Precision cutting and grooving with the Laser MicroJet

Dr Alexandre Pauchard
CTO
Synova SA, Switzerland

Outline

- Company – Products – Markets
- Laser MicroJet principle
- Selected applications
    - metal cutting
        - fuel injection nozzles
        - micro-springs
    - wafer dicing
    - laser doping of solar cells
- Conclusion

Company

Founded: 1997
Headcount: 60 employees

Products

Cutting of masks

Laser Stencil System (LSS)

General purpose

Laser Cutting System (LCS)

Cutting / grooving of wafers

Laser Dicing System (LDS)

Laser Grinding System (LGS)

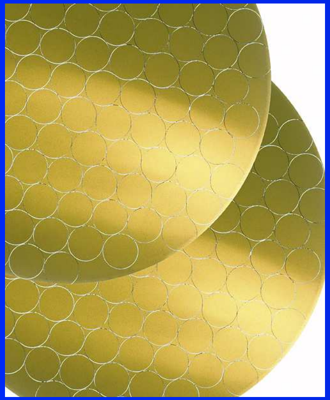
Hybrid Laser Saw
(HLS) w/ Disco Corp.

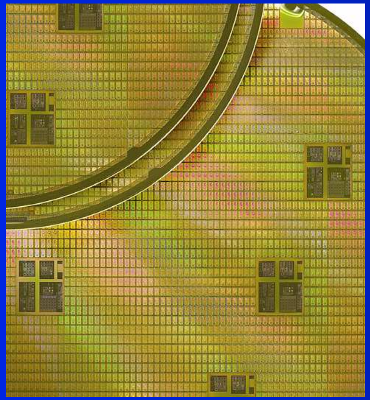
Selective doping of solar cells

Manual LCP Doping

Inline Doping w/ Rena Gmbh

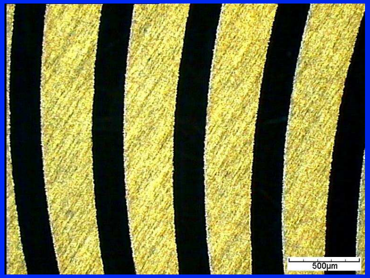
Markets


Solar

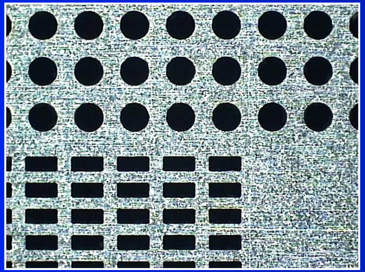

Semiconductor


Hard tooling

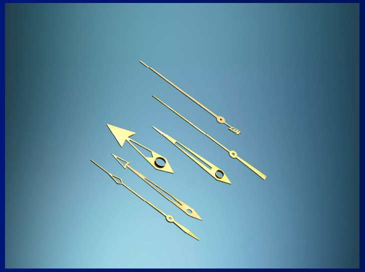

MedTech



Consumer goods

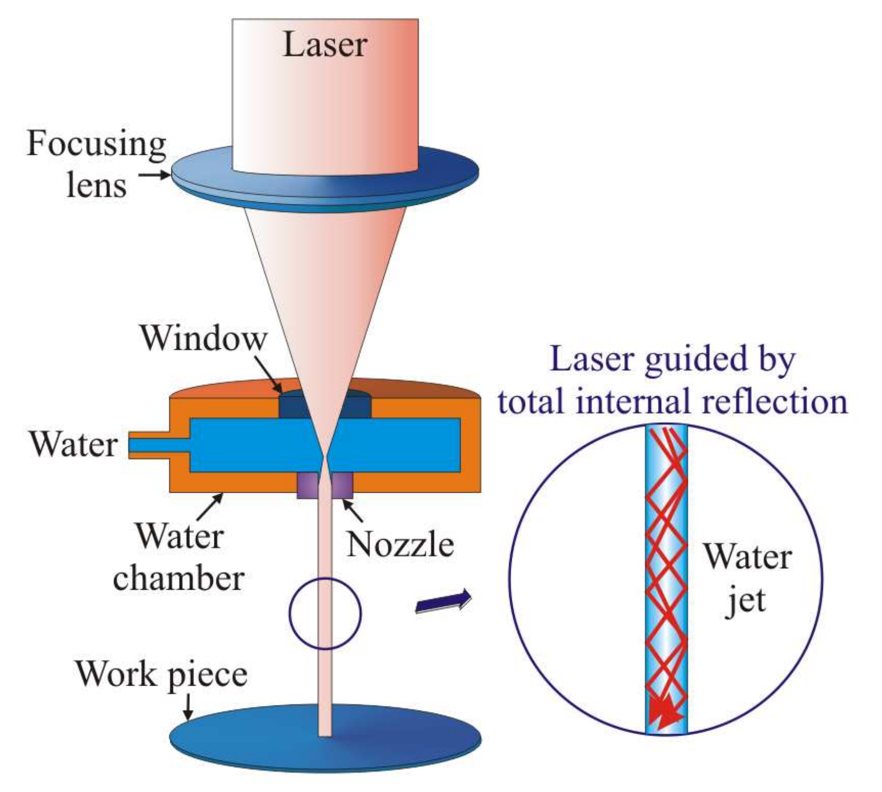

Displays


Automotive


Watch

Laser MicroJet Principle

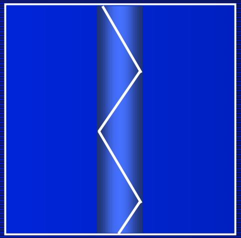
- Water jet generated using small nozzles (20 – 160µm) and low water pressure (100 – 300bar). The water jet is not cutting.
- High-power pulsed laser beam focused into nozzle in water chamber
- Laser beam guided by total internal reflection to work piece
- Long working distance (>100 mm)



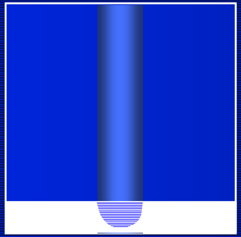
Laser MicroJet Principle

Avantages:

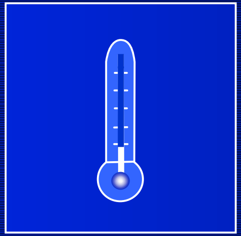
Water jet guides laser ⇨ long working distance

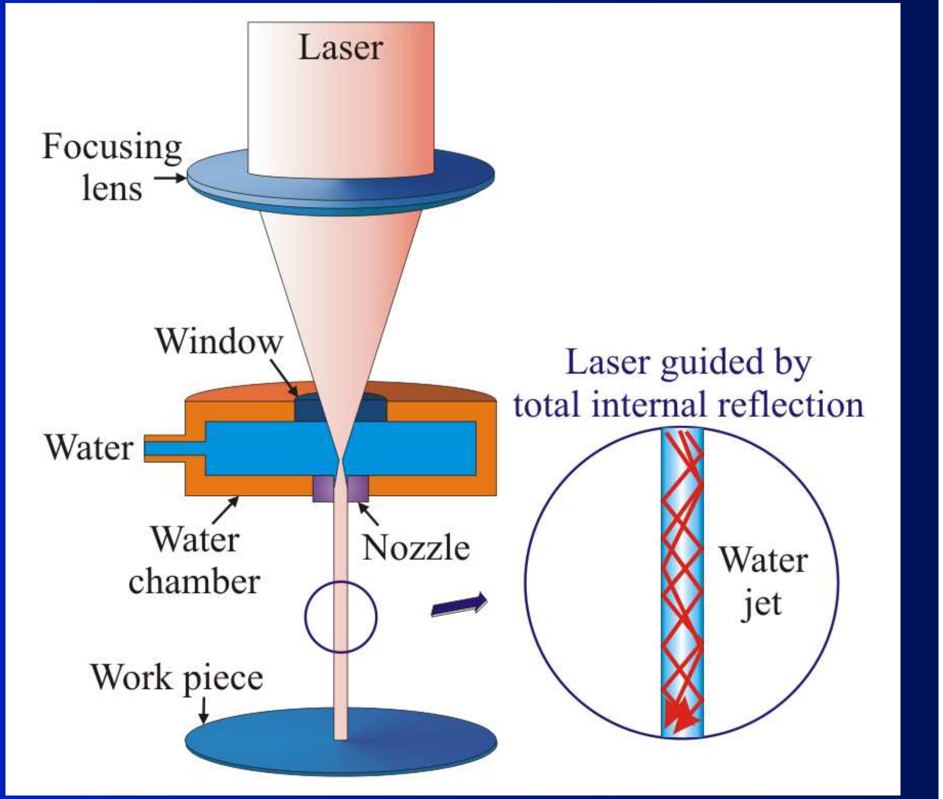


Water jet expels molten material ⇨ cleaner surfaces



Water jet cools material ⇨ less HAZ



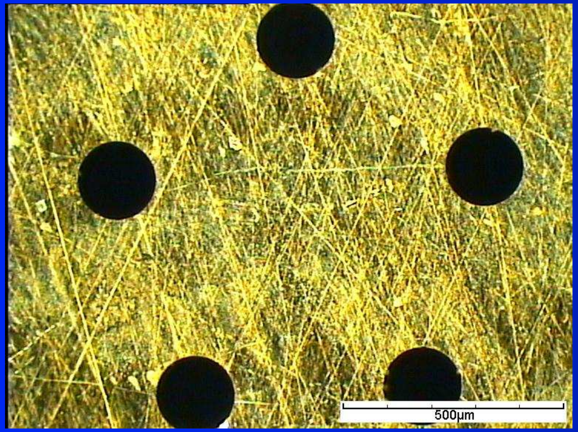


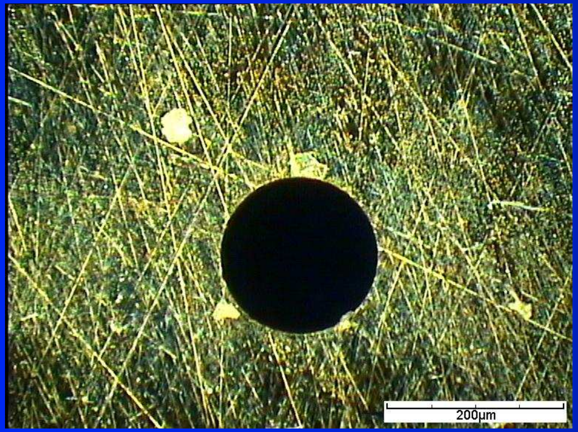
Fuel injection nozzles

Goal:

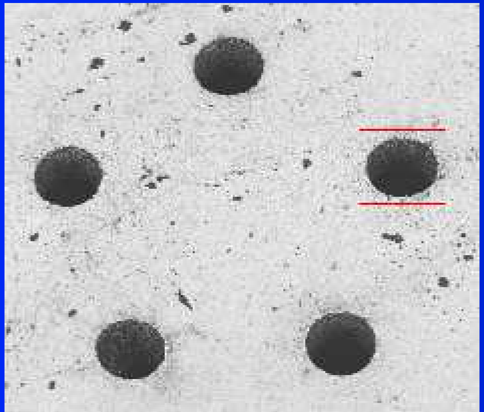
- direct and optimize fuel flow into combustion chamber
- high pressure to atomize fuel into spray
- dimensions: 180 – 260 µm, **± 2 µm**
- thickness 120 – 220 µm
- materials: stainless steel, AISI 440C (hard, resistant to wear and corrosion)

Fuel injection nozzles

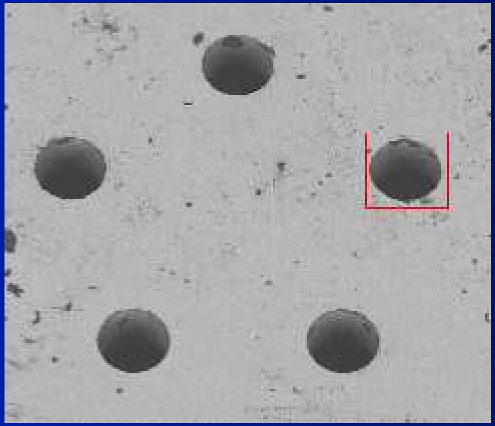




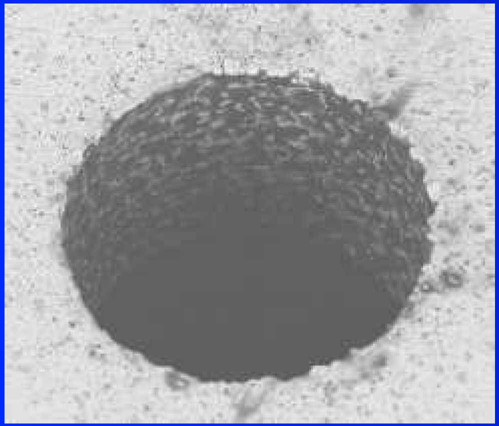
Fuel injection nozzles

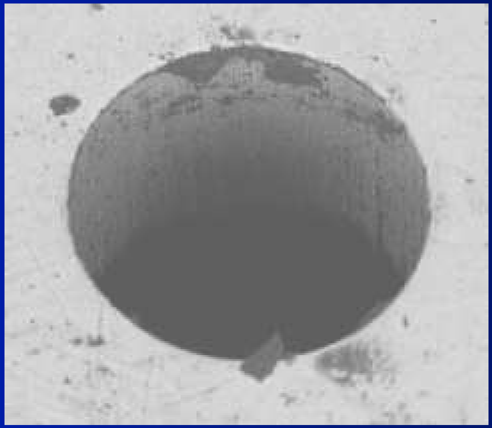


Drilled with EDM



Drilled with LMJ

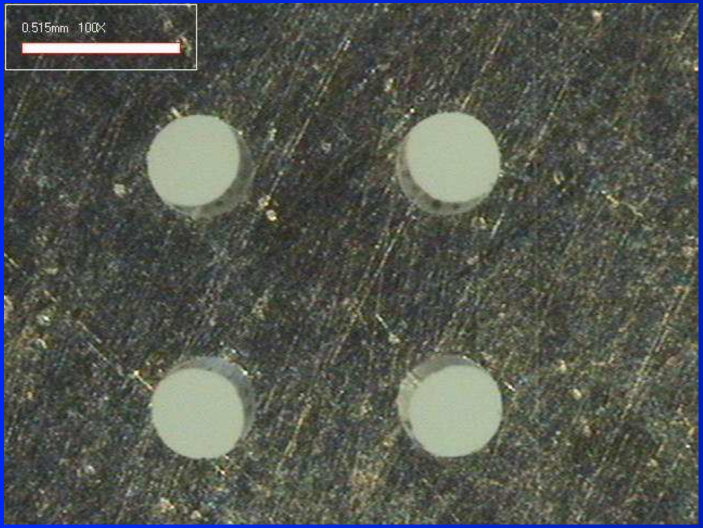


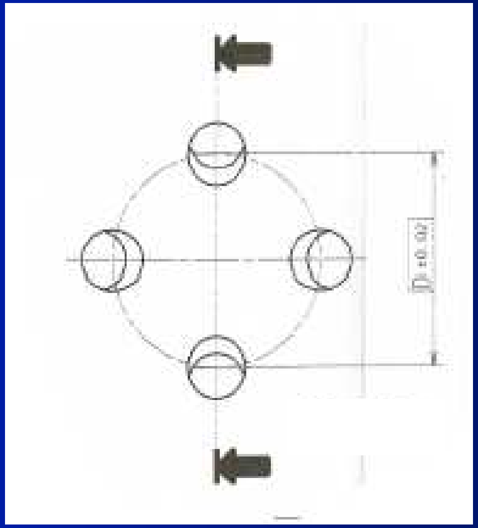


Cutting speed: 4 times higher with LMJ

Fuel injection nozzles

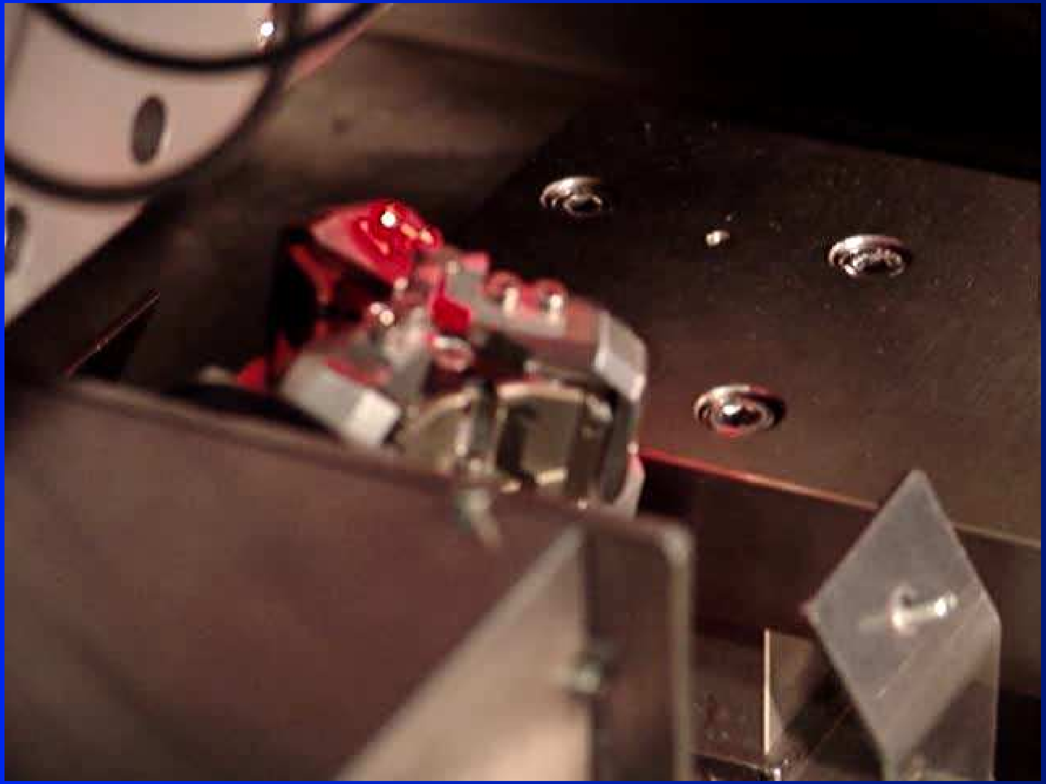
- **Process: cut four 310 μm holes with 18° angle**





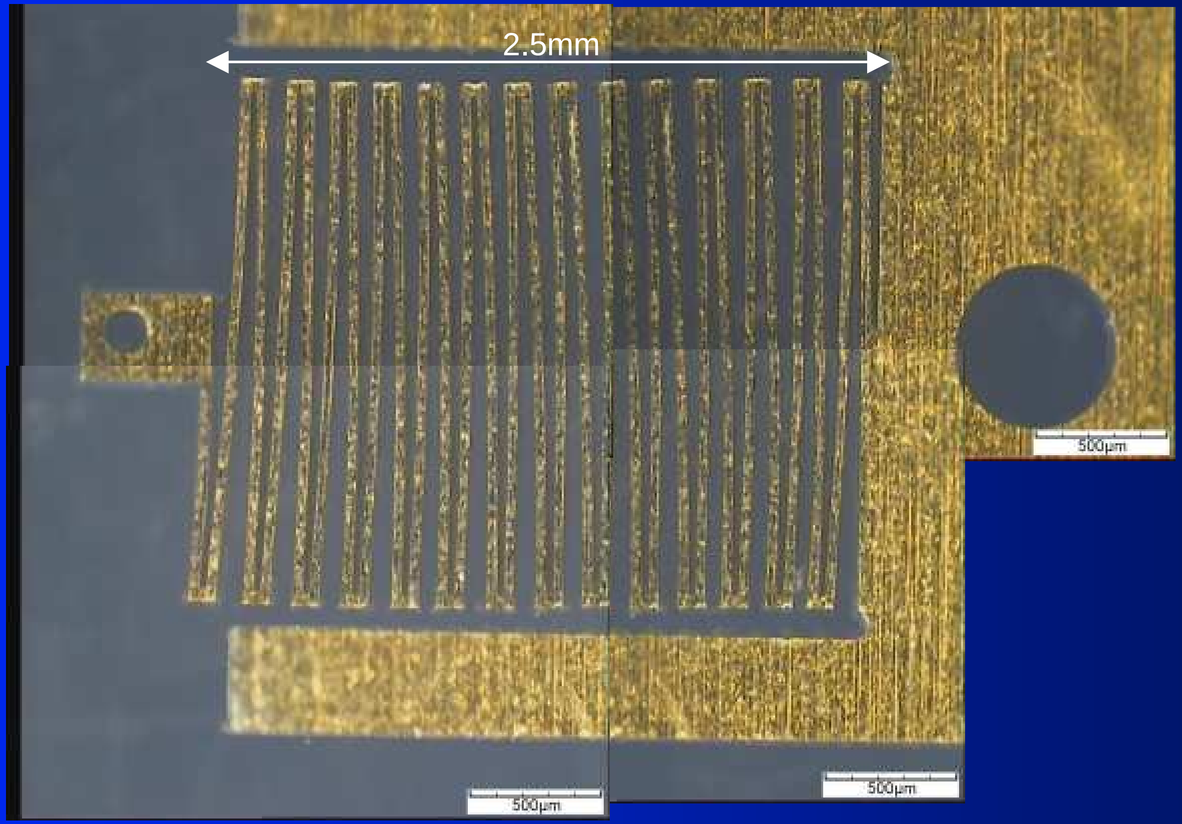
- **Automation: 200 nozzles / hour**

Fuel injection nozzles



Cutting of micro-springs

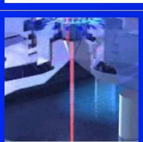
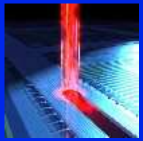
Annealed stainless steel - 150µm thickness



No post cleaning treatment

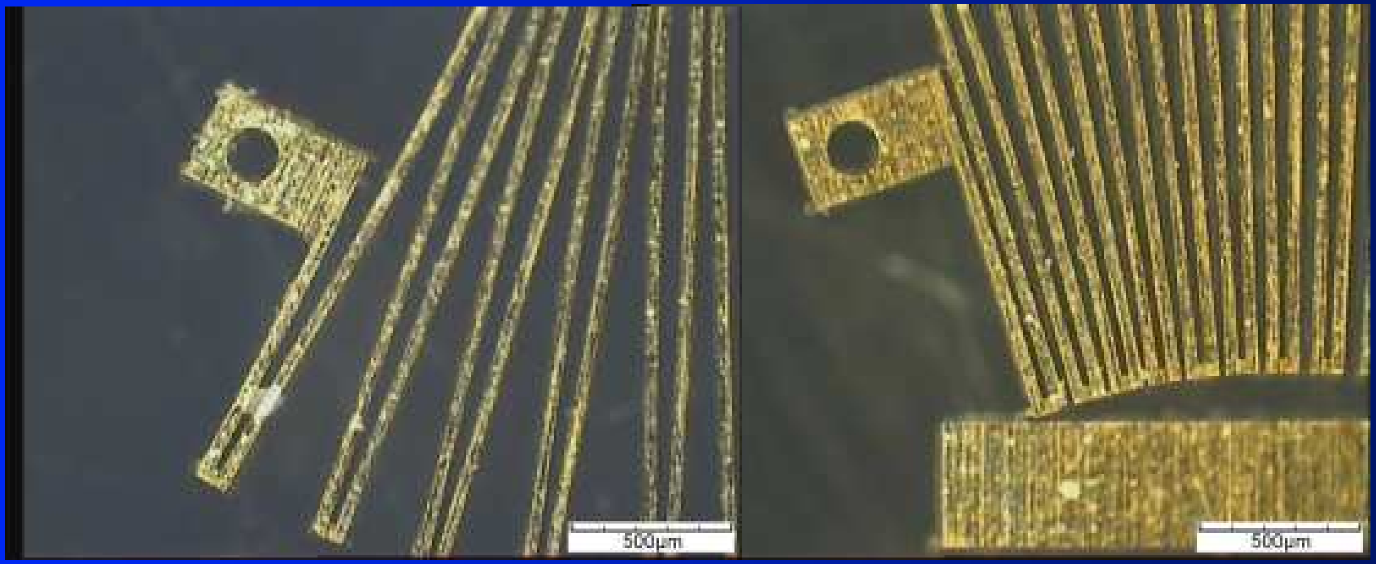
Cutting of micro-springs

1. Cutting of micro-springs made of annealed stainless steel (150µm thickness)
2. Process parameters:

	**SYSTEM**	Machine type	LCS300
	**MICROJET® PARAMETER**	Nozzle diameter	40 *µm*
		MicroJet® diameter	36 *µm*
		Water pressure	400 *bar*
		Assist gas	He
	**LASER PARAMETER**	Laser type	L101IR
		Wavelength	1064 *nm*
	Peckholes	Pulse frequency	1 *kHz*
		Laser Power %	100 %
		Pulse width	100 *µs*
	Lines	Pulse frequency	0.5 *kHz*
		Laser Power %	75 %
		Pulse width	60 *µs*
	**CUTTING PARAMETER**	Scanning speed	1 *mm/s*
		Number of passes	1
		Time / piece	260 *s*
		Fixture	clamped

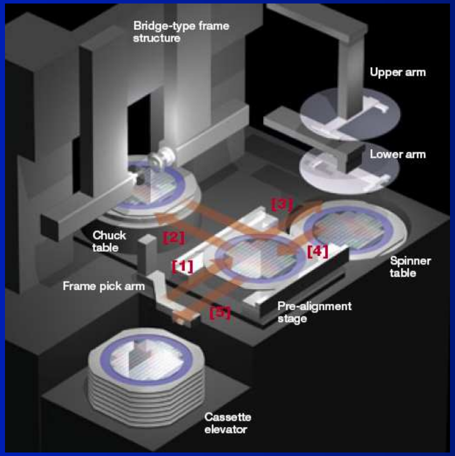
Cutting of micro-springs

Initial cut strategies resulted in a twisted spring.
Optimization in cutting strategy allowed to eliminate built-in stress !

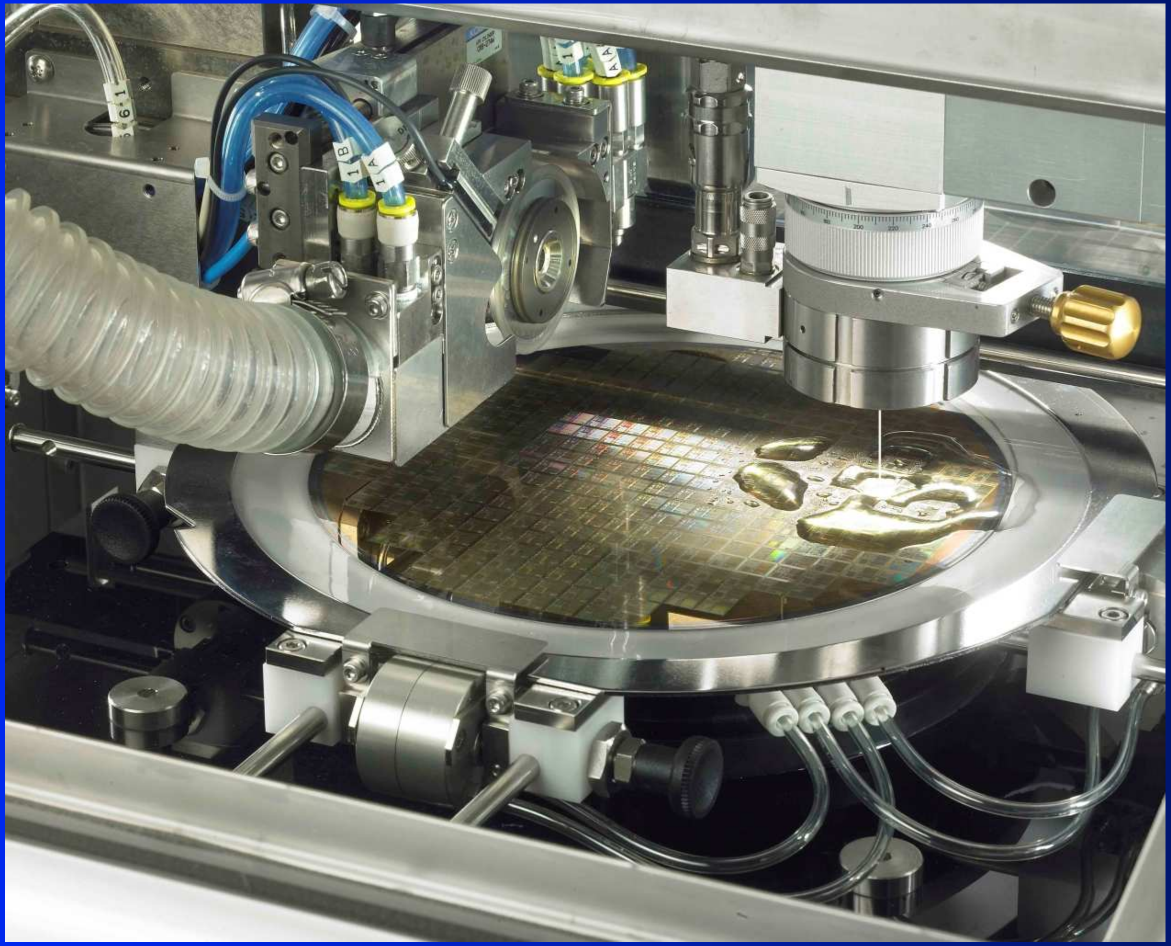


Hybrid Laser Saw (HLS)

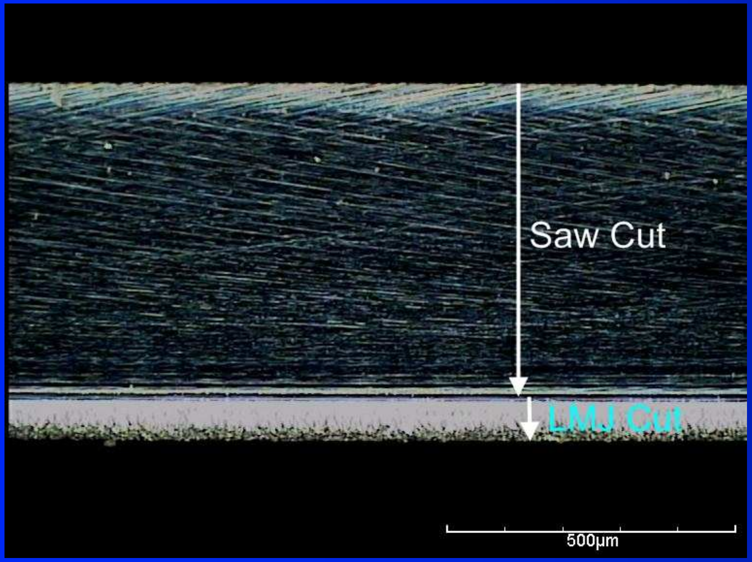
- Based on Disco dual parallel spindle DFD6361 Fully Automatic Dicing Saw
- Performs loading, alignment, cutting, cleaning, drying and unloading fully automatically
- Wafer diameter up to Ø300 mm
- Cutting speed 0.1 - 600 mm/s

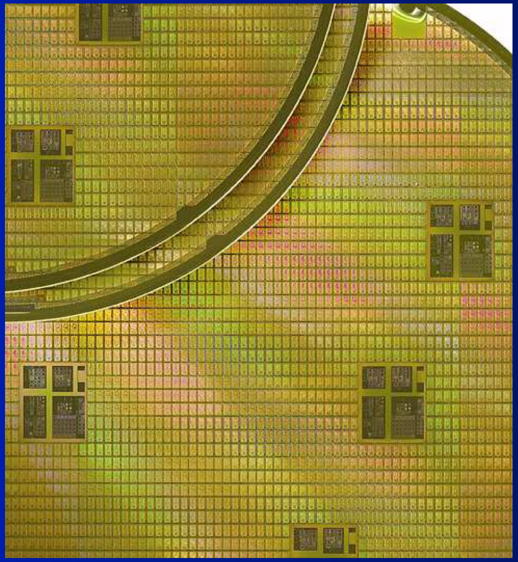


Hybrid Laser Saw (HLS)



Hybrid Laser Saw (HLS)





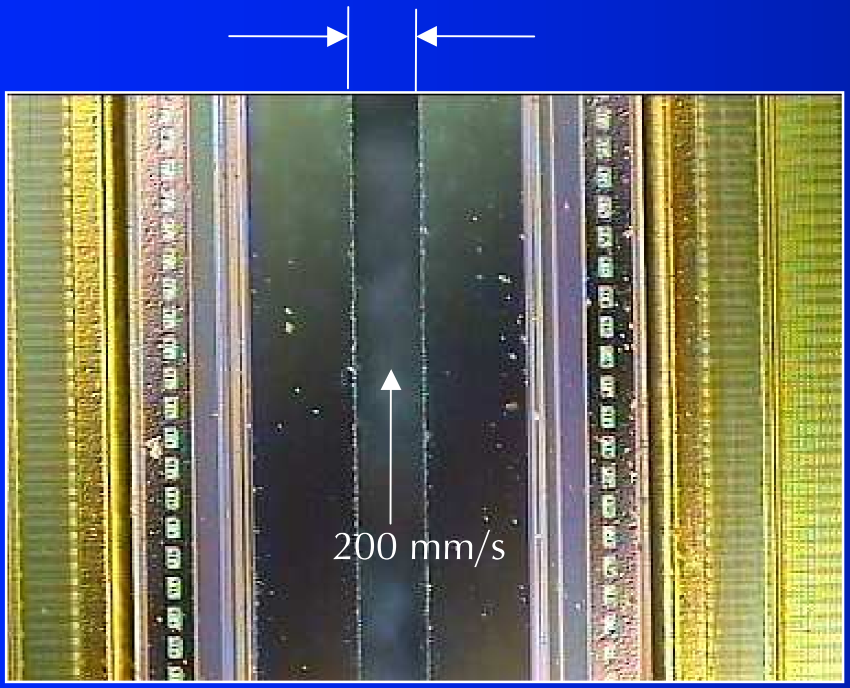
Cutting 600µm thick silicon wafer using saw followed by LMJ,

cut in sequential passes

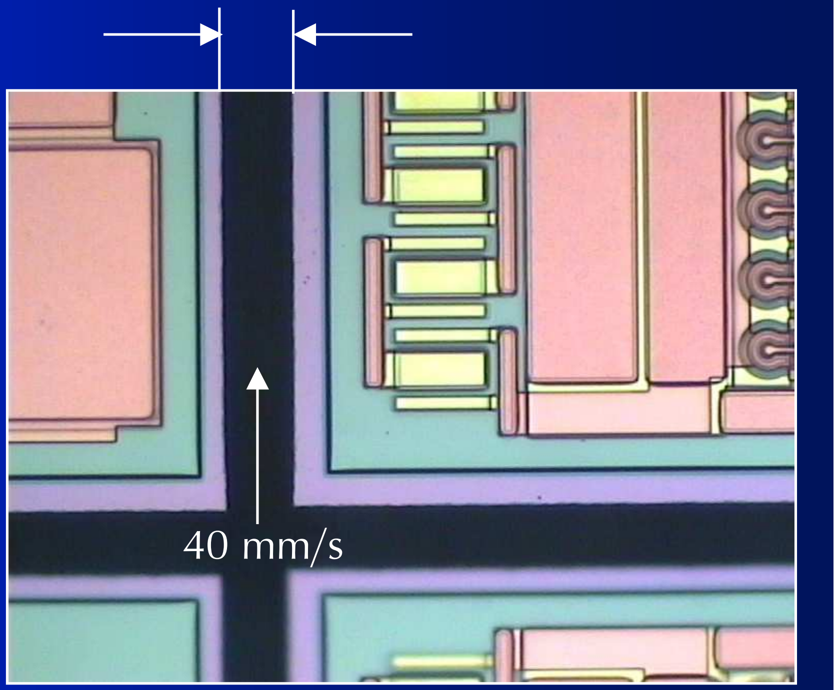
Dicing of thin wafers

Cutting of thin Si wafers

Cutting of thin GaAs wafers



50 microns thick Silicon wafer



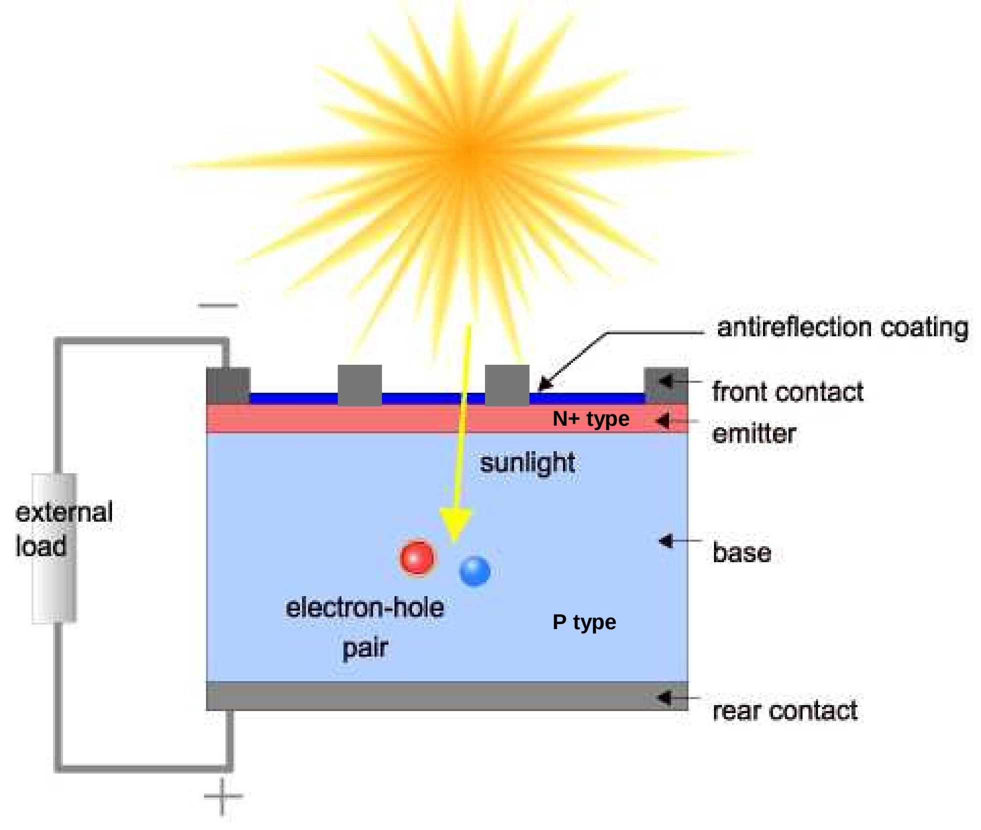
100 microns thick GaAs wafer

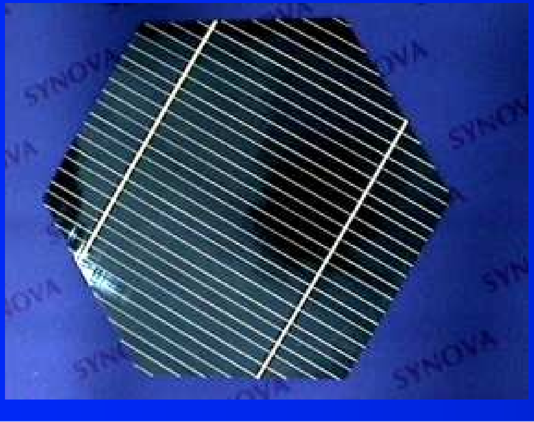
Solar cells

High doping emitter layer necessary to obtain good ohmic contact to metallization

Standard solar cells:
Uniform emitter doping introduced using diffusion furnaces

Consequence:
N+ emitter over entire surface





Solar cells

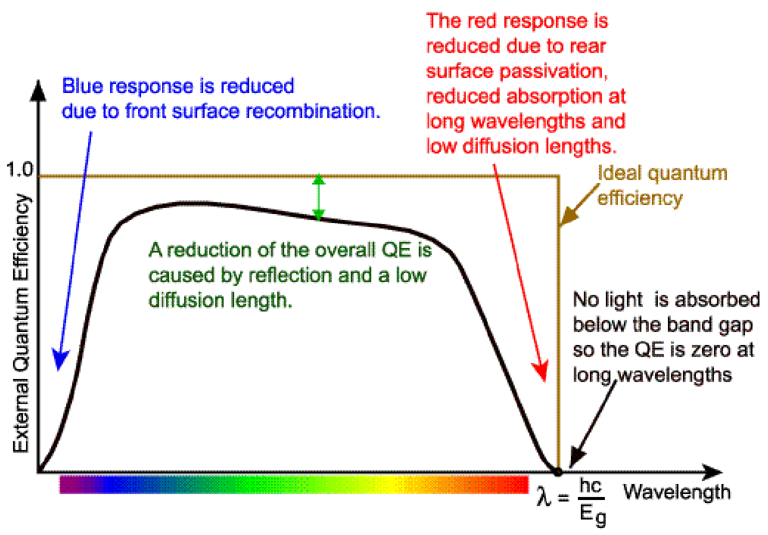
Consequence of having N+ emitter over entire surface:

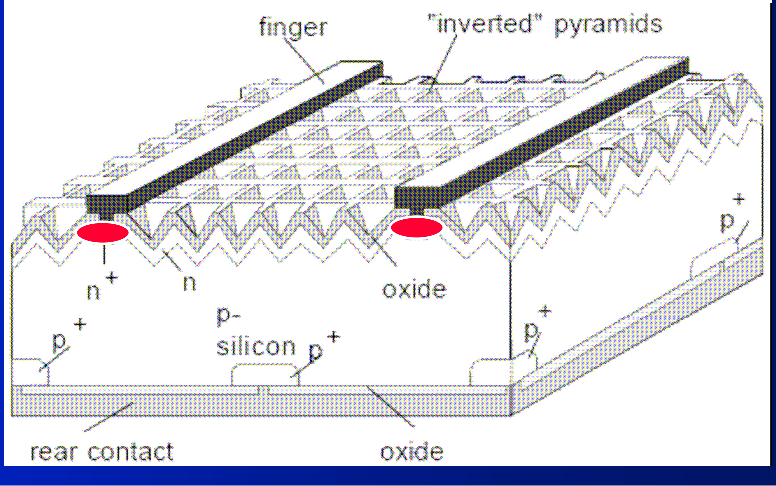
High surface recombination in blue response (photons with high absorption coefficient)

Solution: use of selective emitters

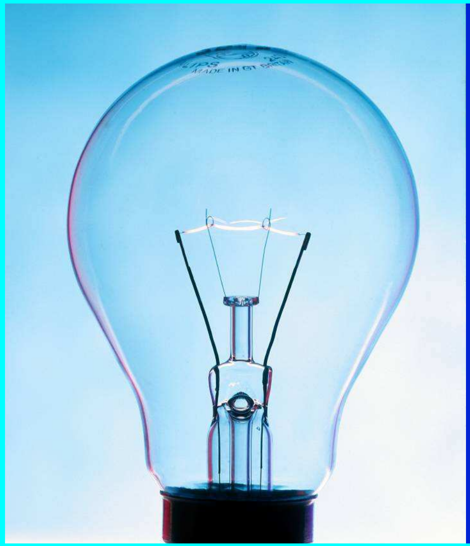
Deposit high doping layer only below metallic fingers, not between fingers

Different techniques to introduce selective emitters exist, some based on lasers





Laser Chemical Processing



Idea from ISE*, based on Synova IP:

Start from water jet-guided laser technology; replace water by chemical jet

⇨ Laser Chemical Processing (LCP)

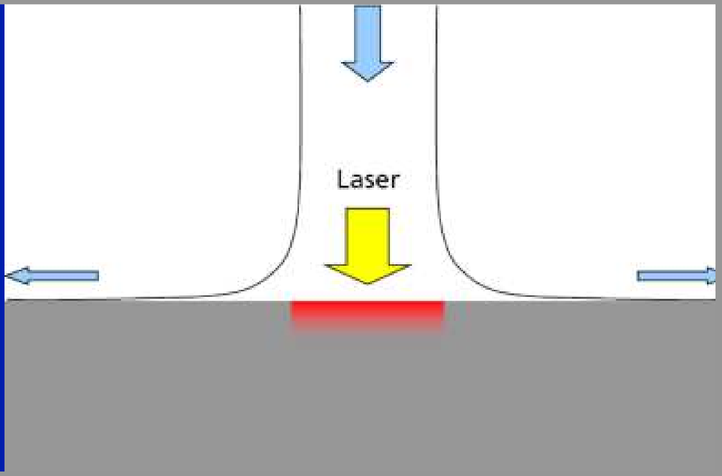
* Willeke, G.P. and D. Kray, A new route towards 50 µm thin crystalline silicon wafer solar cells Proceedings of the 17th European Photovoltaic Solar Energy Conference, 2001, Munich, Germany

Fraunhofer ISE Institut Solare Energiesysteme

LCP-doping physical model

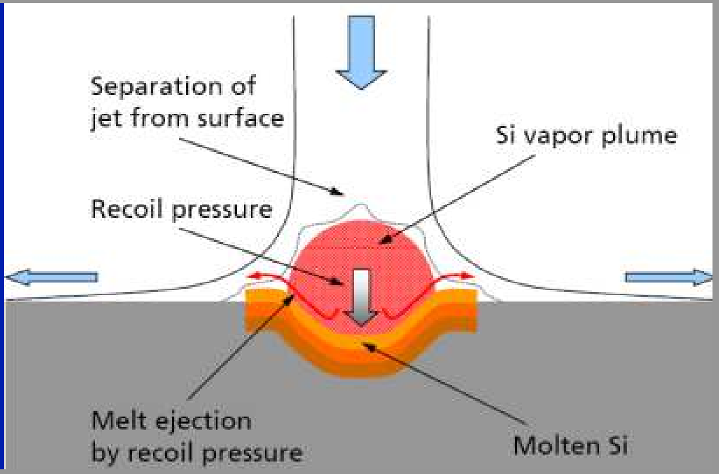
Step 1

- Guide laser beam into chemical jet (H_3PO_4 for selective emitter)
- Laser pulse heats up surface (532nm, 1W, 10ns, 30kHz)



Step 2

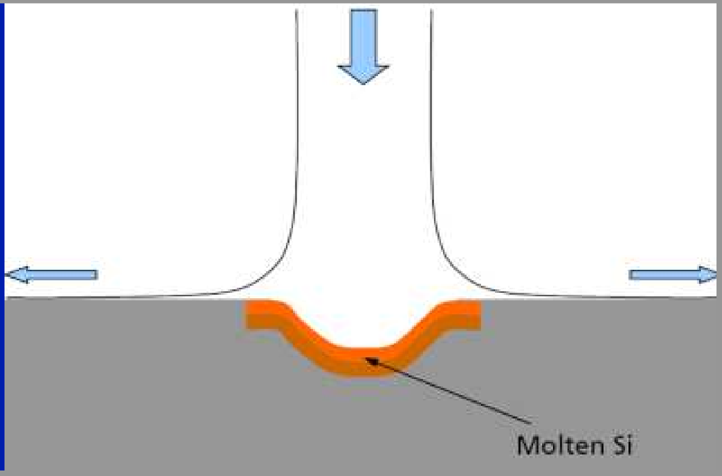
- Evaporated / melted material ejected
- Separation of jet from surface



LCP-doping physical model

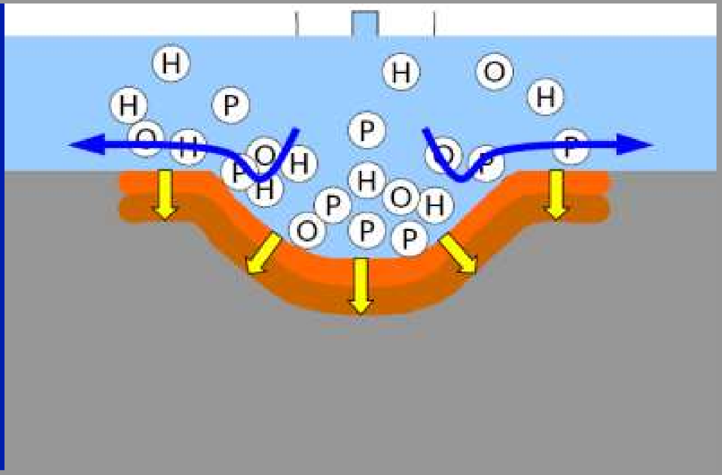
Step 3

- Vapor flume collapses
- Jet carries away debries
- Contact jet to surface reestablished



Step 4

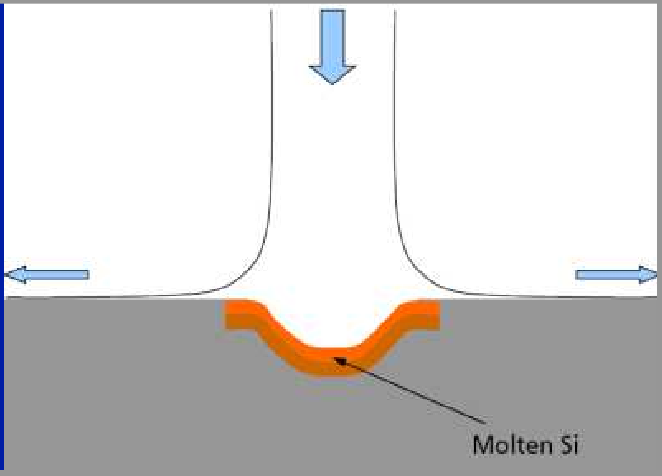
- Carrier liquid decomposes thermally
- Liquid phase diffusion of dopant



LCP-doping physical model

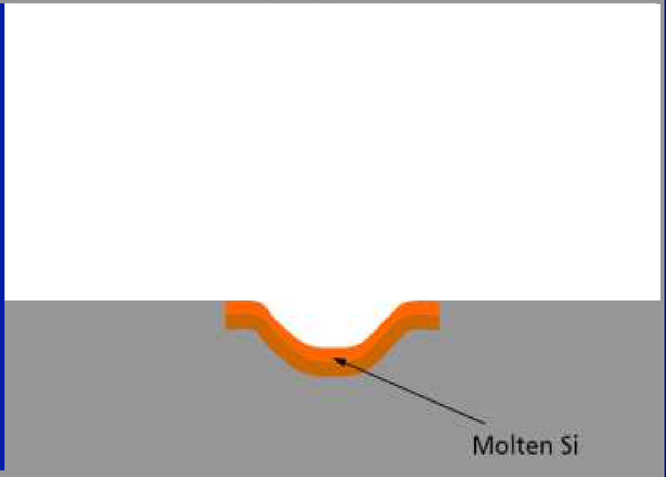
Step 5

- Si resolidifies



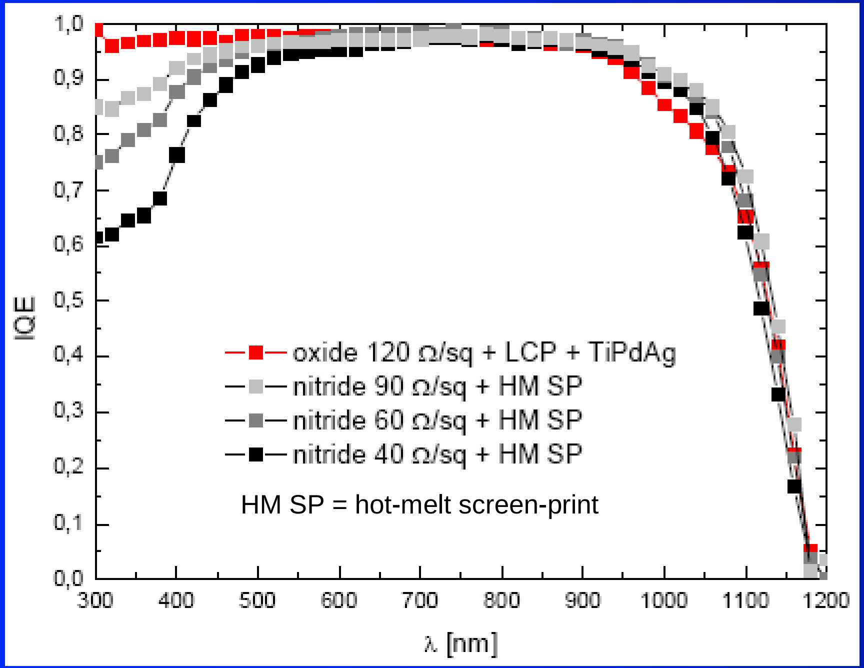
Conclusion

- Self-aligned process
- Perfect epitaxy if pulse not too short
- Damage-free local diffusion
- No need for post-process anneal



Solar cell experiments

- Strong improvement of blue response using selective emitter by LCP-doping
- IQE close to 100% from 300nm to 900nm
- Dip around 1000nm due to non-optimized LFC process



Efficiency gain of
0.5 – 0.7% absolute

(e.g. efficiency increases from17% to 17.5%)

Laser-doped Silicon Solar Cells by Laser Chemical Processing (LCP) exceeding 20% Efficiency, D. Kray et al, 33^rd PVSEC, 2008.

Fraunhofer ISE
Institut
Solare Energiesysteme

Manual LCP machine

For R&D purposes

Manual loading / unloading

About 15’ per wafer

Automated LCP machine

Automated LCP machine

Areas of application:

- local diffusion without thermal defects
- structuring combined with standard metallisation techniques
- structuring combined with self aligning electrolytic NiAg plating, NiCuAg plating in preparation
- single process for selective emitter or local BSF forming

Machine specification:

Process:	local SiN ablation and n^{++} type diffusion
Dimensions:	9500 x 3500 – 4000 x 2000 mm (length x width x height)
Throughput:	1200 – 4800 wafers / h
Wafer thicknes:	> 160µm
H_3PO_4 consumption:	0.4 – 0.8 l/h
Power consumption:	30 – 50kW

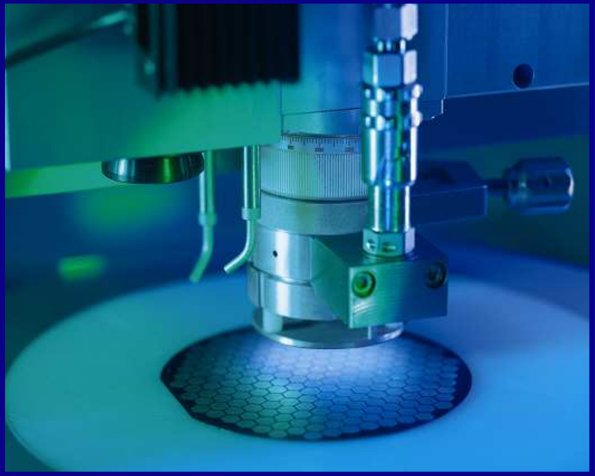
Conclusion

Laser MicroJet technology is a versatile and cost-effective tool for precise cutting of

- Thin metals
- Semiconductors
- Hard materials
- Ceramics
- Diamonds

Extensions of the technology, like Laser Chemical Processing (LCP), opens up a whole range of new applications.
Example: laser doping for introduction of selective emitters in solar cells

Contact



Dr Alexandre Pauchard
CTO
Synova SA
pauchard@synova.ch

Where others see impossibilities, we see solutions