



CIGSSe absorber formation equipment for high scale production

Dr. D. Kolovos-Vellianitis



Introduction SINGULUS AG

Basic CIGS background

Process definition

Technical furnace information (CISARIS)

Outlook / Summary

Introduction SINGULUS AG - Global Presence

- Headquarters Singulus
- Sales & Service Subsidiary
- Headquarters Stangl Solar
- Representative



Total Singulus Group
459 employees (per 31.12.2010)

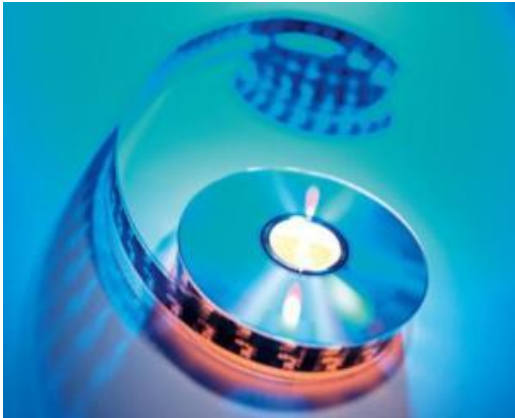


- 01 Headquarters Kahl
- 02 SINGULUS STANGL Solar, Fürstenfeldbruck
- 03 SINGULUS MANUFACTURING GUANGZHOU

Introduction SINGULUS AG - Business Segments

Optical Disc

- Mastering
- Molding
- Replication



Solar

- Coating
- Wet Processing
- Thermal Processing*
- Systems Business



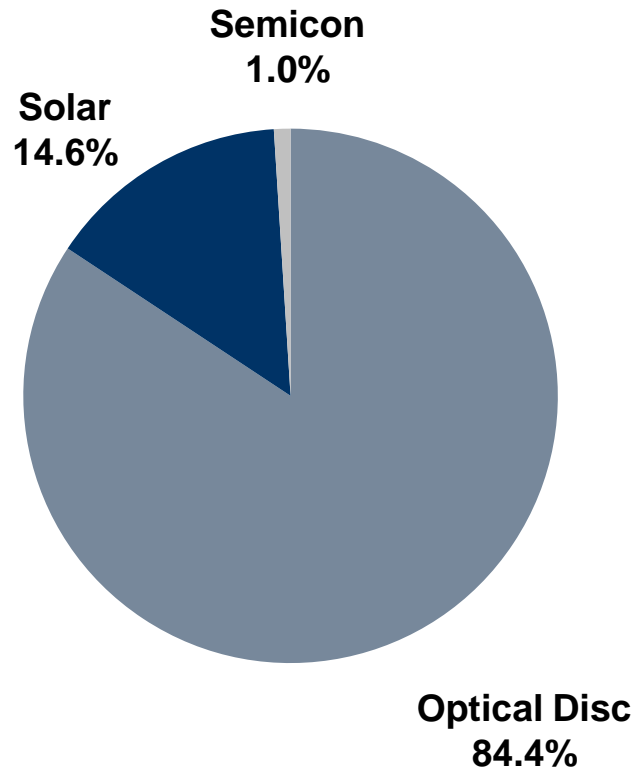
NDT-Semiconductor

- Thin Film Heads for HDD
- MRAM
- Sensors

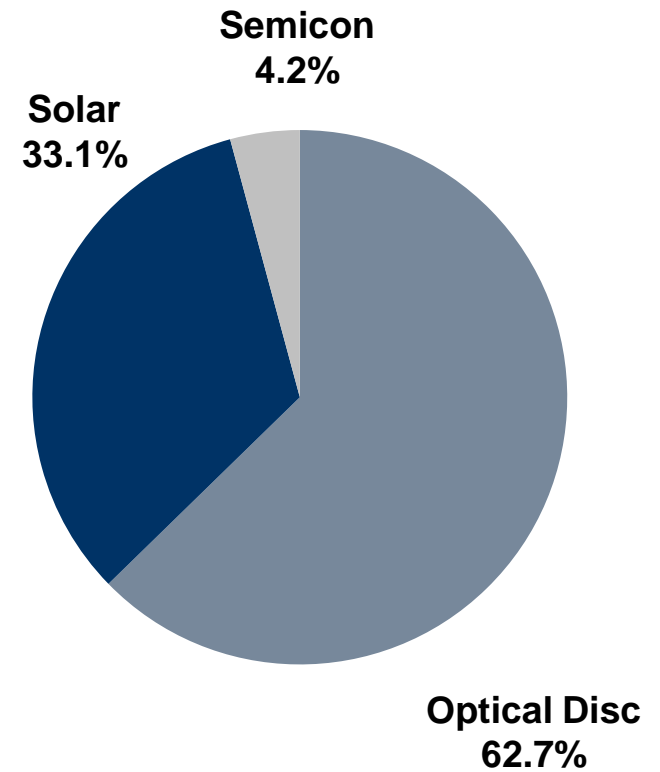


Introduction SINGULUS AG - Sales Split

1st Half Year 2010

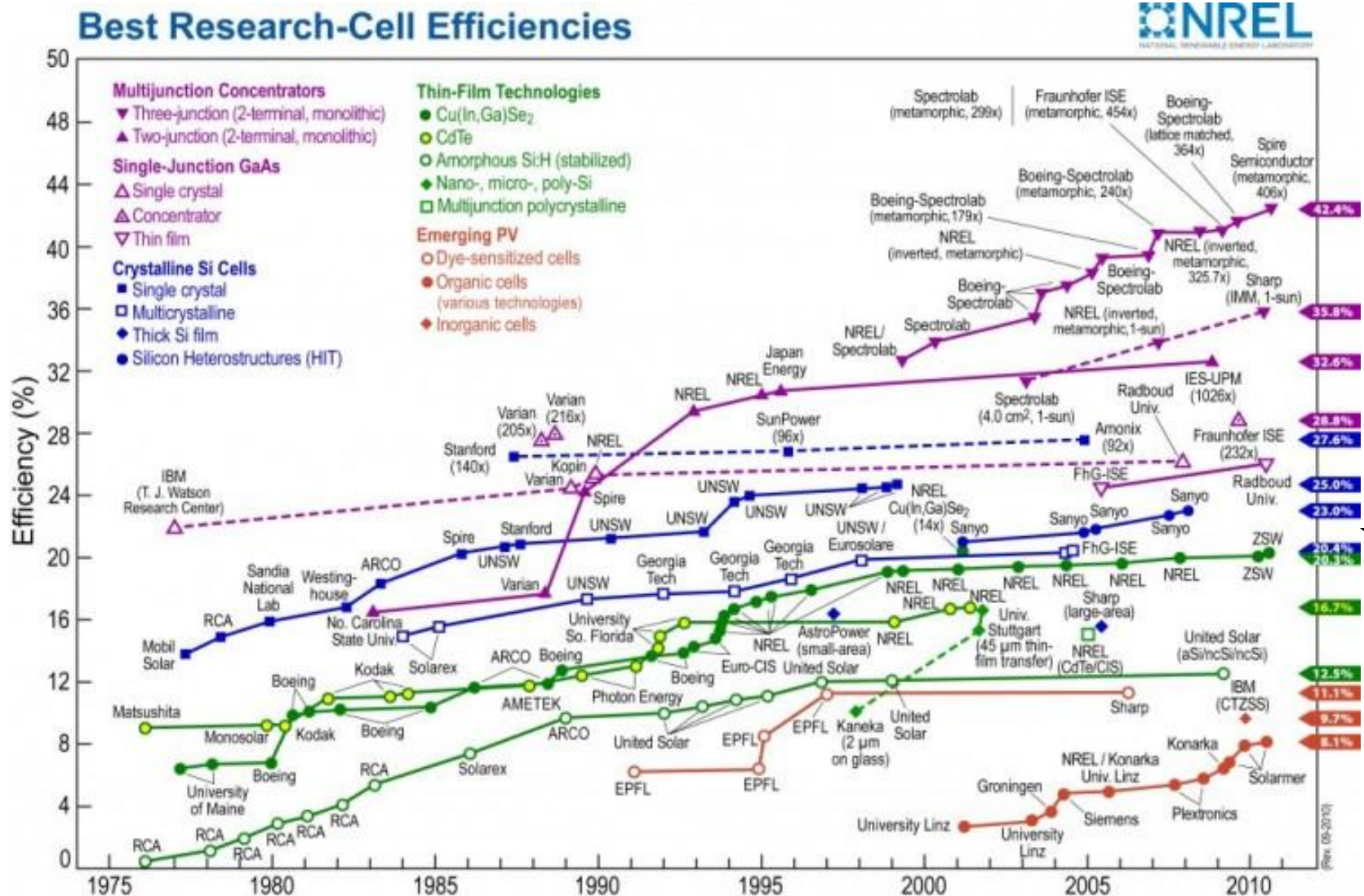


1st Half Year 2011



Why CIGS?

Basic CIGS background – cell efficiencies



Basic CIGS background - Key CIGS Benefits

- **high efficiencies** (over 20% in the lab, over 13% in production mode)
- **new Cd - free technology** (already implemented by several companies)
- **cutting edge but also well established and reliable technology**
- **high throughput and high yield**
- **low manufacturing costs**
- **limited number of handling steps**
- **production on various types of substrates**
- **no material degradation → long term stability**
- **large innovation and development potential**
- **high aesthetics**

Basic CIGS background – Market analysis

Over 50 companies active in the CIGS area!

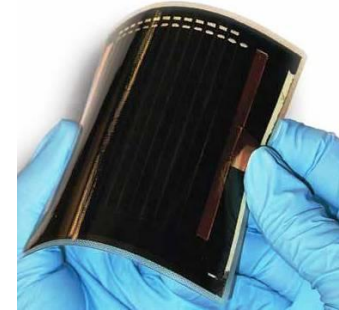
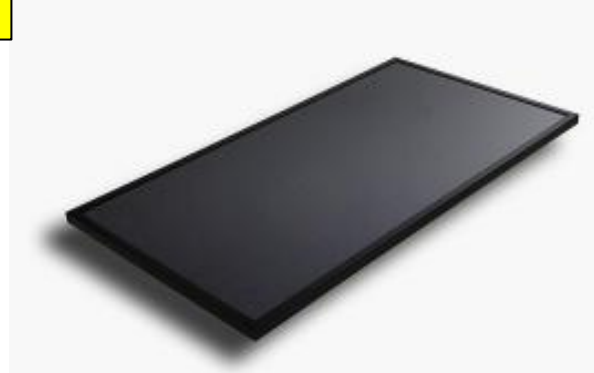
Company	Country	Substrate	Core Process	Equipment supplier	Core Process	Equipment supplier	Buffer layer	Equipment supplier	Substrate Size	Capacity 10/ut.	Remarks	List Update	Contact
APA BV	NL	Glass	Spraying, roll to roll							-8 MW	h=		www.apabv.com
Amelio Solar	US	Glass	Tandem cell, a-Si + CIGS		Tandem cell, a-Si + CIGS					0/22 MW	h=		www.ameliosolar.com
Applied Quantum Technol.	US	Glass	Sputtering, no Se		no Se					1/15 MW	h=		
Ascent Solar	US	Polymer	Coevaporation		Coevaporation		CdS (CBD)	Stangl		1,5/60 MW	h=		www.ascentsolar.com
Avancis	DE	Glass	Sputter	LO	RTP	LO/ Singulus				20/120 MW	h=		www.avancis.de
AxunTek Solar	TW	Glass	Sputter		RTP				1245 x 635	25MW	75MW planned Q4/2011 200MW planned 2012	15.06.11	
Sunshine*	TW	Glass	Sputter	FHR / Centrotherm	RTP	FHR / Centrotherm	CdS (CBD)	Stangl		30/200 MW	h=		www.sunshine-pv.com
Centrotherm*	DE	Glass	Sputter	FHR / Centrotherm	RTP	FHR / Centrotherm	CdS (CBD)	Stangl		Tumkey	h=		www.centrotherm.de
CIS Solar	CA	Polymer	Coevaporation		Coevaporation					No data	h=		www.cissolar.com
CIS Solartechnik	DE	Flex	Electrodep		RTP, no Se					0,5/30 MW	h=		www.cis-solartechnik.de
Dayang Metal	KR	Steel/Flex	Coevaporation	Veeco	Coevaporation	Veeco	CdS (CBD)	Rena		0/200 MW	h=, Veeco		www.dayangmetal.co.kr
Daystar Tech	US	Glass	Sputter		RTP					0,5/25 MW	h=, Veeco		www.daystartech.com
Dow Chemicals	US	No data	No data		No data						h=		www.dow.com
EPV Solar	DE	Glass	Evaporation		RTP					2/25 MW	h=		www.epv.net
Filsom	CH	Polyimid	Coevaporation		Coevaporation					No data	h=		www.filsom.ch
Global Solar	US	Steel/Flex	Coevaporation		Coevaporation					75/175 MW	h=		www.globalsolar.com
GroupSat Solar	CN	Flex	Coevaporation	Veeco	Coevaporation	Veeco	CdS (CBD)	Rena			h=		
Honda Soltec	JP	Glass	Sputter		RTP					30/30 MW	h=		http://world.honda.com/gr-caps/hondasoltec
Heliovolt	US	Glass/Flex	FASST, printing		RTP		CdS (CBD)	Stangl		-/20 (20) MW	h=		www.heliovolt.net
Illies Renewables*	DE	Glass	Sputter		RTP					-/50 MW	h=		www.illies-renewables.com
In-Solar Tech	KR	Flex	MOQVD		MOQVD					No data	h=		
InterPhases	US	Flex	Electrodep		RTP					No data	h=		www.interphases.com
ISET	US	Flex	Printing		RTP					No data	h=		www.isetinc.com
ISTAR Solar	IT	Flex	No data		No data					No data	h=		www.istarsolar.com
Jenn Feng	TW	Glass	Printing / Sputter	own developed / ?	RTP	Smith Owens				12/360 MW	h=		www.jennfeng.com
Johanna Solar	DE	Glass	Sputter	Von Ardenne	RTP	Vitro	CdS (CBD)	Stangl		30/30 MW	h=		www.johanna-solar.com
Miasole	US	Flex	Sputter		RTP					5/55 MW	h=		www.miasole.com
Nanosolar	US	Flex	Printing		RTP					110/150 MW	h=		www.nanosolar.com
NEXCIS		Glass/Flex	Electrodep		RTP					labline	h=		-
Nuvo Sun	US	No data	Printing		RTP					No data	h=		www.nuvosun.com
Odersun	DE	Flex/Glass	Electrodep		RTP (no Se)					5/30 MW	h=		www.odersun.de
PV Flex	DE	Flex	Electrodep		RTP					0/50 MW	h=		www.pvflex.de
Ritek Solar	TW	Flex	Electrodep		RTP					No data	h=		www.riteksolar.com
Scheuten Solar	NL	Flex	Microspheres		RTP					20/120 MW	h=		www.scheutensolar.com
Showa Shell	JP	Glass	Sputter		RTP		In2S3			80/900 MW	h=		www.showa-shell.co.jp
Shurjo Energy	IN	No data	No data		No data					No data	h=		-
Solar Frontier	JP	Glass	Sputter		RTP	Batch	In2S3			80/900 MW	h=, Showa		www.solar-frontier.com
Solarion	DE	Flex	Coevaporation		Coevaporation					0/10 MW	h=		www.solarion.de
Solibro	DE	Flex	Coevaporation		Coevaporation		CdS (CBD)	Stangl		45/135 (30) MW	h=		www.q-cells.com
SoloPower	US	Flex	Electrodep		RTP					20/20 MW	h=		www.sdopower.com
Solyndra	US	Glass	Evaporation		Evaporation					110/420 MW	h=		www.solyndra.com
Stellaris	US	No data	No data		No data					No data	h=		www.stellaris-corp.com
Stion	US	Glass	Sputter	Von Ardenne	RTP	PVI (USA)	CdS (CBD)	Other Batch		No data	h=		www.stion.com
Sulfurcell	DE	Glass	Sputter		RTP		CdS (CBD)			35/75 MW	h=		www.sulfurcell.de
Sunvim	CN	Glass	Sputter	Von Ardenne	RTP	Vitro	CdS (CBD)	Stangl	1200 x 500	30/240 MW	h=		-
Suzhou	CN	Flex	Coevaporation		Coevaporation					12/24 MW	h=		-
Telio Solar Corp	US	Glas	Coevaporation		Coevaporation					No data	h=		Website expired
Terrasolar	US	Glass	Sputter		RTP					No data	h=		www.terrasolar.com
Thin Film Solar Techn.	SA	Glass	Sputter		RTP					10/ 30 MW	h=		-
TSMC	TW	Glass	Sputter	Von Ardenne	RTP	PVI (USA)	CdS (CBD)		1650 x 650	1/100MW	Under installation	16.06.11	
Würth Solar	DE	Glass	Coevaporation		Coevaporation		CdS(CBD)			40/40 MW	h=		www.wuerth-solar.de

Type of substrate

(a) Glas

(b) Metall foil

(c) Polymer foil



Formation techniques for the CIS absorber

(a) Two stages process - Sputtering/(Se-Evaporation)/RTP

(b) One stage process - Coevaporation

(c) Roll to Roll process

(d) Electrodeposition/RTP

(e) Print/RTP

(f) MOCVD

Process definition - CIS/CIGS production flow



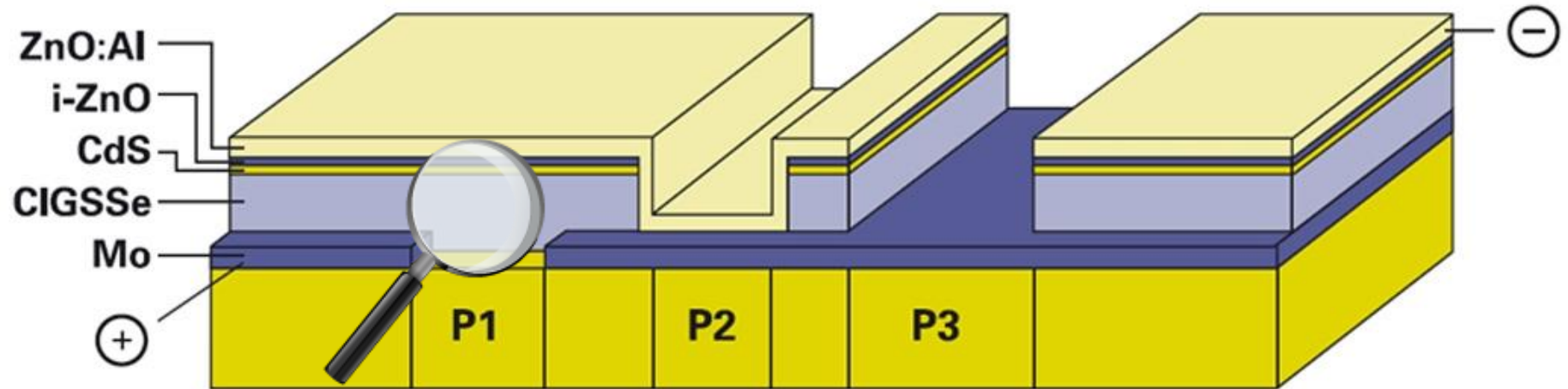
SST Product Portfolio	
1	VITRUM Clean
2	PVD Mo *
3	PVD Absorber*
4	CISARIS
5	VITRUM KCN
6	TENUIS altn. ILGAR or IMPEDIO
7	PVD TCO *

* SOLAYER

- Singulus / Stangl (SST)
- Not at SST Portfolio

Process definition – Solar cell cross section

Functionality of the CIGSSe layer: Generation of charge carriers



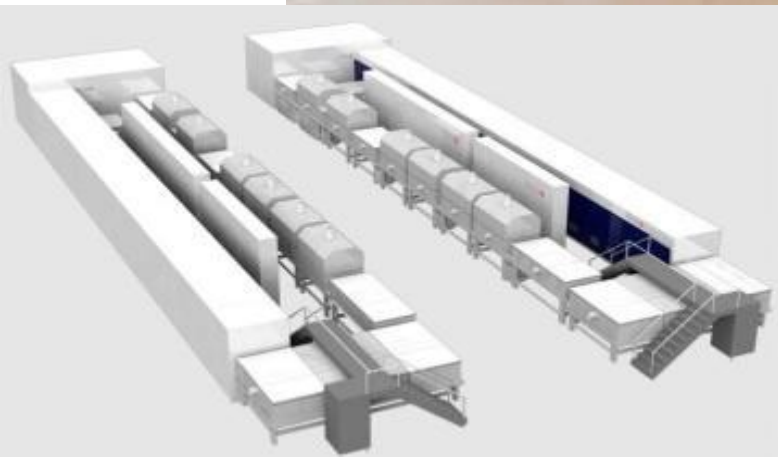
Scope: Formation of the CIGSSe absorber on glass substrates

Process: RTP In-Line-Selenisation process of the CuInGaSe-precursor with H₂S inlet

Key process parameters

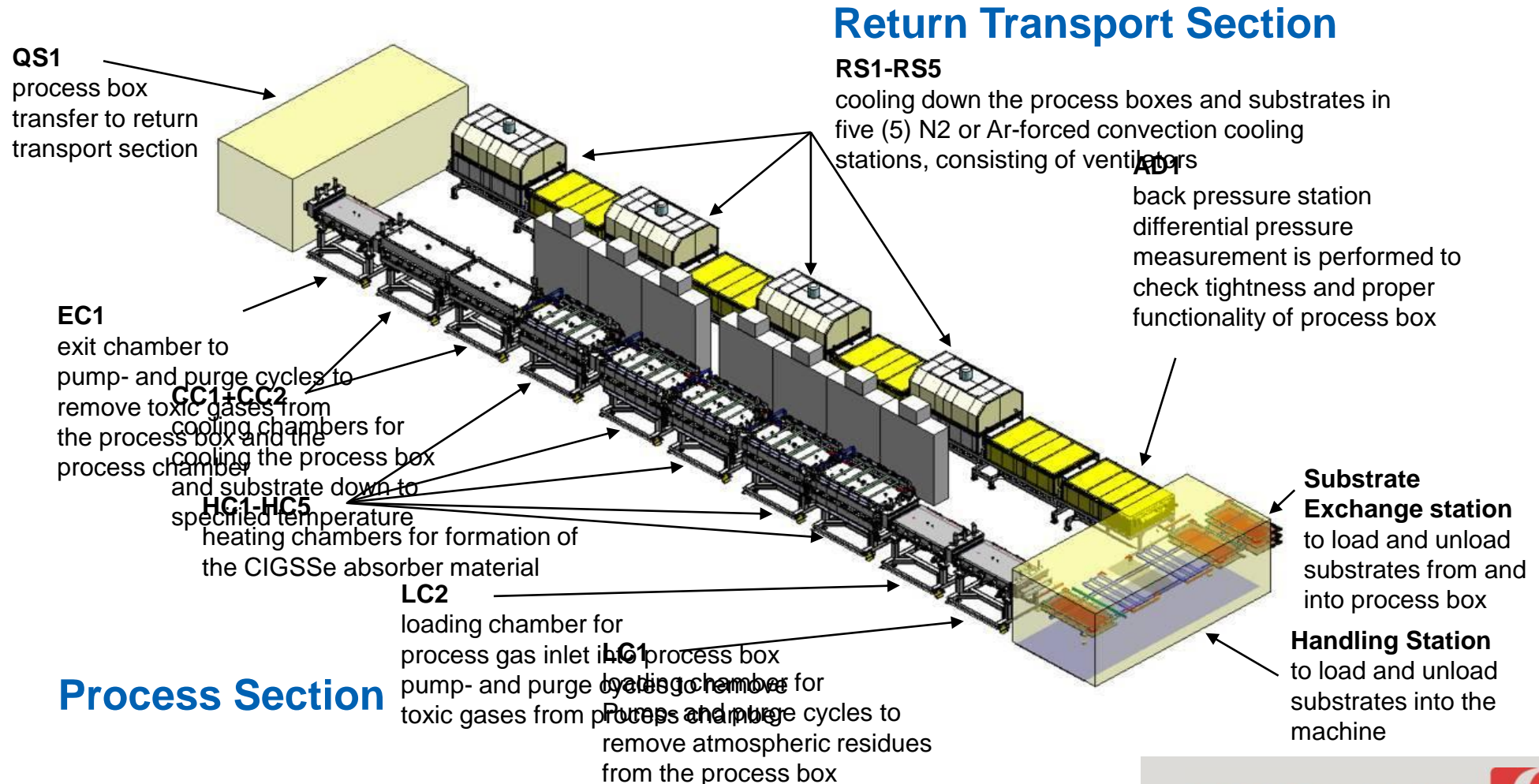
- **Material: Cu/Ga/In/Se precursor on Mo-coated glas**
- **Glas dimensions: 1600 mm x 660 mm**
- **Heat rate: up to 4 K/s**
- **Temperature profile: RT → 550 °C, max. homogeneity**
- **Process gases: Se, H₂S, N₂**
- **Process cycle: ~ 10 min**
- **Gas atmosphere: inert (< 10 ppm O₂)**

CISARIS Inline Diffusion Furnace for CIGS Solar Cells



- Product introduced 2010
- 8 Machines already sold / FAT for 1. machine passed
- up to 25 MW capacity per machine

CISARIS Inline Diffusion Furnace for CIGS Solar Cells



Technical furnace information



- Rapid heating (up to 4 K/s) of large substrates with Se-covered metal precursor coating (CIG)
- Homogeneous gas distribution and low consumption through optimized inlet
- Introduction of H_2S (H_2Se) gas at various stages of the process possible
- Tact time < 135 s
- Footprint: 36 m x 10 m

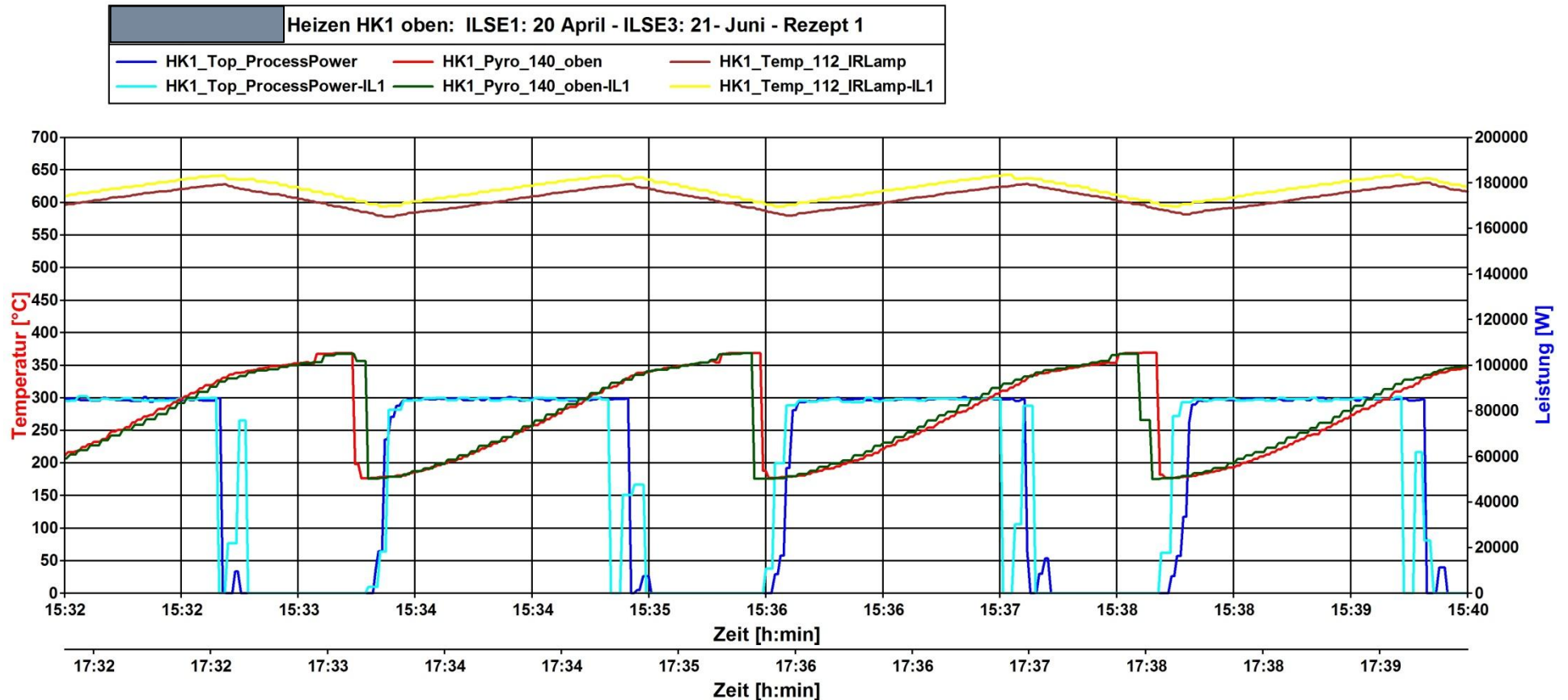
Technical furnace information



- Uniform heating of large substrates up to 550 °C by using optimized IR radiators for achieving the required crystal quality
- Uniform substrate cooling to avoid glass warpage
- Excellent temperature control (~ 2 K) at all process stages
- Process at atmospheric pressure
- Oxygen and water vapour free process atmosphere guaranteed through pump/ purge cycles

Technical furnace information

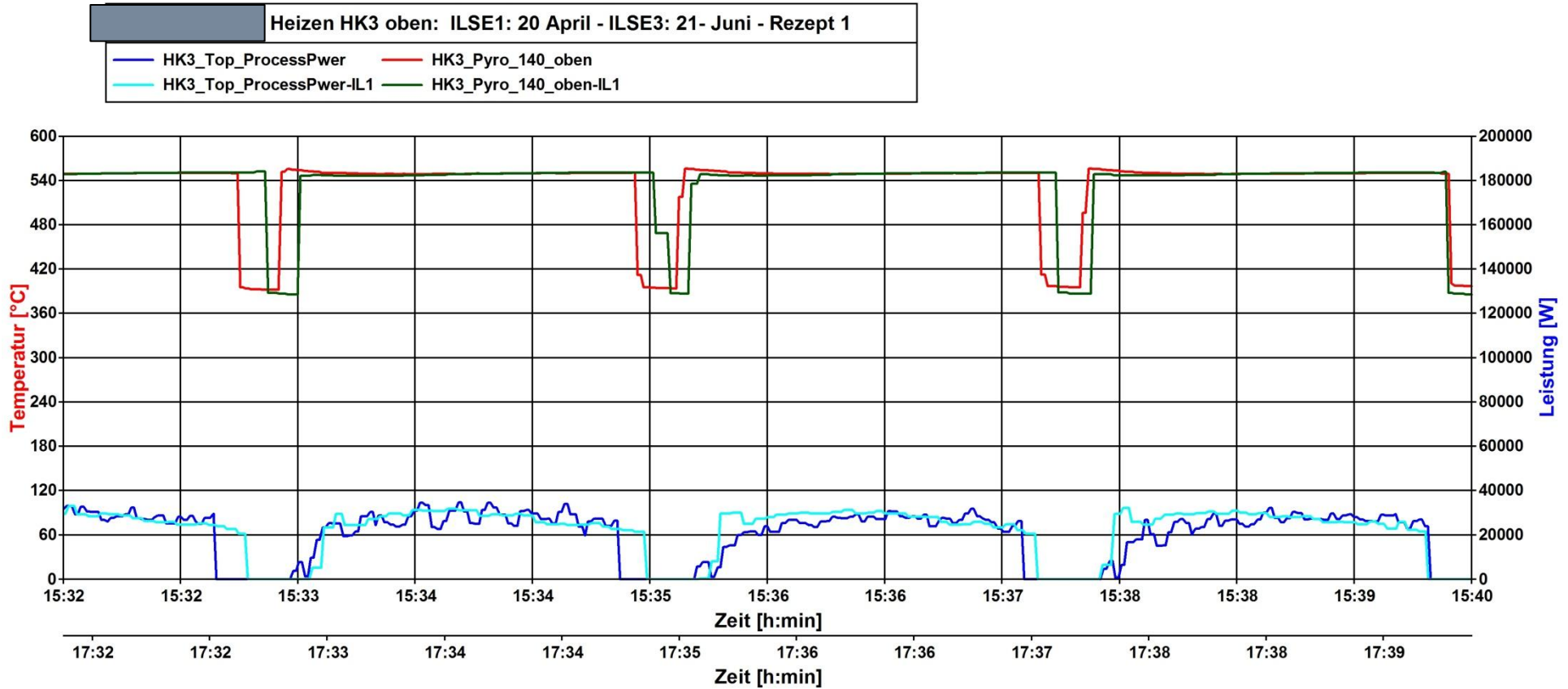
Substrate heating: Adjustable heater array



Target: Homogeneous substrate heating at heating rates $> 3\text{K/s}$

Technical furnace information

Substrate heating: Adjustable segmented heater array

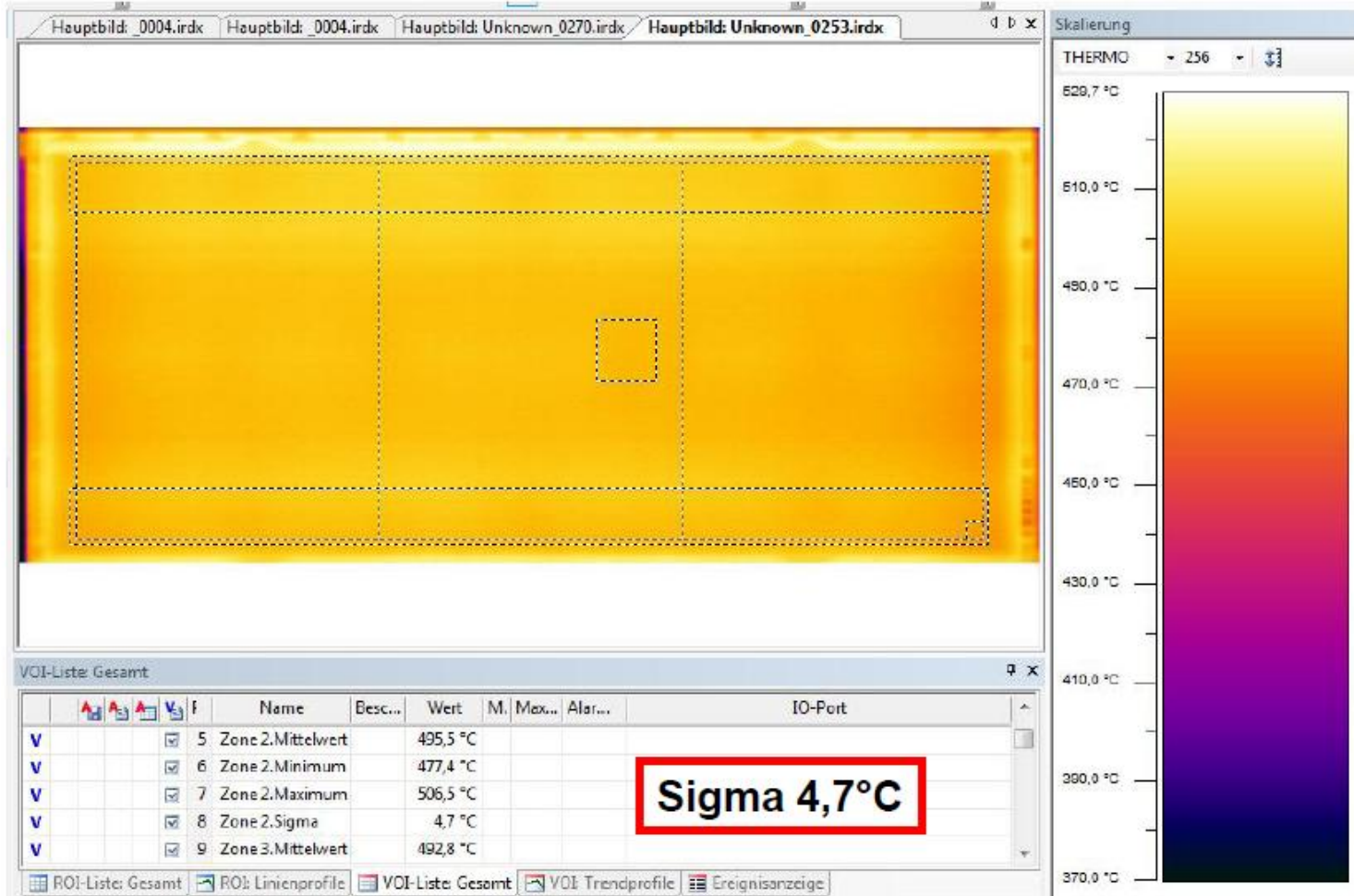


Target: Homogeneous substrate heating

Technical furnace information

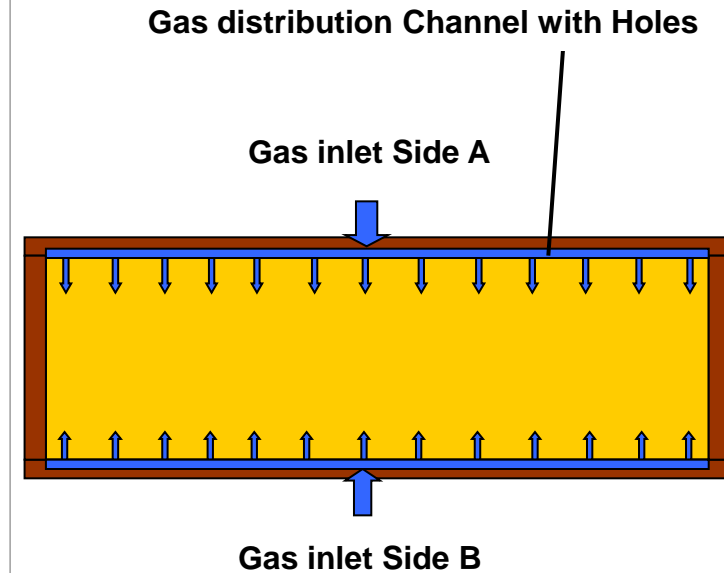
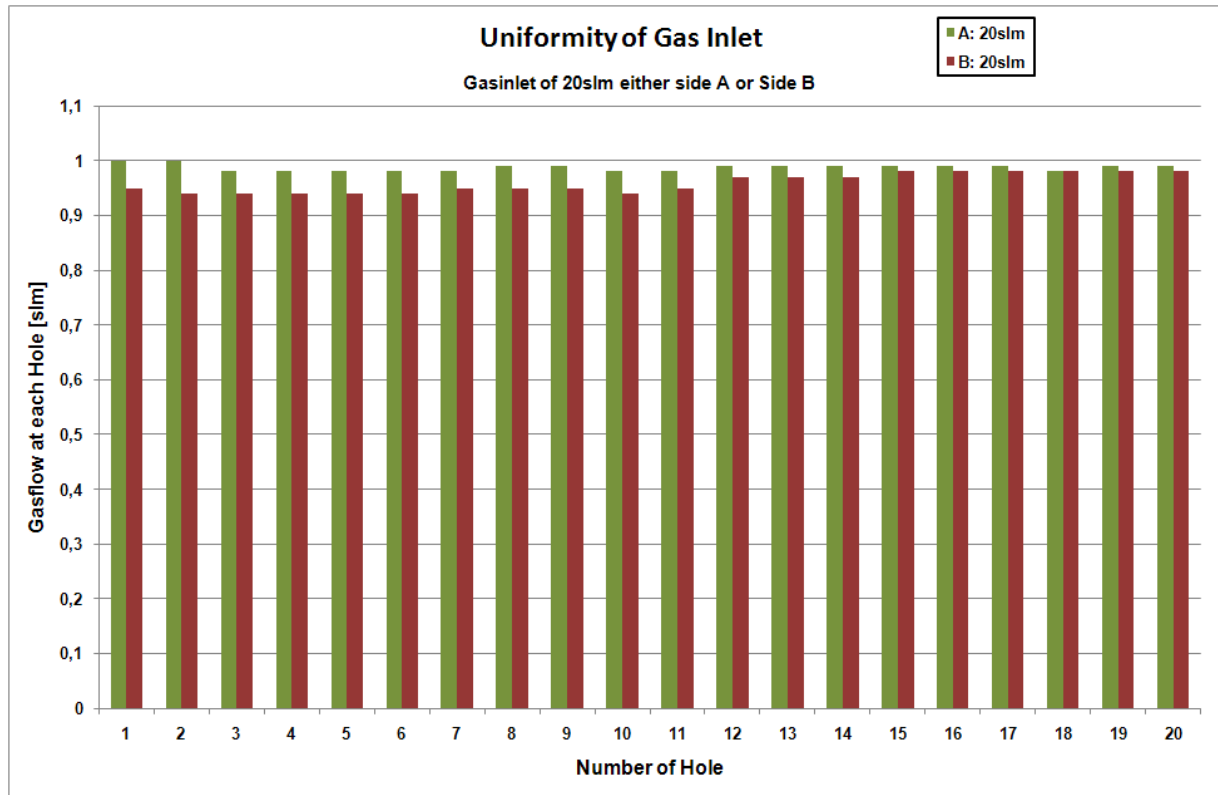
Temperature homogeneity

Temperature cross section over glass sheet



Homogenous gas distribution

Measurement of homogenous gas flow into the box



- **Safety**

- Alle HSE aspects due to use and formation of toxic gases are considered and a series of actions are taken in order to prevent any risks ($\text{H}_2\text{S}/\text{H}_2\text{Se}$ absorbers, pump/purge cycles, exhaustion of the housing, modern detection systems inside and outside of the machine).

- **Hardware**

- The corrosion of machine components by S and/or Se containing atmosphere is avoided by the use of qualified materials.
- The deposition of volatile species such as sulfur and selenium in the machine is avoided by optimized heating of the chamber walls and the exhaustion tubes.
- The maintenance of the equipment has been optimized, so that a maximum uptime is guaranteed.

- In Line Selenisation furnaces of the same type have been running successfully in a German 20 MW production site since 2 years, efficiencies of over 12,5 % have been achieved on a 1 m² substrate surface (best modules > 135 Watt, in average ~ 125 Watt)
- New furnaces provided by SINGULUS can be operated at faster cycle times (100% increase of the throughput) and higher uptimes
- Prototype of the In Line Selenisation furnace designed by SINGULUS can be used for experiments
- Scientific and construction know-how available
- Ongoing project for further process and machine developments for the next generation (e.g. increase of the throughput, introduction of H₂Se for the absorber formation, reduction of gas and power consumption)
- Full time process engineers and technicians during design, assembly and test phase

Summary



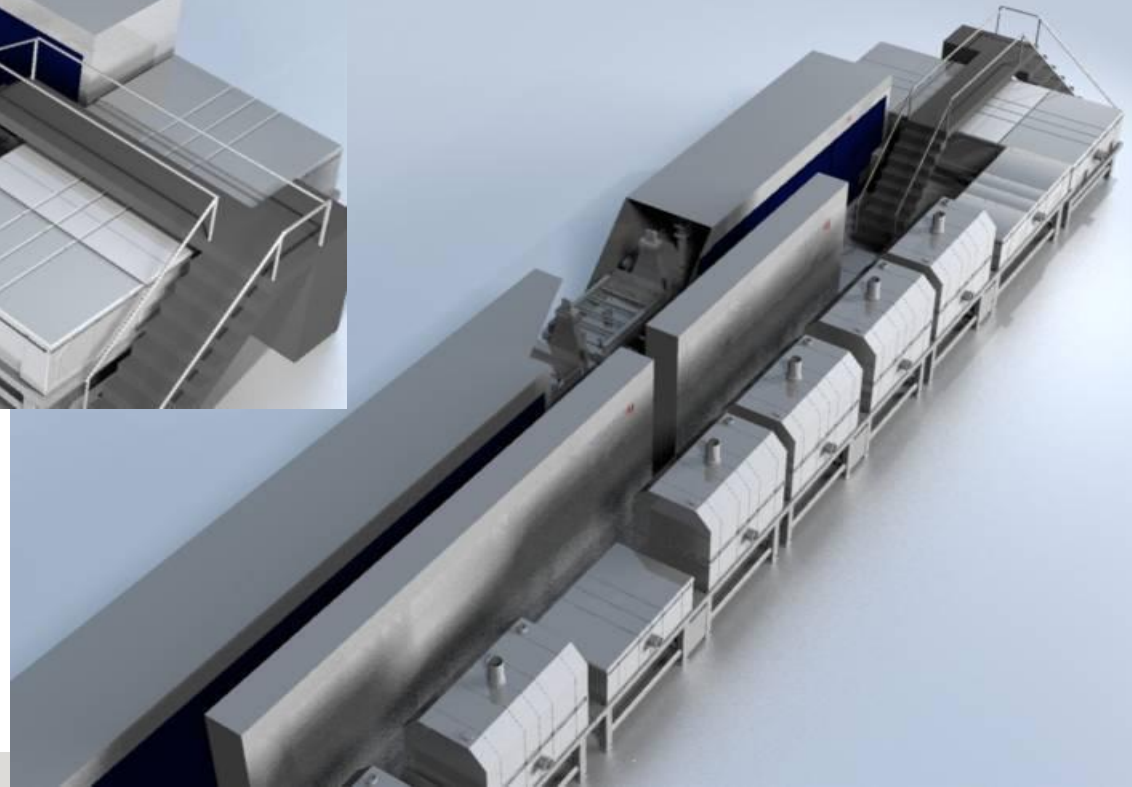
Basic facts

Throughput: up to 25 MW*

Machine Yield: 99,5%

Uptime: >85%

**depending on efficiency, substrate size and process time*



**Thank you
for your attention!**