Artificial Neural Networks for Process Control

How to measure less than 10,000 chips instead of over 100,000 and still get the same result.

Maike Stern
Group Equipment and APC, 13.12.17
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- Some Intuition about Fully Convolutional Networks
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Probing

- Probing – electrical and optical measurement of every single chip:
  - Electrical and optical properties
  - Defect chips

→ Time-consuming and thus expensive

Probing

measurement needle

LED-chips

Probing result

el./opt. chip values

defect chip

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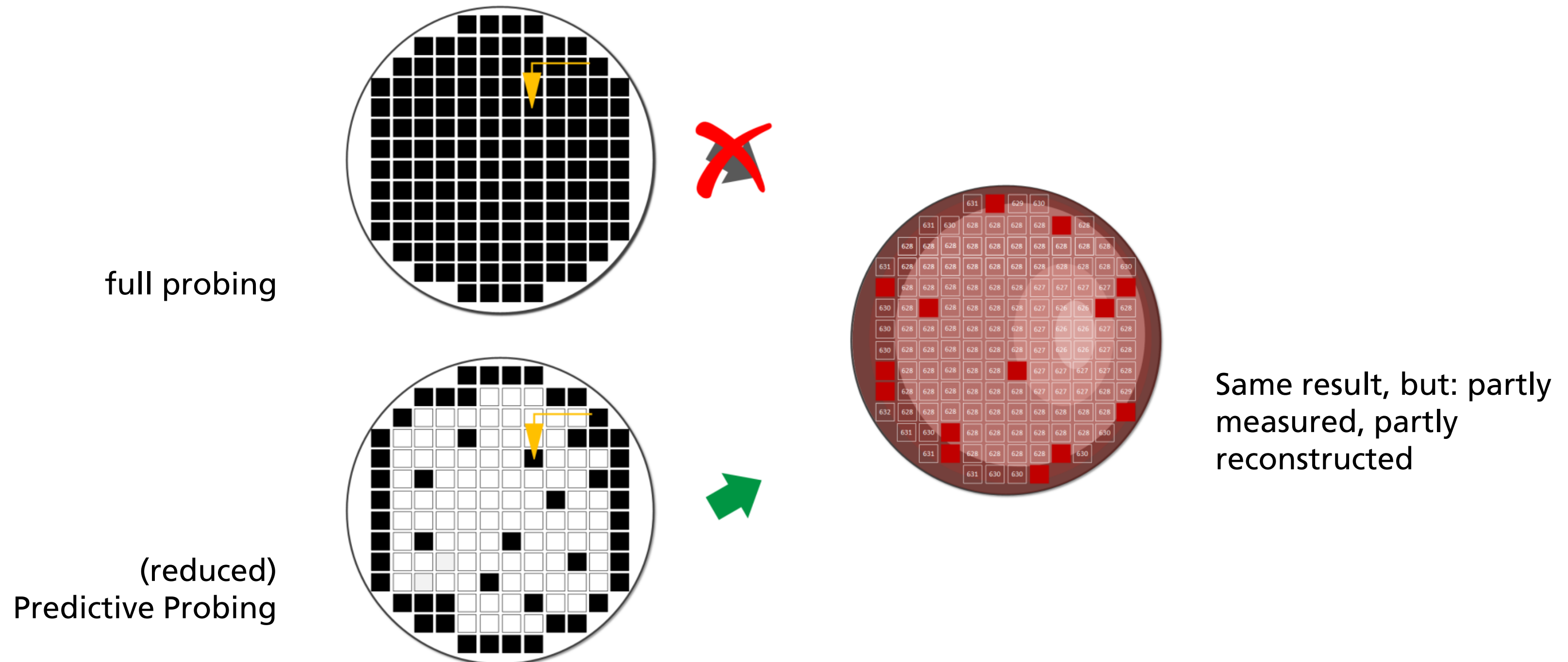
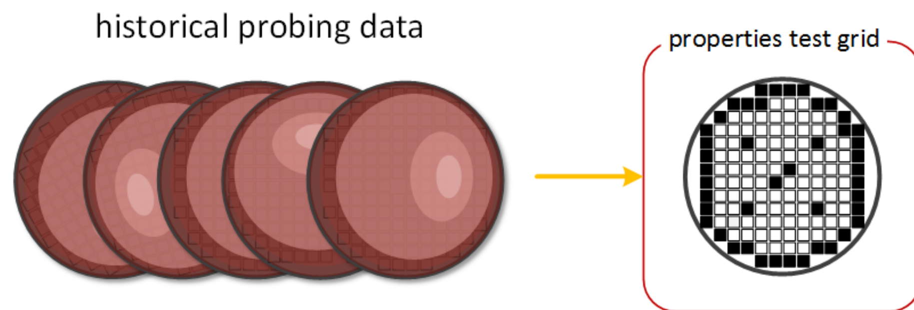
Predictive Probing

- Predictive Probing [1]
  - Reduced probing of a selected number of chips
  - Based on data analysis



Predictive Probing | Probing Map

- Optical and electrical properties:
  - Basic test grid based on analysis of historical probing data



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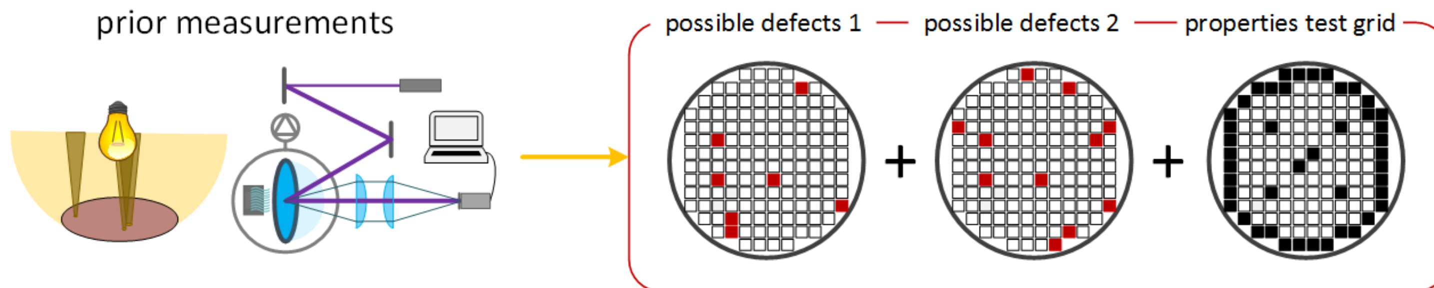
Predictive Probing | Probing Map

- Optical and electrical properties:
  - Basic test grid based on analysis of historical probing data
- Defects:
  - Analyse measurements prior to probing
  - Individually calculate specific defect test grid for every wafer



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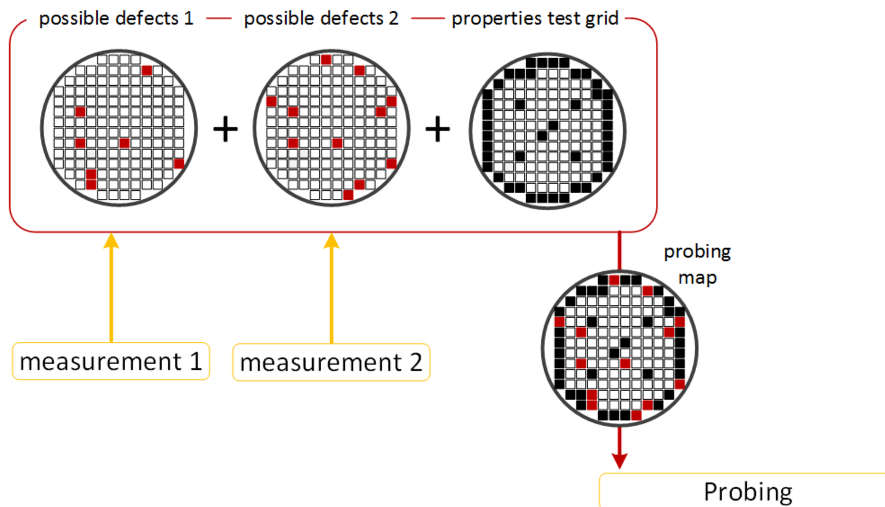
Predictive Probing

Two-step Predictive Probing process:

- Compile probing map to determine electrical and optical properties as well as defects and then probe selected LED-chips



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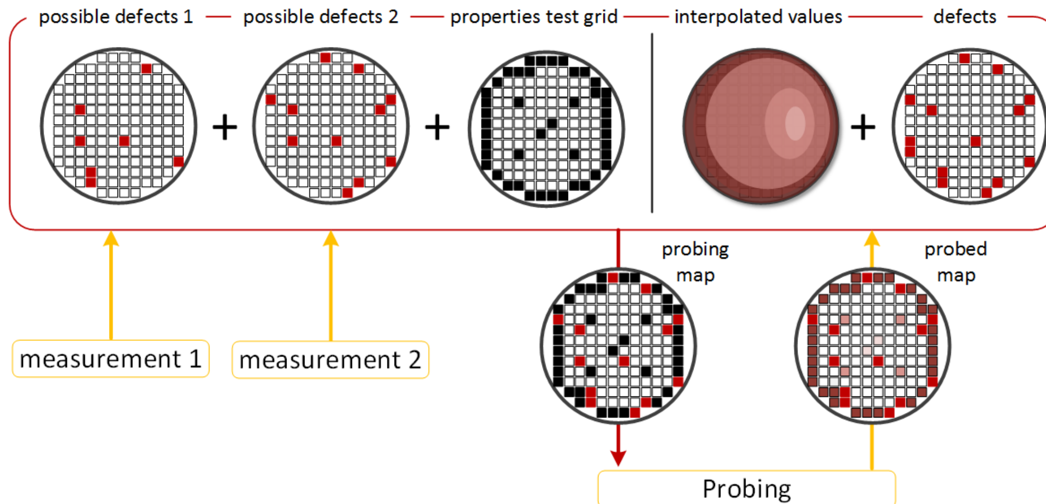
Predictive Probing

Two-step Predictive Probing process:

- Analyse prior measurements, compile probing map to determine electrical and optical properties as well as defects and probe selected LED-chips
- Read measurements, interpolate optical and electrical values and mark defect LED-chips



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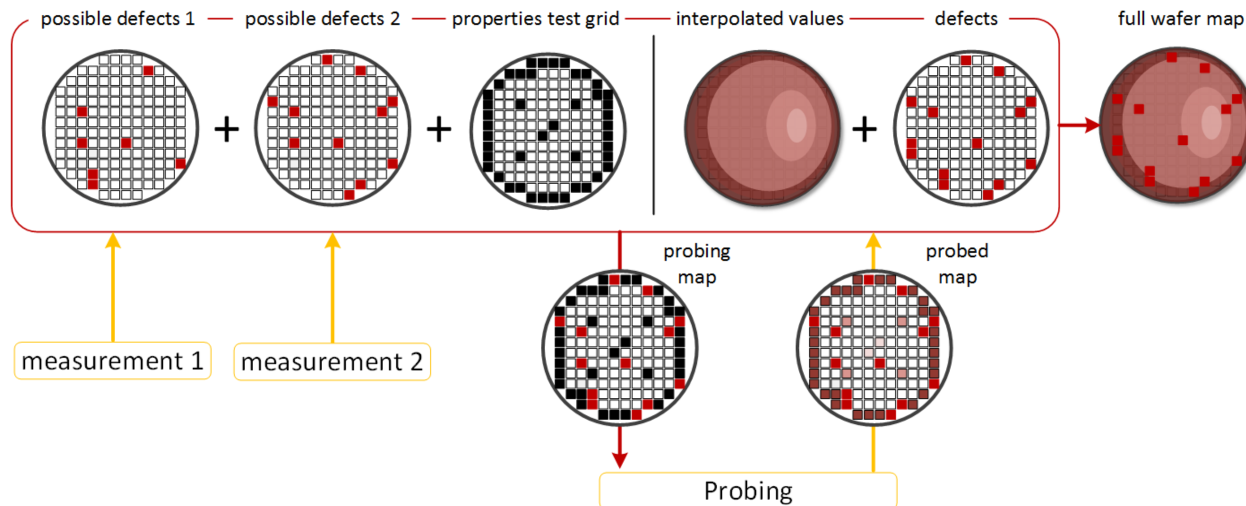
Predictive Probing Summary

- Accurate interpolation of LED properties with < 5% measured chips
- Significant time and cost savings achieved
- Defect detection accuracy meets application requirements, almost always...



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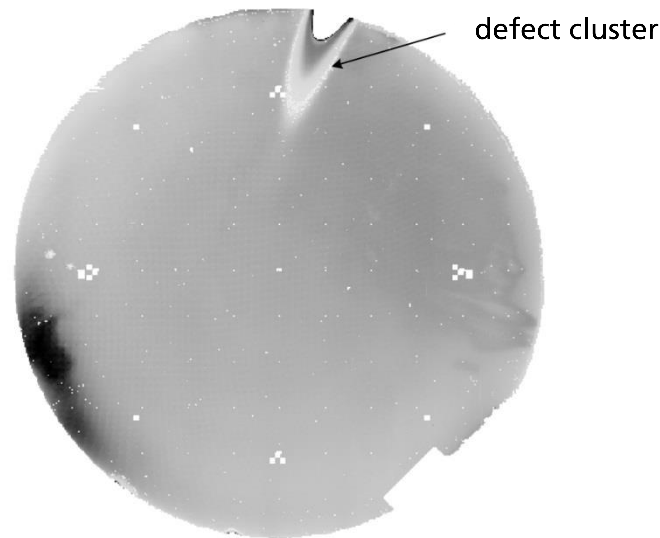
Predictive Probing | Improving defect detection

… but not for wafers with defect clusters:

- A small percentage of wafers show defect clusters usually on the wafer edge
- No accurate detection with data analysis methods possible, only work-around solutions
- Visible for the human eye in photoluminescence measurements, though



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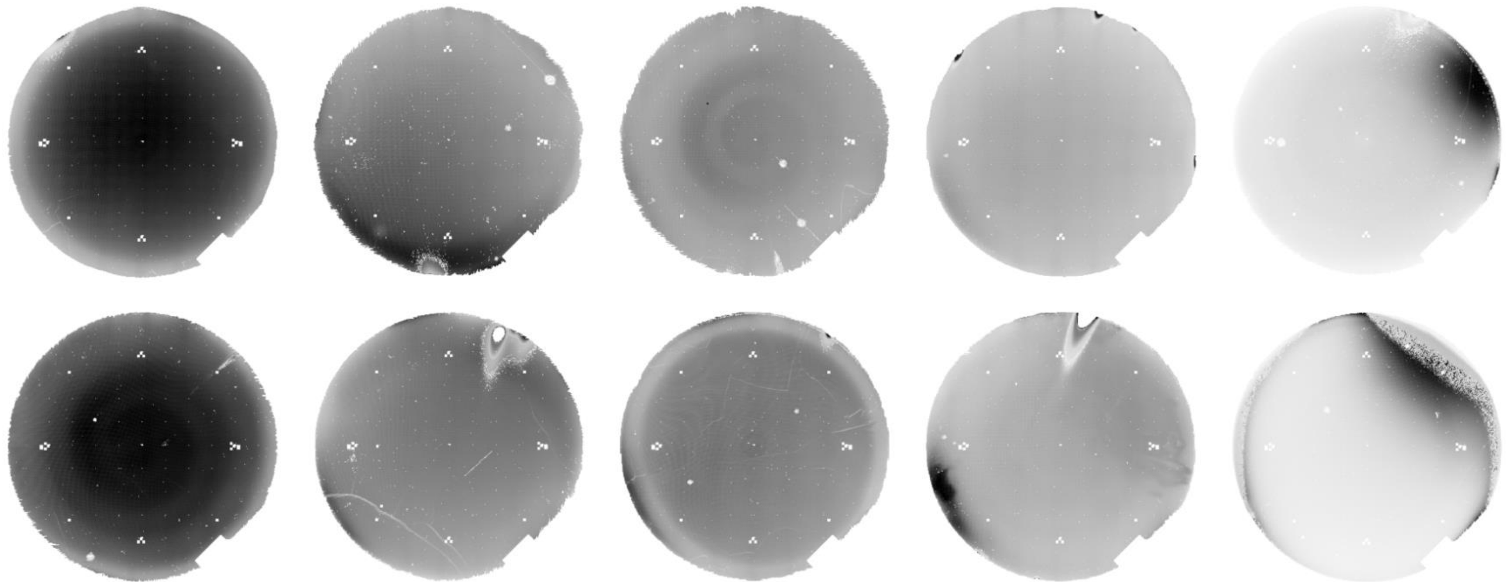
Predictive Probing | Defect Cluster Classification

Challenges:

- Measured brightness varies highly
- So do cluster shapes and sizes
- Every single chip (>130,000) must be classified



photoluminescence measurements

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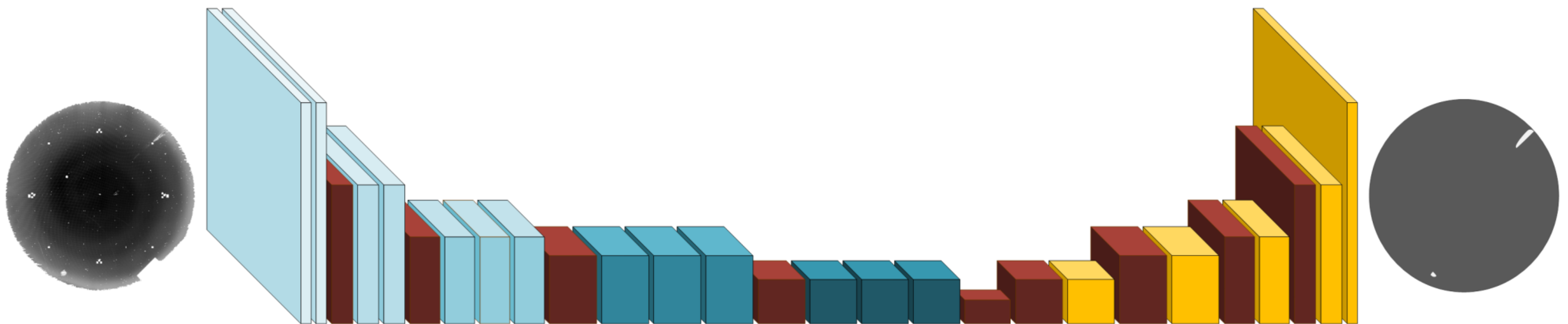
Defect Cluster Classification | Solution Approach

Fully Convolutional Networks [2]:

- Based on a special network architecture for computer vision
- Self-learning algorithm for pixel-wise classification



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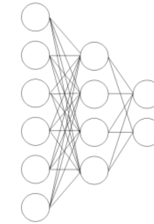
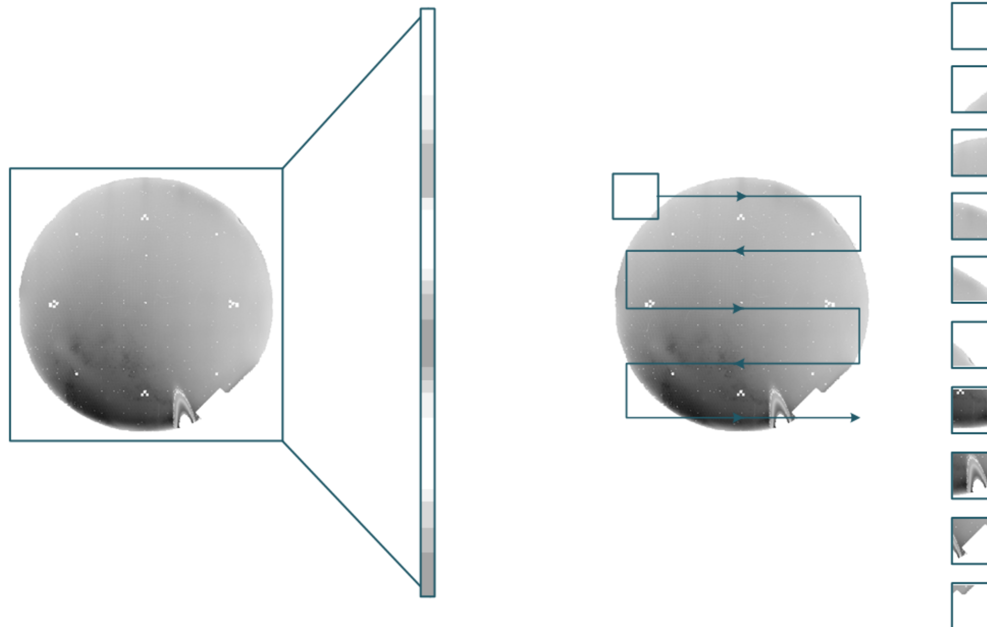
Some Intuition about Fully Convolutional Networks



Fully Convolutional Networks:

- Vanilla (regular) neural network process vectorised data
- Computer vision networks, by contrast, preserve spatial information by filtering the image



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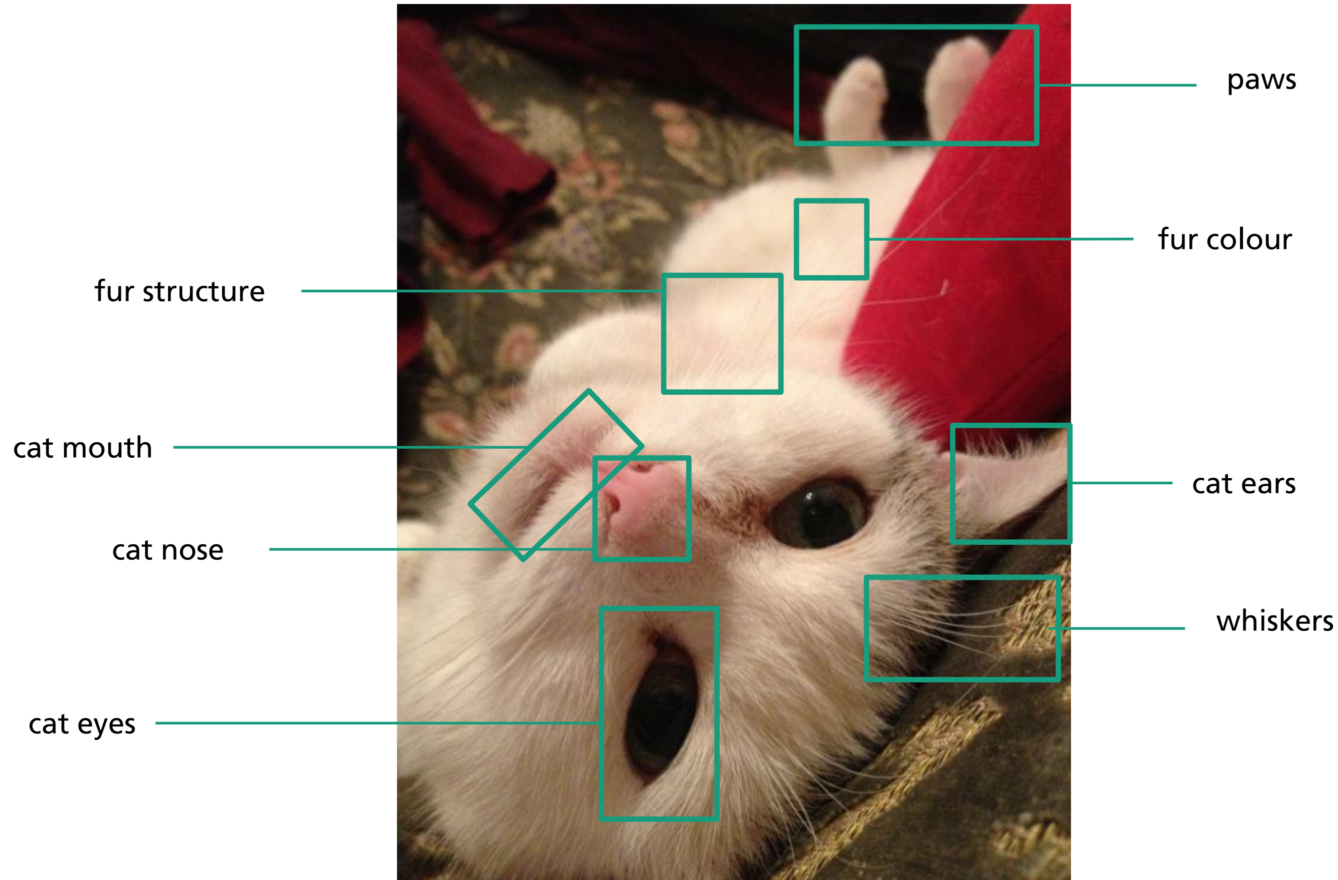
Some Intuition about Fully Convolutional Networks

Filters: feature detectors, that enable robustness against rotation, scale and translation variance



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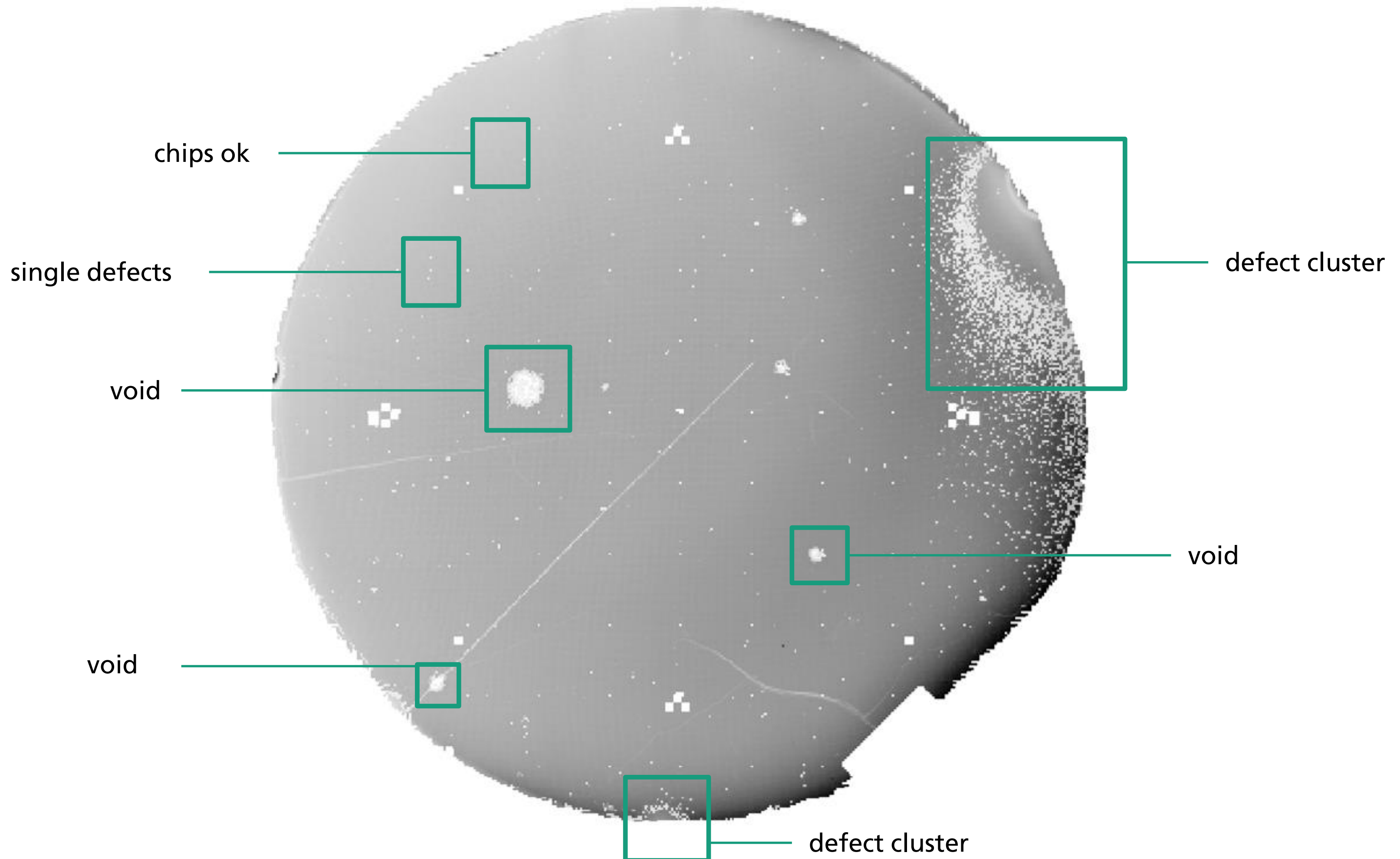
Some Intuition about Fully Convolutional Networks



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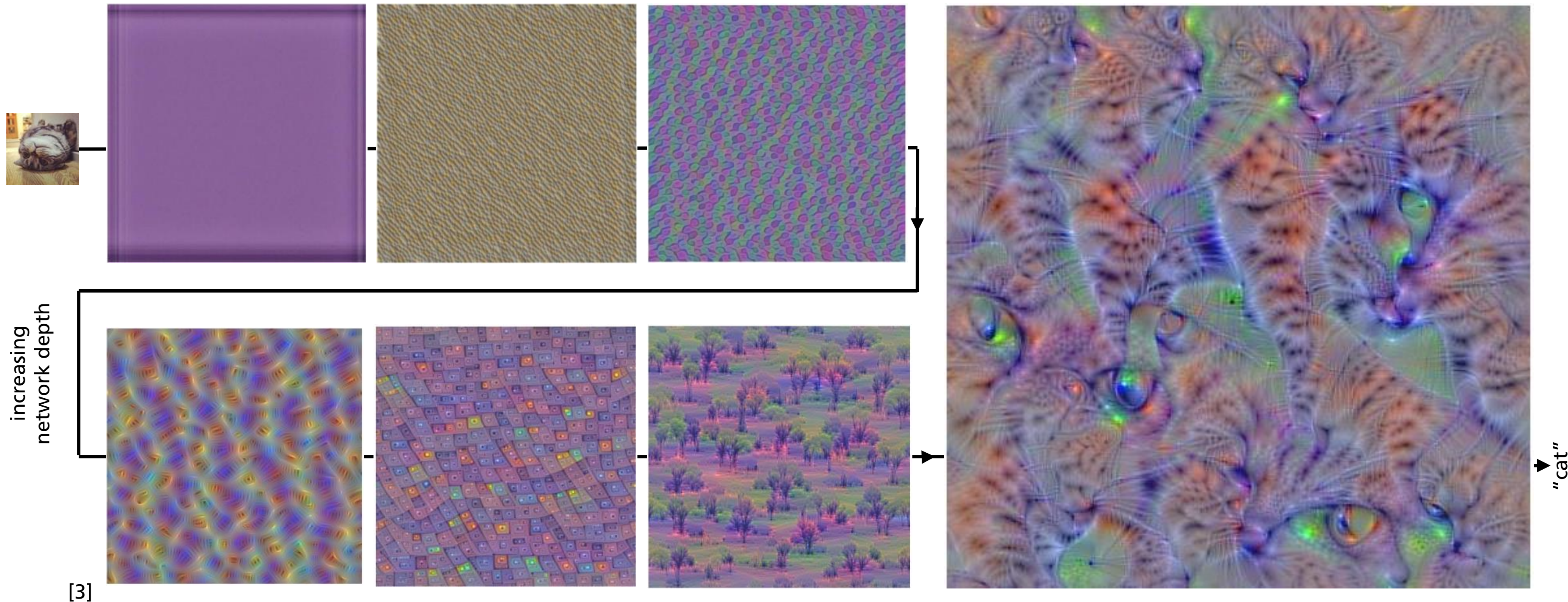
Some Intuition about Fully Convolutional Networks

- A typical network contains thousands of filters, allowing the classification of highly variant images
- With increasing network depth filters are getting more complex



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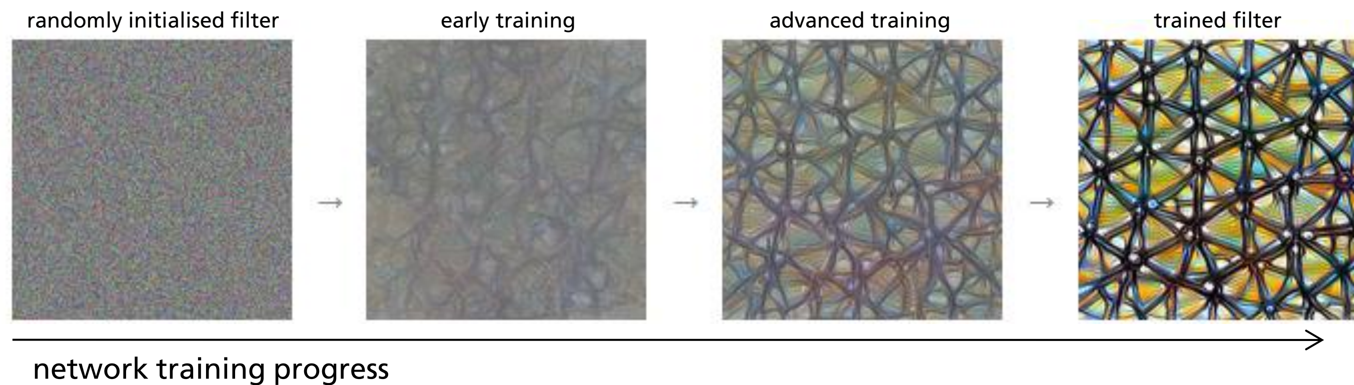
Some Intuition about Fully Convolutional Networks

- The network's performance is to learn suitable filters for the given classification task
- Therefore the network has to be trained with a carefully assembled dataset of inputs and corresponding labels



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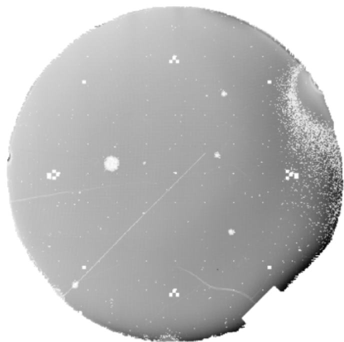
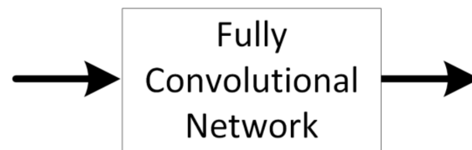
Defect Cluster Classification | FCNs

Network training:

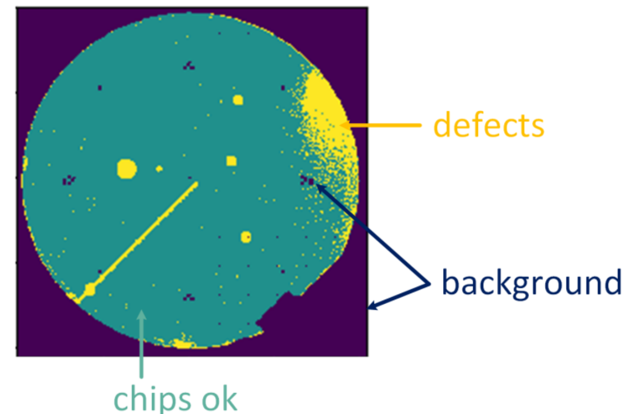
- Input: about 100 photoluminescence measurements
- Labels: 3 prediction classes - chips ok / background / defect chips

input: photoluminescence measurement





labels: class categories based on the measurement of every single chip



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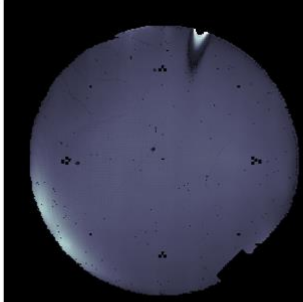
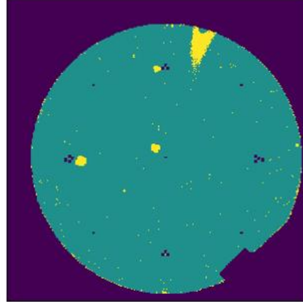
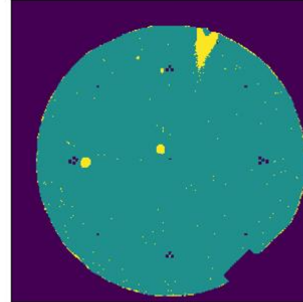
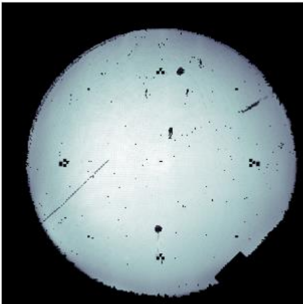
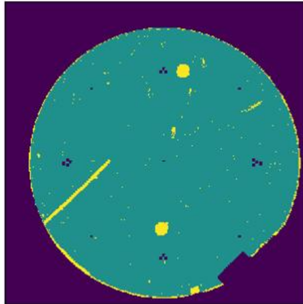
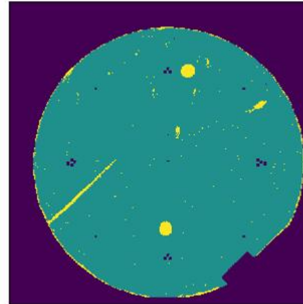
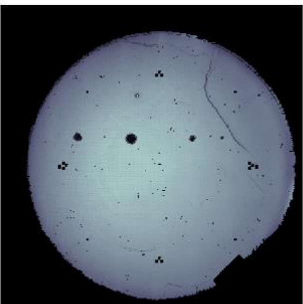
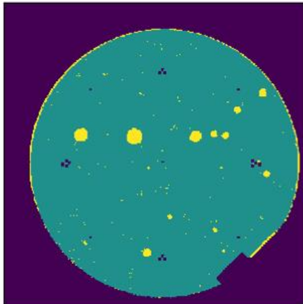
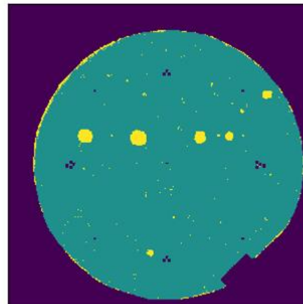
Edge Void Classification | Results

PL measurement | label (prober measurement result) | FCN prediction

Over 98.5 % of all 168,100 pixels correctly classified (test accuracy, 98.9% training accuracy)

test images = not used for network training

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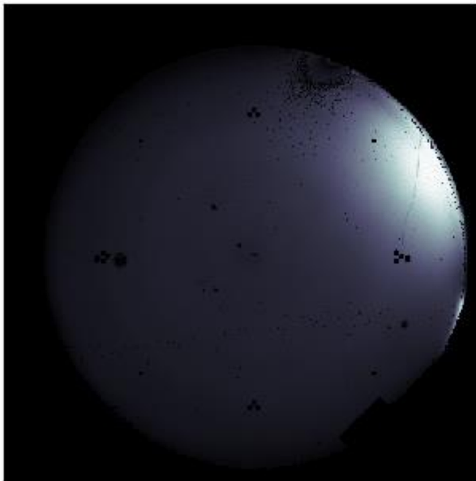
Summary

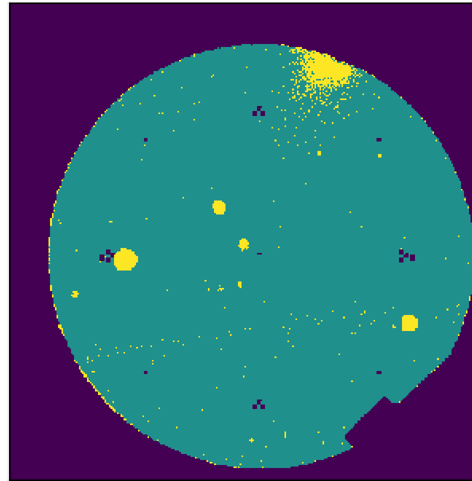
Predictive Probing supplemented with a pixel-wise defect cluster classification algorithm

- Predictive Probing defect detection accuracy significantly improved
- Deployable with every wafer / chip size
- Network knowledge transferrable to other pattern recognition tasks

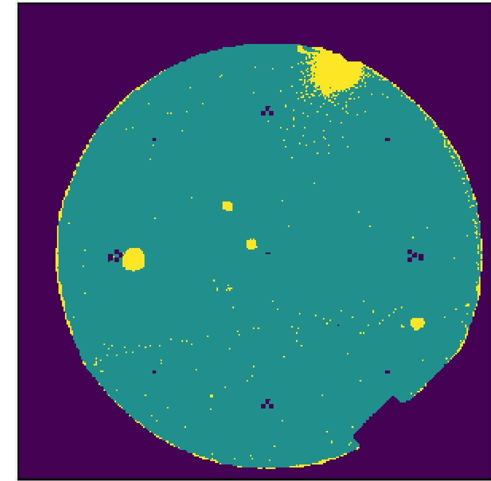
PL measurement



measurement result



network prediction



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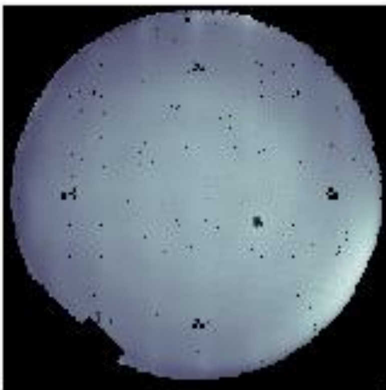
Summary & Outlook

Predictive Probing supplemented with a pixel-wise defect cluster segmentation algorithm

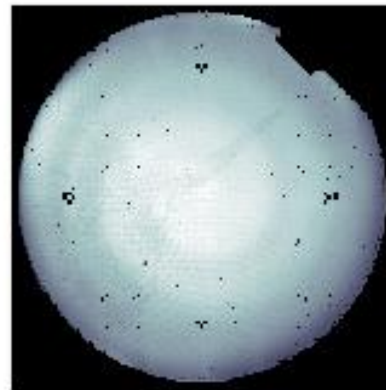
- Predictive Probing defect detection accuracy significantly improved
- Deployable with every wafer / chip size
- Network knowledge transferrable to other pattern recognition tasks
- Current work: object detection algorithm for process specific patterns: stripes, spirals, defect clusters, …

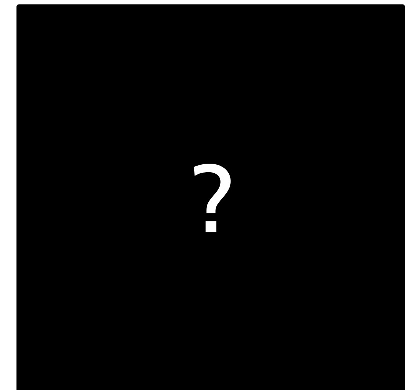
stripes



defect cluster

spiral





Thank you for your attention!

GEFÖRDERT VOM

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Sources

[1] Patent pending

[2] Evan Shelhamer, Jonathan Long, et al.: Fully Convolutional Networks for Semantic Segmentation, 2016

[3] https://storage.googleapis.com/deepdream/visualz/vgg16/index.html

[4] https://distill.pub/2017/feature-visualization/

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