

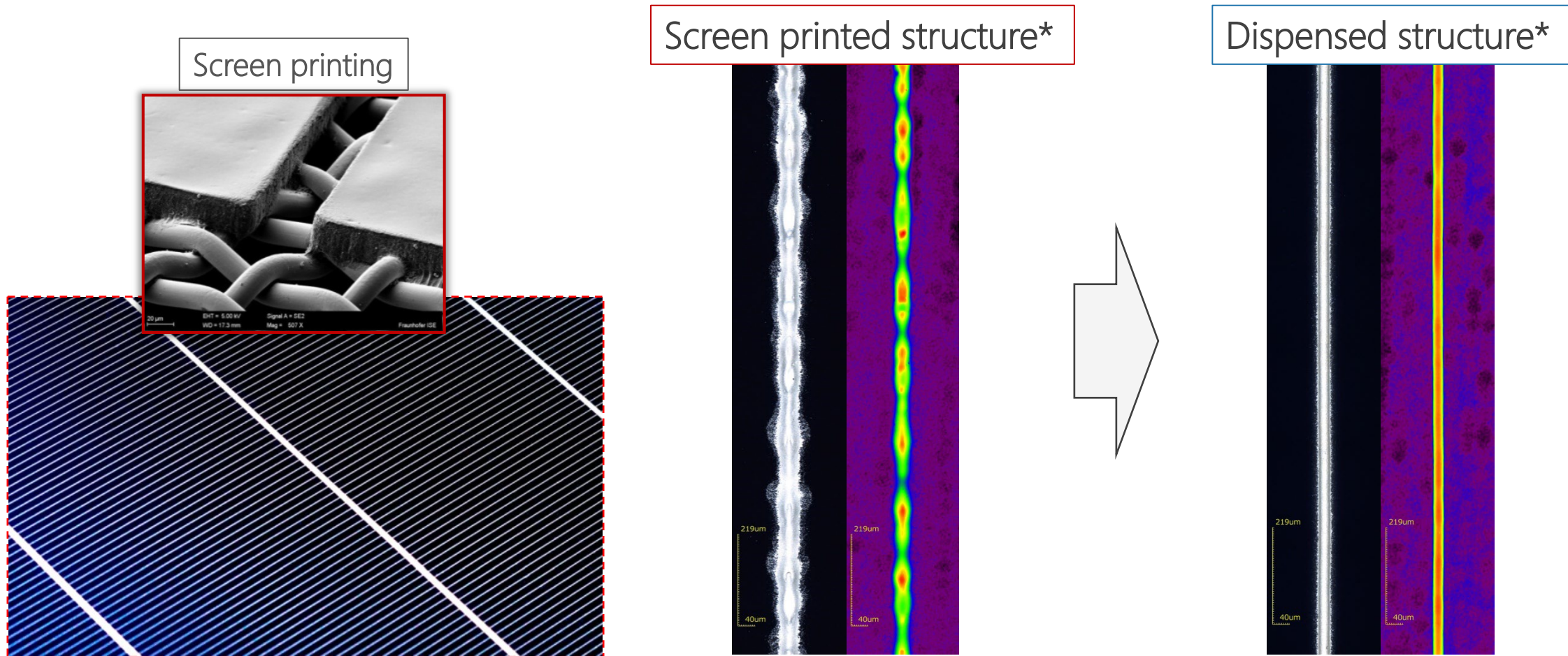
HIGHLINE

T E C H N O L O G Y

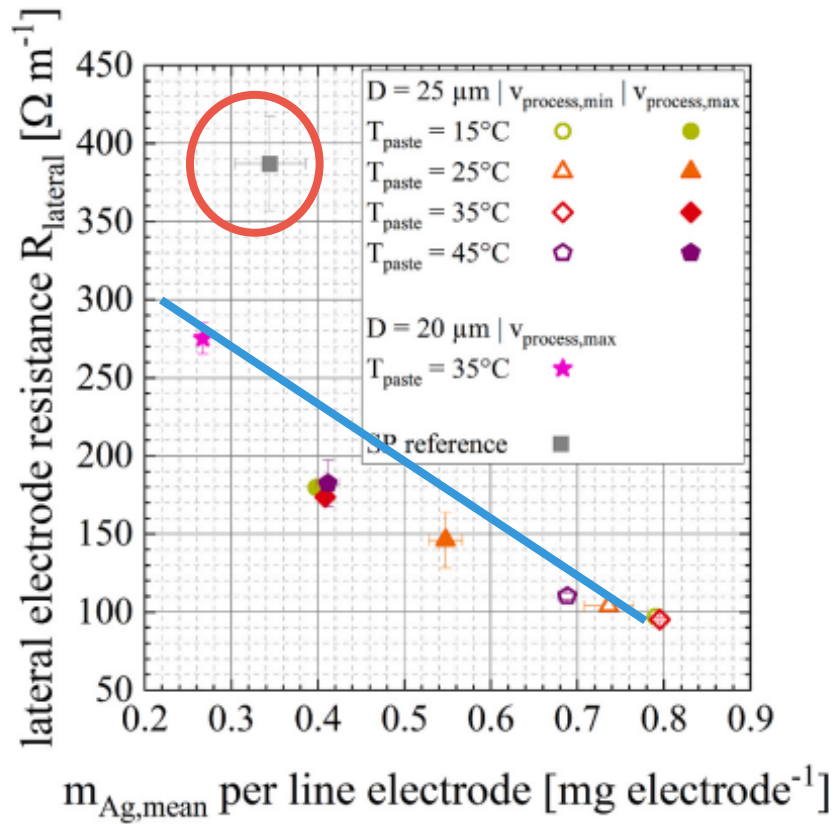
OPTIMIZING SOLAR CELL METALLIZATION BY PARALLEL DISPENSING

M. Pospischil, S. Molinero, F. Heitmann, M. Palme, N. Heuser,
M. Weil, O. Zuaiter, E. Milione, M. Kuchler and M. Breitenbücher

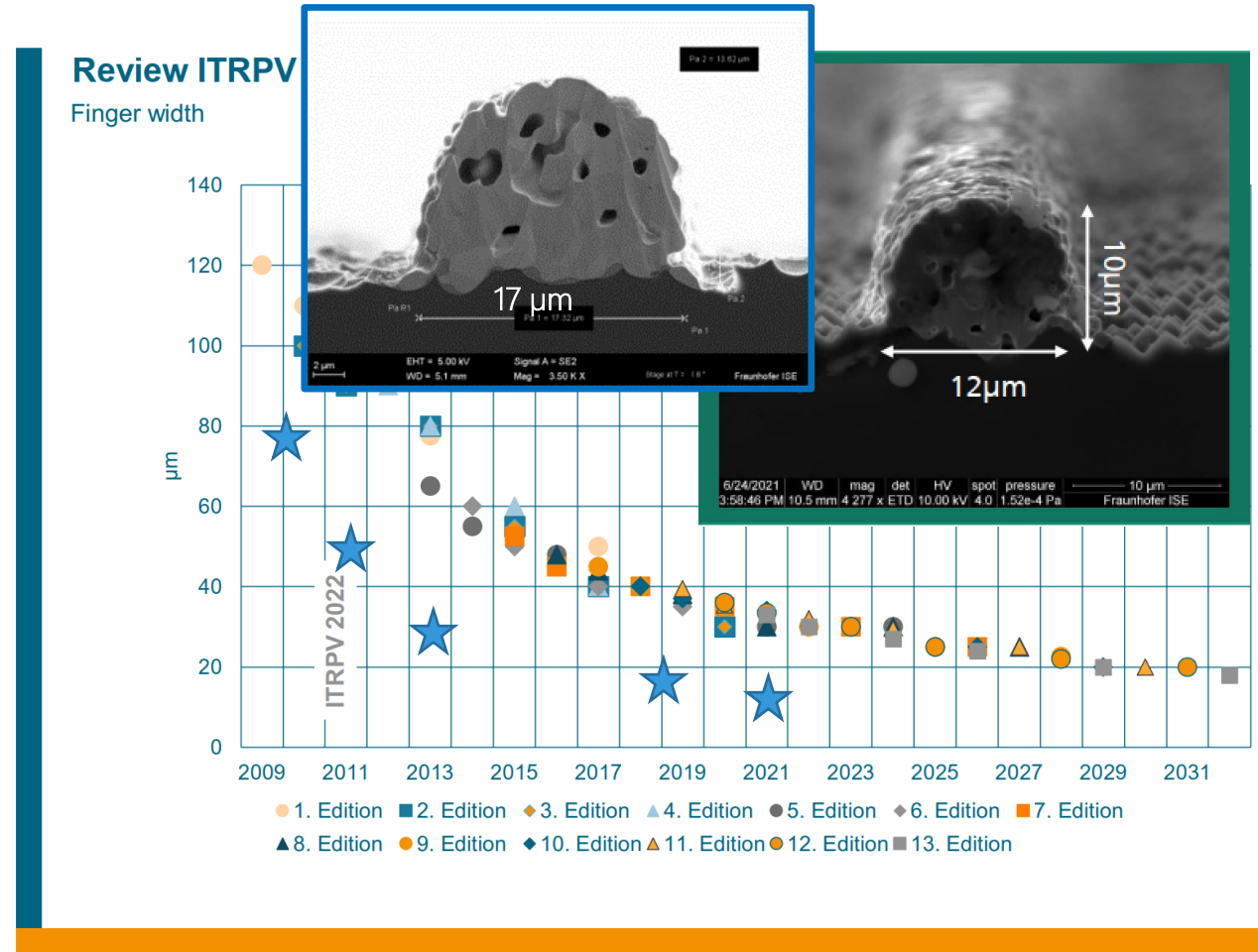
The Idea: Using our Resources more Efficiently

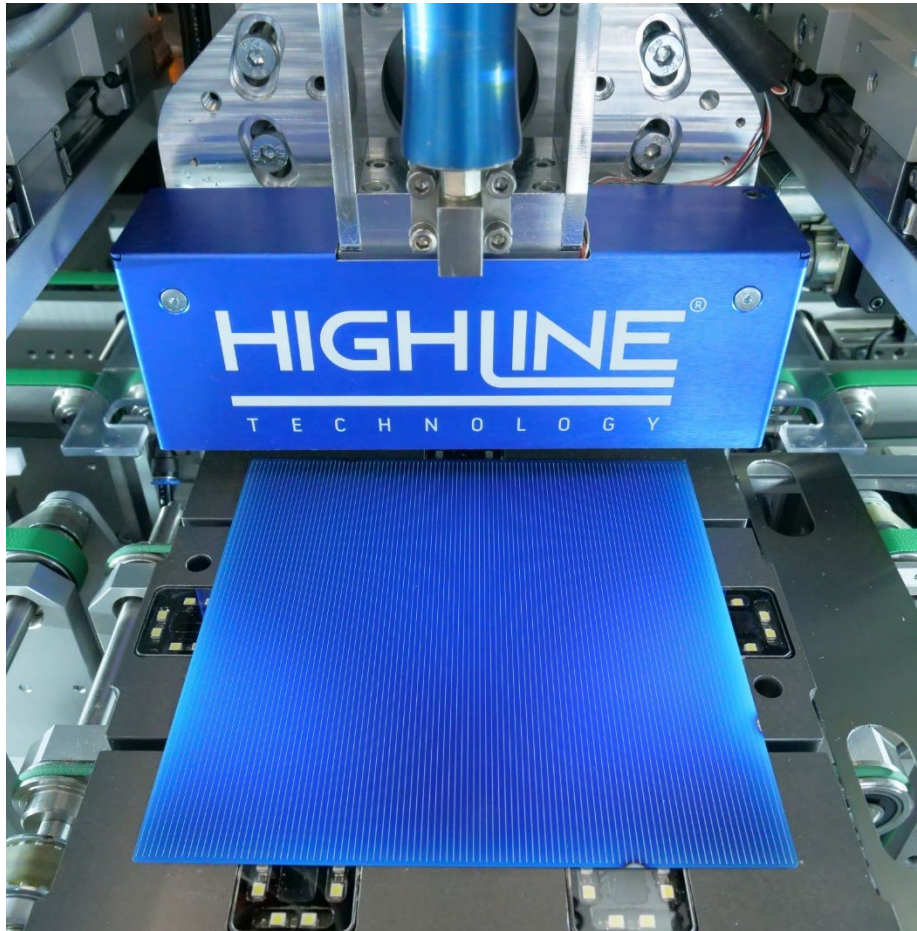
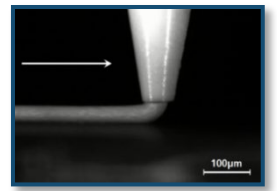


Reduction of Fingerwidth on Solar cells, ITRPV



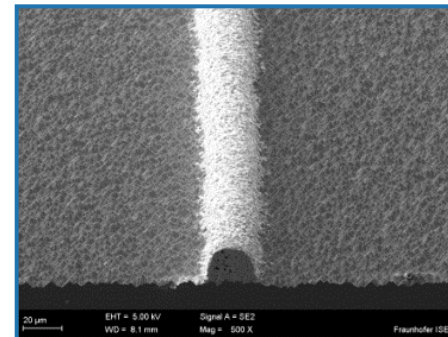
- o Dispensing allows for up to 42% effective silver reduction on SHJ cells



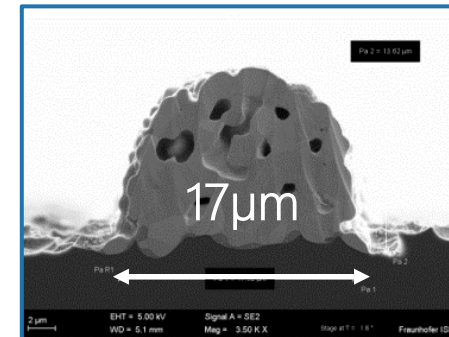


HighLine Dispensing System

Homogeneous extrusion of metallization pastes through parallel arranged nozzles



Homogeneous Geometries
(up to 25% silver savings)



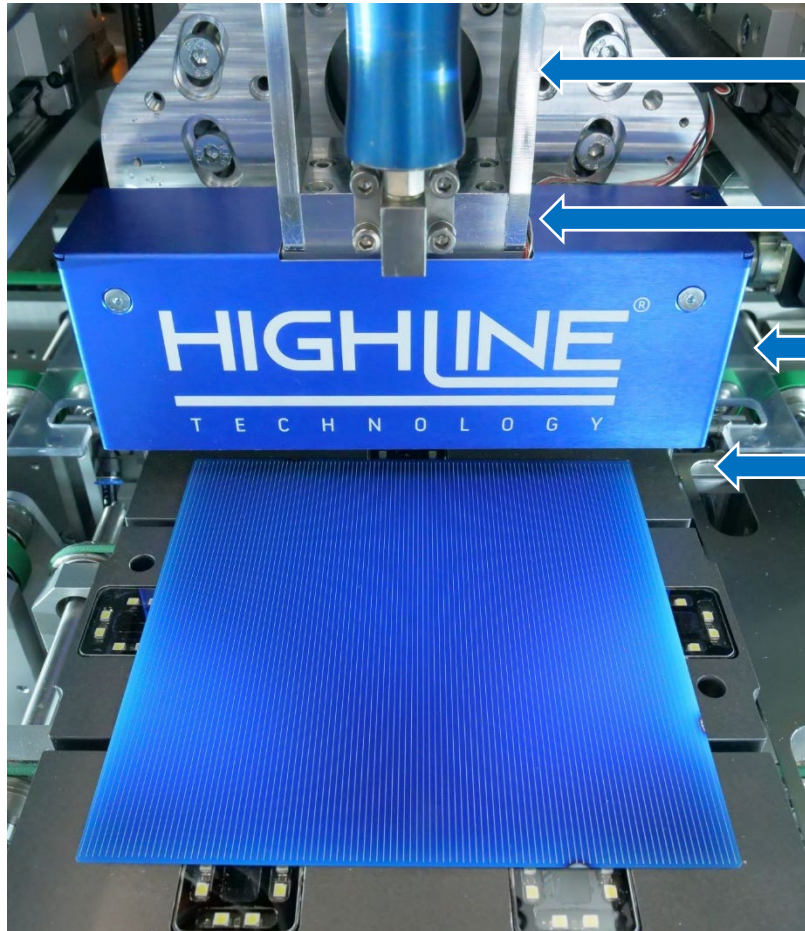
Low width / High Aspect Ratios
(1 % rel. η increase)



High Throughput Process
(≥ 4000 cph)

→ Significant savings in CoO and increase in η

HighLine Dispensing System

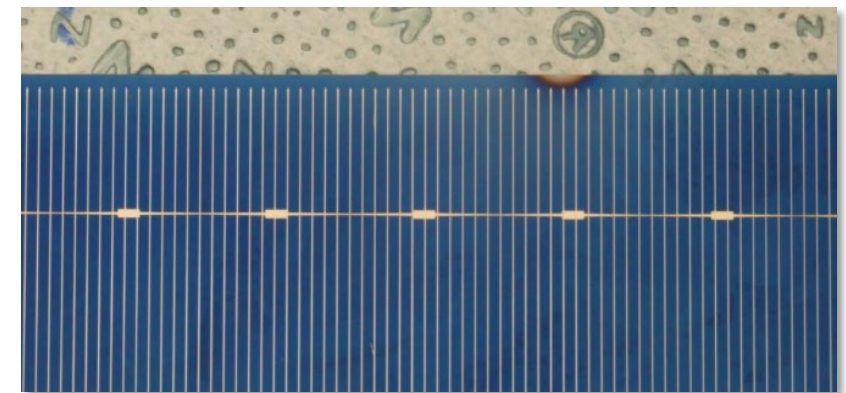
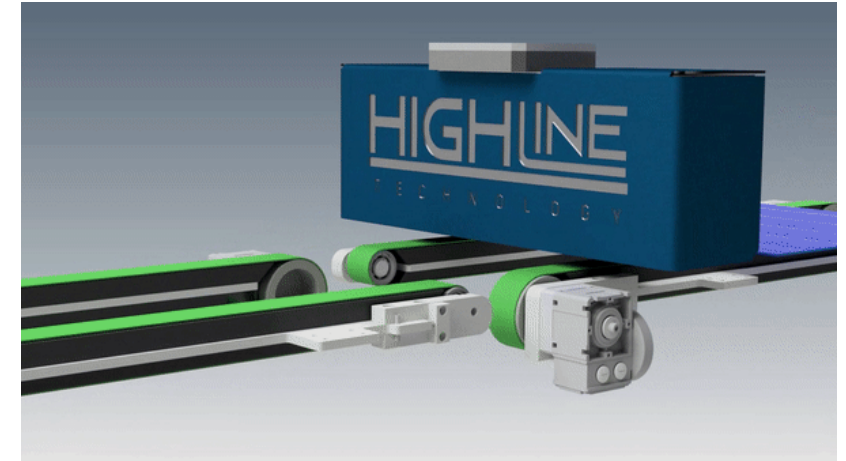
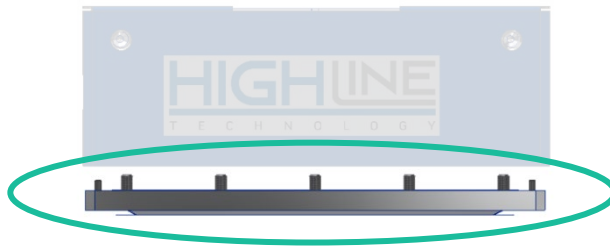


Paste conveyor system:
From 960cc syringe or
conventional pots

Central Paste Inflow with
Valve technology

CFD optimized fluid
geometry

Exchangeable Nozzle-KIT
(Consumable)



Process

- Paste Development
- Application HJT

Software

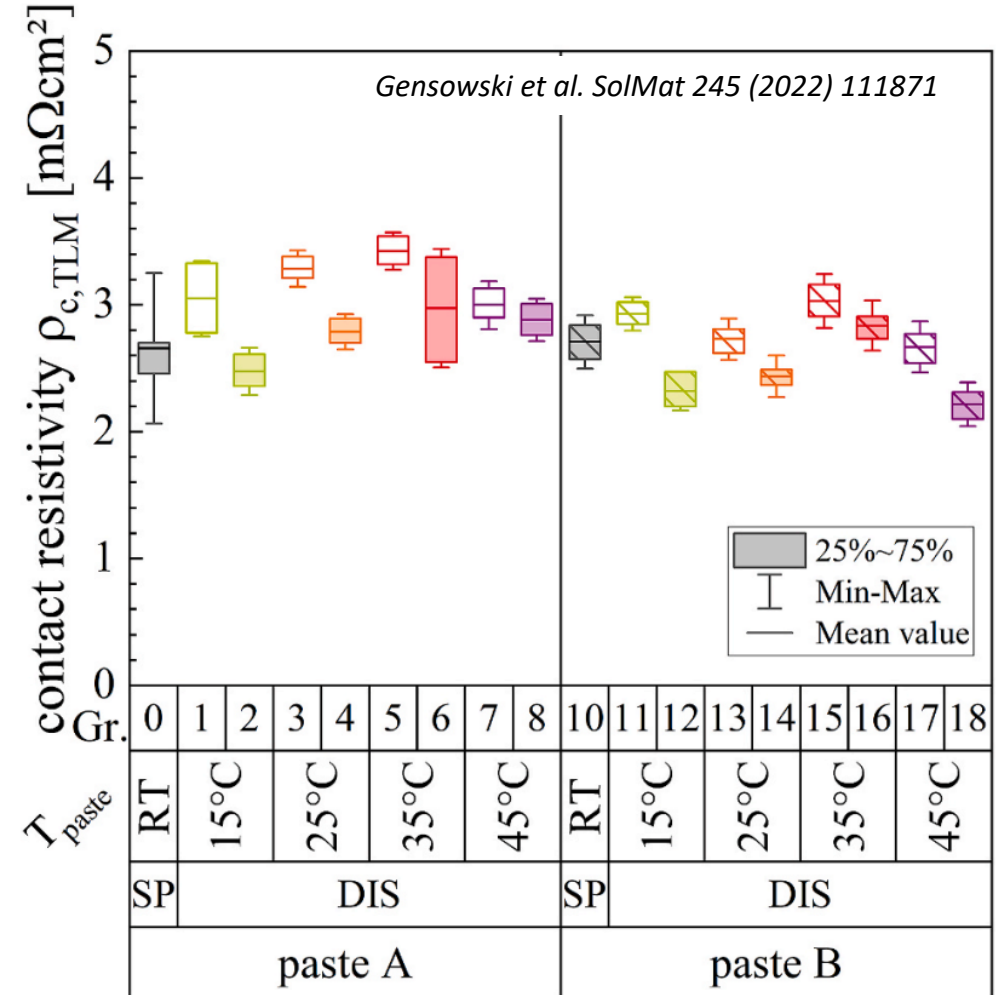
- Machine Control (PLC)
- Process Control

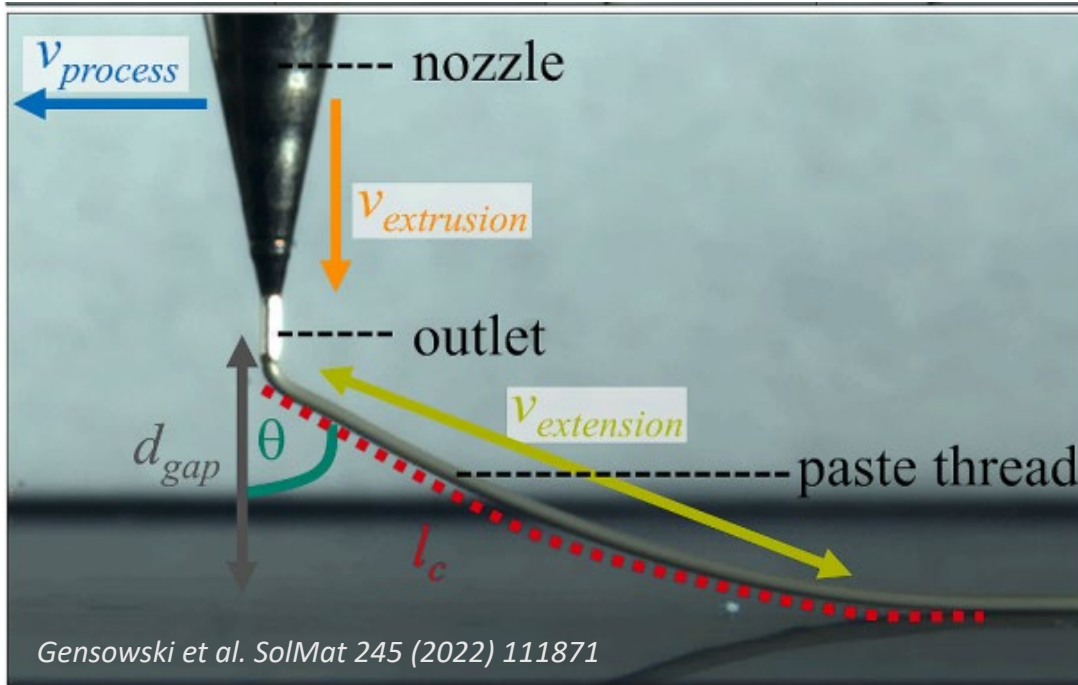
Hardware

- System Development
- Durability

Challenge: Ag Reduction vs. Contact Resistivity

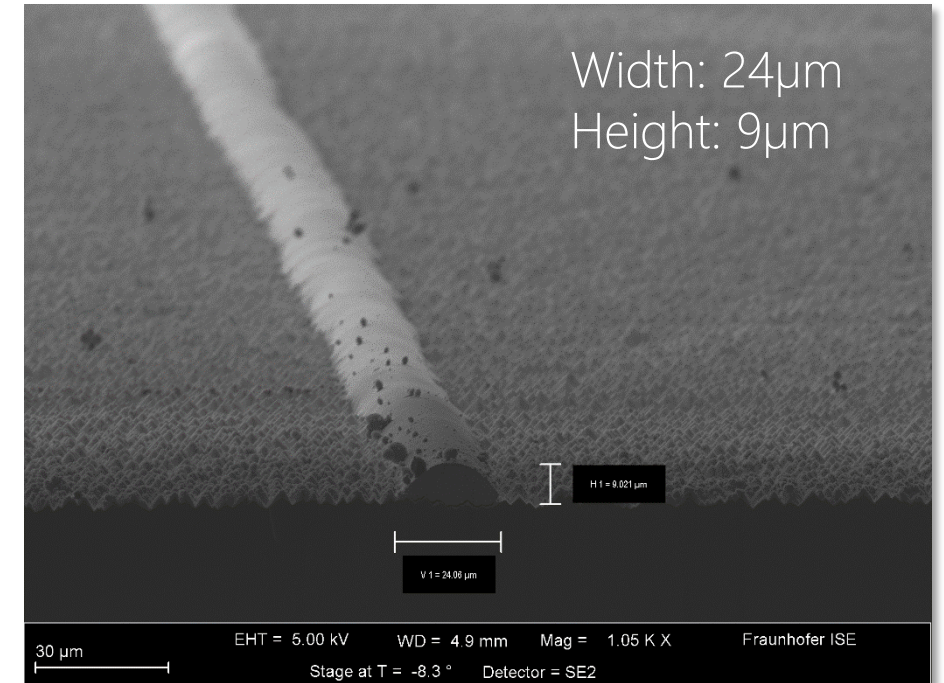
- Before changing the material
→ How small can we get?
- Values of around 3 mOhmcm² are too high for fine line printing
→ Can we compete here with pastes?
- Flake like particles are problematic for dispensing with small nozzles
→ Are there other solutions?





Solution 1:

Impact of tackiness: **Stretching** the paste thread allows smaller line width at larger nozzle diameters



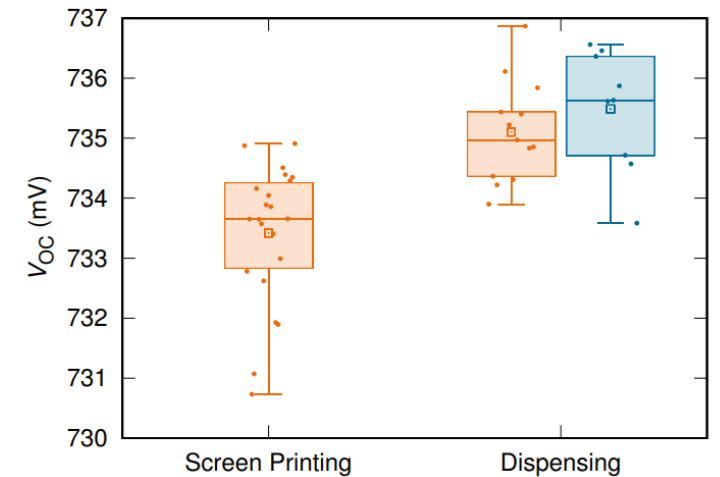
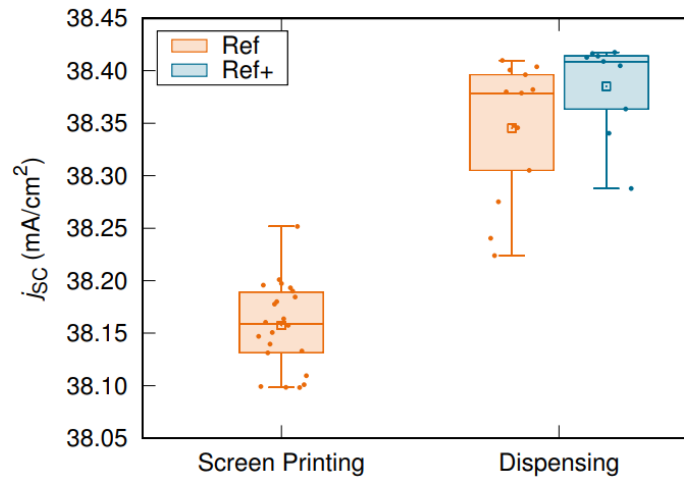
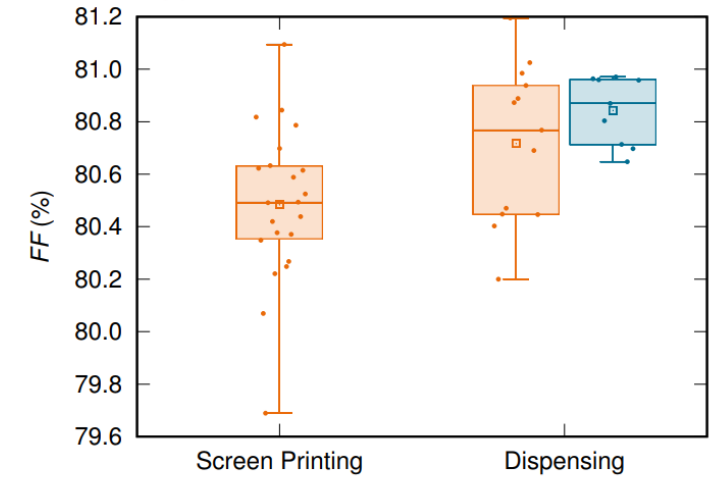
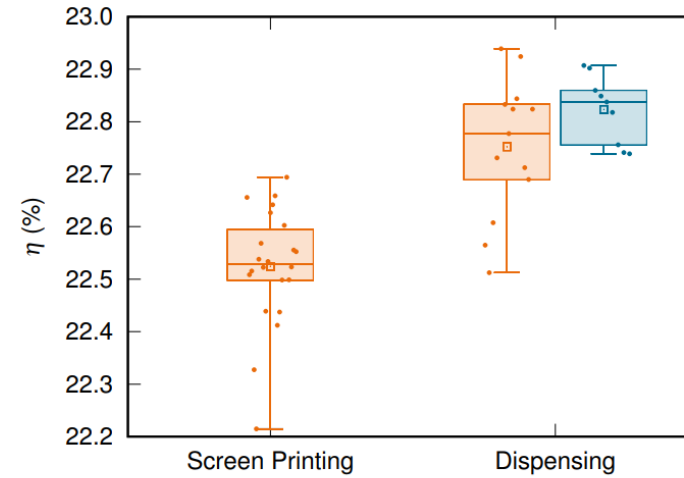
Solution 2:

Nano-Pastes allow for excellent conductivity and contacting behaviour (< 1 mOhmcm²!)

Latest IV Results, high AR and low AR paste

- Solar Cell Samplings (all precursor), no BB printed
- 80 contact lines for all ref. Groups

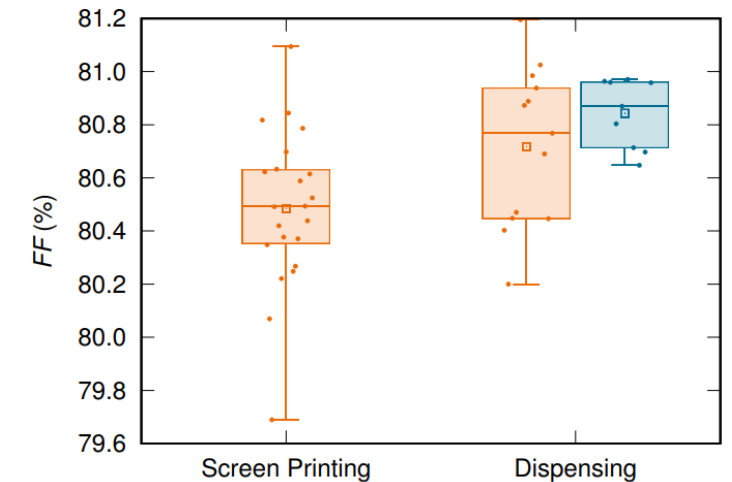
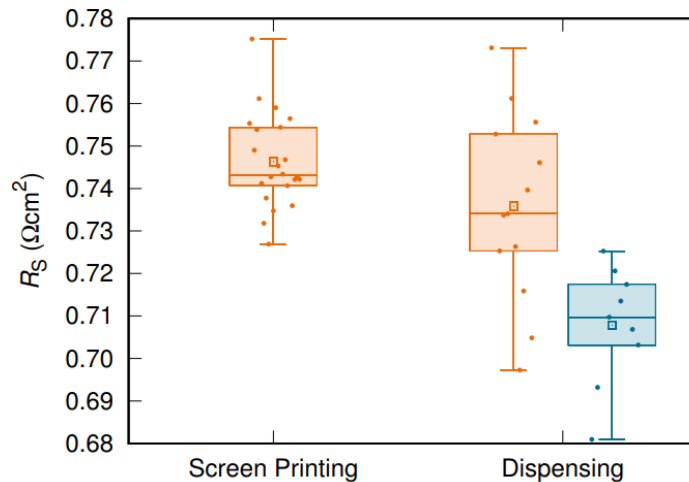
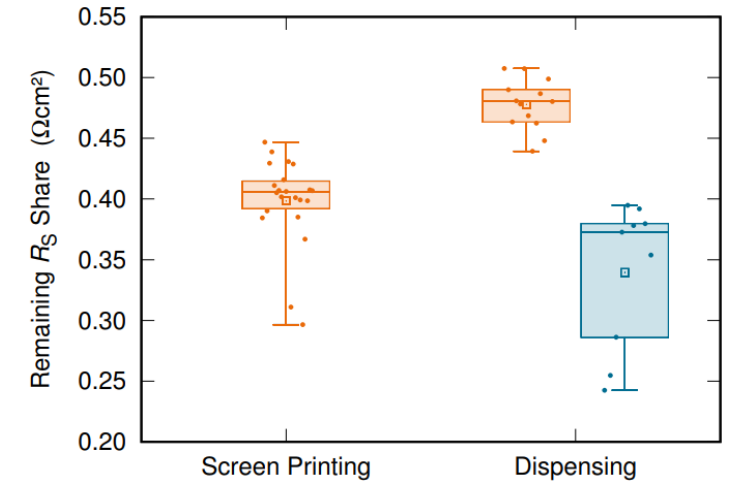
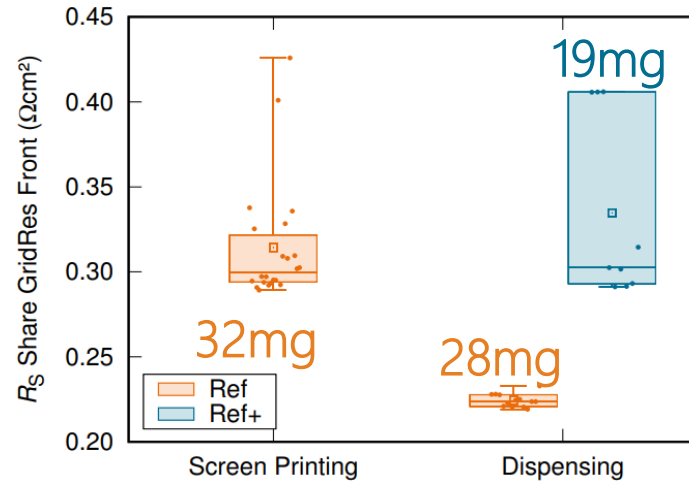
→ Substantial increase of η for all dispensed groups



Series Resistance Analysis

- Drastic reduction of paste laydown
- > 30% via stretching
- Substantial reduction of R_s due to improved homogeneity and contacting behaviour

→ Dispensing releases its full potential, once pastes are adapted as well!



Process

- Paste Development
- Application HJT

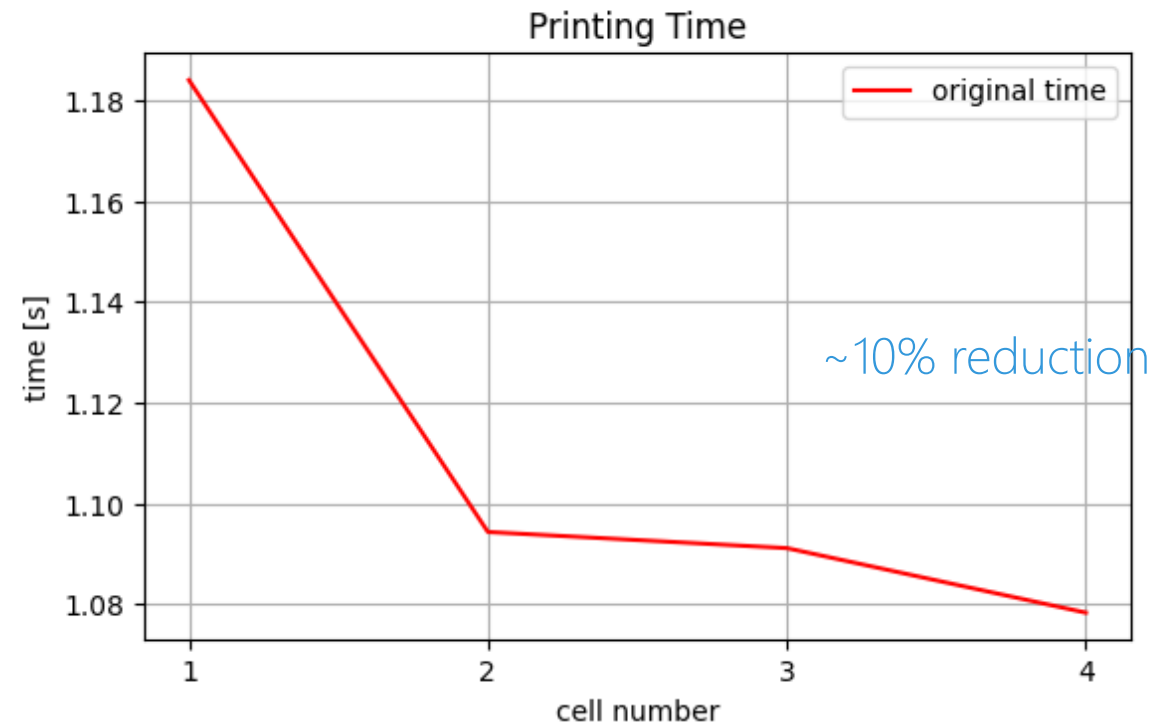
Software

- Machine Control (PLC)
- Process Control

Hardware

- System Development
- Durability

- Machine Control:
accurate height control is key for high yields
- Process Control:
 - Cell imaging and processing enables insitu optimization of printing parameters
 - All parallel dispensed lines can be seen as average result of process parameters

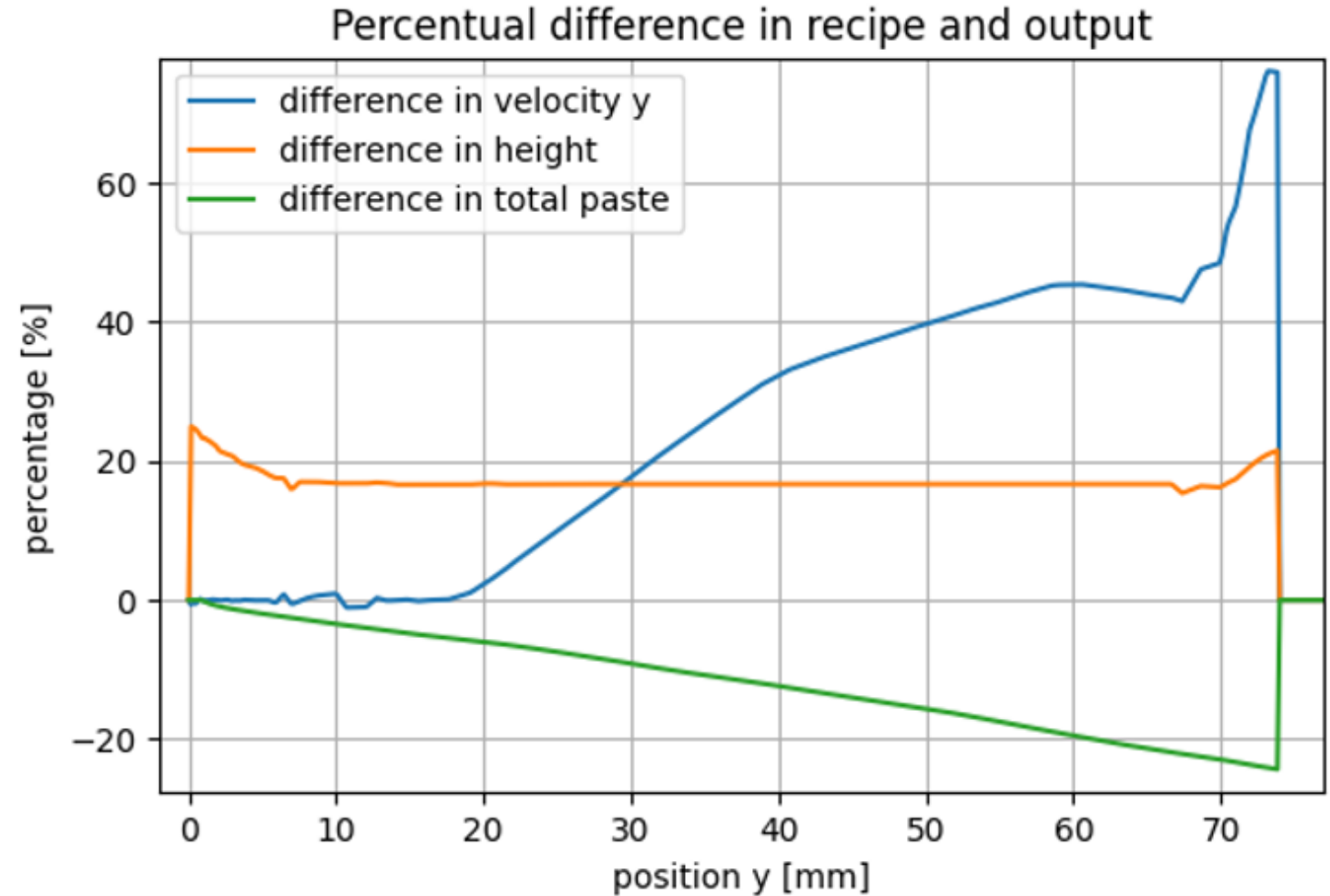


Example: Impact of Automated Optimization

Key results after four consecutive cells:

Parameter	Change
Paste Laydown	-20%
Process Time	-10%

→ Goal: fully automated machine



Process

- Paste Development
- Application HJT

Software

- Machine Control (PLC)
- Process Control

Hardware

- System Development
- Durability

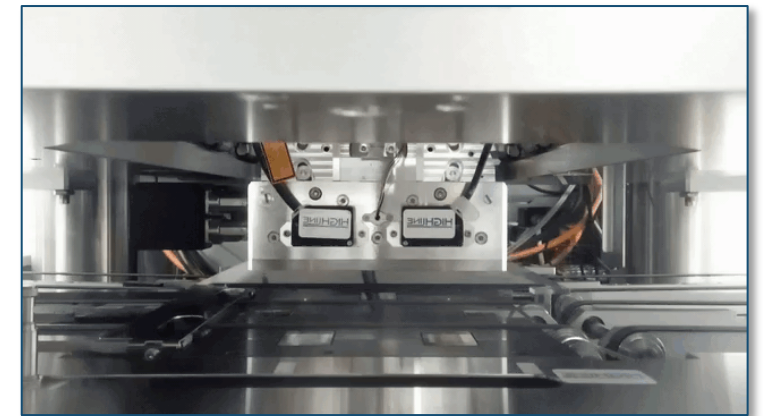
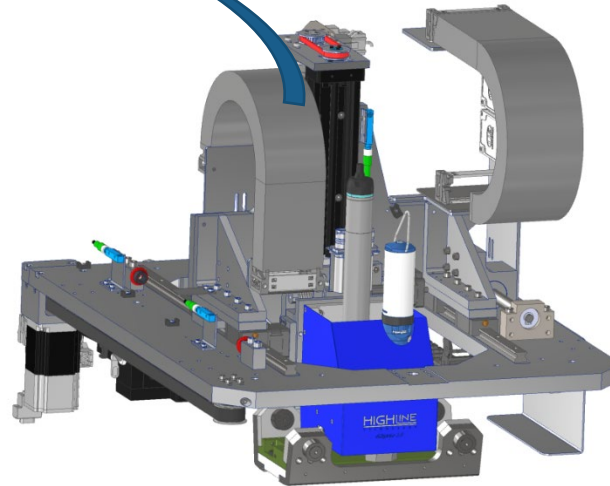
HighLine Dispensing System – Integration KIT

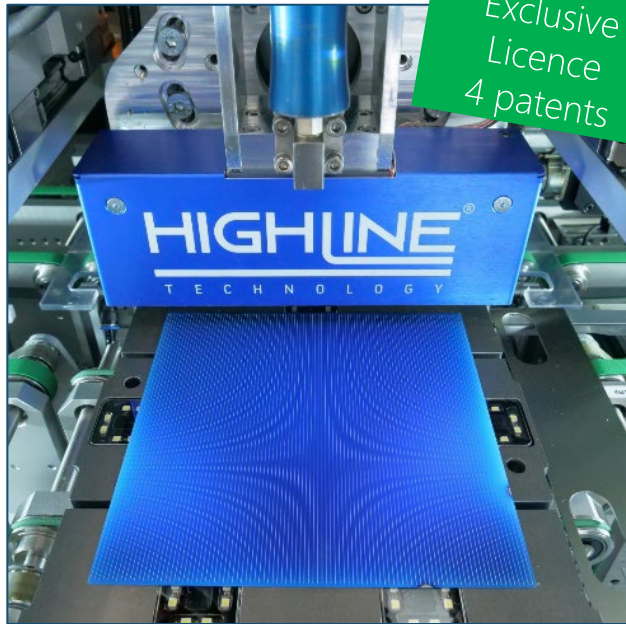
HighLine's Cuckoo (Integration-KIT)

- Collaboration with equipment manufacturer (→ 3-4 months)
- Upgrade of existing screen printing lanes/platforms (new and retro-fit)



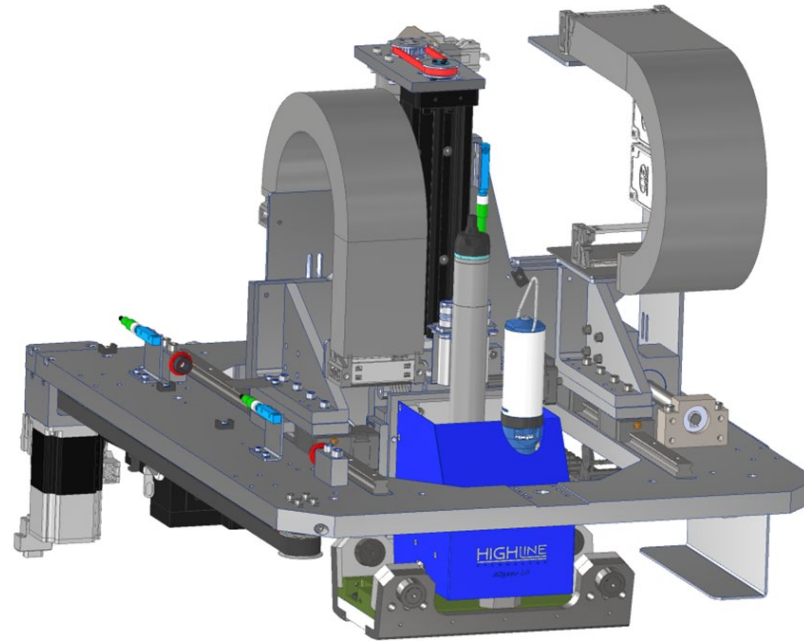
Industrial screen printer





Dispensing Print-heads

- High printing speed
- Ultra fine nozzles (<math><25\mu\text{m}</math>)
- Contactless process



The Upgrade KIT (Cuckoo)

- Upgrade of existing screen-printing platforms
- Integration in new production lines
- Prototype in operation in PVTEC, Freiburg

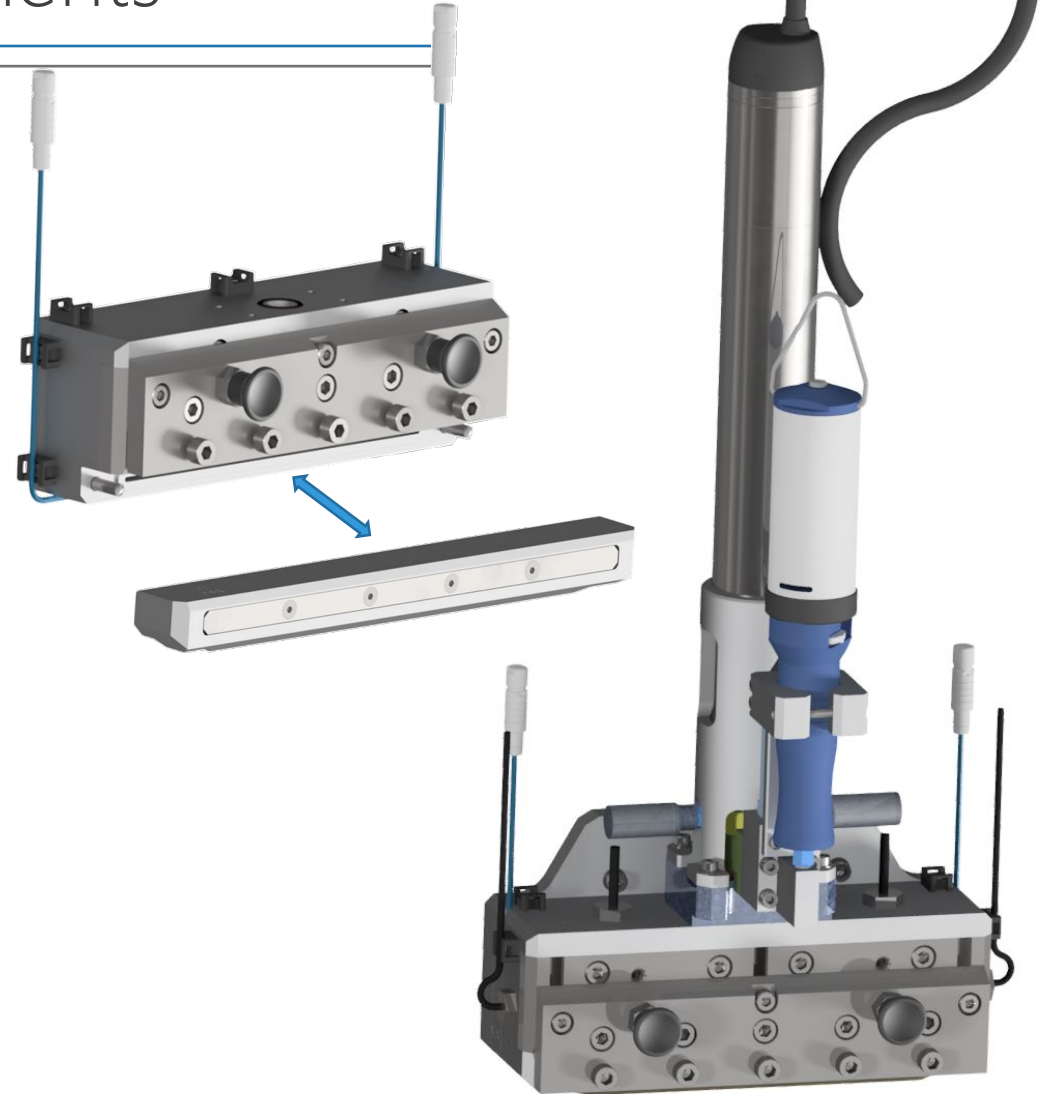
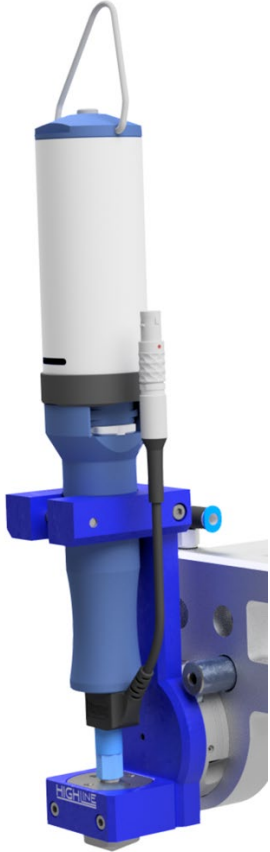


The Nozzle-KIT Consumable

- Integration of ultra-fine nozzles (10 - 25 μm)
- Flexible regarding design
- Quickly exchangeable for high uptime

Hardware Enhancements

- **Single Nozzle**
 - For flexible paste and process testing
- **Scaleable Parallel Print Heads**
 - Improved paste distribution
 - Now with horizontal mounting
 - Quick exchange of nozzle kit

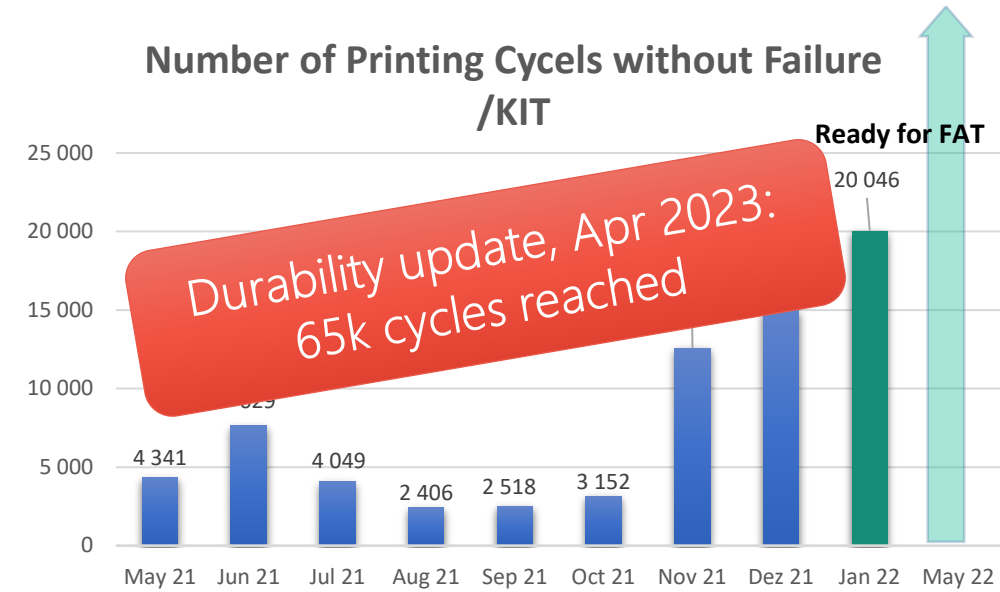


Durability of Nozzle KIT

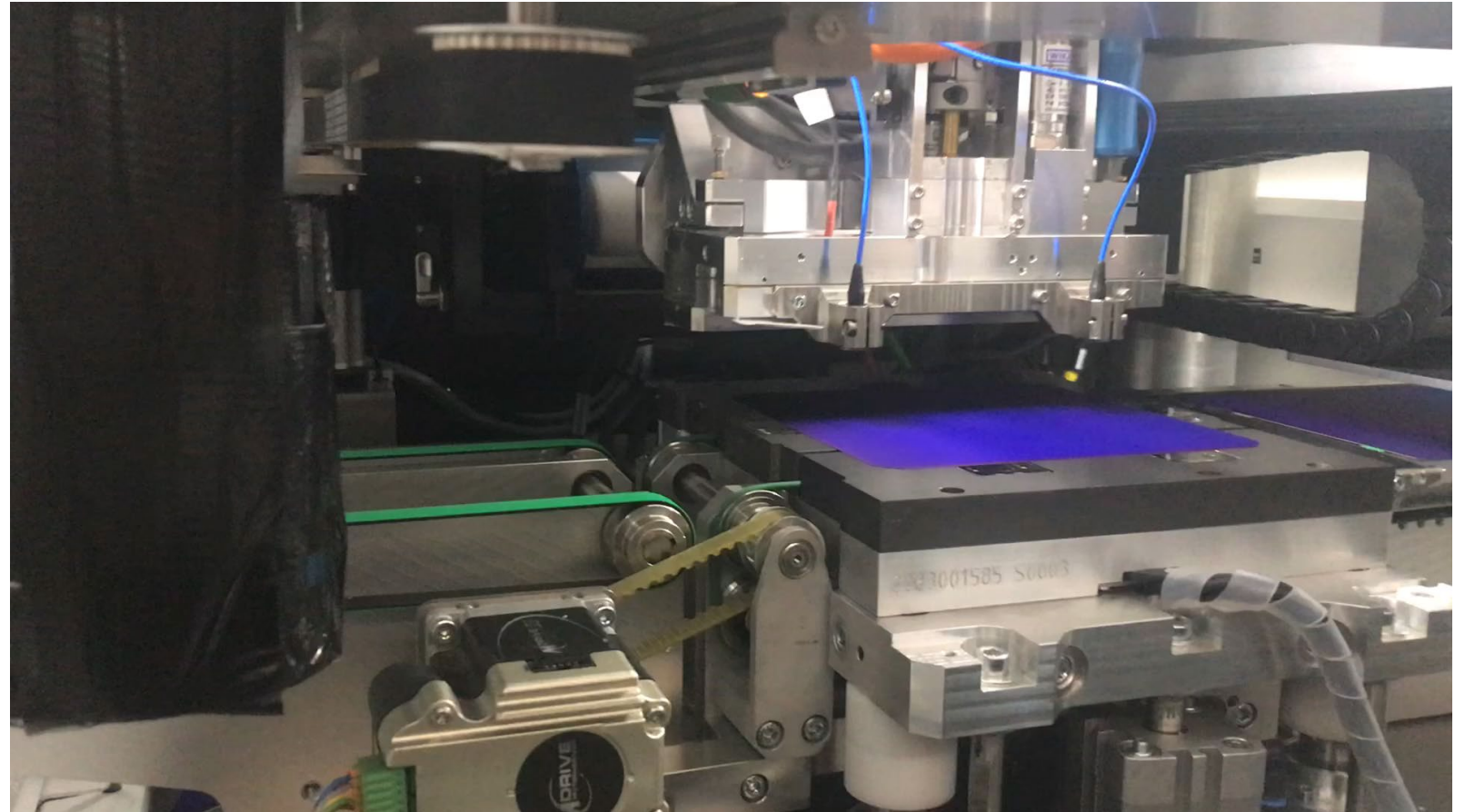


Goal: KIT Lifetime >> Screen Lifetime

- Flexibility regarding:
- Number of nozzles
 - Arrangement of nozzles
 - Pitch between nozzles
- Quickly exchangeable (< 30 sec)

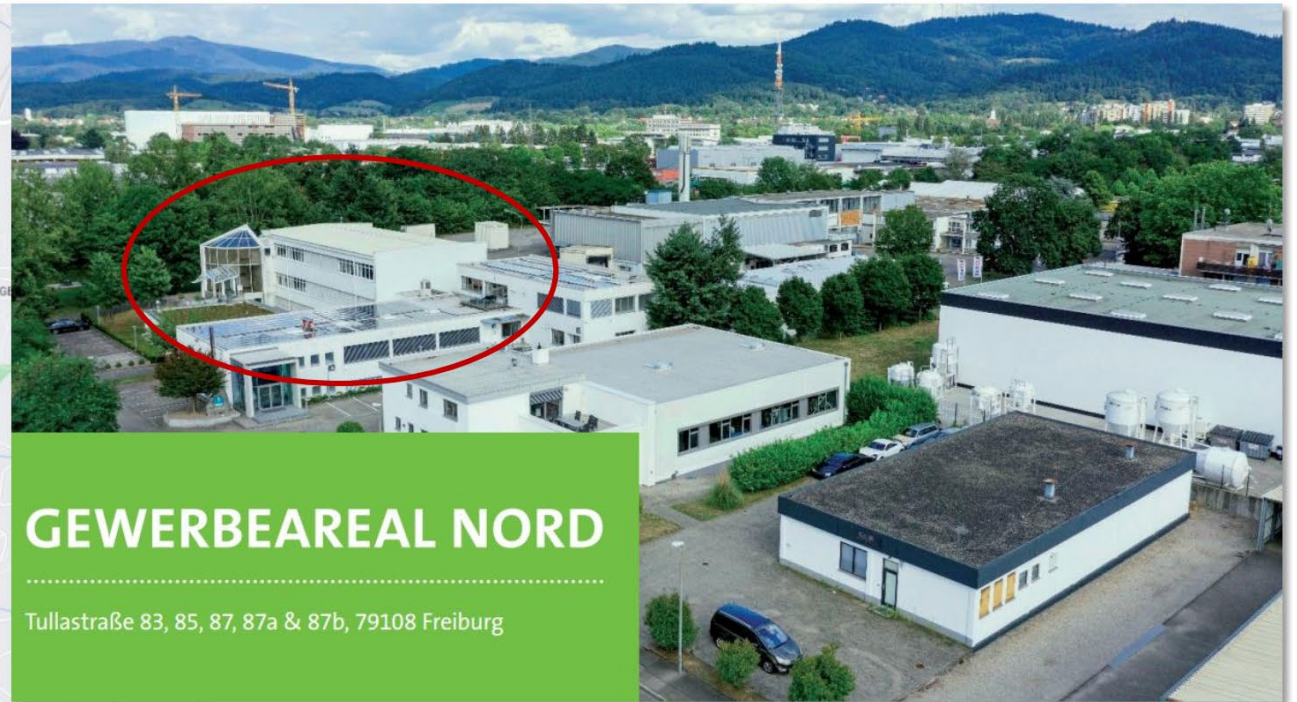


- Targeted industrial testing in PV for Q3/23
- Current focus on
 - yield and stability
 - alternative materials/pastes
 - different PV applications
- Open for potential scalable applications



Enduring dispensing at Fraunhofer ISE's PVTEC with HighLine's Cuckoo 2.0

Outlook: New Site in Freiburg from Q3/23



- > 800 m² Lab and Office Space
- Pilot Production for first Customers

- This work was partly funded within following public research projects

- Contracting number: 03EE1071B, 03EE1086E (Bussard, Presto)
- Contracting number: BW1_0145/01 (DiDi)



- Special acknowledgment to employees from Fraunhofer ISE and HighLine due to enduring support around our R&D in Fraunhofer ISE's PVTEC

HIGHLINE

T E C H N O L O G Y

Many thanks for your attention

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