Optical Waveguides fabricated by combination of ink-jet and flexographic printing

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Talk Structure

1. Motivation & Research environment
2. Flexo-printed optical waveguides
3. Ink-jet printed optical waveguides
4. Combination of both techniques
5. Next Steps
6. Printing of fluorescent elements

Motivation and Research Environment

Research Environment

All-optical sensor networks on flexible foil substrates

PlanOS
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HOT - Hannoversches Zentrum für optische Technologien

IMTEK - Institut für Mikrosystemtechnik

T. Wolfer, ITA Hannover

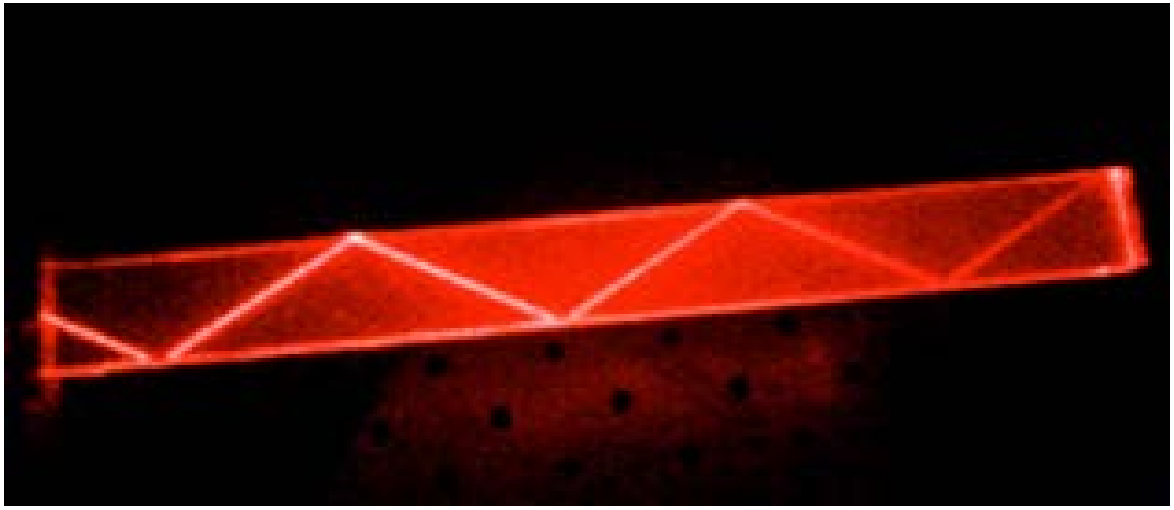
created by additive mass fabrication of polymers

Applications for Planar Optronic Sensors

T. Wolfer, ITA Hannover

Optical Waveguides

A high refractive index causes
total internal reflection.
Light can be confined and guided!



PMMA guiding a red laser beam

Requirements:
Low interface roughness
High transparency

Why Printing?

- Liquid materials allow effortless creation of optical structures
- Printing typically aims to cheap mass-production
- Polymers are established for printing techniques

Water on glass = microlenses

Research Question

Can optical waveguides on foils be fabricated by printing techniques?

Investigated Techniques:

Flexographic printing

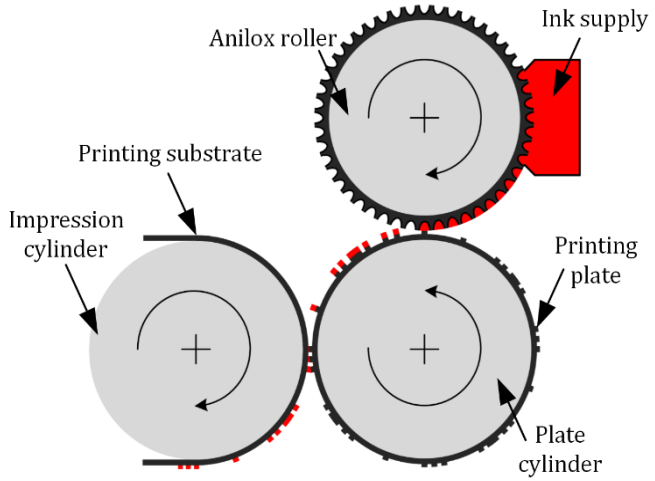
Ink-jet printing

Is a combination of both techniques feasible?

Flexo-printed optical waveguides

Flexographic Printing (Tim Wolfer, ITA Hannover)

- High-throughput (1 sheet of 350*500 cm per second)
- Printed pattern defined by printing plate
- Ink: Commercial acrylate varnish from Jaenecke-Schneemann Druckfarben) (viscosity: 200 – 250 mPas)



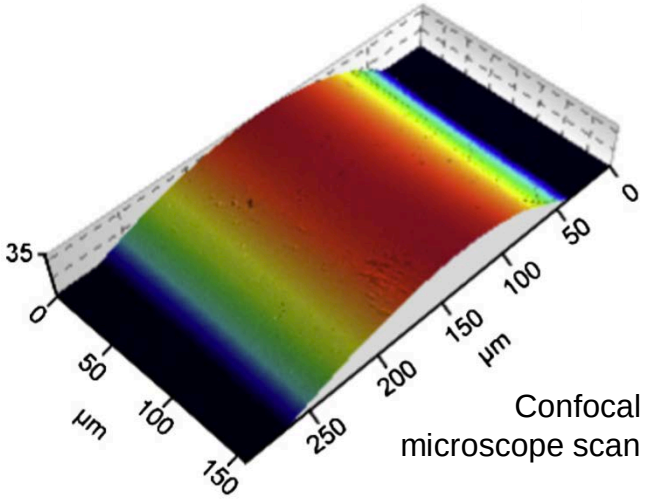
Heidelberger Speedmaster SM 52 (Heidelberger Druckmaschinen AG)

Flexo-printed optical waveguides (Tim Wolfer, ITA Hannover)

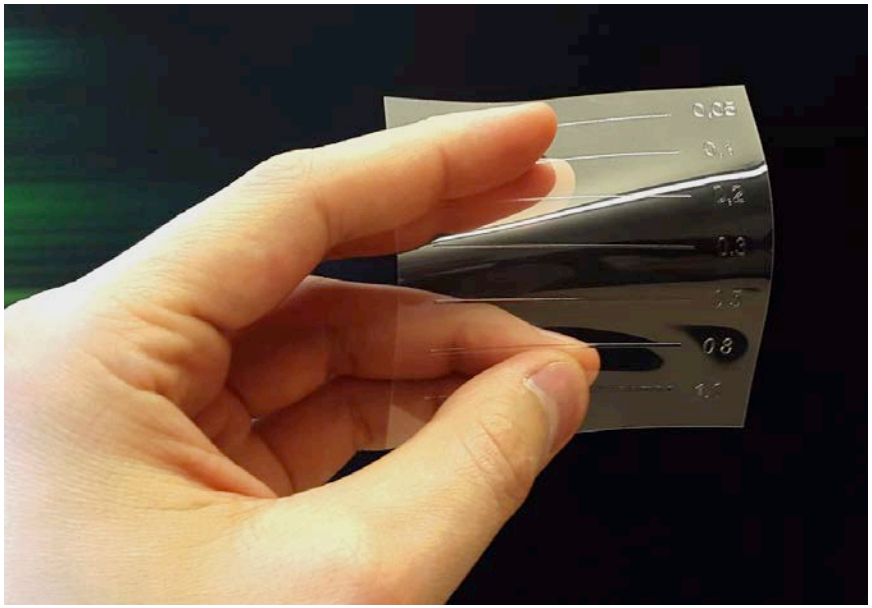
No pre-treatment, printing at room temperature under normal air

Printing Cycles: 10

Post-treatment IR+UV, each layer



Confocal microscope scan



T. Wolfer, ITA Hannover

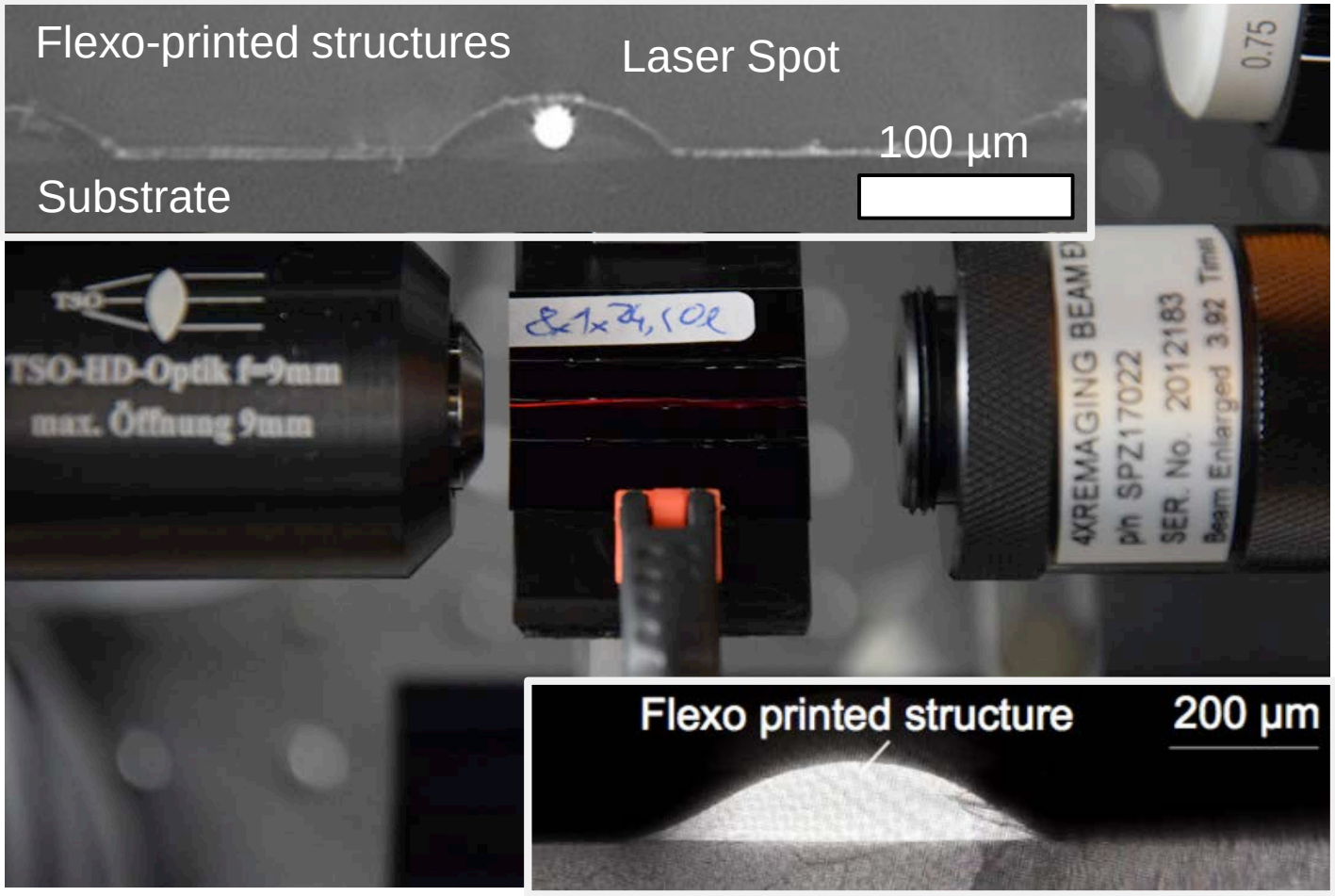
Width: 100 µm - 1000 µm

Height: 4 µm - 110 µm

Surface Roughness: 40 nm

Attenuation: 0.5 dB/cm

Optical Characterization



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CW-Laser @ 638 nm,140mW

Camera at back facet.

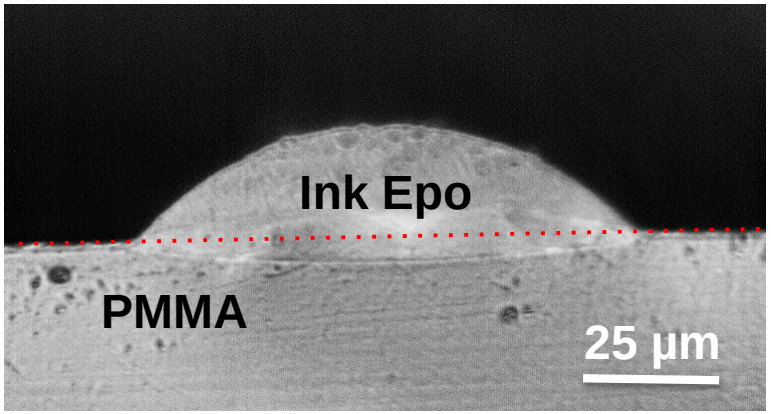
Integration sphere for power measurement

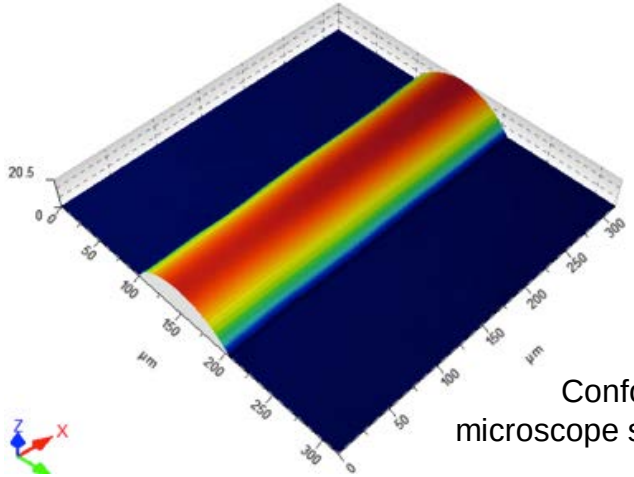
Cutback-method to rule out coupling losses

Ink-jet printed optical waveguides

Ink-jet printed optical waveguides

Material:	InkEpo
Pre-treatment:	None
Substrate T during Printing:	60° C – 75° C for edge pinning
Printing Cycles:	20 layers
Post-treatment:	60° C for 1h, 2 J @ 365nm





Confocal microscope scan

Width: 75 µm - 200 µm

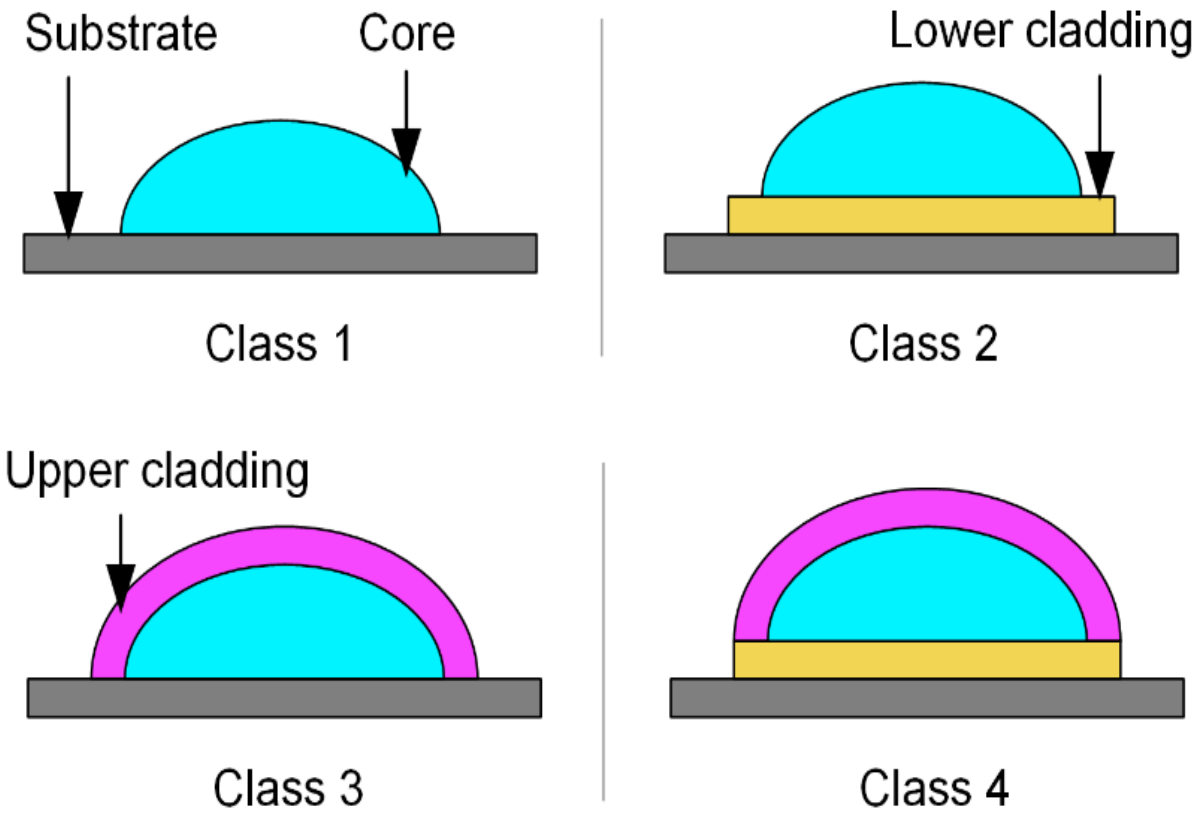
Height: 5 µm - 40 µm

Surface roughness:
<100nm, depending on ink

Attenuation:
Typically 5 dB/cm

Combining both methods

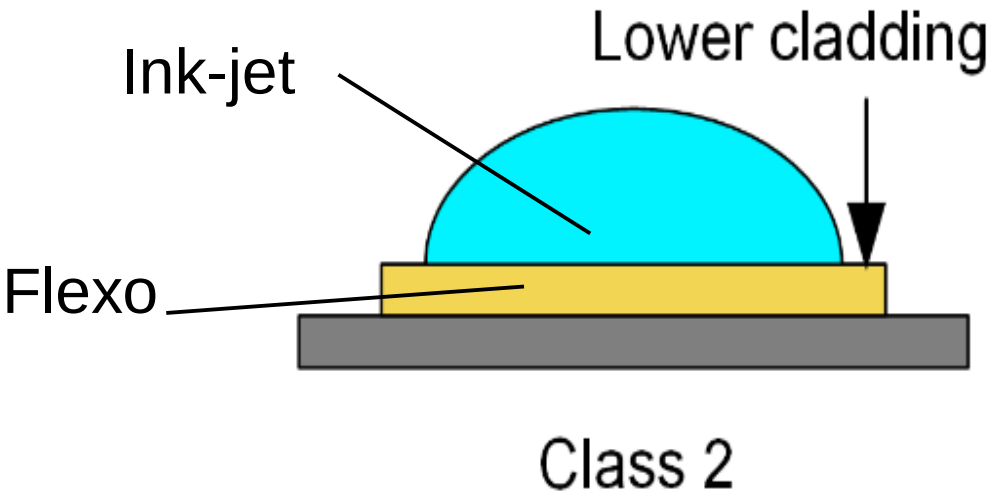
Combination of Flexo- and Inkjet



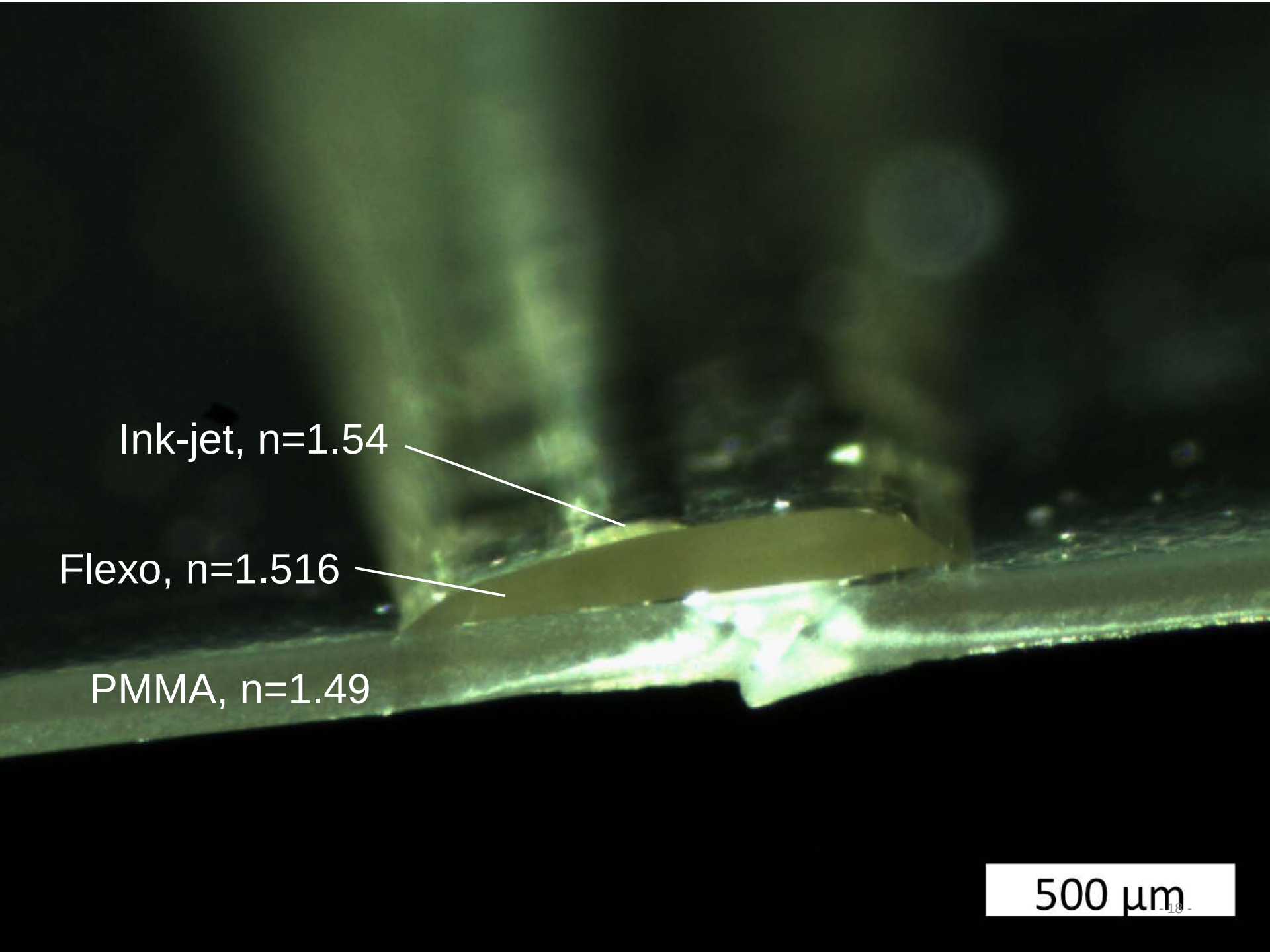
Possible waveguide concepts by combining the core and cladding layers (Wolfer, ITA Hannover).

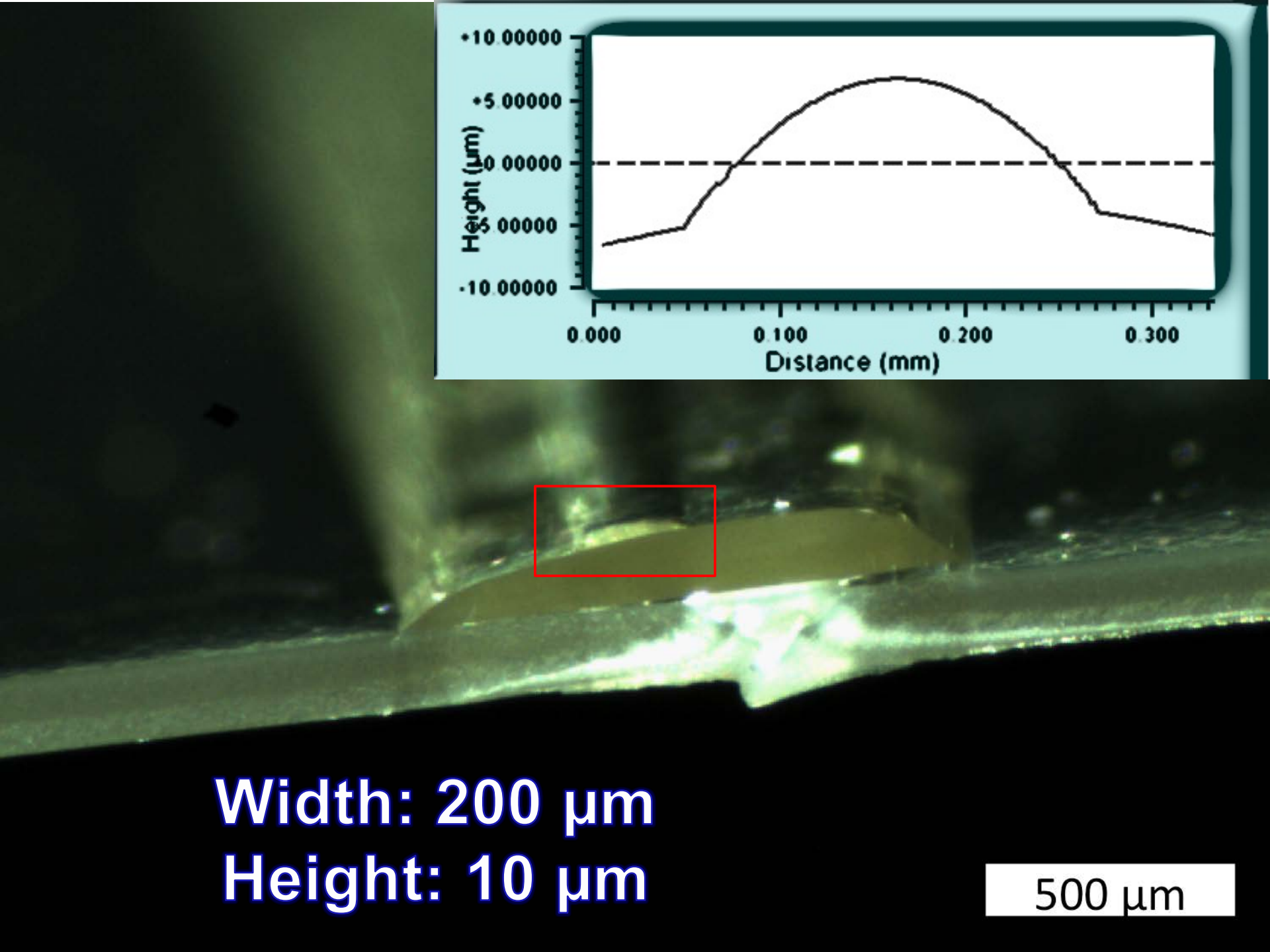
Combination of Flexo- and Inkjet

Core is the new cladding!

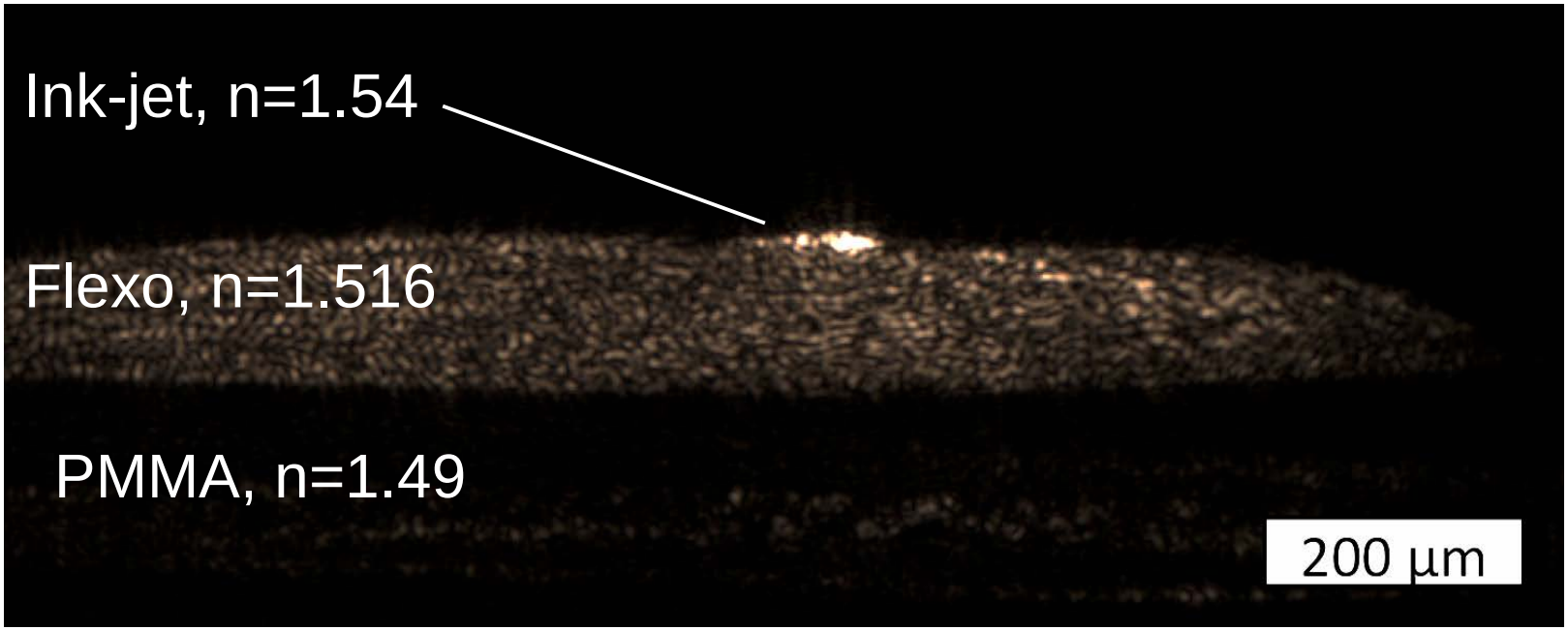


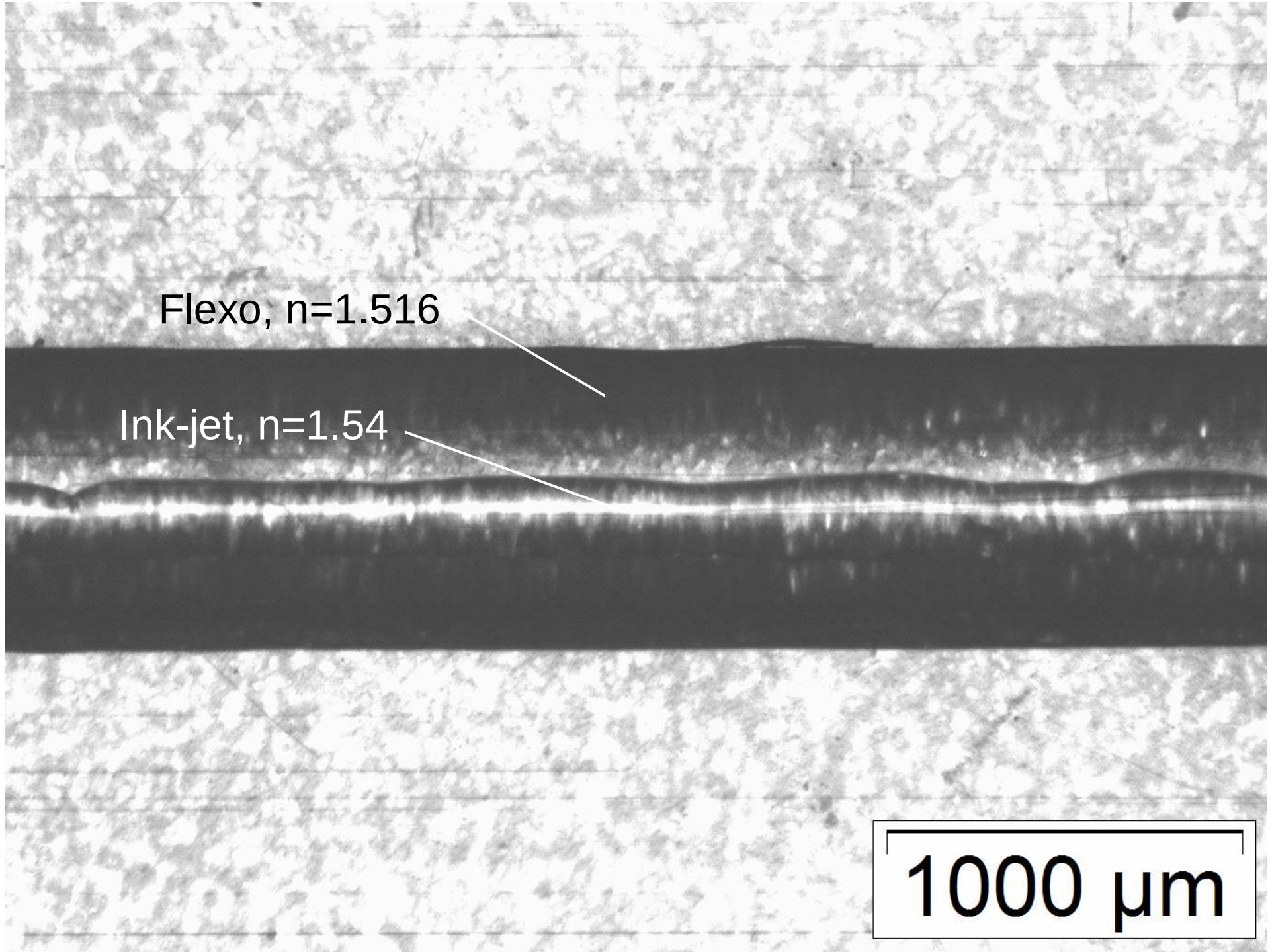
Material:	InkEpo
Pre-treatment:	Plasma for 60s
Substrate T during Printing:	60° C
Printing Cycles:	12 Layers
Post-treatment	60° C for 1h, 20 J at 365 nm

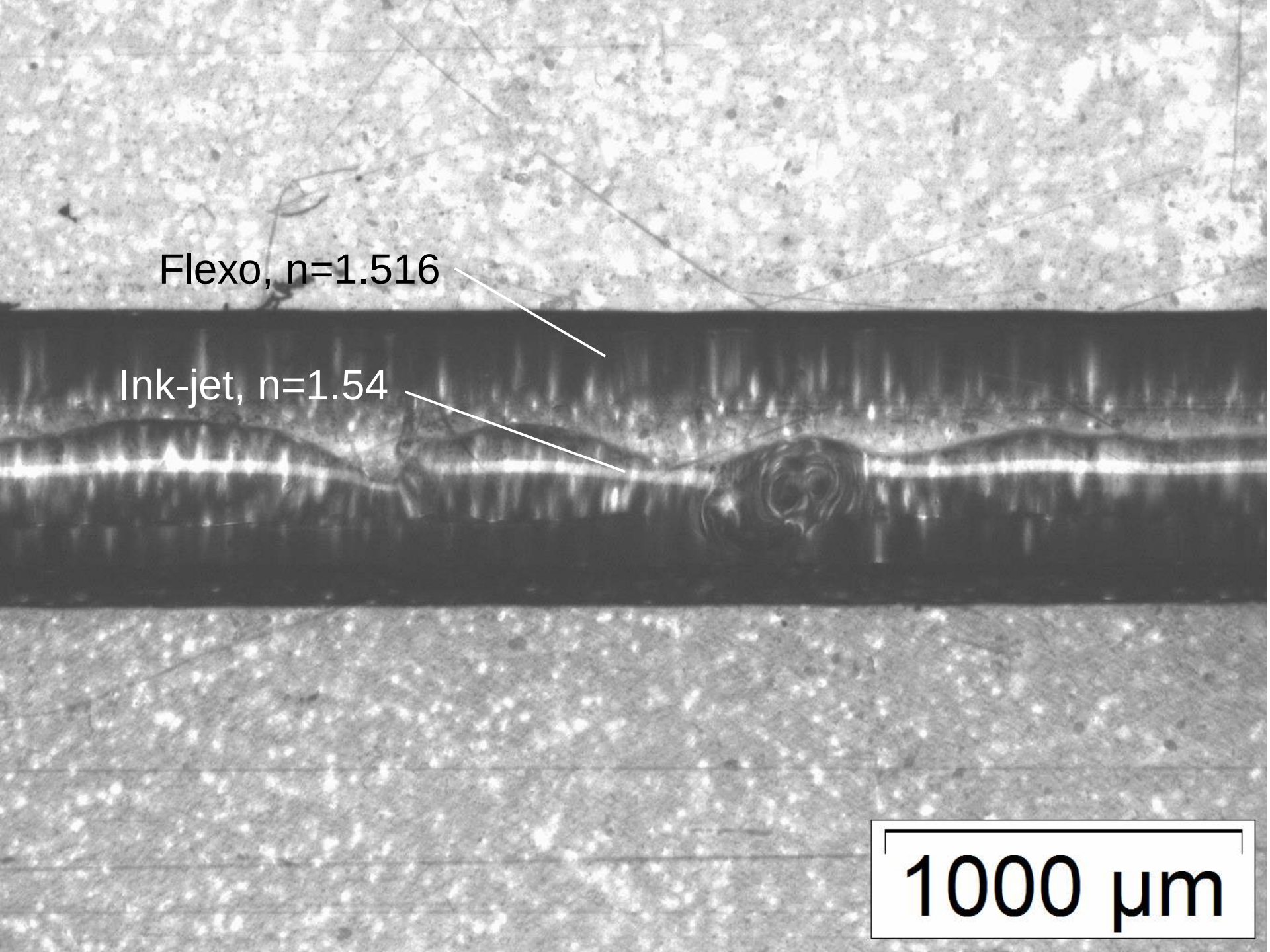

Ink-jet, n=1.54
Flexo, n=1.516
PMMA, n=1.49
500 µm


+10.00000
+5.00000
0.00000
-5.00000
-10.00000
Height (µm)
0.000
0.100
0.200
0.300
Distance (mm)
Width: 200 µm
Height: 10 µm
500 µm

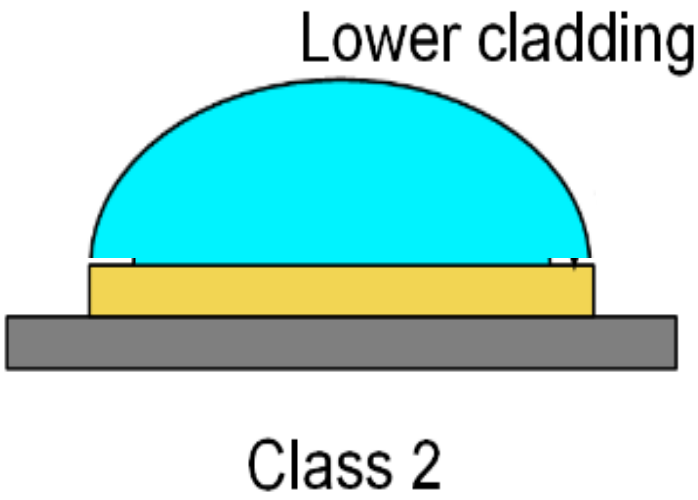
Waveguide?



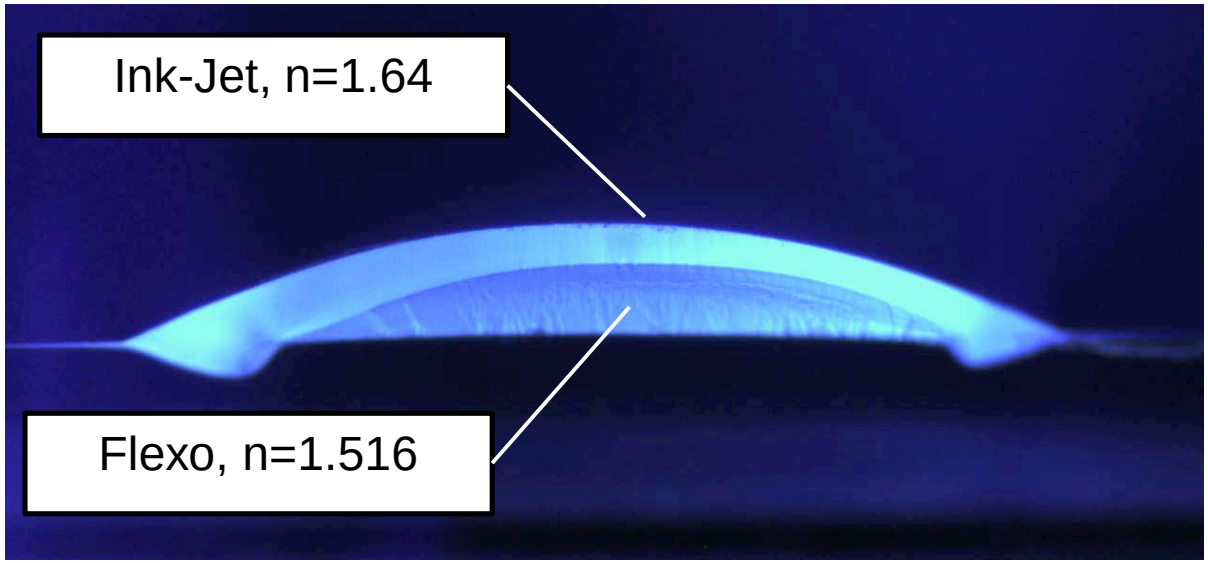

Flexo, n=1.516
Ink-jet, n=1.54
1000 µm


Flexo, n=1.516
Ink-jet, n=1.54
1000 µm

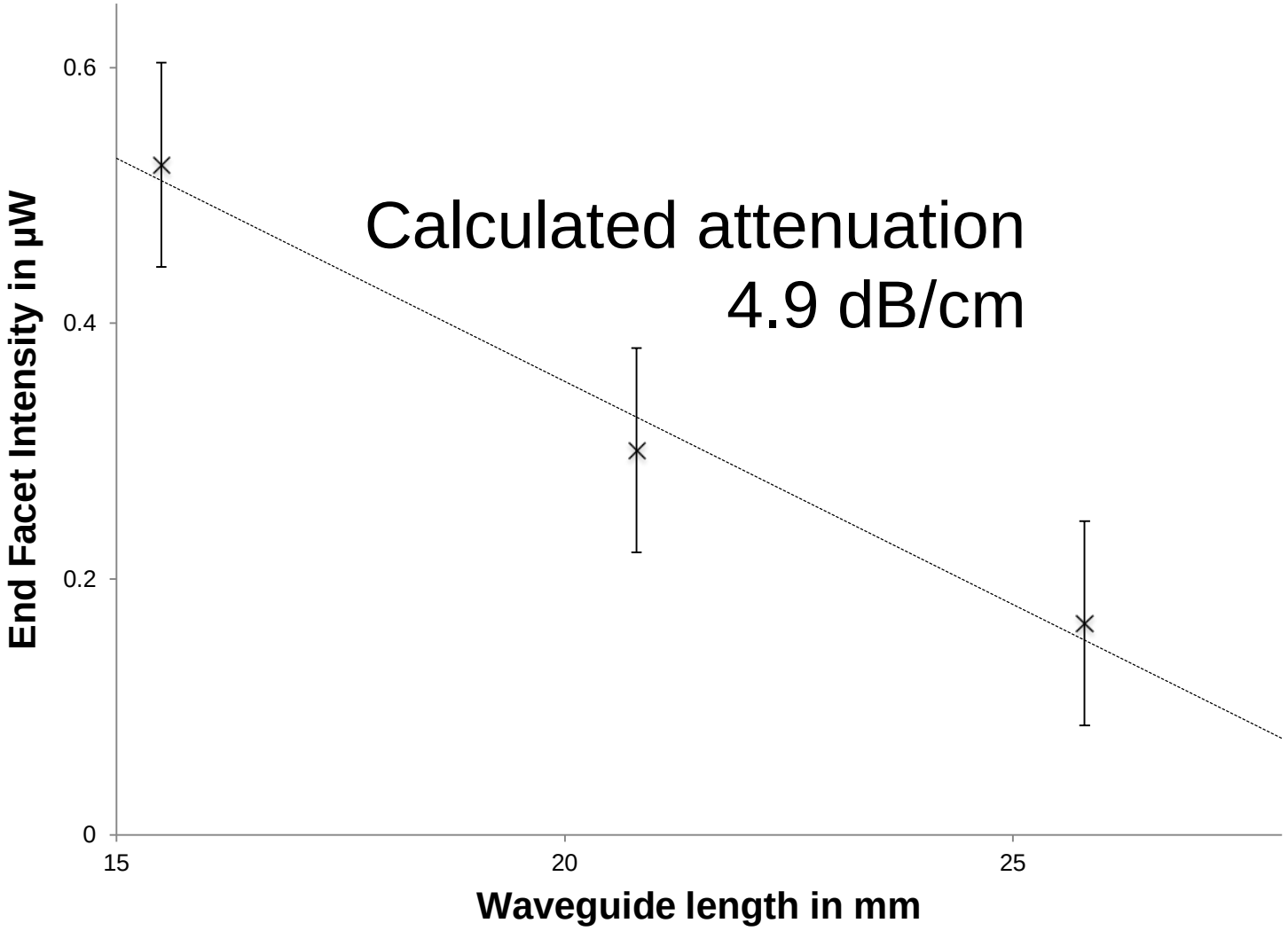
Alternative Method: Edge Pinning!



Material:	UG 164
Pre-treatment	Plasma for 60s
Substrate T during Printing	60° C
Printing Cycles:	24 Layers
Post-treatment:	20 J at 365 nm



Attenuation measurement by cut-back

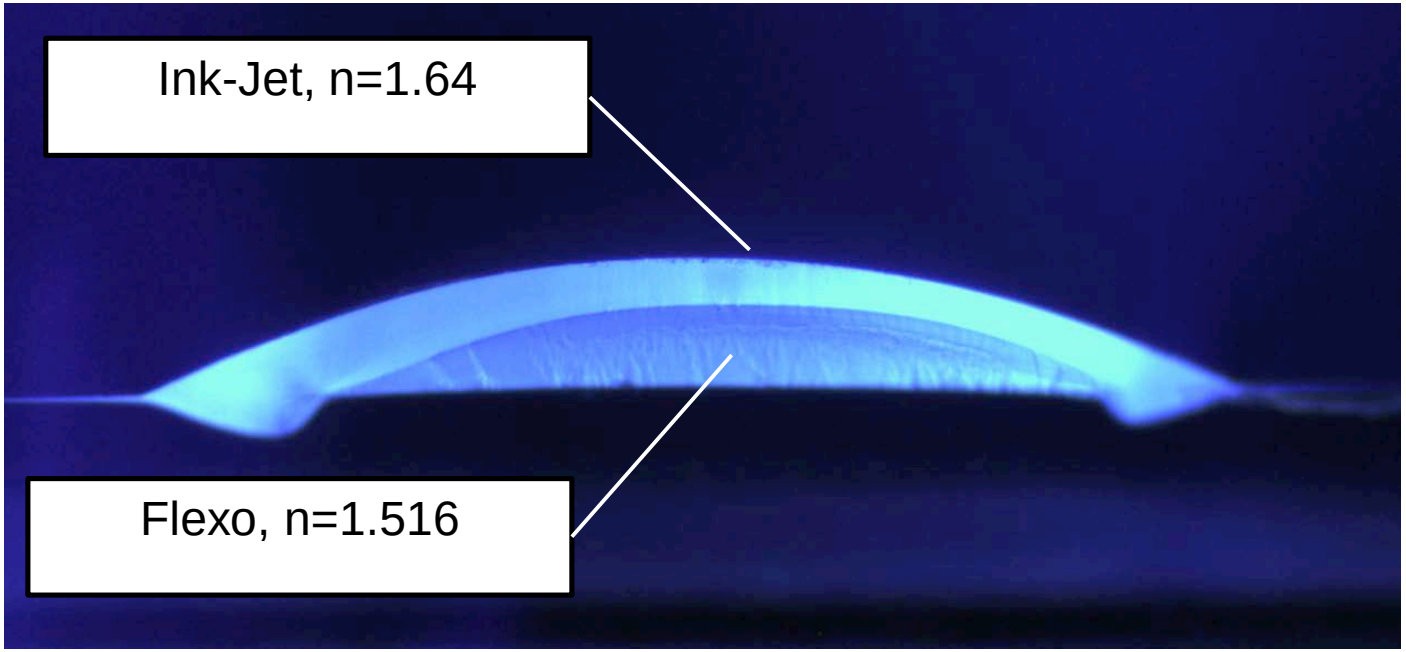


Possible Reasons for Attenuation

High Attenuation, similar as Ink-jet printing

Same diffusion into foil as seen at ink-jet printed waveguides.

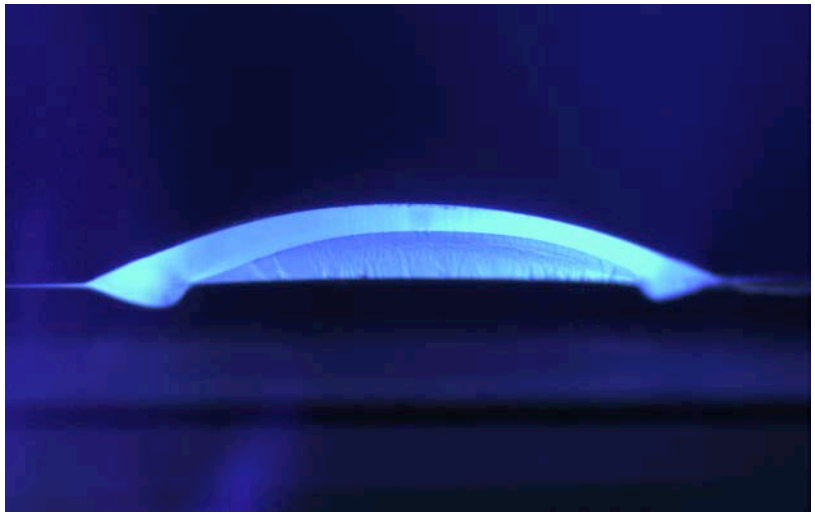
Explanation for high attenuation

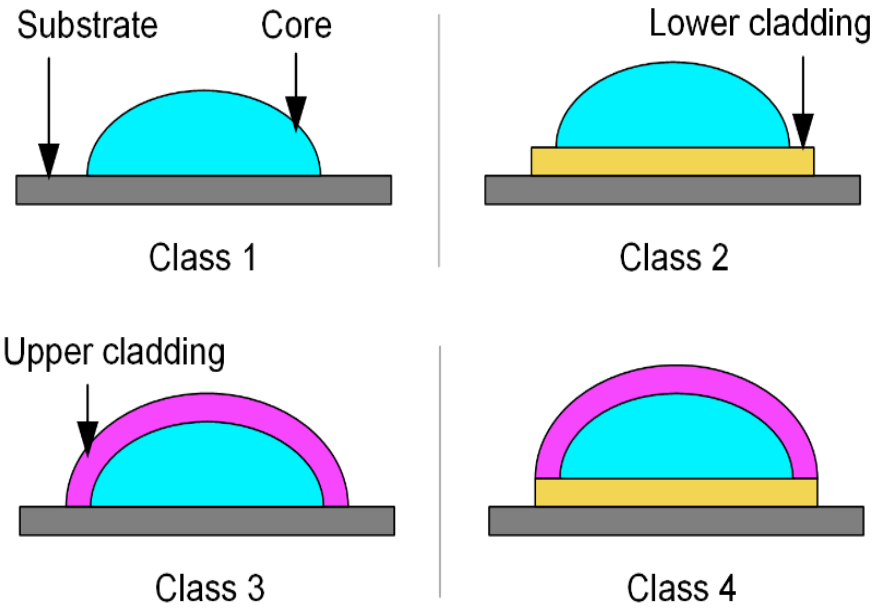


Next Steps

Combination of Flexo- and Inkjet

Class 2? Or Class 3?





Next Step
Class 3 Waveguide with lower refractive index

Possible waveguide concepts by combining the core and cladding layers (Wolfer, ITA, 2014).

Research Question

Can optical waveguides on foils be fabricated by printing techniques?

Investigated Techniques:

Flexographic printing **Yes!**

Ink-jet printing (but Ink-jet has high attenuation)

Is a combination of both techniques feasible?

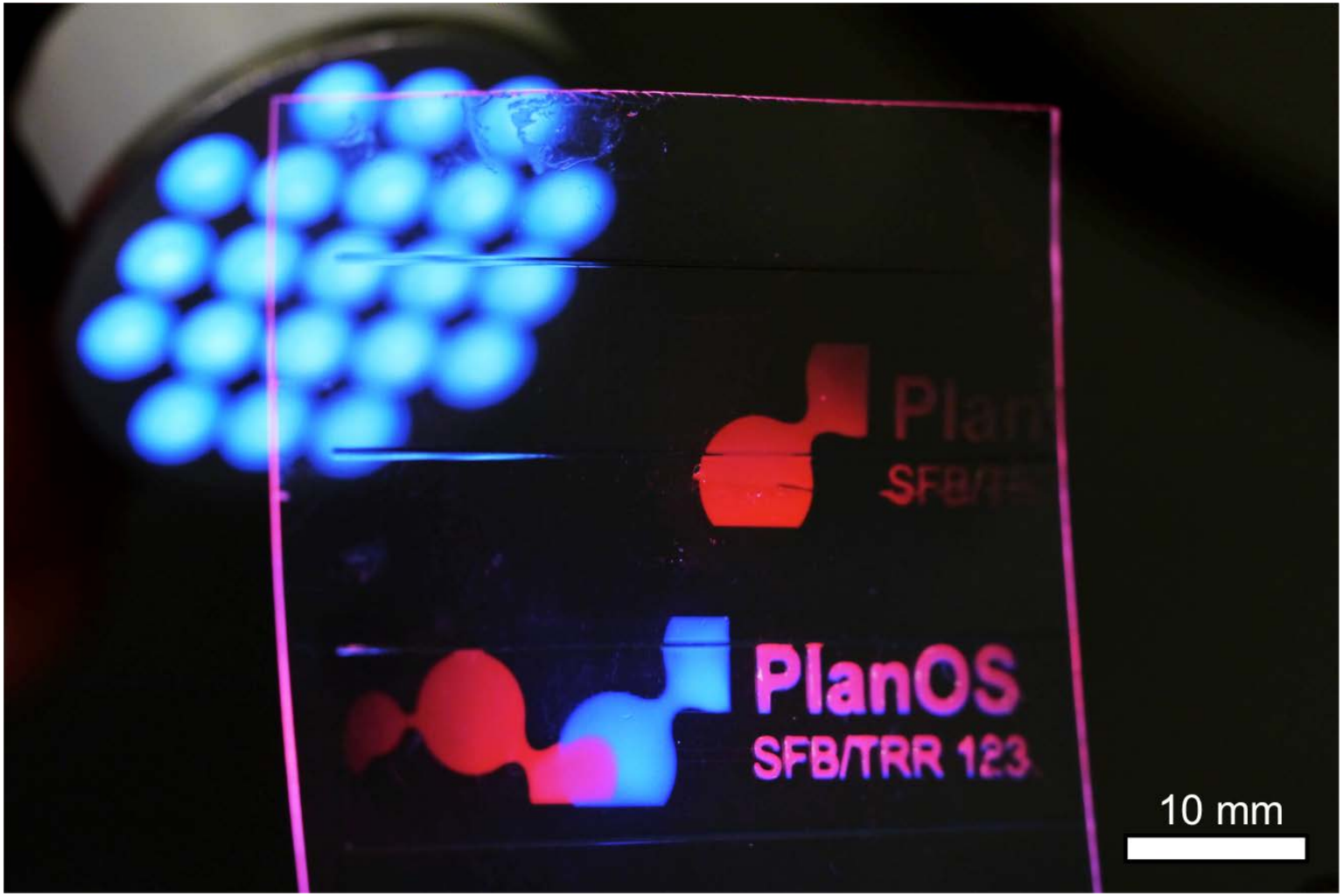
Not yet

Ink-jet printing – Available Inks

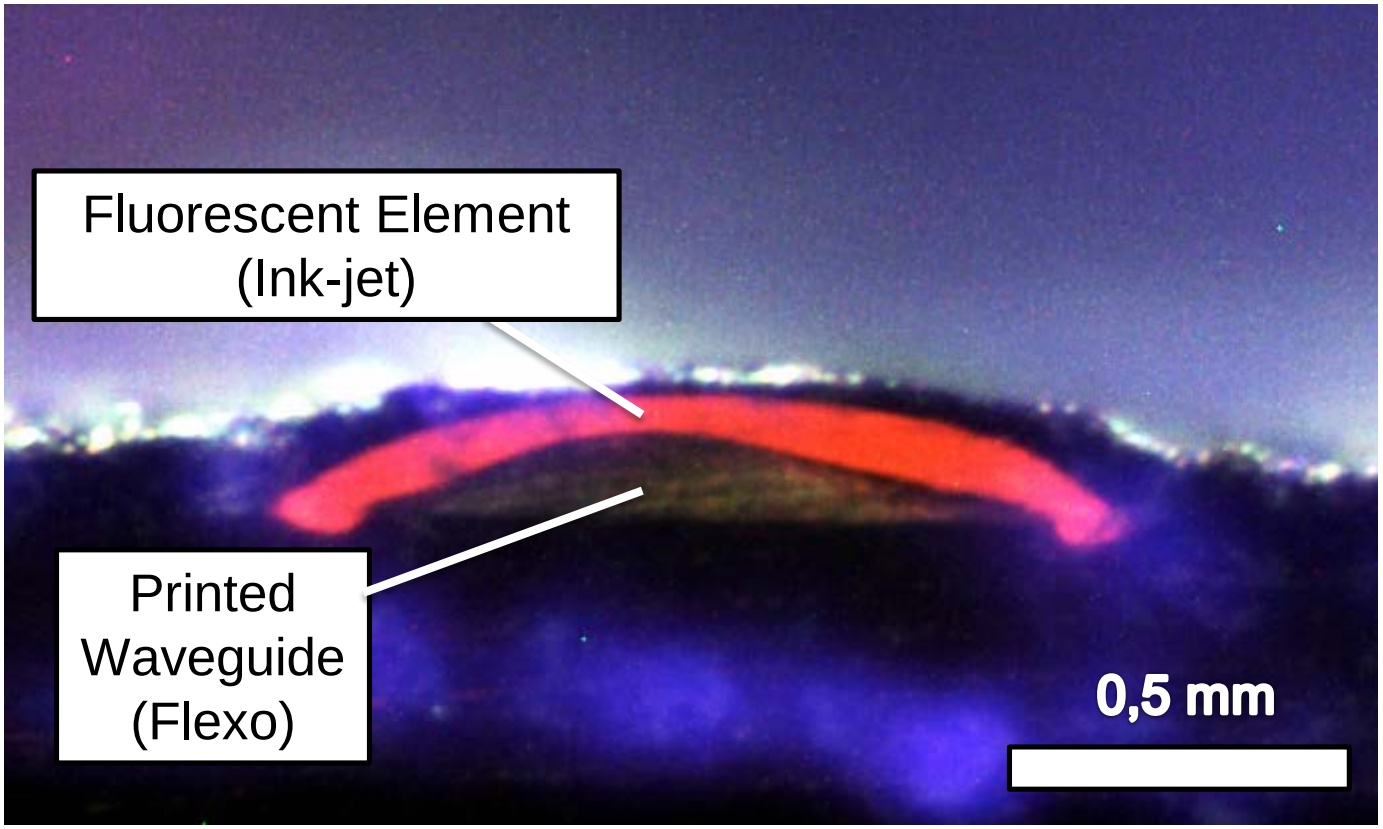
Ink Name	Manufacturer	Solvent	Purpose	Comments
InkEpo	Microresist Technology	GBL (Evaporates)	Waveguides	Volatile and aggressive solvent
InkOrmo				
UGS70E	IMTEK, Prof Hanemann, Uwe Gleissner	EGDMA (Polymerizes)		Scattering dots after polymerisation
UG164				High refractive index
Europium-Ink			Light Emission	405 nm → 612 nm
Antracene-Ink				365 nm → 430 nm

Printing of fluorescent elements

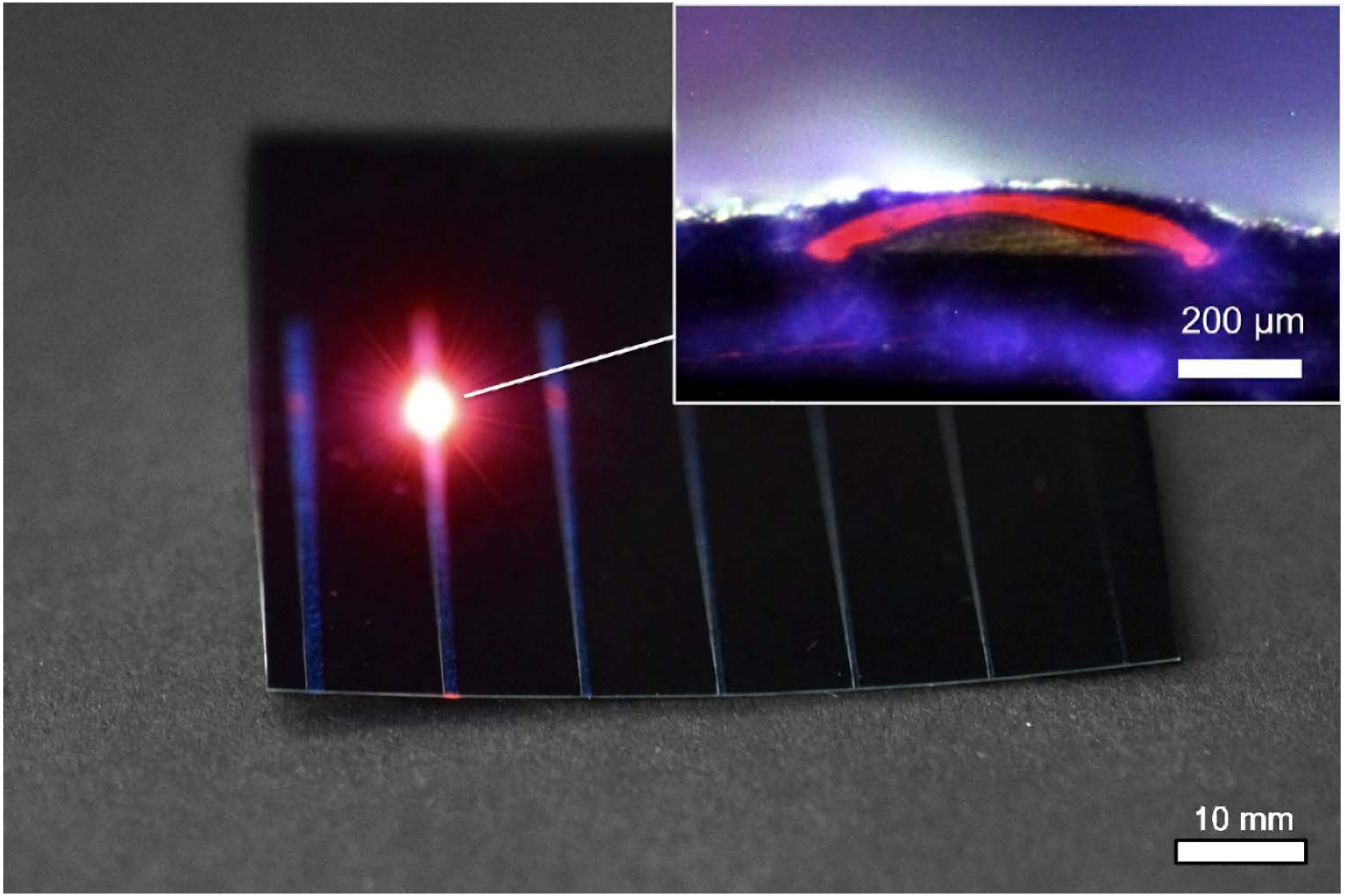
Fluorescence



Fluorescence



Fluorescence



Thank you for your attention

Thanks to
for funding

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Ways to improve Ink-jet attenuation

Prevent ink mixing with substrate

- Polymerize between layers
- Guide Ink by conditioning lines or grooves in the substrate
- Switch to chemically more stable substrate like PET