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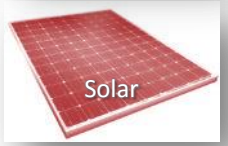
GPsolar

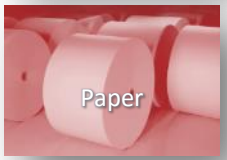
Challenges for Inline Optical inspection in PV: High Performance at High Speed and Low Cost

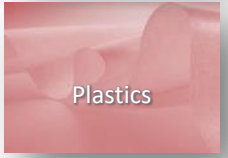
PV Days 2017 / Fraunhofer CSP,
Session: Metrology and Quality Control in PV

Dr. Christopher Berge
24. October 2017

ISRA Vision worldwide markets



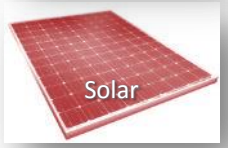


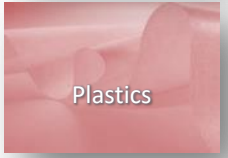


HIGHLIGHTS of ISRA Vision

›	Established	1985
›	Legal form	AG, public company
›	Employees	> 700 (incl. >100 in China)
›	Sales (16/17)	146.5 mill. €
›	R&D – Invest	~ 19 mill. € p.a.
›	Equity	159 mill. € >55%

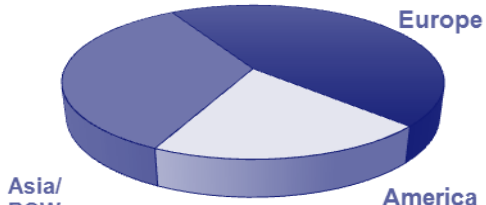
ISRA Vision worldwide markets

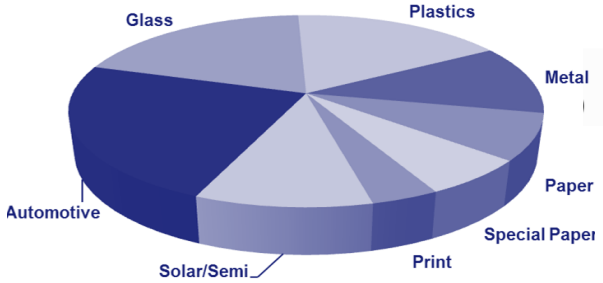




HIGHLIGHTS of ISRA Vision

- German Company
- Active in world-wide markets since > 20 years
- Semi-EL and Solar are strategic markets
- Long-term growth strategy

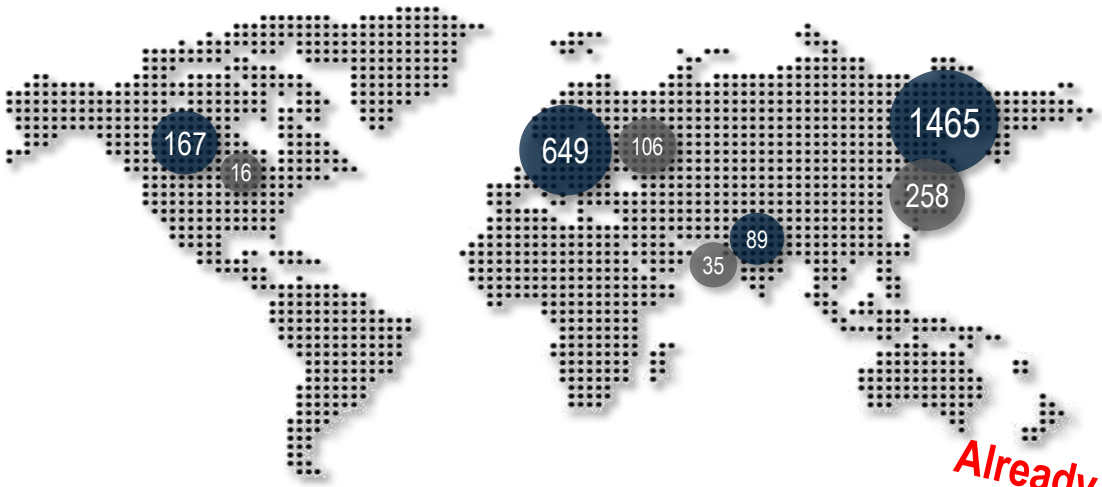




ISRA VISION / GP Solar – No. 1 for PV Industry

Leading world-wide installed Base

- more than 2.600 systems installed



ISRA VISION / GP Solar

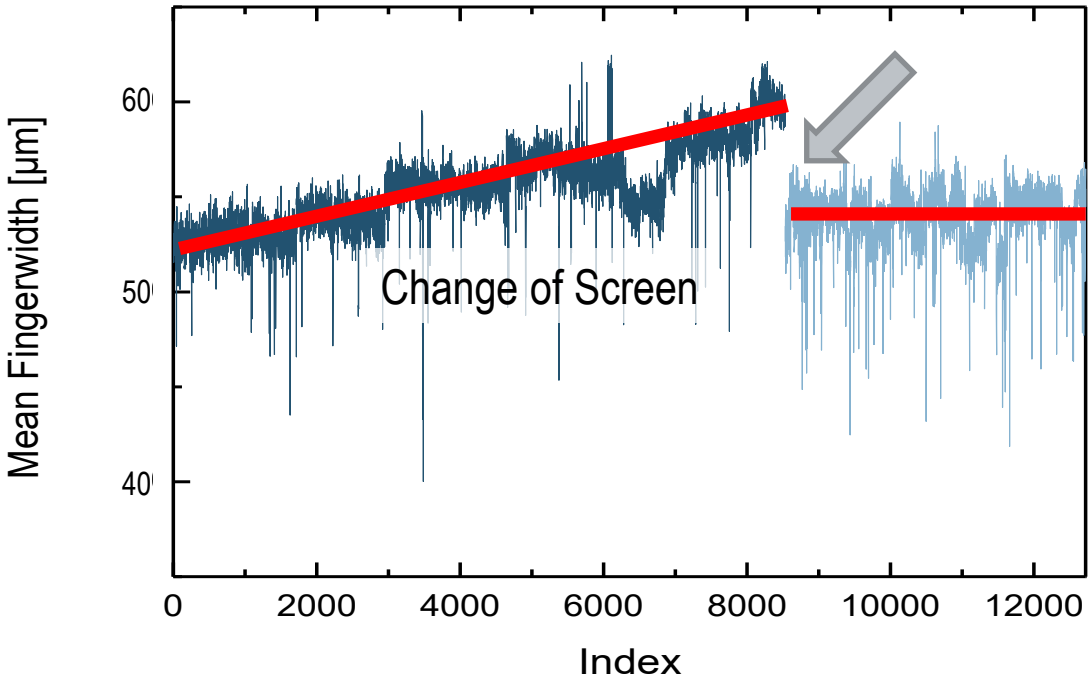
- Inspection Solutions from
  > Solar Wafer to Module <
- Latest solar technology support
- Inline Inspection integrated in all major automation suppliers world-wide
- Stand-alone Inspection Solutions

Already >340 new installations in 2017.
> 8 GW inspection technology for PERC

Process Control Benefits

PRINT-Q – Screen Printing Inspection

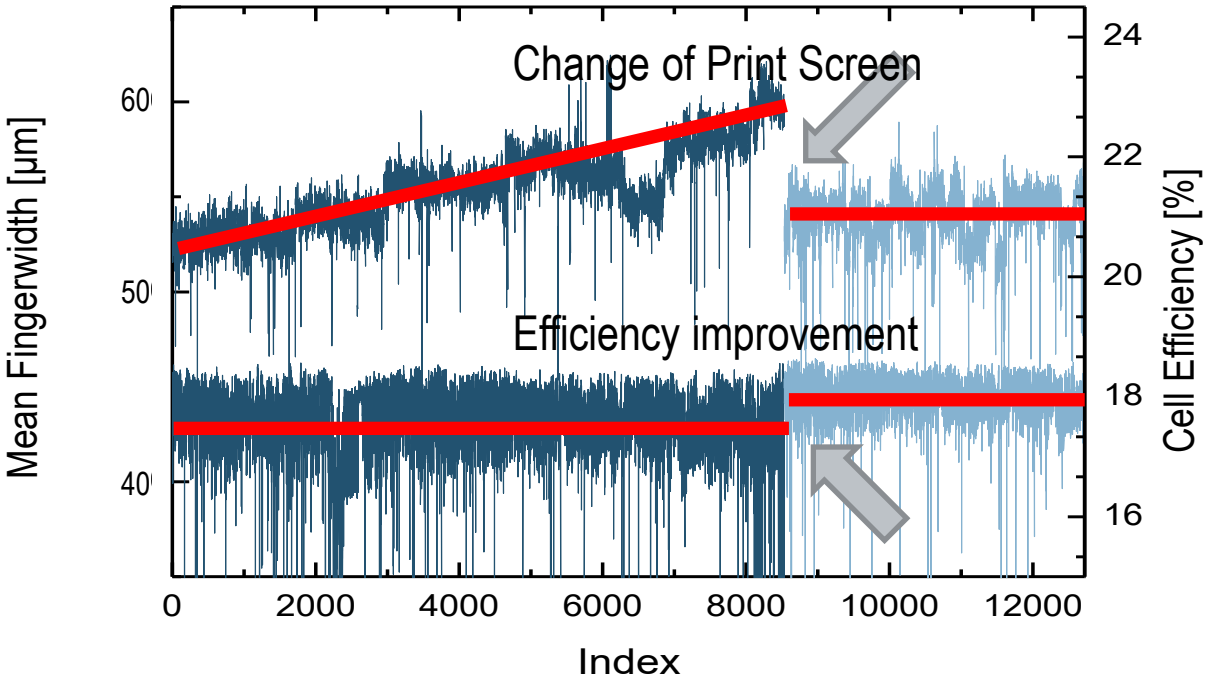
Effect of screen change



Bad print screen can be detected by finger width unstability.

Is it relevant?

Effect on Fingerwidth & Efficiency



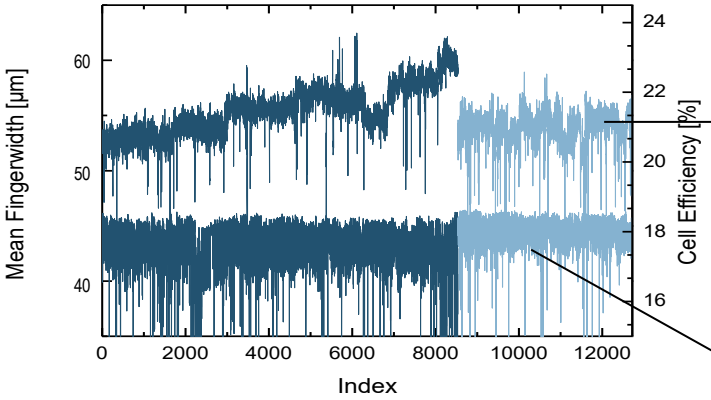
Fast Reaction on Process leads to Efficiency improvement

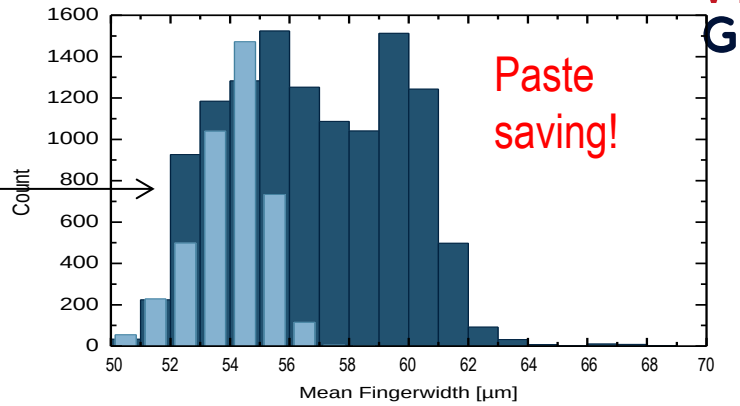
Bad print screen can be detected by finger width unstability.

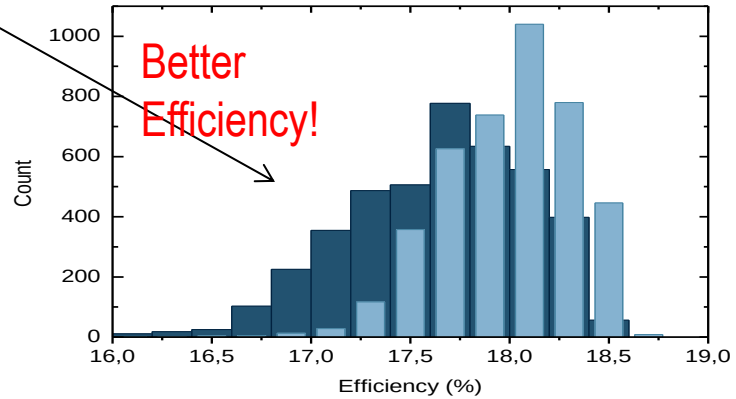
Is is relevant?

YES IT IS!

Effect on Fingerwidth & Efficiency





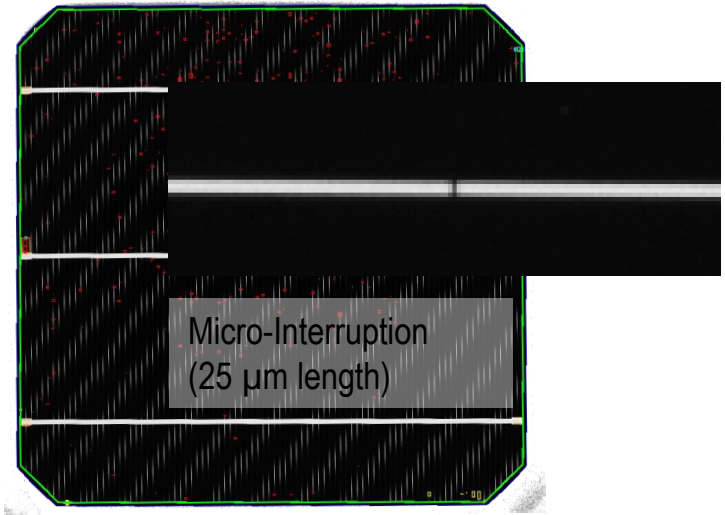


Inspection can improve average efficiency

High-Resolution Defect Example: Micro-Interruptions

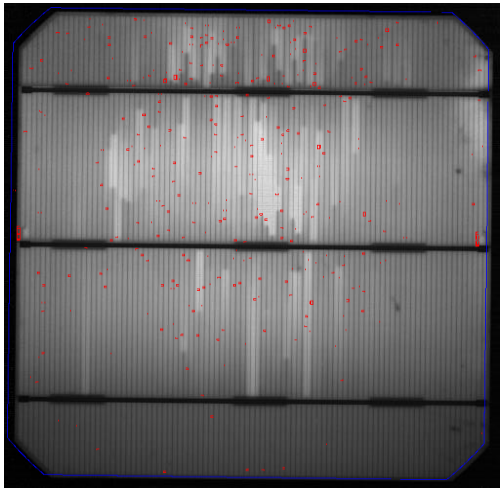
Print-Inspection of bad cell

Finger width < 50µm
Many micro-interruptions visible (<30µm)



PL Rseries Image of bad cell

Overlay of detected interruptions shows:
the micro-interruptions are reason for bad contacting



➔ **High-resolution print inspection PRINT-Q 30M+ can reduce cost structure more than 10% - improve production at once!**

Challenges for Inline Optical inspection in PV

Requirements and Benchmarks

Processing Aspect

New processes - material "looks" different

- new texturisation approaches
- Diamond wire cutting of wafers (mono, multi)
- "DirectWafer" approaches

New cell designs

- Inspection of new processing steps
- New critical defects
- New materials
- More complex designs/patterns/features

Industry Aspect

Integrated Multi-GW fabs

- multiple lines running parallel on same product (sometimes different process equipment)
- multiple production sites with same quality requirements

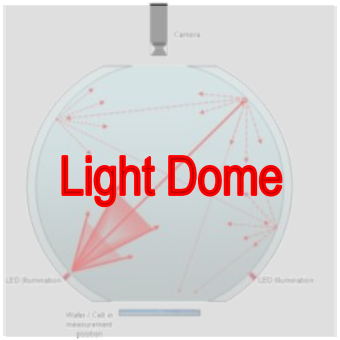
Cost pressure

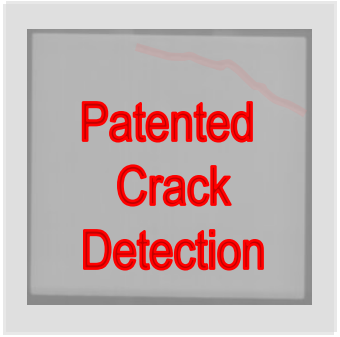
- reduced maintenance / operator costs
- higher availability and productivity (UPH)
- improve quality, but do not add complexity!

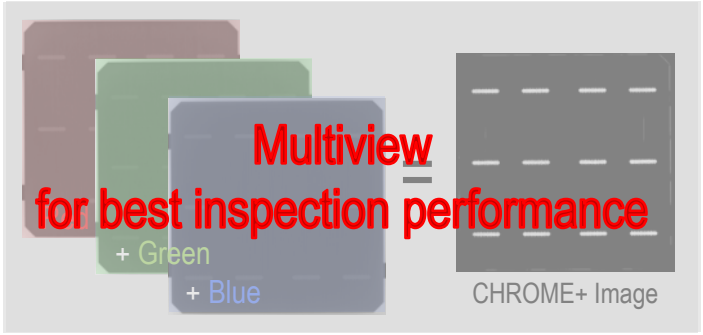
ISRA GP Technology – Solar Industry Inspection Standards

ISRA VISION GPsolar

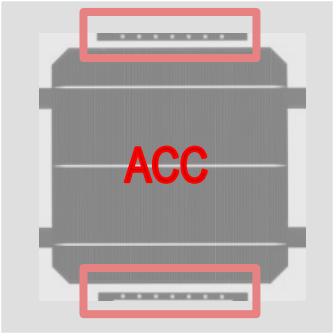
Processing Aspect

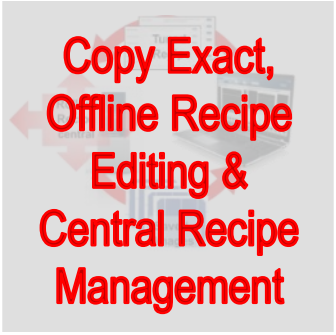






Industry Aspect





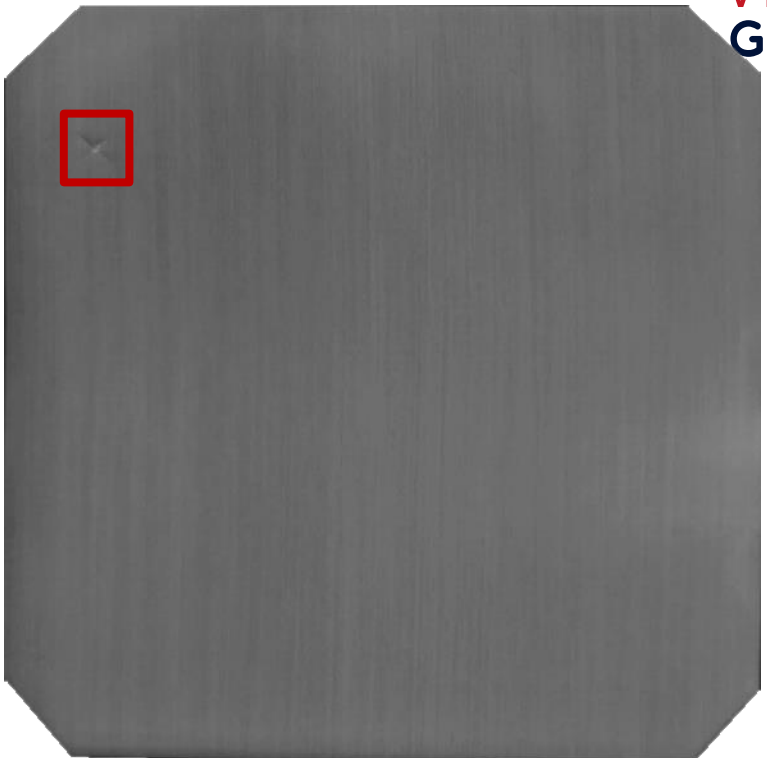
Micro-Crack Inspection on Diamond Wire Cut (DWC) Wafers

Micro-Crack Inspection on Diamond Wire Cut Wafers

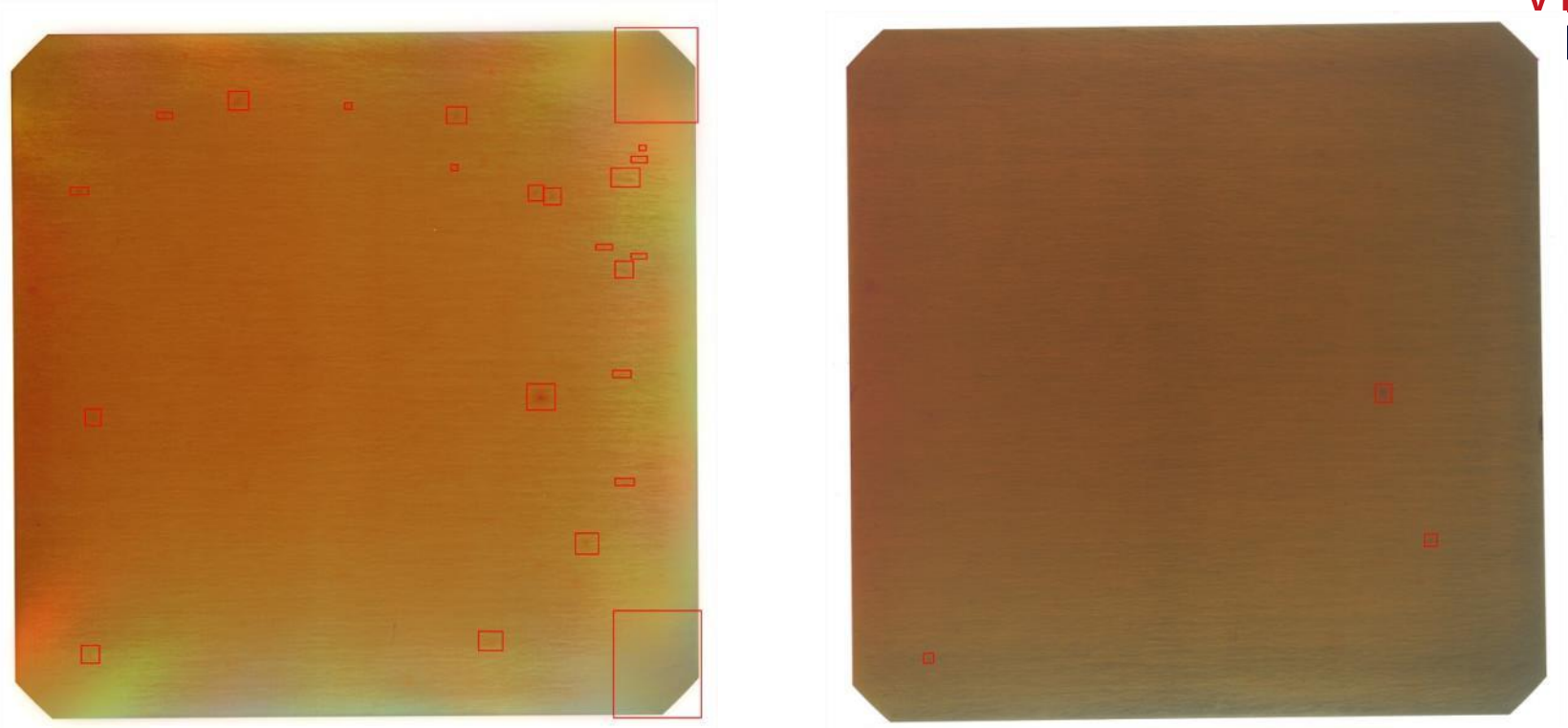
Challenge:

- anisotropic structure on surface caused by "pilgrim“ movement of the cutting wire
- shiny surface with anisotropic speculiar reflectance

Solved with NANO-D Inspection setup



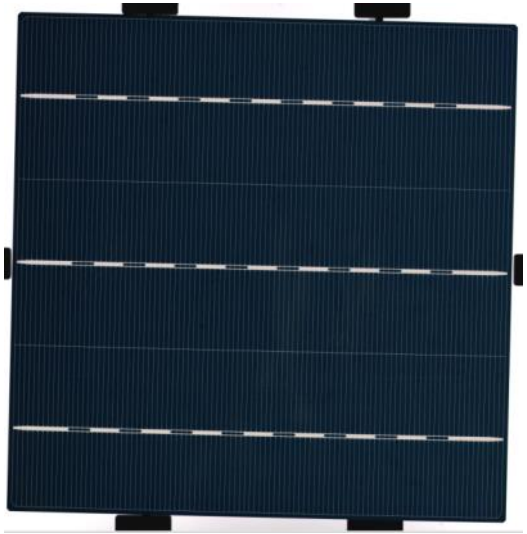
DWC Wafers – PERC Rear Side Coating inspection



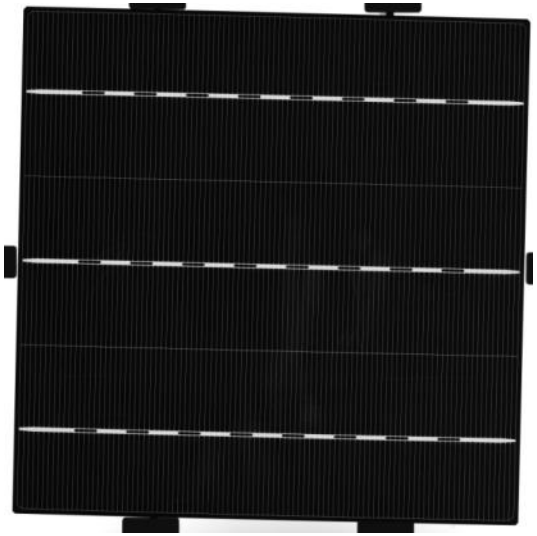
Standard Illumination (left) affected by direct reflexes ("streaks") causing overkill or reduced sensitivity

Surface Inspection Improvements

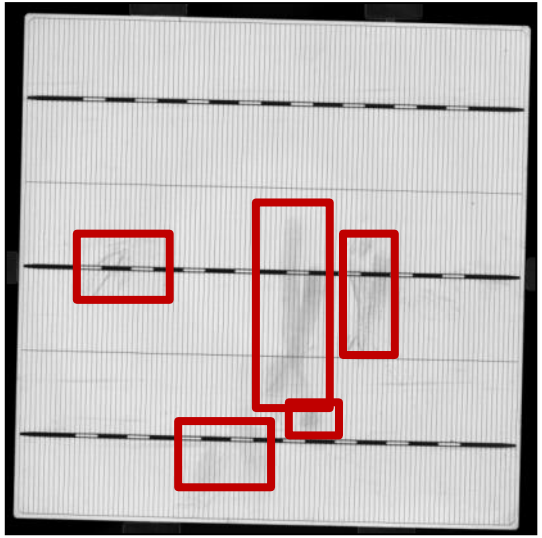
Practical Example



Color Image



Red Image



Saturation Image

Front and Rear Print Designs - Standard and PERC Cells

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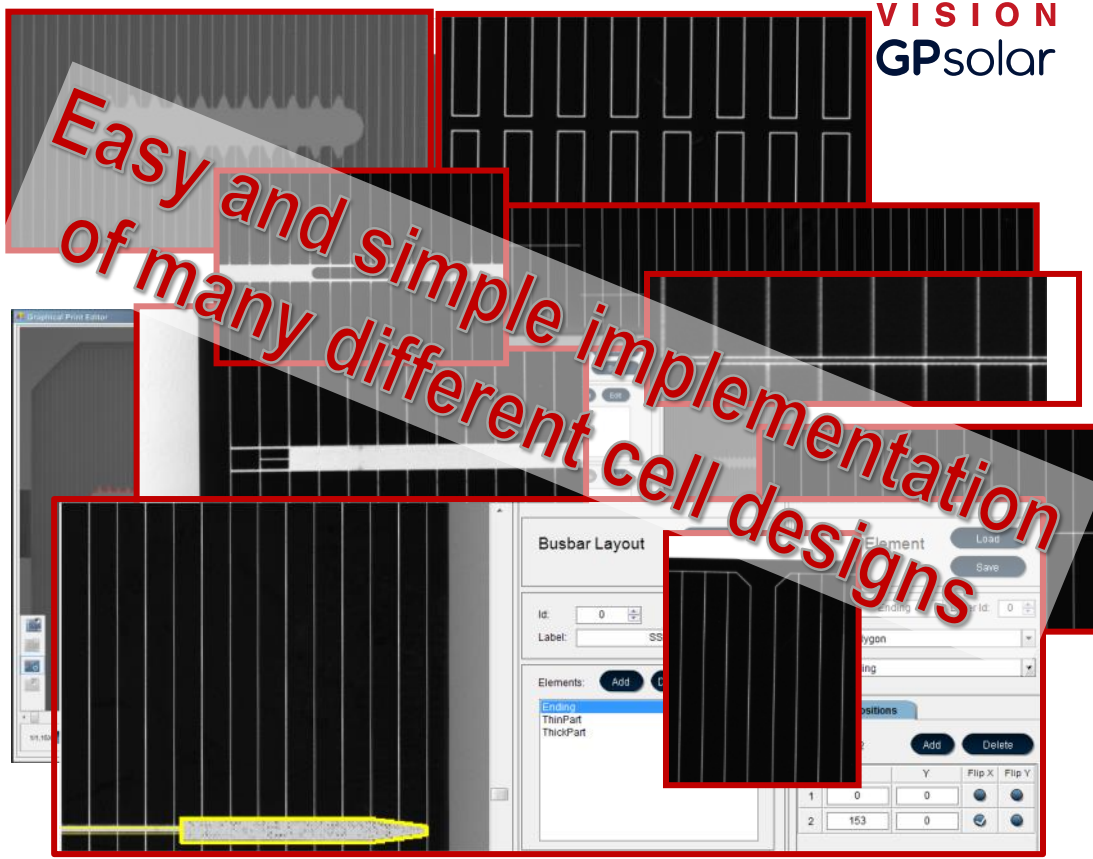
Front Side Inspection
Multiple Design Elements - Busbars, Fingers, Closings, Inner Redundancy Lines, …

Rear Side Inspection
Special Rear Side Busbar Design
Combined with PERC process

Bifacial Cell Designs
Rear side print patterns similar to front, new inspection features

IBC Cell Designs, HIT structures

Solved with Advanced Print Editor in GP Software Suite



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Cost pressure

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Global Quality with Copy-Exact-Concept - *minimize engineering costs*

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CHINA
FAB 1

Copy
Exact

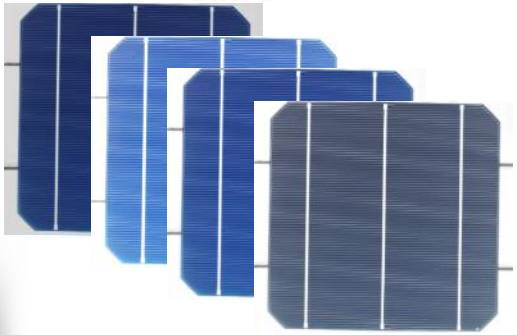
MALAYSIA

Copy
Exact

THAILAND

Copy
Exact

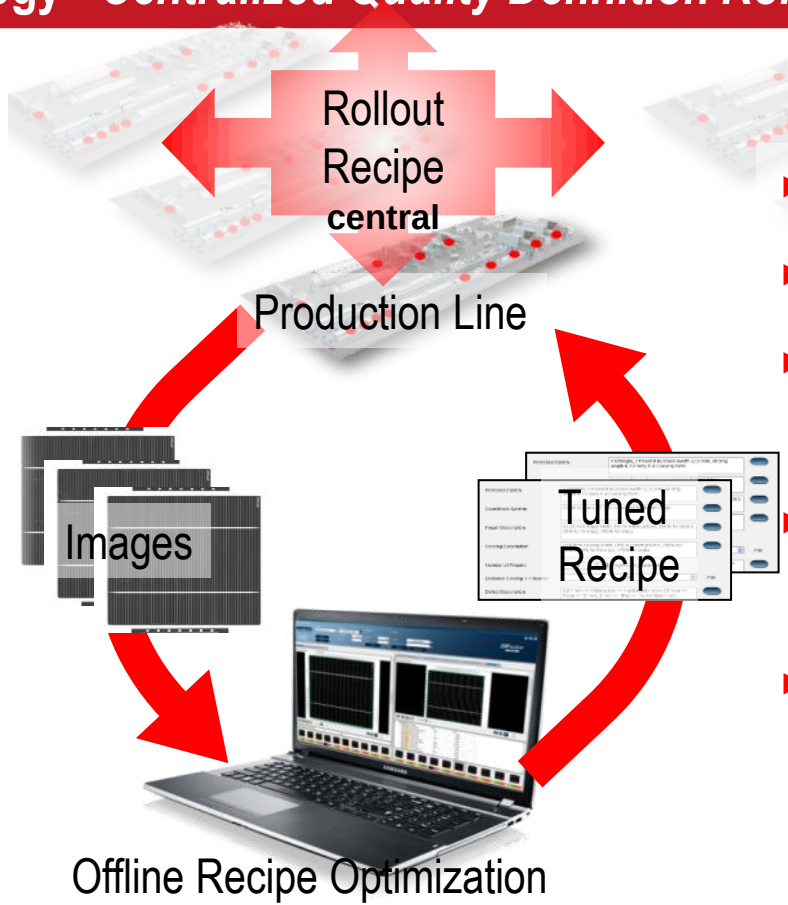
CHINA
FAB 2



ISRA GP Calibration
generate equal images

SAME Quality Sorting,
independent of location:
One Global Standard - Anytime, Anywhere

Inspection Technology - *Centralized Quality Definition Rollout*



- Save images in the production line
- Transfer images and recipe to office PC
- Edit recipe with **Offline Recipe Manager** and test recipe on stored images
- Transfer **optimized recipe** back to production
- **Recipe management, version history and centralized rollout** with Central Recipe Tool (CRT)

CRT 2.0 Components

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Recipe Files (xml or gp-archive)

Recipe Compare Tool

Compare Recipe two Versions

2 Specific Recipe Version

Shows all Recipes, Activities & Inspection Systems

CRT Client

Specific Recipe Version

Offline Recipe Tool

Edit and Show Recipe Version

CRT Server

Download & Execute Central Recipe

AutomaticTool

Recipe Tool

Edit Recipe Version

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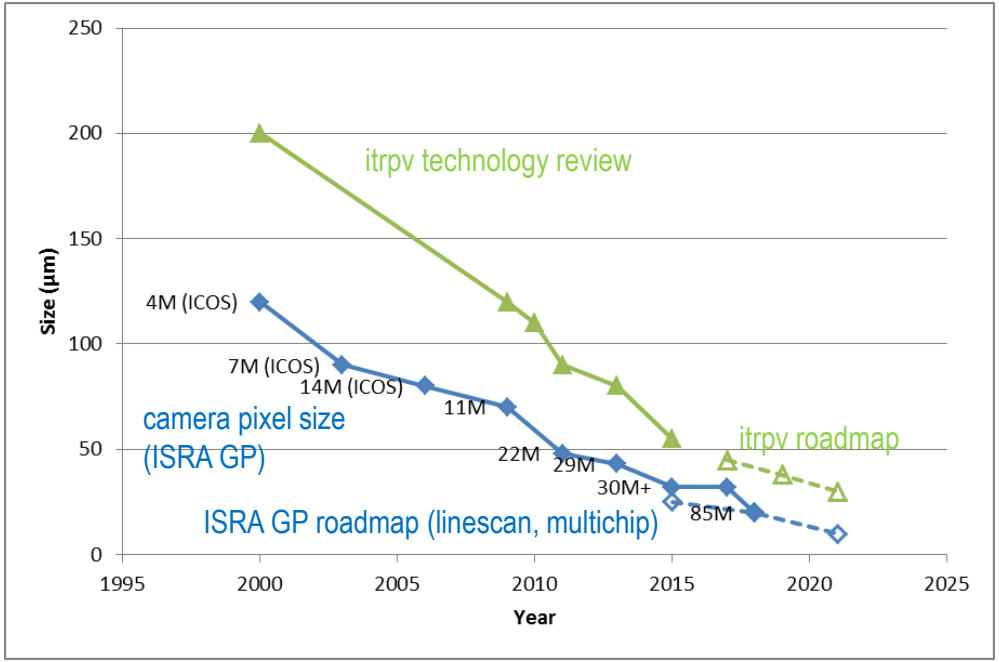
International Technology Roadmap PV (itrpv)

Available chip resolutions (matrix camera) scale with target print feature sizes – but price scales with pixels!

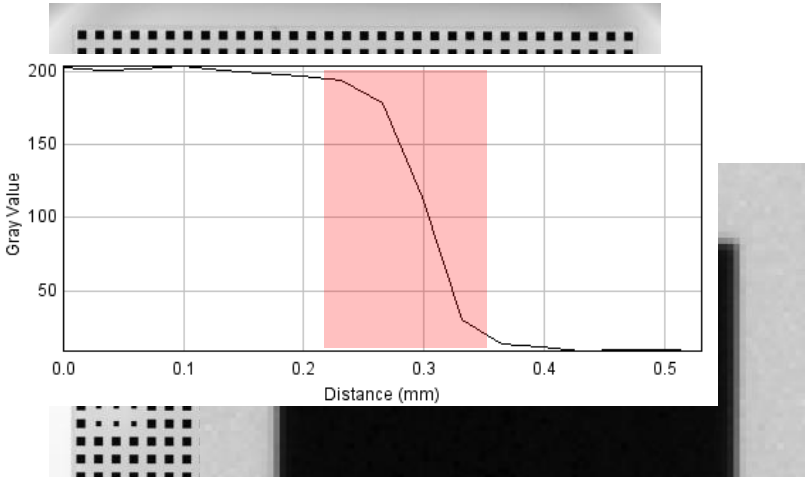
And: the air becomes thinner!

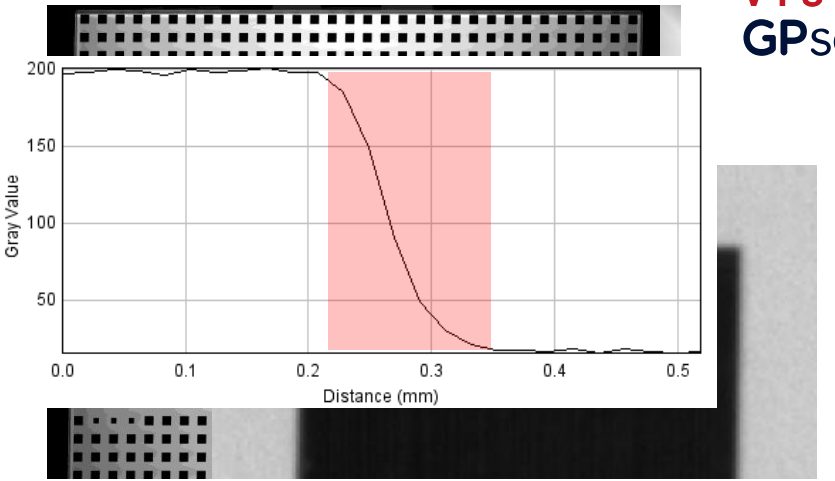
- Print Sizes drop faster than Matrix Camera Resolutions increase (not talking about costs…)
- "Defect sizes" (defects to detect) are already smaller than pixel sizes!
  - Status (2017): 32 µm pixel size, interrupts > 40 µm can be detected
  - customers request already <30 µm
- Good news: 85M camera (20 µm) on the way…
- but what about the price?
- What about the amount of data?



More features → Higher resolution → more data to process - at shorter cycle time – for less money!

Calibration Target in High Resolution





- Width of transition region is same for both resolutions
- The additional resolution does not make the transition "sharper
- The 30M+ camera already works at the diffraction limit:
  - higher resolution does not give more information!
  - We are not yet talking about vibration…

Comparison Line Scan vs. Matrix / Finger Defects

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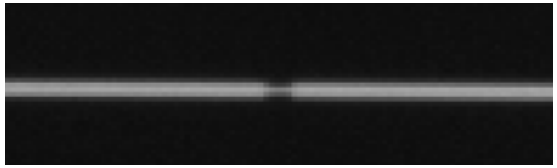
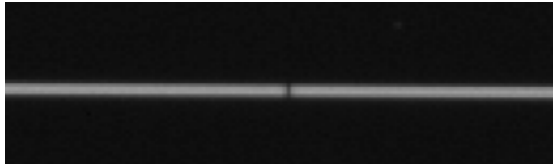
Matrix Image with 25MP
5120 x 5120 / 32 µm pixel size

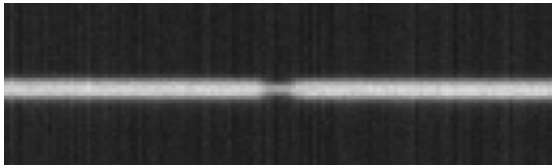


Finger Thinning 50 %
(50 µm width, 150 µm length)



Finger Interruption
(30 µm length)

Linescan Image with 8k / 64M
8192 x 8192 / 20 µm pixel size



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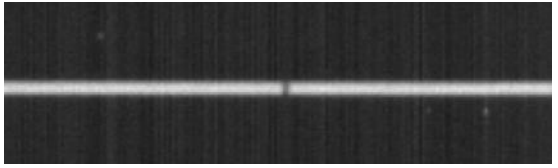


Finger Interruption
(30 µm length)

High pixel resolution of Linescan Image does not increase steepness/sharpness of structures, only "smoothing" - same as interpolating!

Both Images without Flatfield Correction. Linescan Image taken on Montech Transport

If camera technology is solved - what else?

High resolution imaging needs "perfect environment"

Exclude vibration of the camera

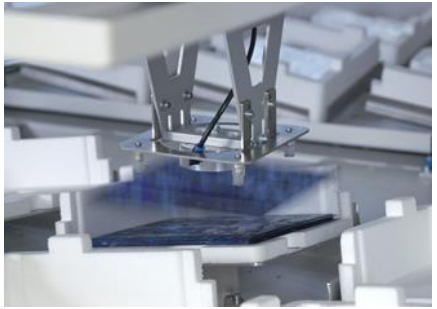
➡ new machine designs needed?

Current Machine Design with integrated inspection

Sources of machine vibration:

Moving handling elements in the machine

- Flex Pickers
- Gripper axles with fast acceleration/deceleration
- Carrier Lifts, Spindle Lifts, …



Transport Belts in the inspection part

- Vibration during transport
- Vibration during standstill

External Vibration

- even with de-coupled machines, vibration spreads via ground floor

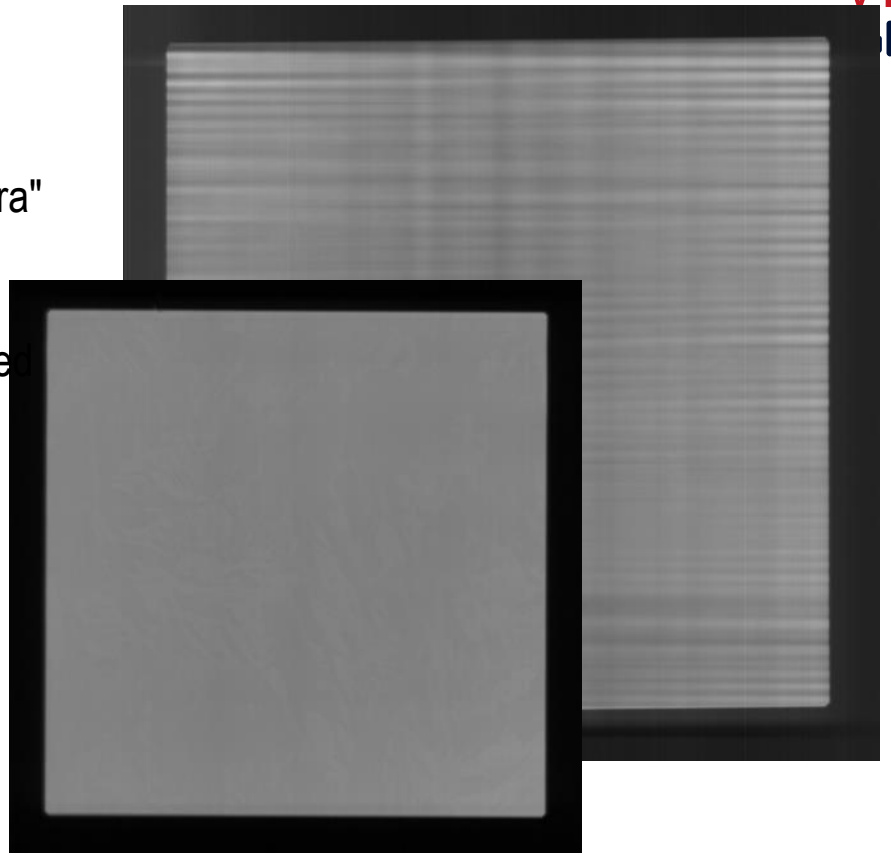
Vibrations are already noticeable with 12M and 30M+ systems!

Vibration is no theory…

NANO-D Scan Image
1k IR Camera

Machine vibration during transport causes "zebra" pattern

Scanning when other machine parts are switched off yields perfect scan image



Requirements for "real" <20 µm pixel resolution for inline inspection

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Stiff and warp-resistant inspection housing - solved at ISRA GP Solar

Vibration-decoupled inspection unit (with integrated inspection housing)

- not connected to any moving parts
- decoupled from ground floor vibrations

Precision Transport

- no "motor vibration" during standstill
- no "after shocks" in the (elastic) belt after stopping
- precision scanning axes for scan systems

This is already standard in the semiconductior industry
…with higher costs and lower throughputs

Joint Effort Required:

Design new machine concepts together with Handling Suppliers:

- low vibration, no shock
- high throughput

New Machine Concepts needed for Solar Industry!
"Low cost linescan" can be more than compensated by "high profile transport"!

Summary

Inspection is technically well prepared for current and future technologies.

- Shorter cycle times and more complex inspection tasks to be addressed by vision suppliers (optimization of inspection algorithms, optimization of inspection hardware)
- "GW Industry" requirements (central recipe management, reduced maintenance etc) by optimized software concepts and centralized data services

However, cost pressure impacts performance: requirements not reachable with "cheap" systems

Resolution for detection of small defects and inspection of small structures

- Image quality vs. transport quality / cost / throughput at ultrahigh resolutions (20 µm and smaller)
  - Vibration during image acquisition
  - Precision of Transport for Linescan
  - Transport speed / scanning speed vs. "antireflection coated, dark light trapping samples" - more light!

As always, unknown obstacles may appear unexpected!

- Early cooperation between customer and supplier R&D at an early development stage

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谢谢
thank you
danke
謝謝
ngiyabonga
teşekkür ederim
gracias
merci
obrigado
bedankt
dziękuję
go raibh maith agat
mochchakkeram
sukriya
kop khun krap
terima kasih
grazie
arigatô
dakujem
takk
tapadh leat
спасибо
рахмат
Баярлалаа
mersi
kia ora
barka
welalin
tack
spas
dank je
misaotra
matondo
paldies
grazzi
mahalo
faafetai lava
vinaka
спасибі
blagodaram
kiitos
dankie
dhanyavad
nanni
nandri
mauruuru
köszönöm
hvala
gràçie
bayarlalaa
enkosi
хвала
asante
manana
obrigada
murakoze
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sulpáy
taiku
sobodi
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sagolun
mèsi
didi madloba
najis tuke
kam sah hamnida
rahmat
ありがとう
tanemirt
rahmet
ευχαριστώ
diolch
dhanyavadagalu
shukriya
mercê
мерси
trugarez
তোমাকে ধন্যবাদ
감사합니다
xièxie