuminated areas
- areal welding possible (not only lines)
- enables welding of fine structures
- multiple parts per sweep possible



cerumen filters hearing aids (Phonak)

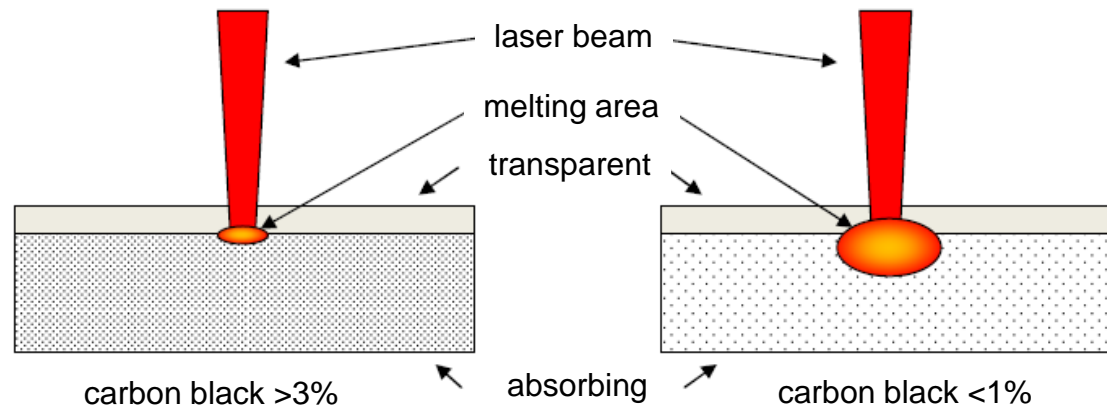


micro-fluidic devices

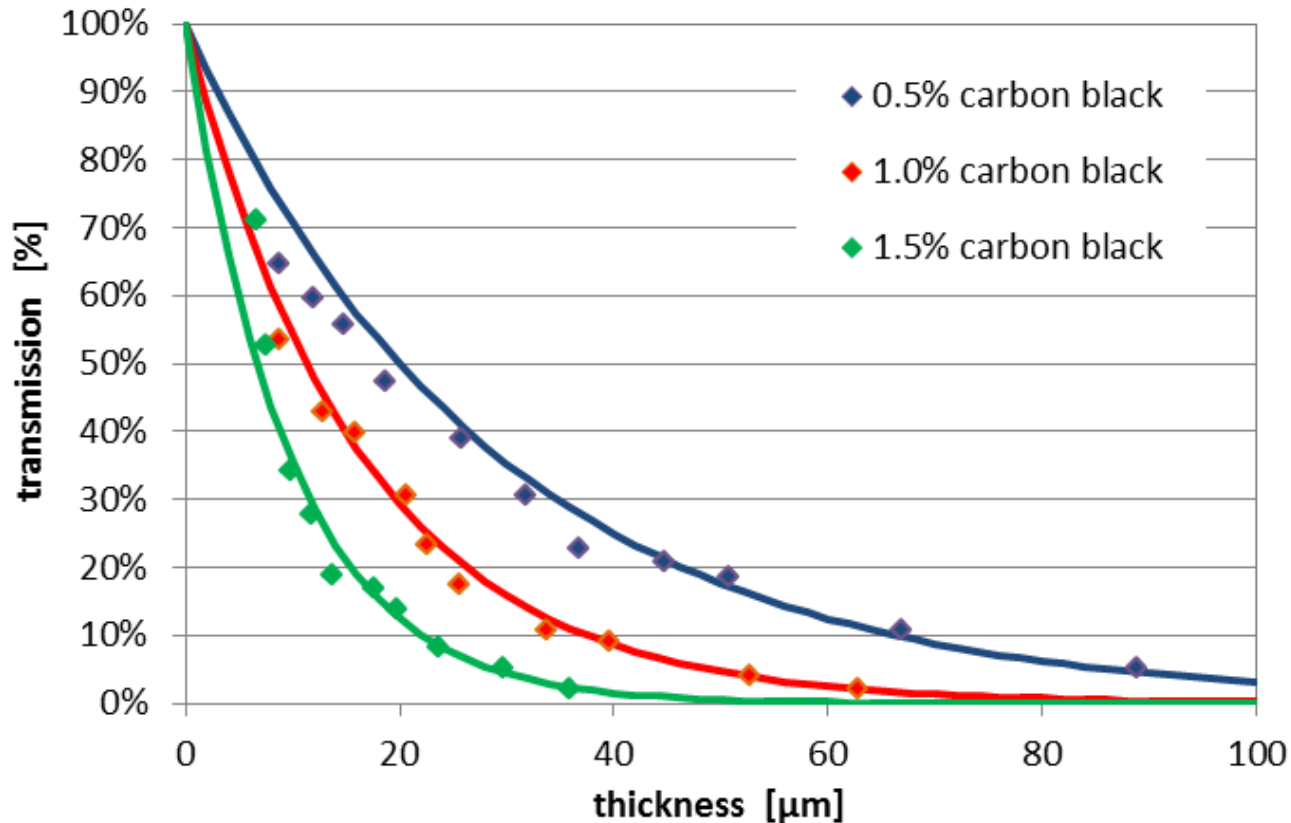


(1) Necessary for good resolution

- good resolution of mask (no problem)
- **well-collimated line-shaped beam**
⇒ **projecting sharp shadow on work piece**
- short stand-off distance mask to weld seam plane
- large enough absorber concentration (see below)
- well-tolerated plastic parts (injection molding sets limits)
- active vision-based alignment of mask to work piece
(passive mechanical alignment in most cases sufficient)



(1) Absorption in surface layer



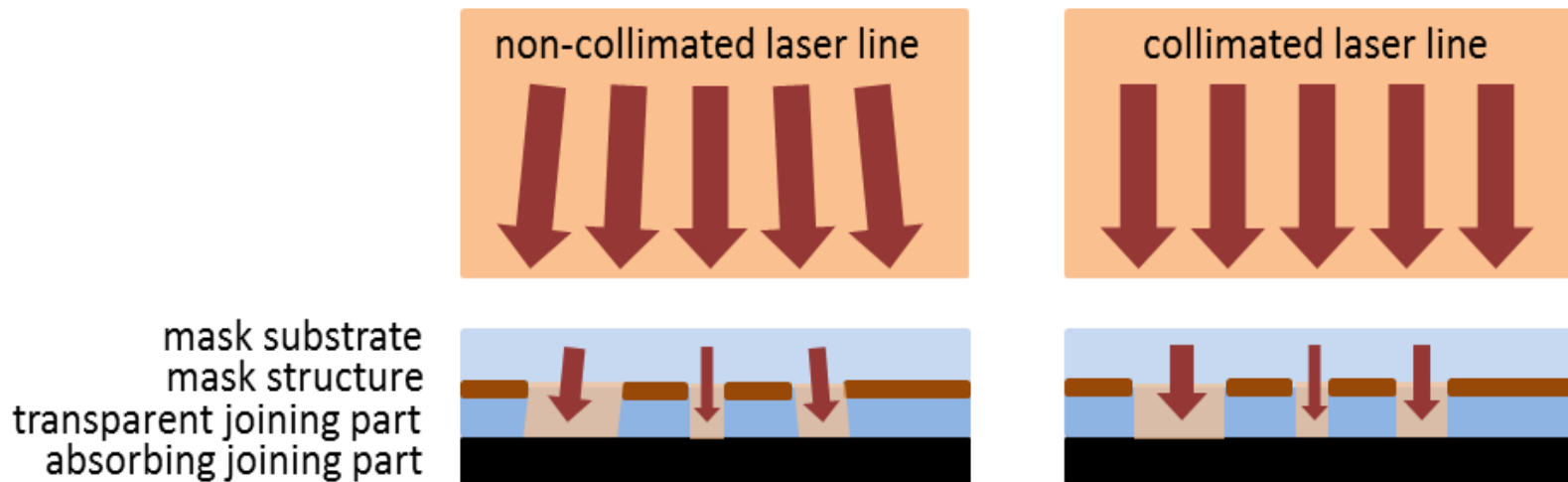
Optical penetration depth ($1/e = 36\%$):

- 0.5% carbon black 28.8 μm
- 1.0% carbon black 16.3 μm
- 1.5% carbon black 9.6 μm

(1) Limitations with current laser source

LineBeam AT based on standard laser diode bars/stacks

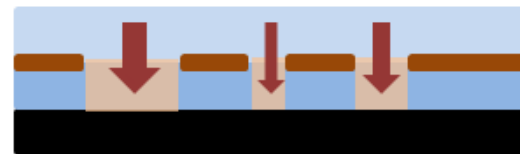
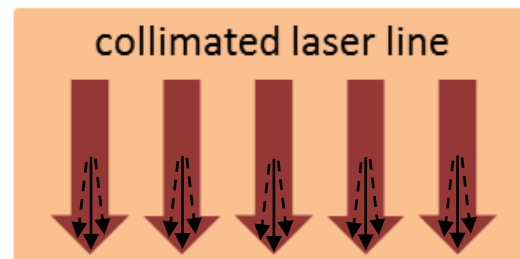
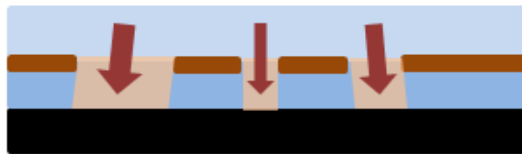
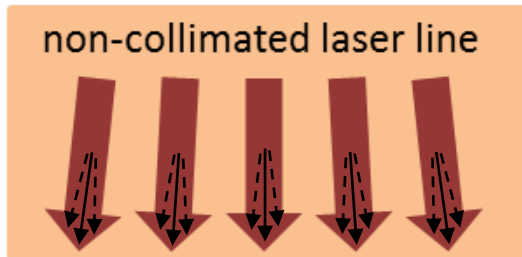
- well-collimated in fast axis of diode bar
- remaining divergence in slow axis of diode bar



⇒ for larger stand-off distance mask to welding plane scaling of mask along line direction

(1) Divergence solved by field lens

- field lens collimates for same main direction along line
(size lens larger than line length)



⇒ but local angular distribution still present limiting resolution

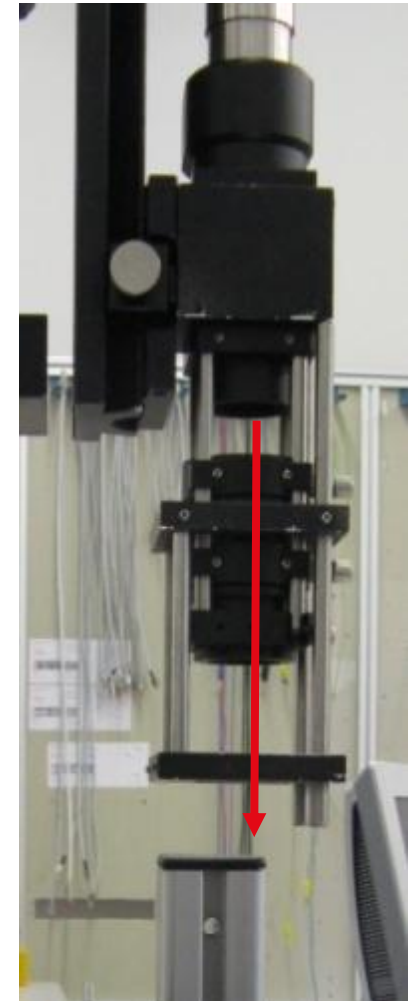
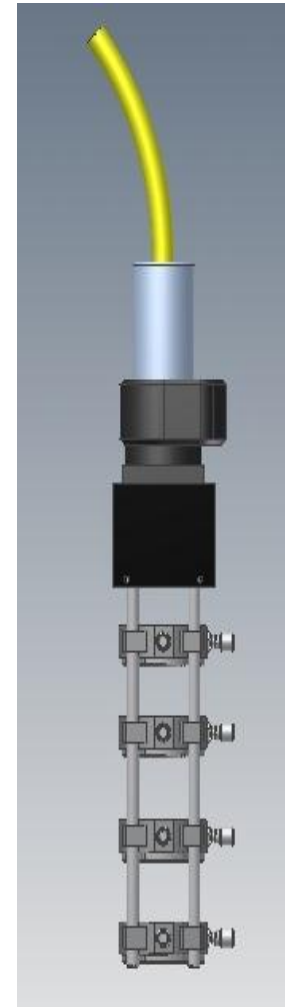
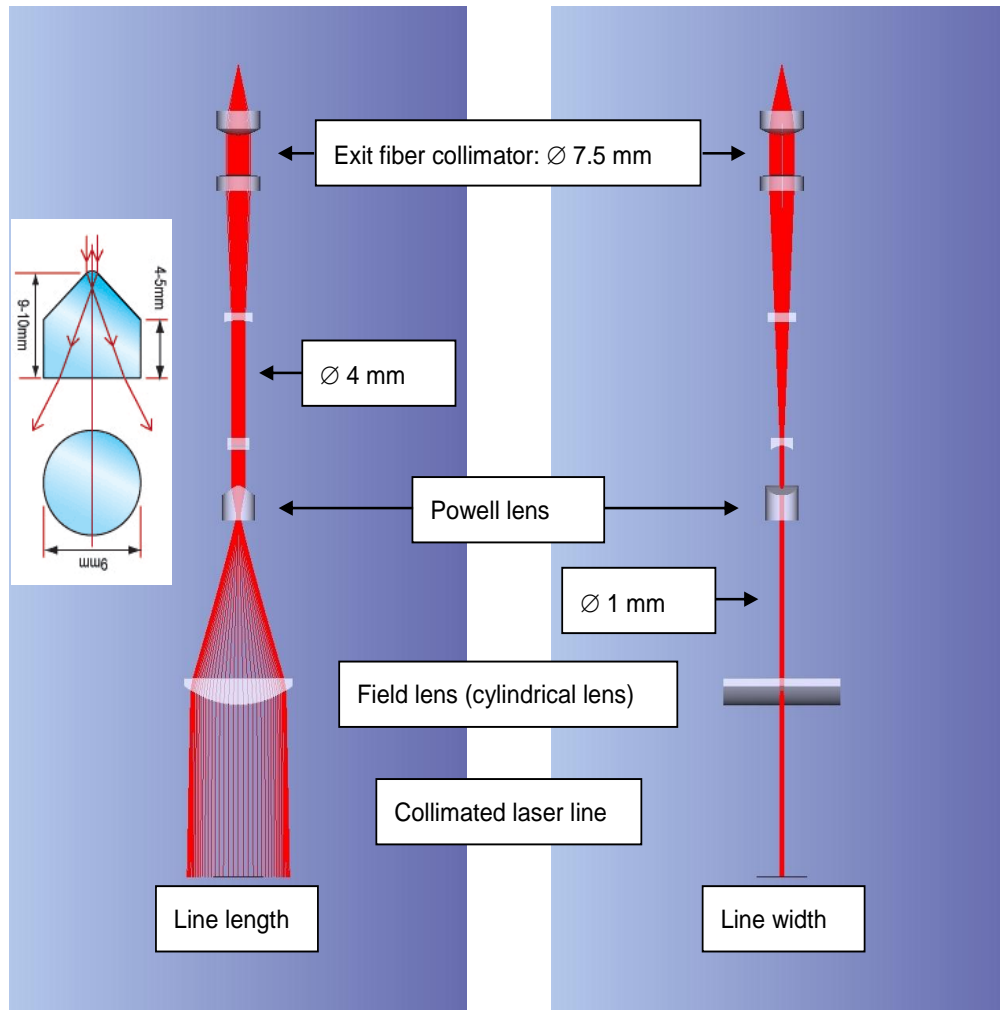
(2) Fiber laser for highly-collimated line?

Basic idea and concept for highly-collimated line:



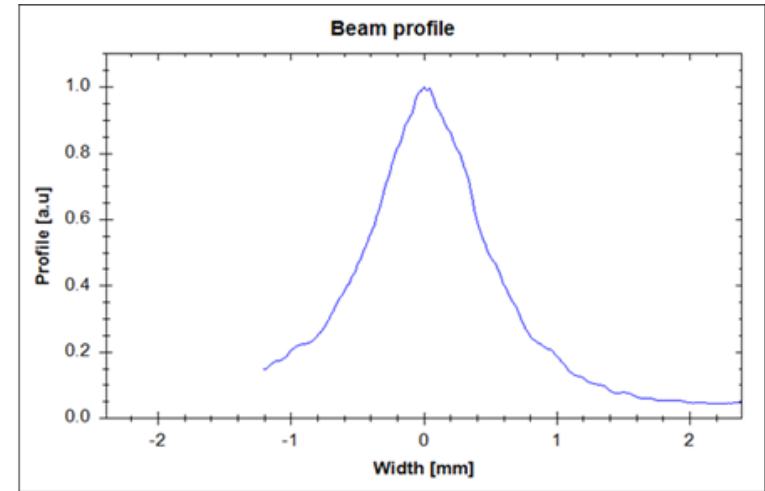
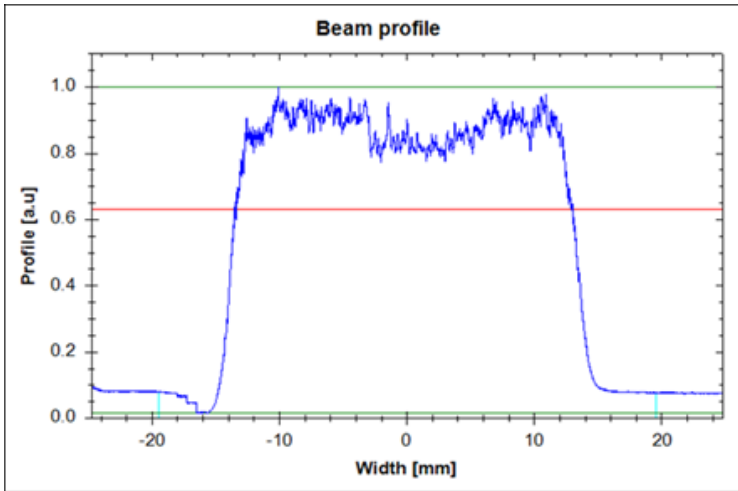
- high-beam quality needed for good collimation
⇒ fiber laser as source
- need homogeneous power distribution in line
⇒ optical free-form surface (Powell lens) to spread Gaussian profile from fiber laser to line
- various line lengths possible after spreading the beam
⇒ field lens with different focal lengths

(2) Optical design and realization

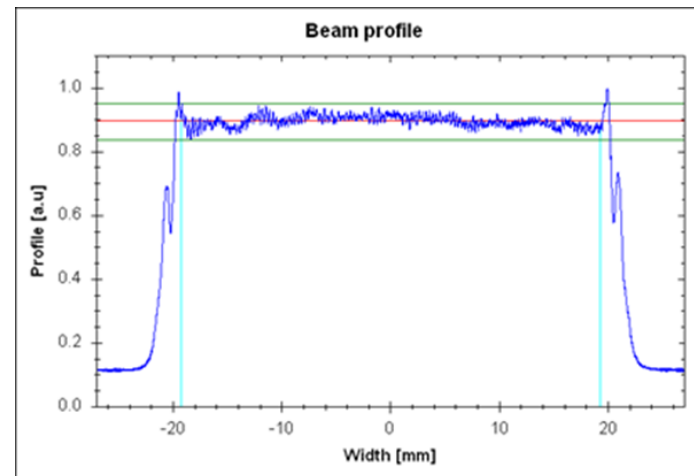


(2) Measurement intensity profile

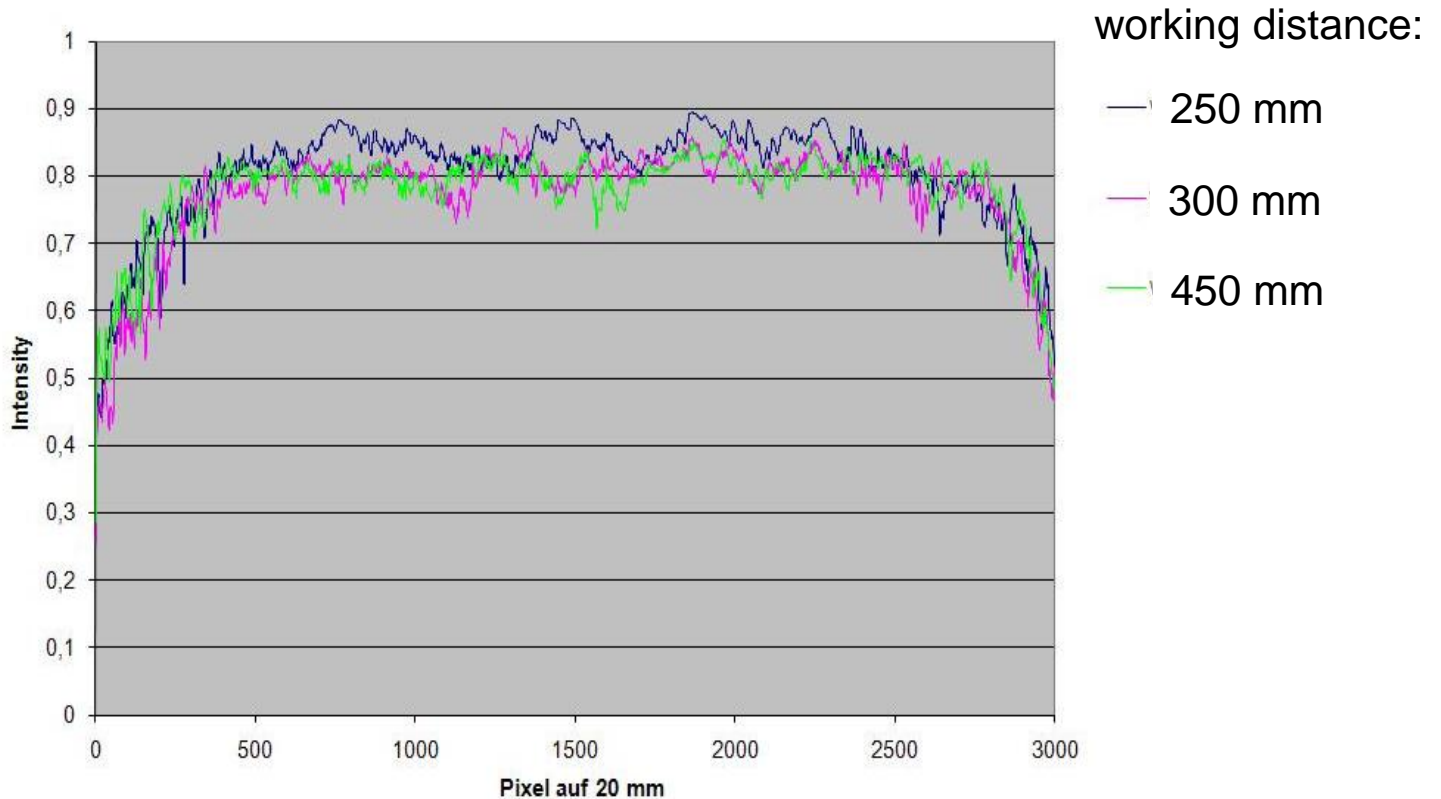
highly-collimated line from fiber laser



for comparison: LineBeam AT

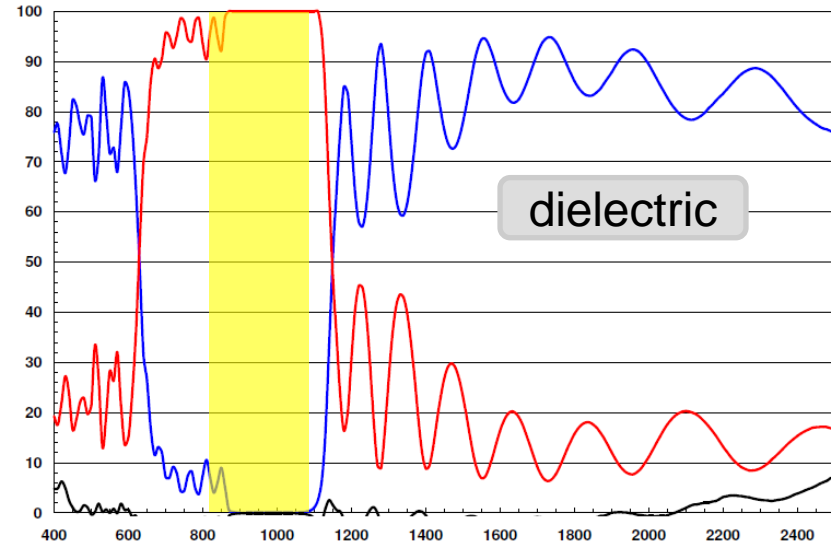
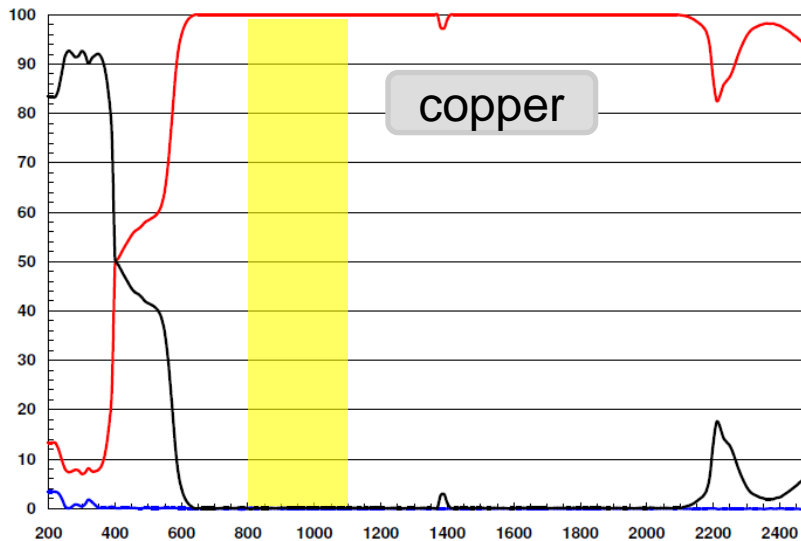
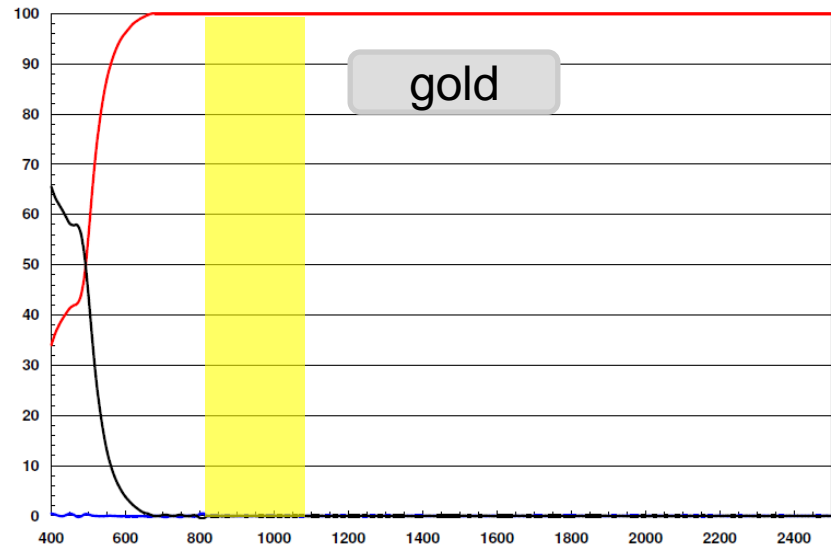
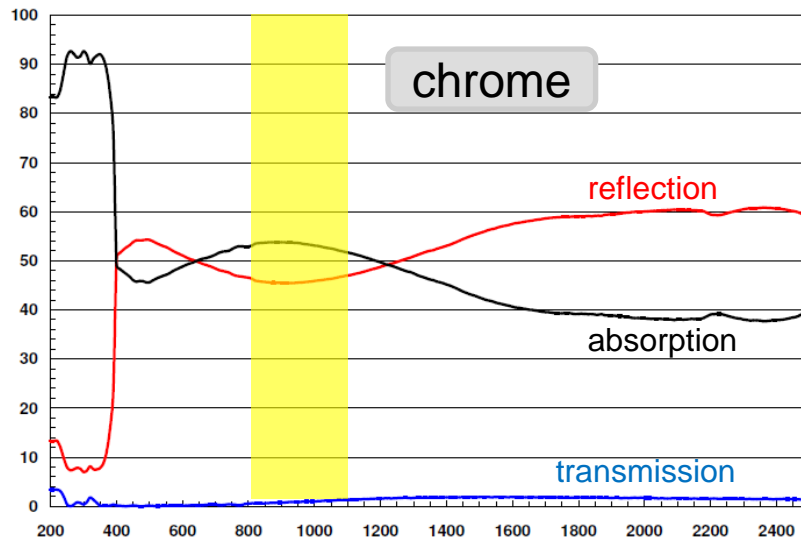


(2) 1st verification of collimation



⇒ no increase in beam width for larger working distance

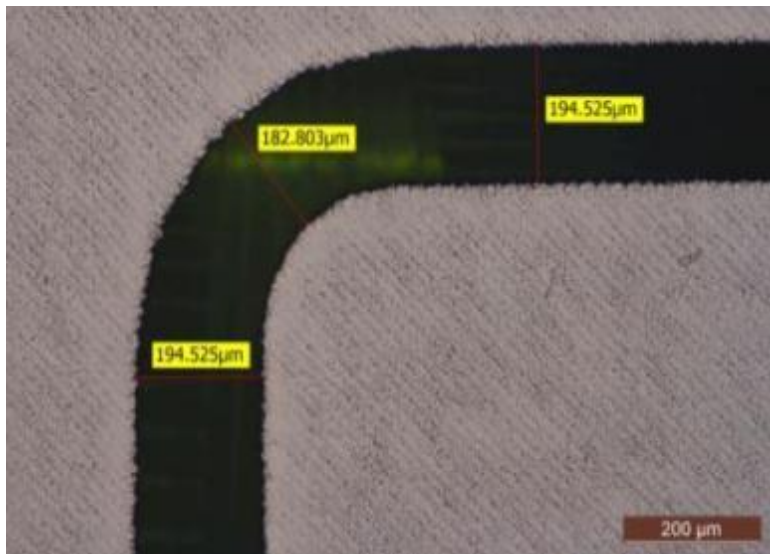
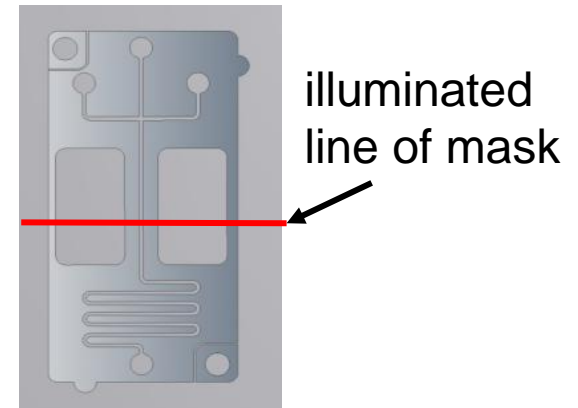
(3) Mask material evaluation



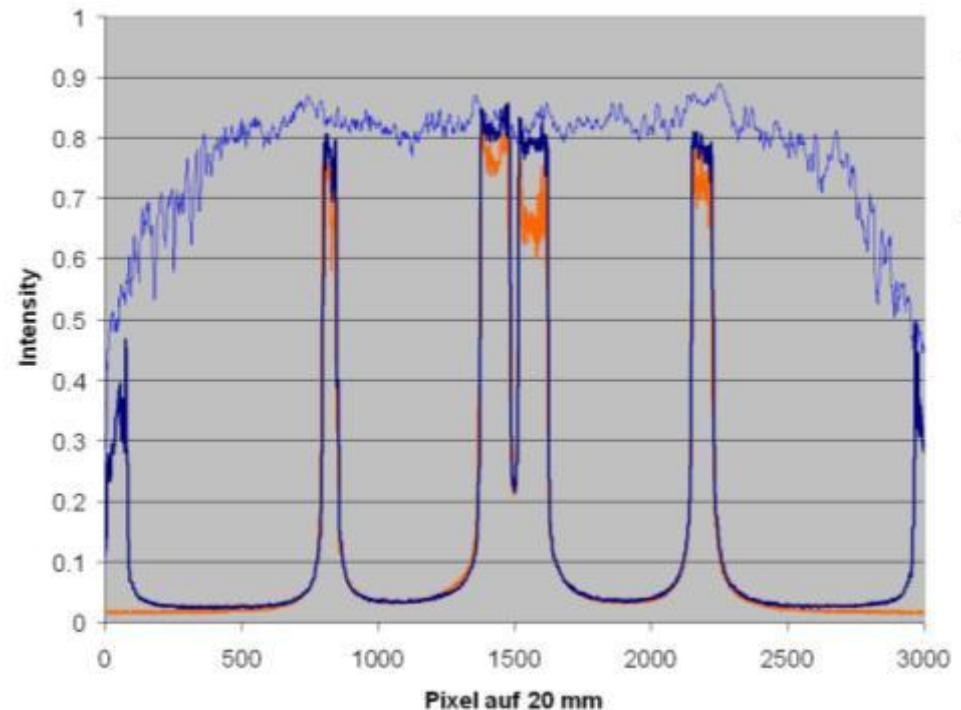
(3) Projection of shadow

Structuring of mask by

- lithography (best quality, longer lead-time)
- laser ablation (fast, edge roughness)



laser ablated gold mask: roughness of edge and incomplete removal



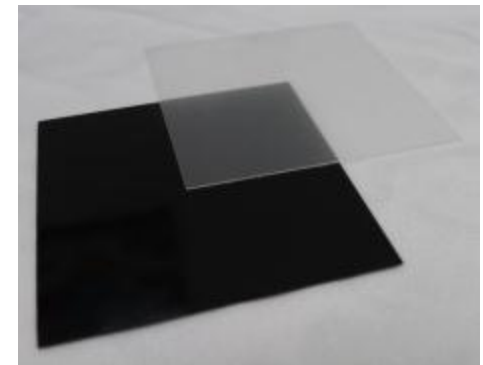
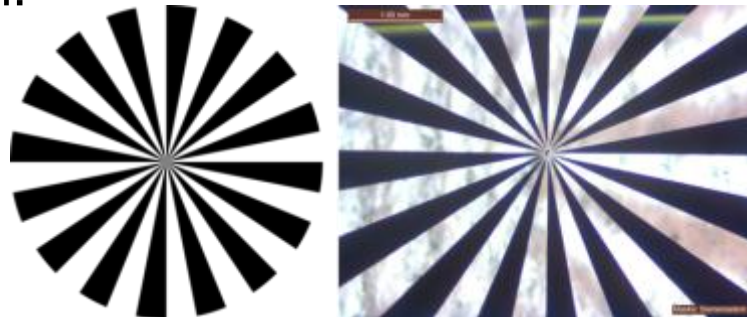
(4) Resolution tests

- beam source: Leister LineBeam AT
 - line length 30 mm
 - line width 1 mm
 - power 300 W
 - wavelength 940 nm



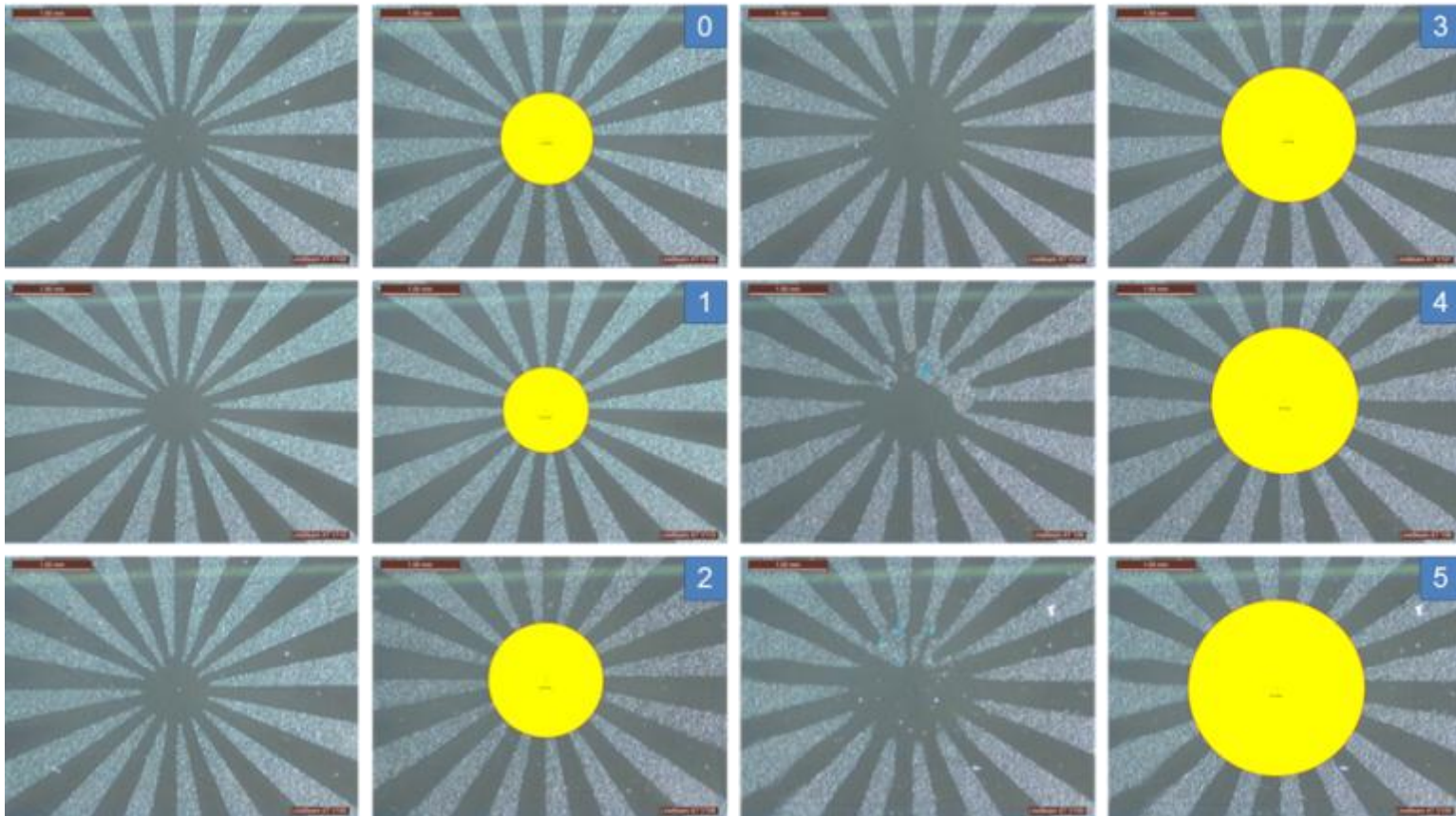
- fiber laser & special optics:
 - power 100 W
 - wavelength 1070 nm

- material: polycarbonate (PC) foils 0.3 mm
- glass plates to change stand-off mask to foils
- resolution pattern:
Siemens-Stern
16 segments



(4) Resolution vs stand-off

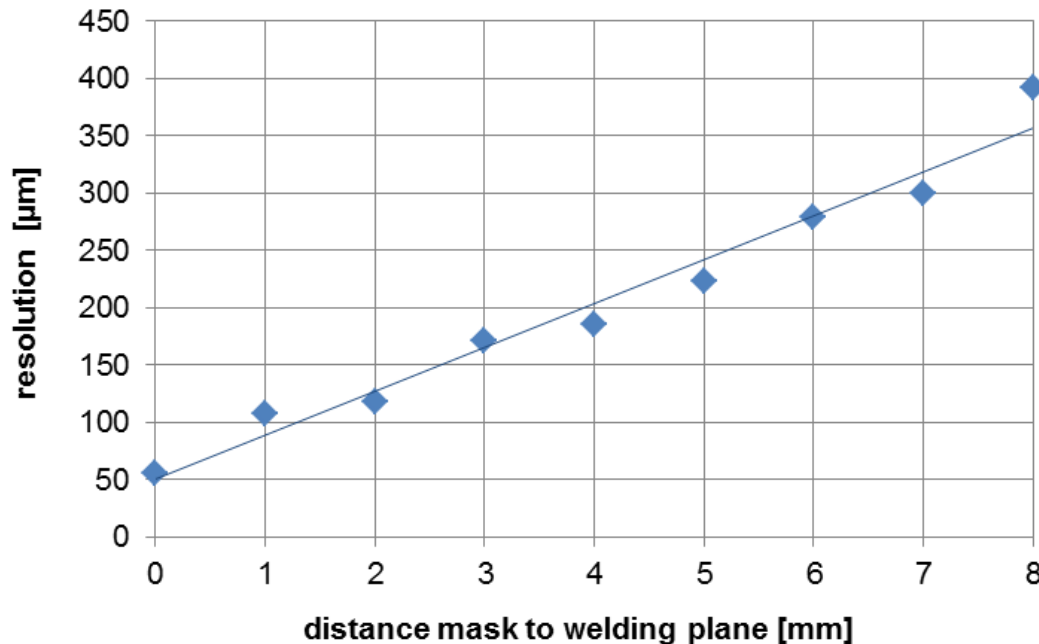
LineBeam AT



$$\text{resolution} = (\pi * \text{diameter}) / \text{segments}$$

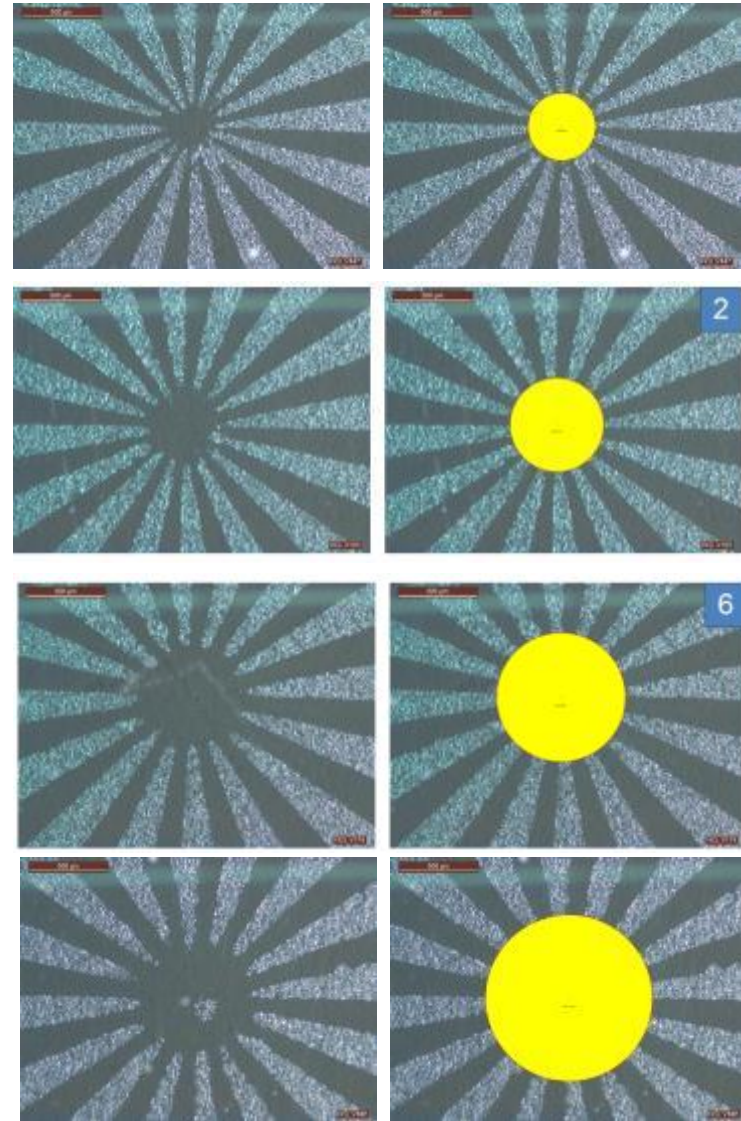
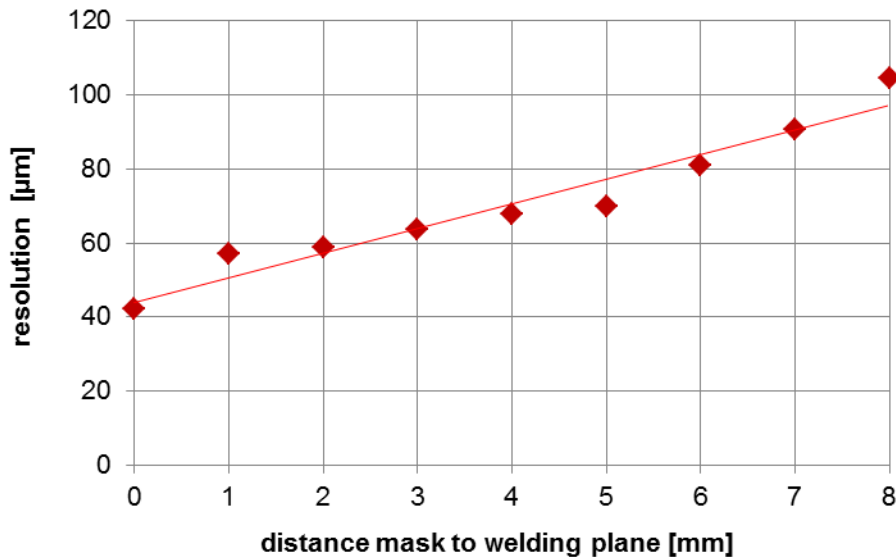
(4) Resolution with LineBeam AT

- limit for used PC samples at about 50 μm
- only little direction dependence
- clear reduction of resolution for larger stand-off distance
- laser power 80 W, speed 20-30 mm/s

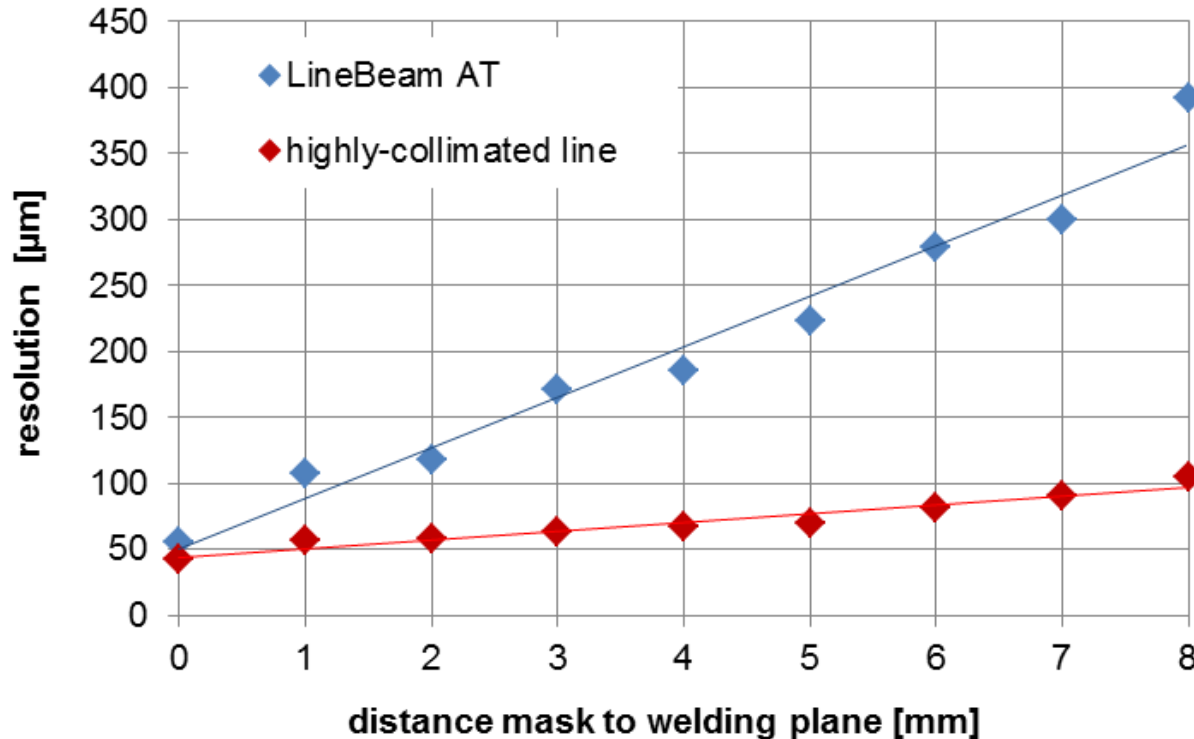


(4) Resolution with highly-collimated line

- limit also at about 50 μm
- only little direction dependence
- resolution better maintained at larger stand-off distances
- laser power 100 W, 20-30 mm/s



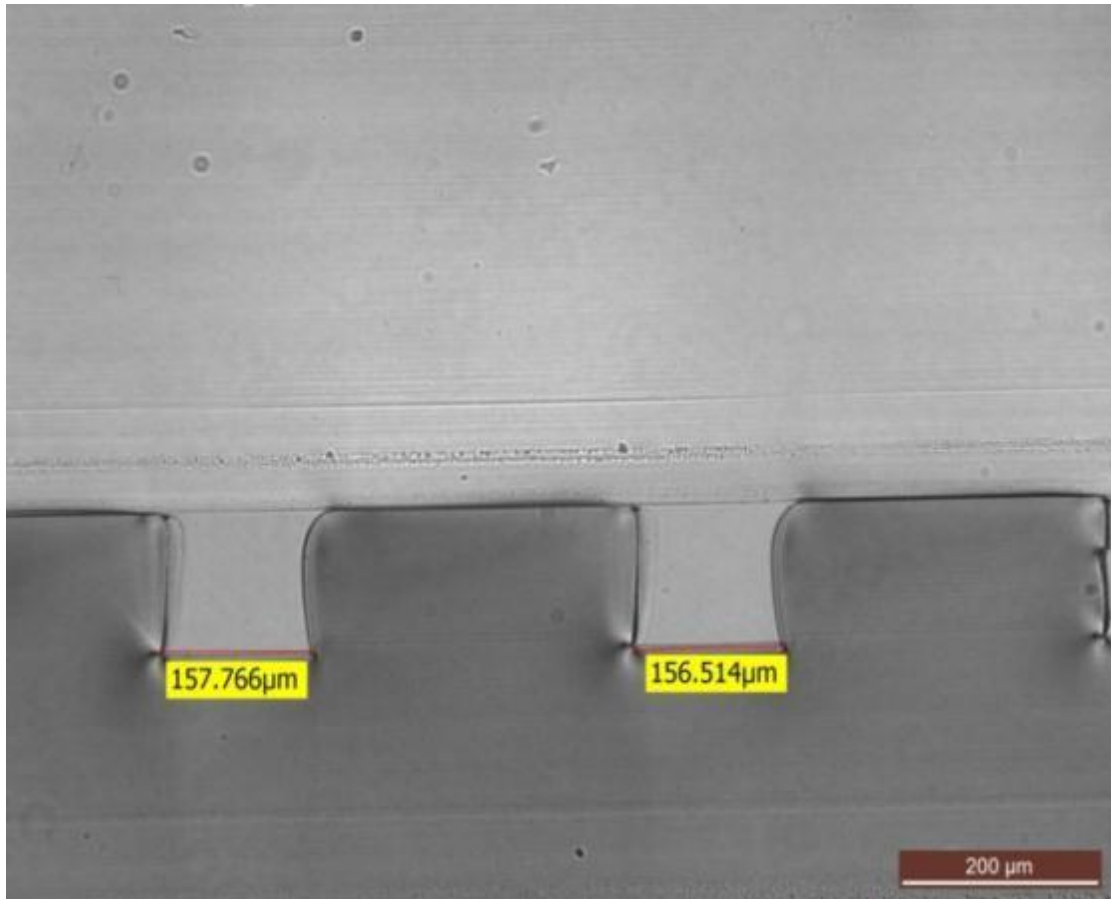
(5) Conclusion



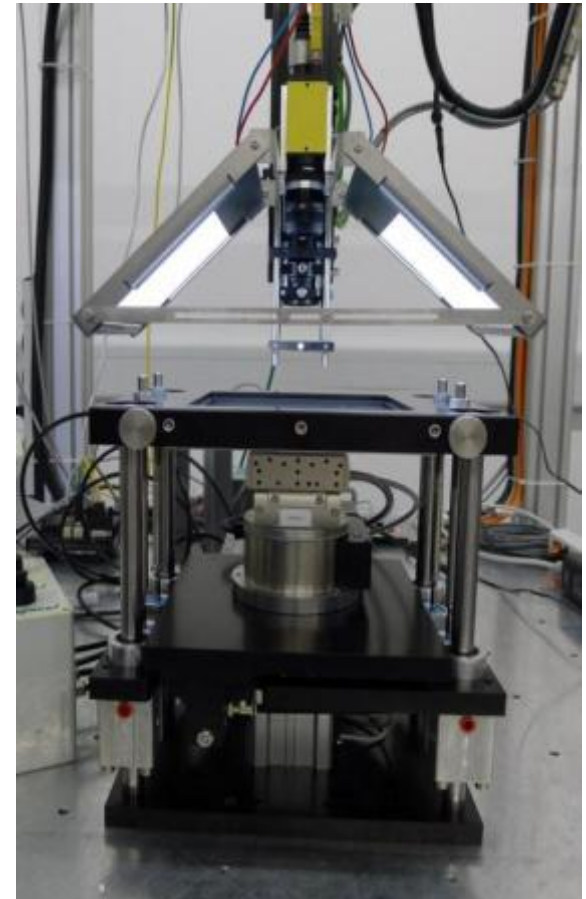
- ⇒ highly-collimated line from fiber laser improves resolution significantly for larger stand-off distances of mask
- ⇒ for short stand-off of 1-2 mm standard LineBeam as good

(5) Example micro-fluidic channel

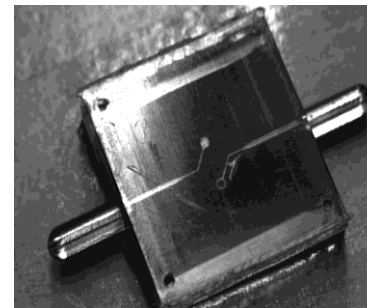
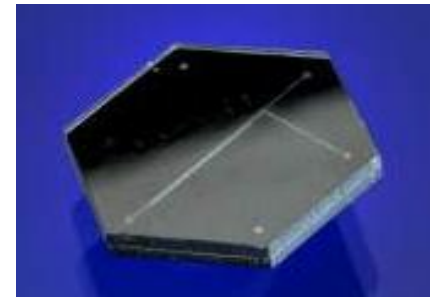
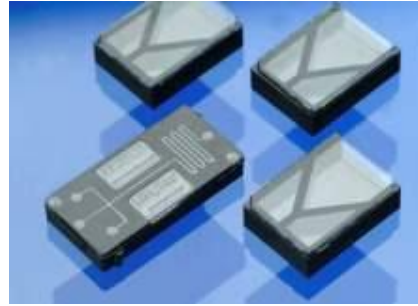
welding direction



clamping unit with vision
(x,y,θ) mask alignment



Thank you for your attention!



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