# AIT Inline Computational Imaging: Motion Artefact Compensation

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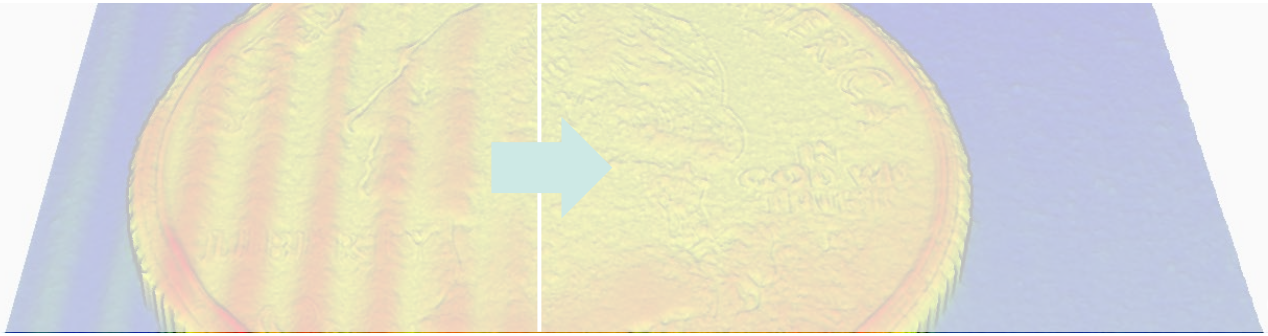
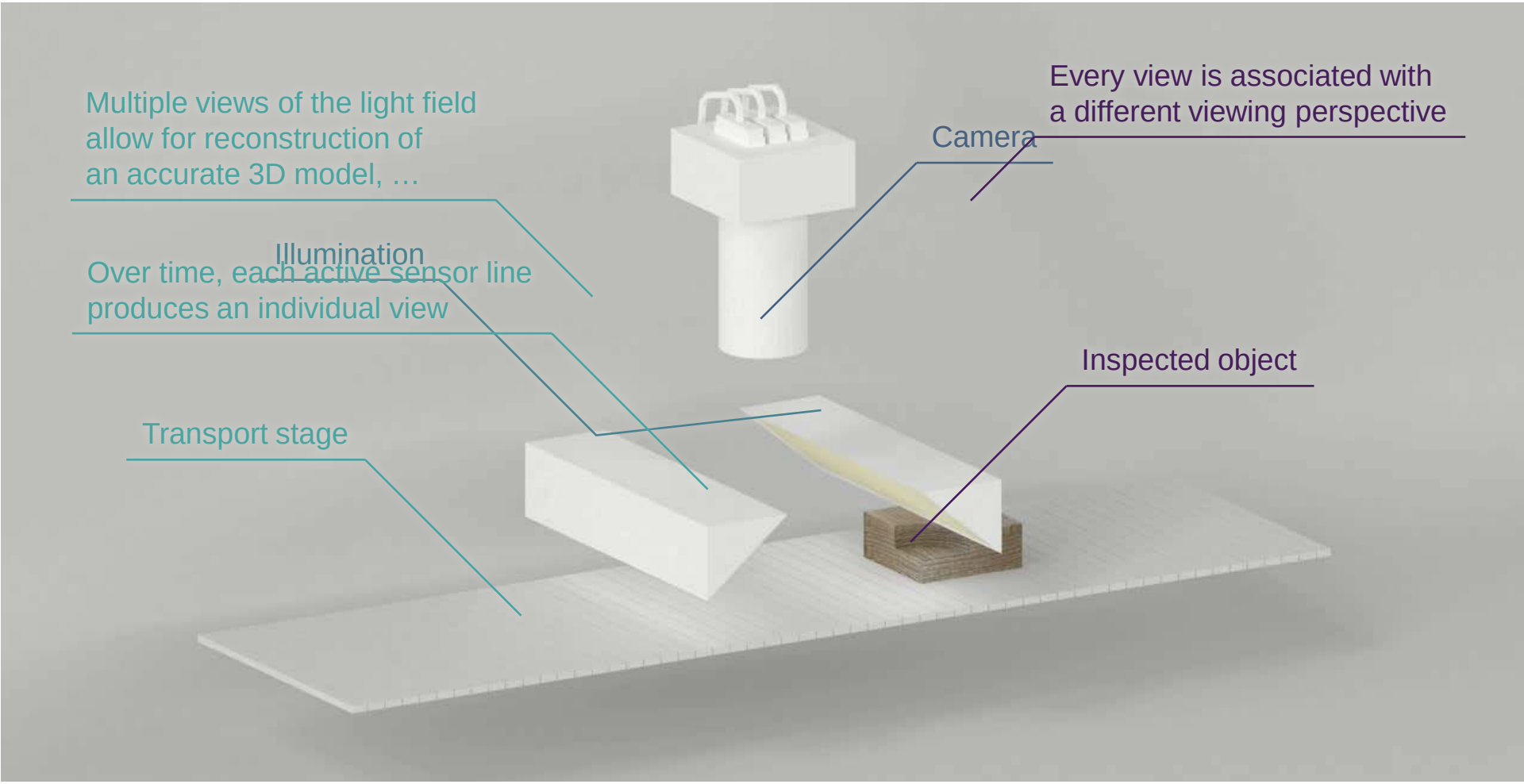
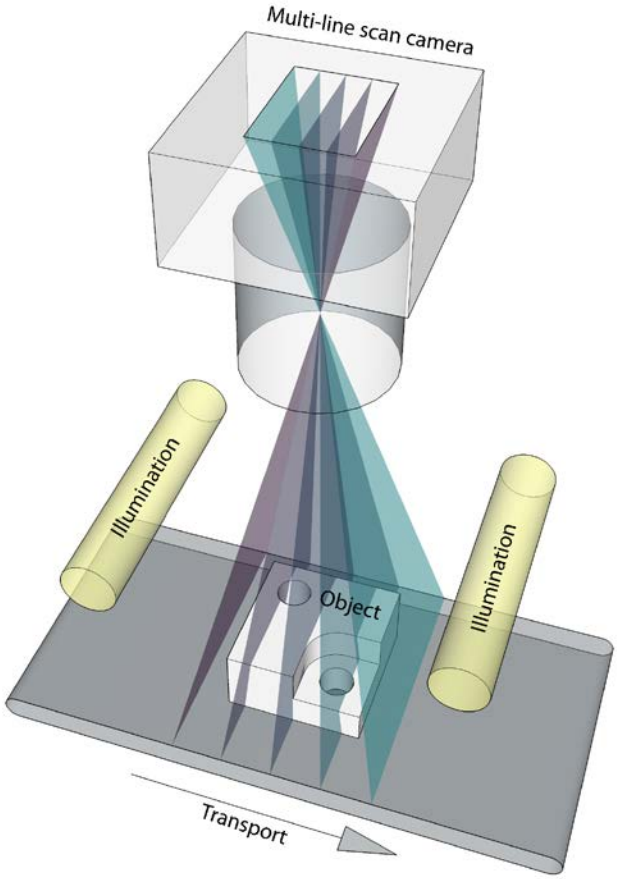


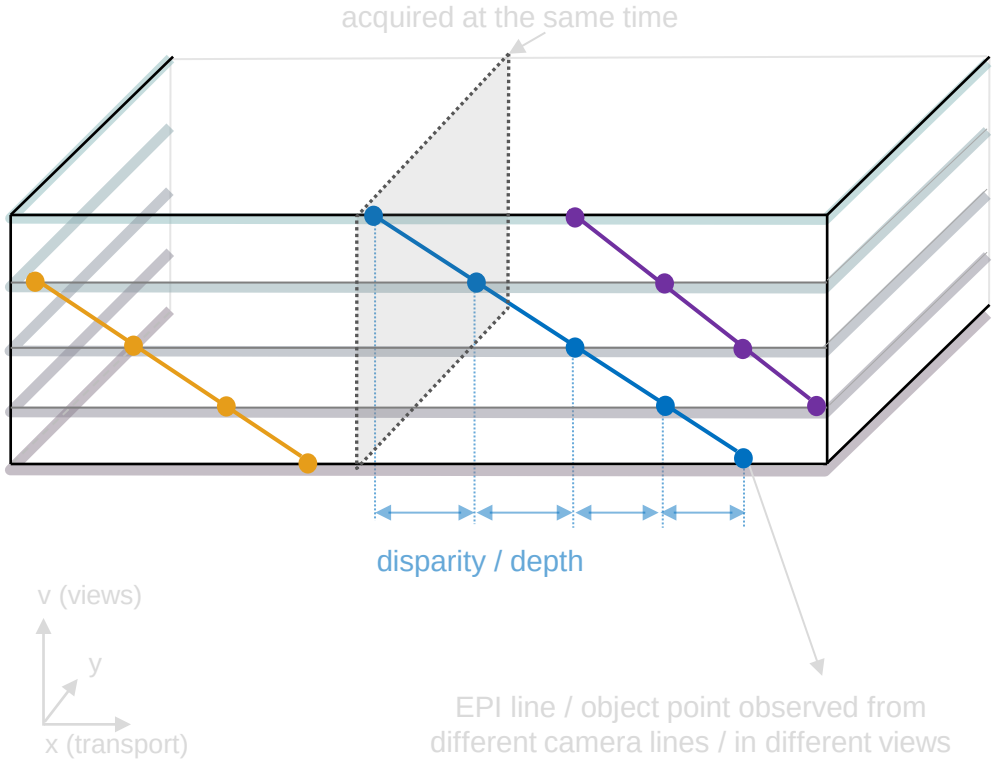
# **AIT ICI:** Inline Computational Imaging



# AIT ICI **Light field:** Multiple viewing & illumination angles




AIT ICI light field: Every view (image) is associated with a different viewing perspective (sensor line)




[Štolc et al., JEI 2014], [Antensteiner et al., CIARP 2016], [Antensteiner et al., CVPR 2017], [Antensteiner et al., EI2017], [Valentín et al., JEI 2017], [Blaschitz et al., EI 2018], …

# AIT ICI **Light field:** Multiple viewing & illumination angles

# AIT ICI **algorithms & methods**

**AIT ICI**: Computational Imaging

- increased signal-to-noise ratio
- all-in-focus imaging
- highlight / shadow suppression

photometric stereo

from *multiple viewing /*

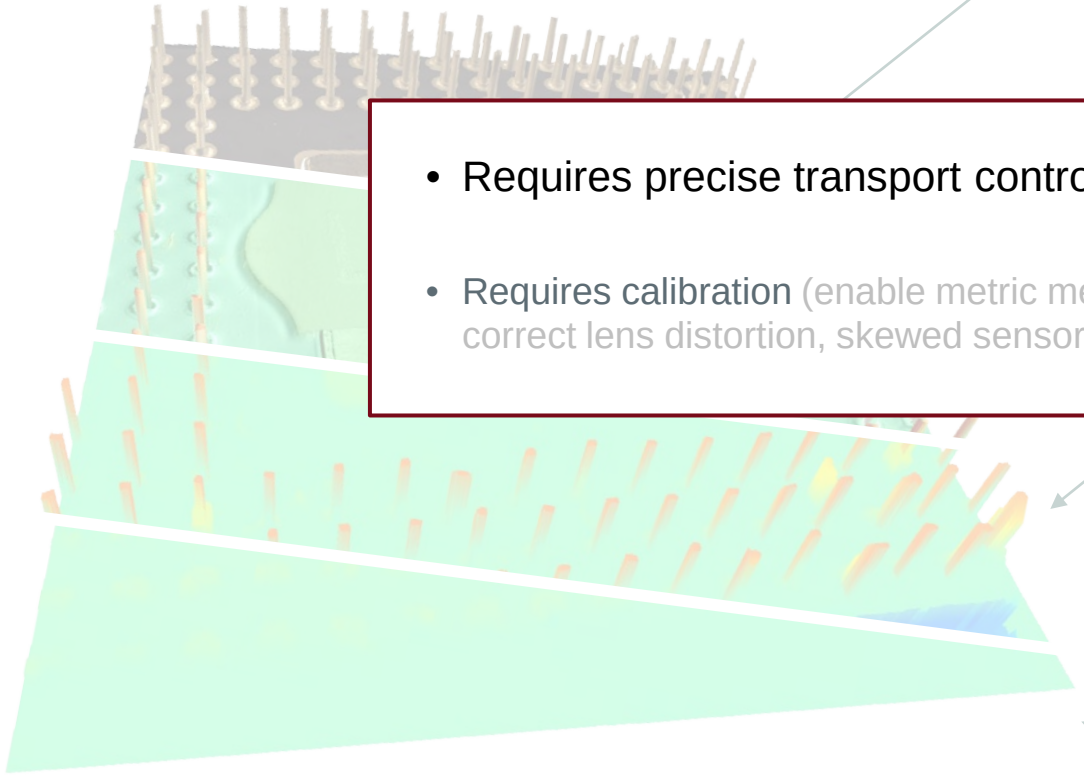
*high detail*

Light field only

- 3D reconstruction from *multiple viewing angles*
- *globally correct*, but low detail

Conventional Stereo Matching

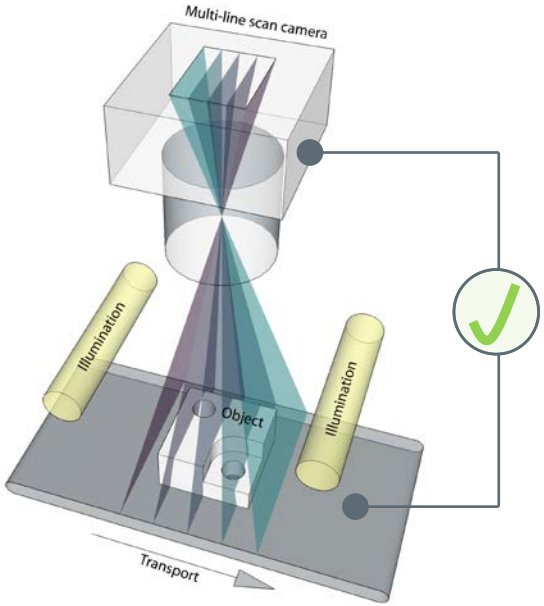
- 3D reconstruction from only *2 viewing angles*
- error-prone and low detail



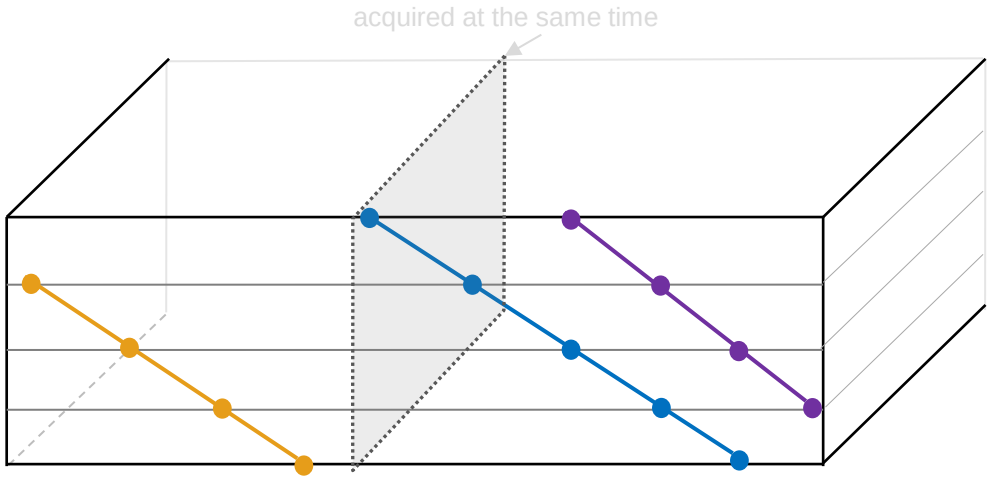
- Requires precise transport control [Brosch et al., EI2018]
- Requires calibration (enable metric measurements, correct lens distortion, skewed sensor) [Blaschitz et al., EI2018]

Encoding of depth values: small large

# AIT ICI **Light field:** Transport synchronization

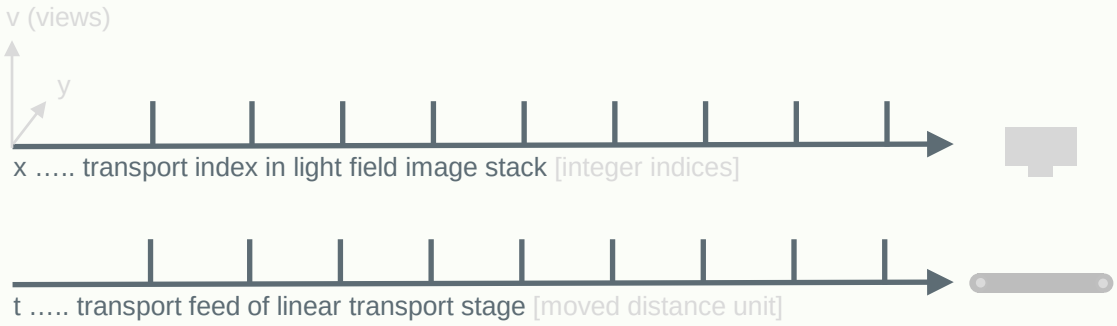



AIT ICI light field

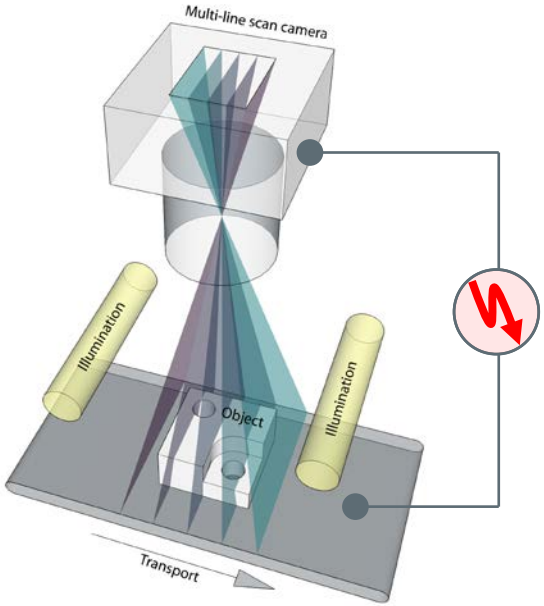



## Perfect synchronization

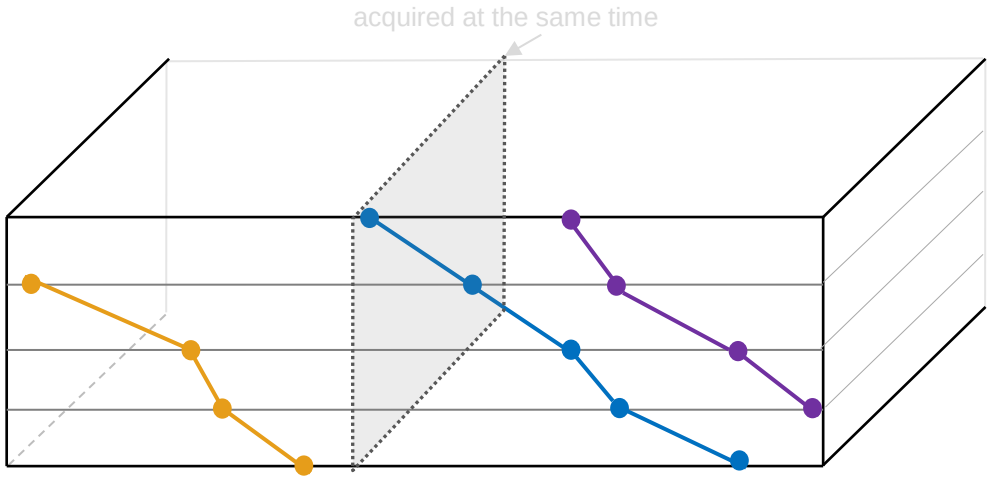
- Uniform & constant gaps / space instances
- Transport index gaps correspond to transport feed gaps
- Linear EPI lines



# AIT ICI **Light field:** Transport synchronization issues

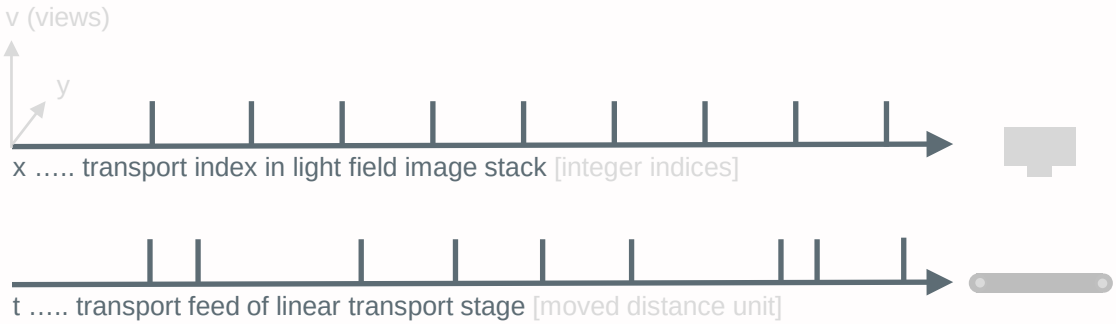



AIT ICI light field




## Synchronization issues

- Non-uniform transport feed vs. uniform transport index
- “Ripply” EPI lines
- Incorrect resolution in transport direction

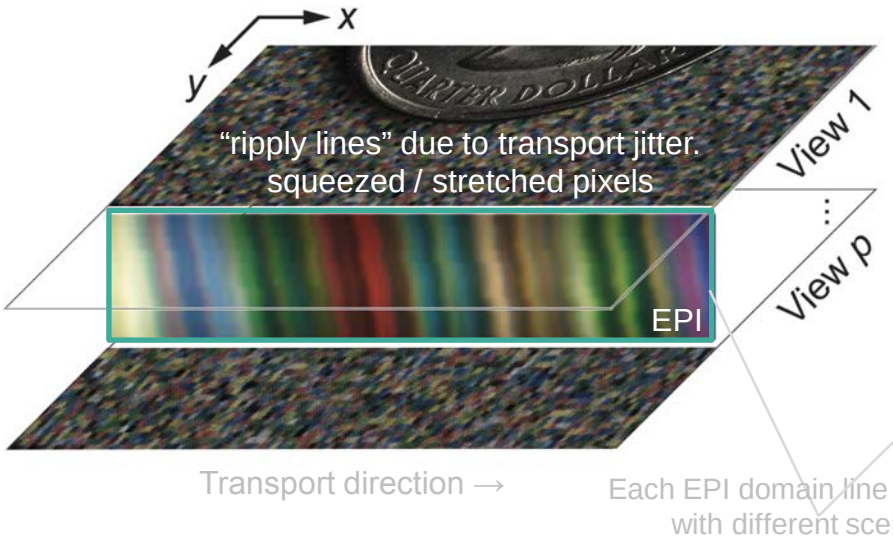


# **Motion artefacts**: “Ripply” EPI lines

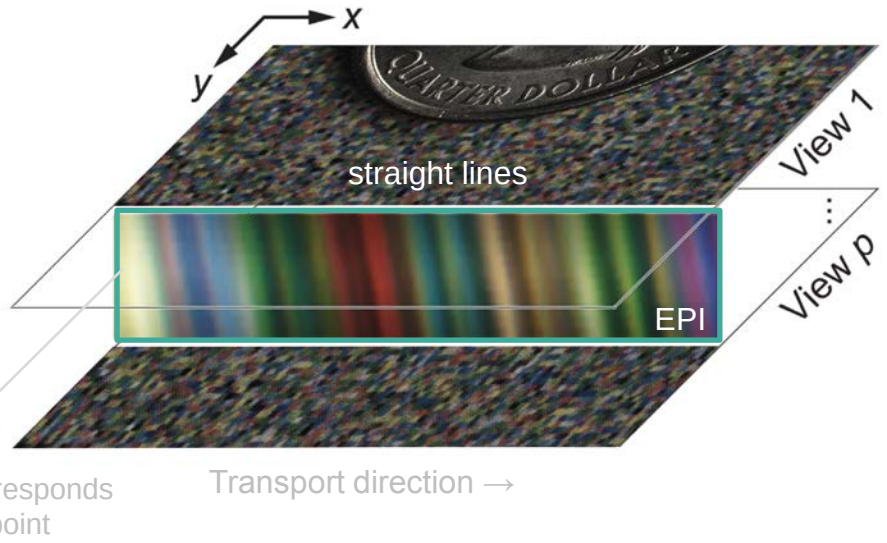
- Motion artefacts are a serious issue when scanning at high magnifications
- With loosely/not synced camera and transport, jitter may cause visible depth artefacts (ripples)

- AIT ICI allows for an efficient correction of the motion artefacts
- Our algorithm exploits data redundancy inherently comprised in the light field

**Original**, not corrected, data acquired with no/loose transport sync.




**Corrected** data using our motion artefact compensation algorithm




Each EPI domain line corresponds with different scene point

# **Motion artefacts**: “Ripply” EPI lines

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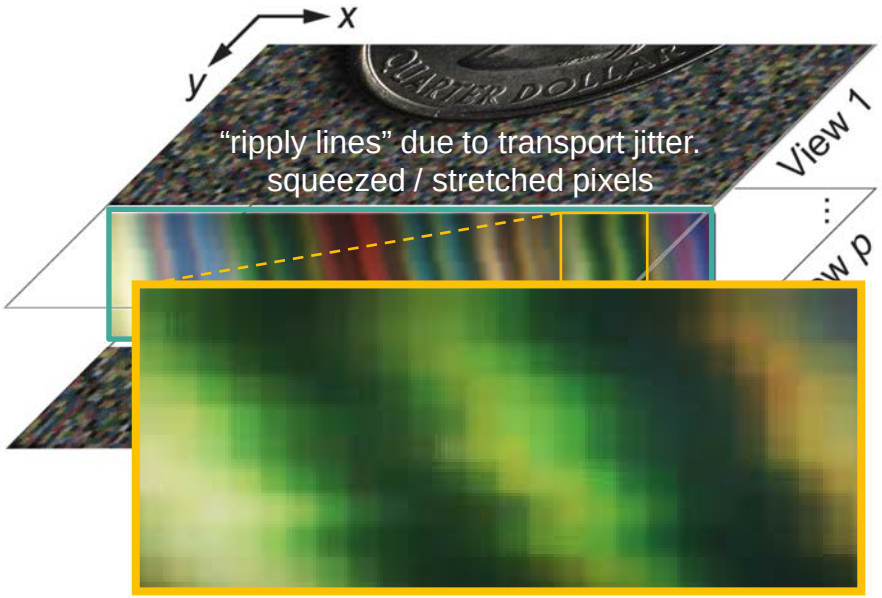
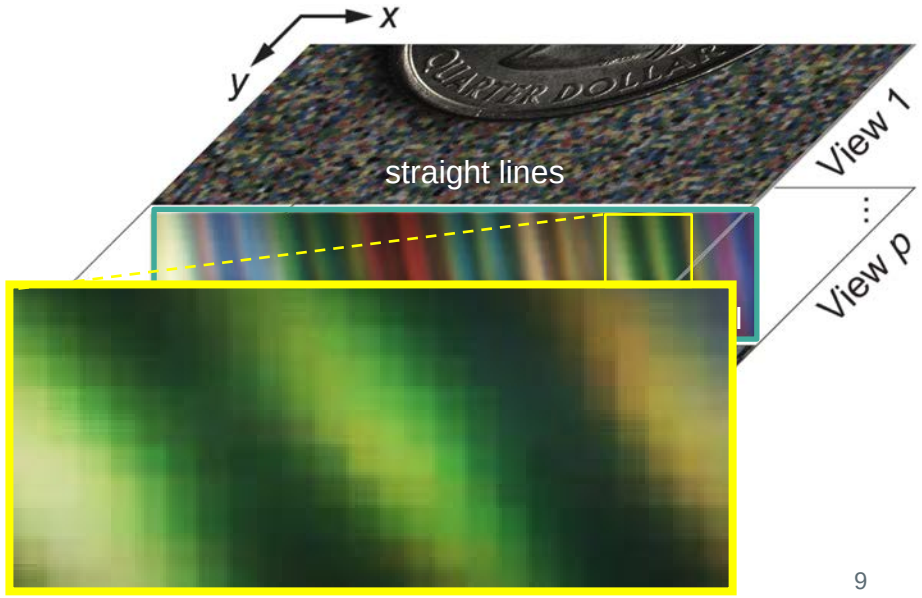
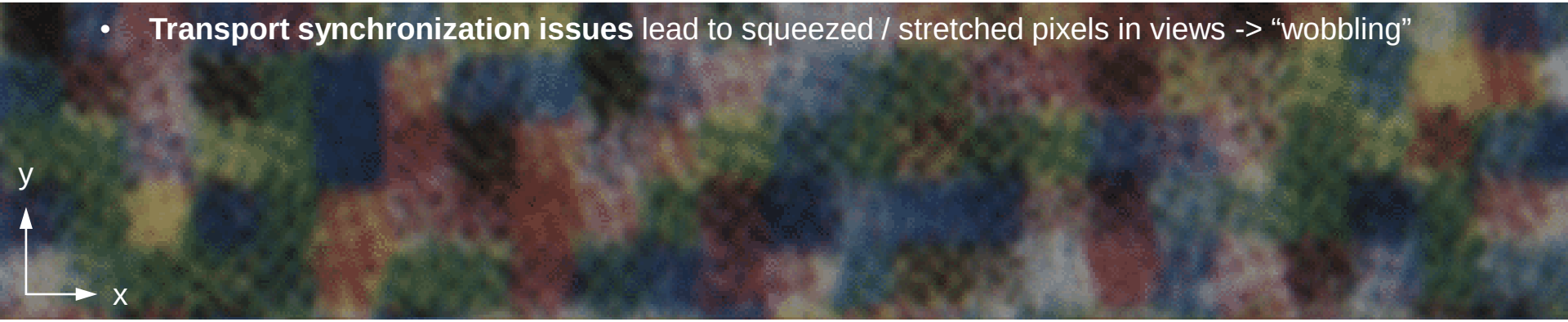
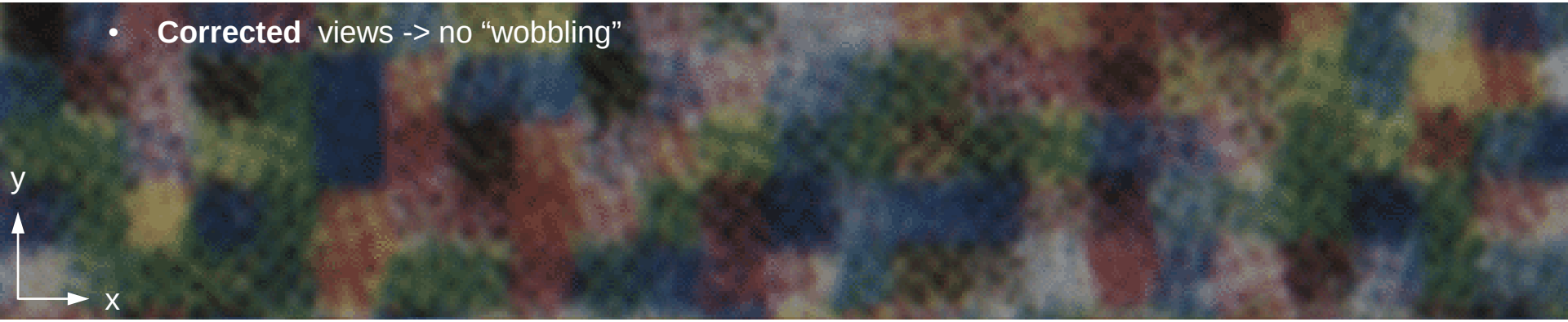



**Corrected** data using our motion artefact compensation algorithm



# **Motion artefacts**: “Wobbling”



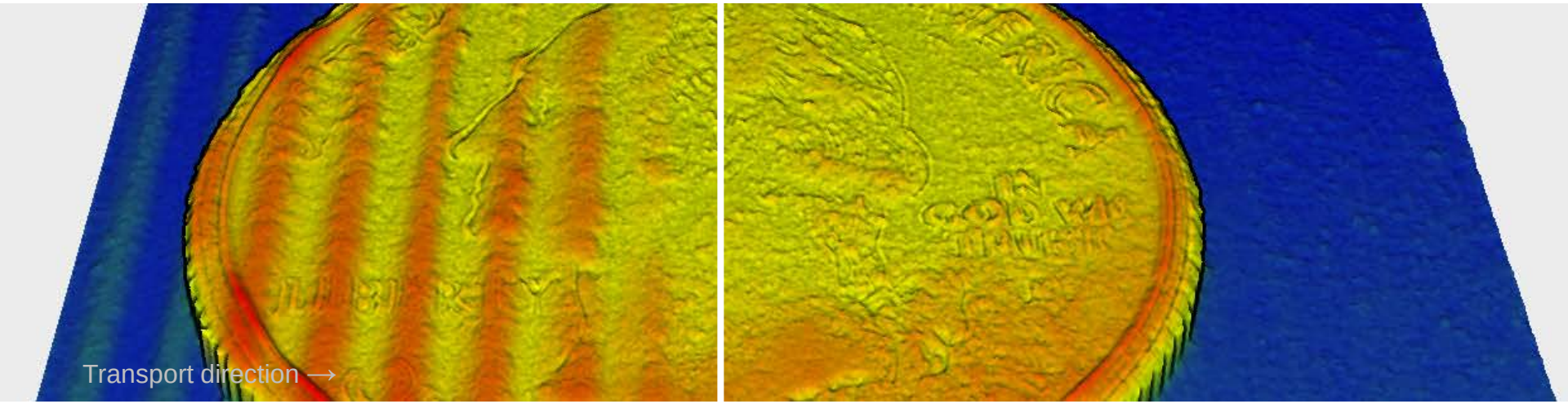
# **Motion artefacts**: Depth ripples

- Motion artefacts are a serious issue when scanning at high magnifications
- With loosely/not synced camera and transport, jitter may cause visible depth artefacts (ripples)

- AIT ICI allows for an efficient correction of the motion artefacts
- Our algorithm exploits data redundancy inherently comprised in the light field

**Original**, not corrected, data acquired without transport sync

**Corrected** data using our algorithm

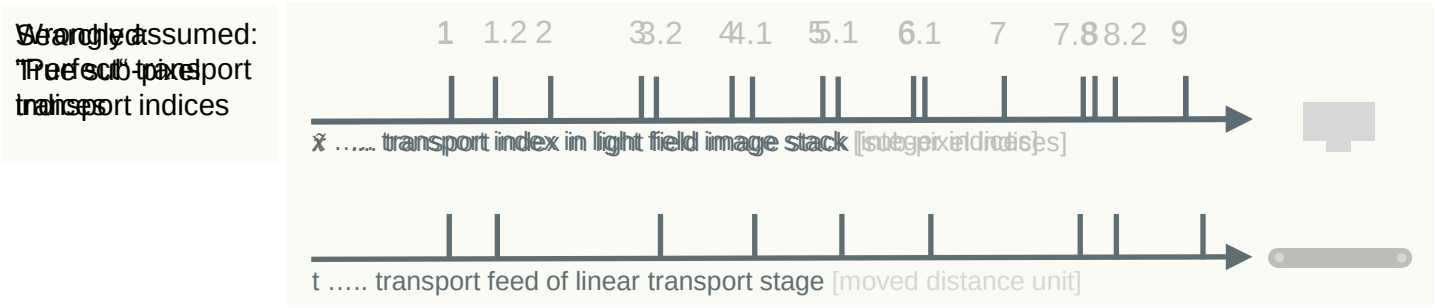



Depth ripples visible due to transport jitter

Depth ripples suppressed

# **Motion artefact compensation**: Overview

- **Step 1:** Determine true sub-pixel transport indices



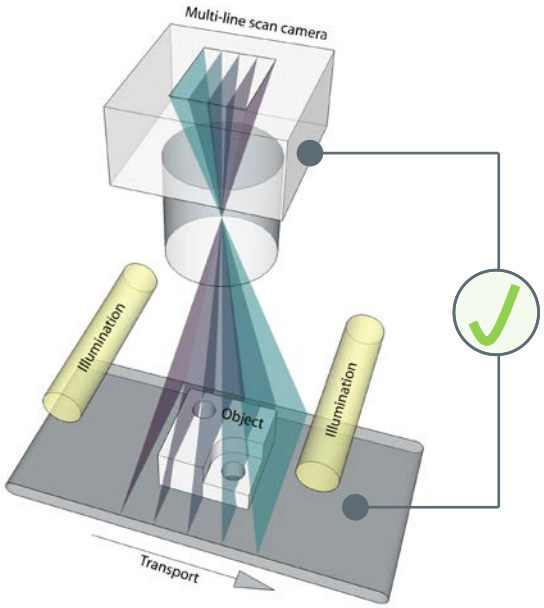

True x-indices ($\tilde{x}_i$) are recovered in an optimization & by constraining them according to *disparities.*
-> Two different approaches: Version 1 & Version 2.

- **Step 2:** Warp light field views accordingly

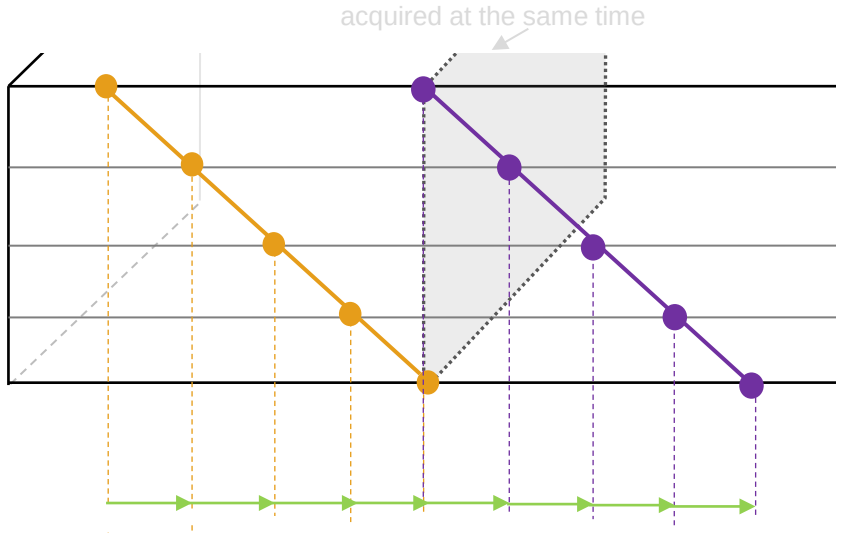
Re-sample views at initially assumed integer indices (uniformly spaced)

# **Version 1:** Constant background disparity

- **Observation:** No transport issues -> the disparity in a background region is constant.

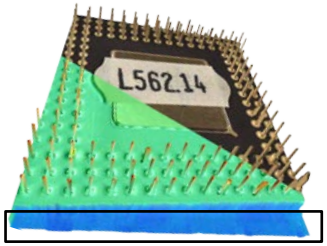



AIT ICI light field




$d_1 = d_2 = d_3 = d_4 = \ldots. = d$

$d_1 = x_1 - x_2, \ldots$



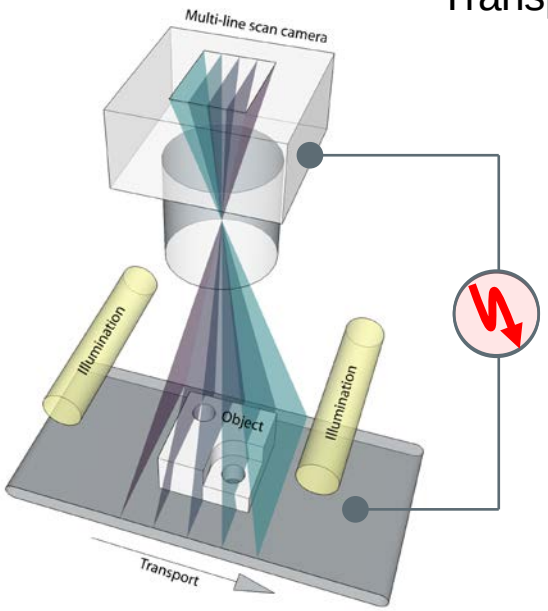

= d

calculated only from background

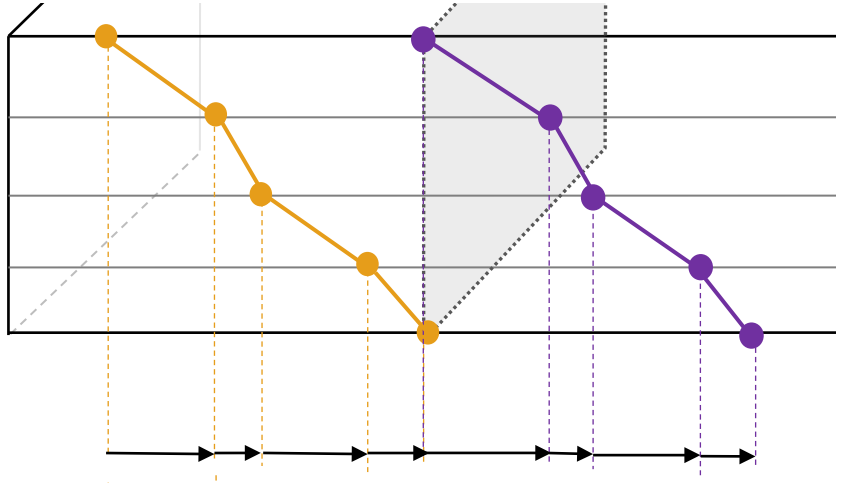

$\tilde{x}$ = x ….. transport index in light field image stack [integer indices]

# **Version 1:** Constant background disparity

- **Observation:** No transport issues -> the disparity in a background region is constant.
  Transport issues -> the disparity in a background region is not constant.

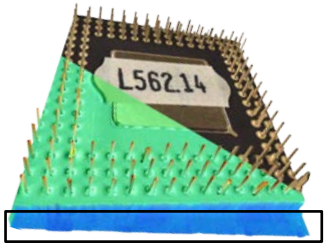



AIT ICI light field



$d_1 \neq d_2 \neq d_3 \neq d_4 \neq \ldots \neq d$

$d_1 = x_1 - x_2, \ldots$



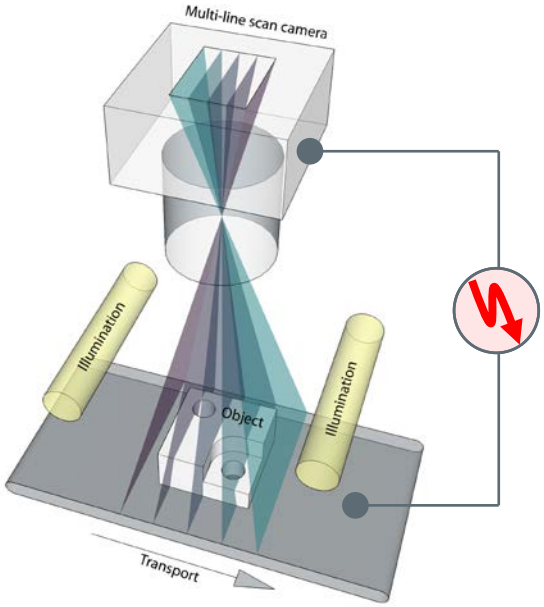

= d

calculated only from background

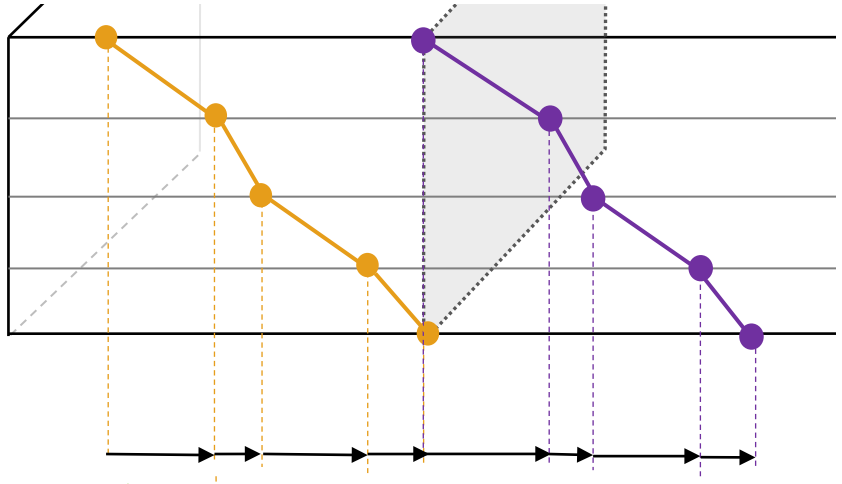

$\tilde{x}$ = x ..... transport index in light field image stack [integer indices]

# **Version 1:** Constant background disparity

- **Compensation:** Enfroce constant disparity **d** and move transport index.

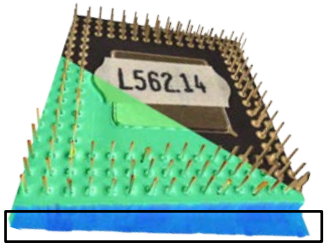



AIT ICI light field



$d_1 \neq d_2 \neq d_3 \neq d_4 \neq \ldots. \neq d$

$d_1 = x_1 - x_2, \ldots$




= d

calculated only from background

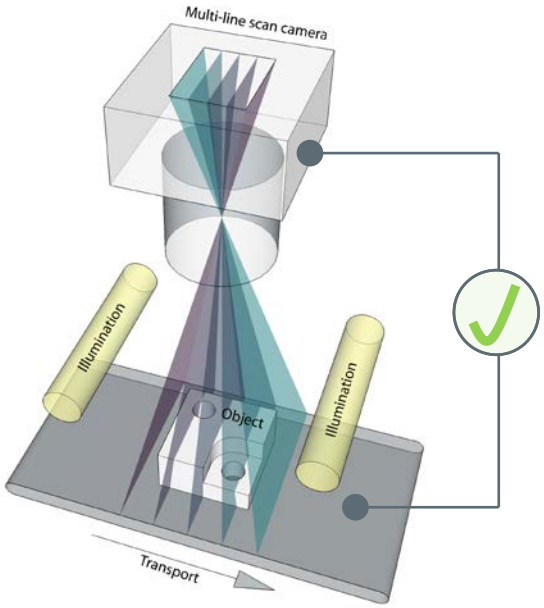
**Optimization:**
finds indices $\tilde{x}$

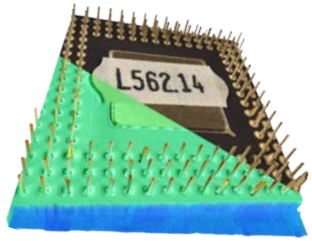

x ….. transport index in light field image stack [integer indices]

$\tilde{x}$ .... transport index in light field image stack [sub-pixel indices]

# **Version 2:** Balanced fore- & background disparities

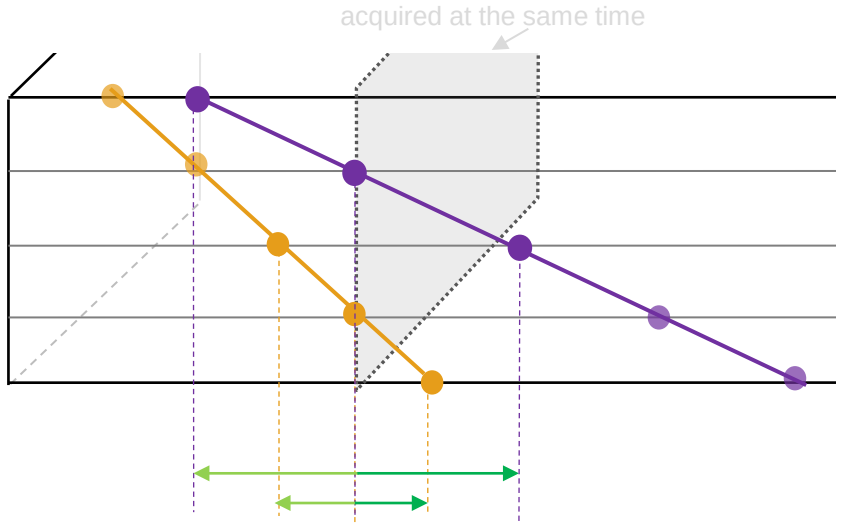
- **Observation:** No transport issues -> backward disparity = forward disparity.



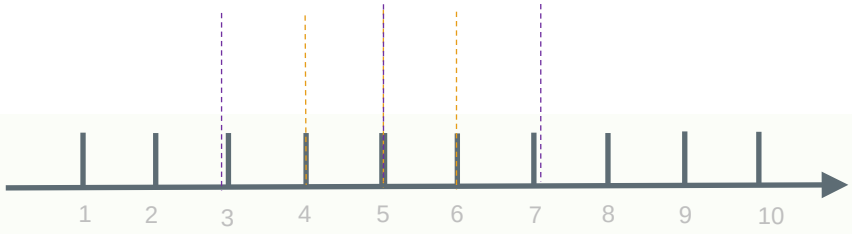




can be calculated anywhere

AIT ICI light field



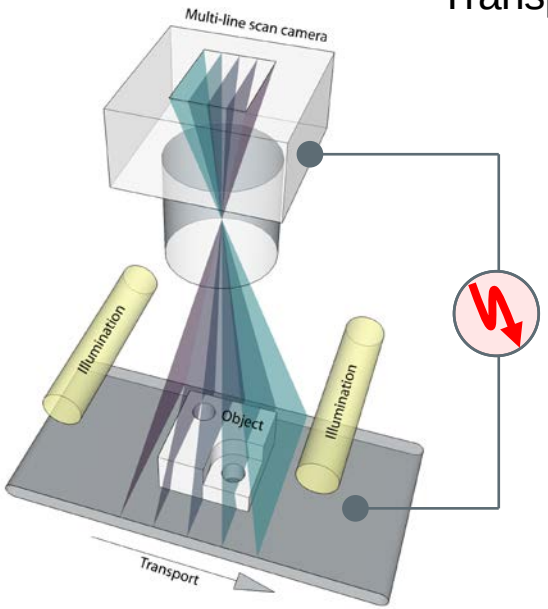

**d = d**

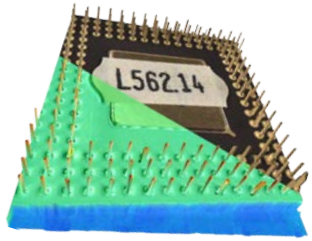



$\tilde{x}$ = x ….. transport index in light field image stack [integer indices]

# **Version 2:** Balanced fore- & background disparities

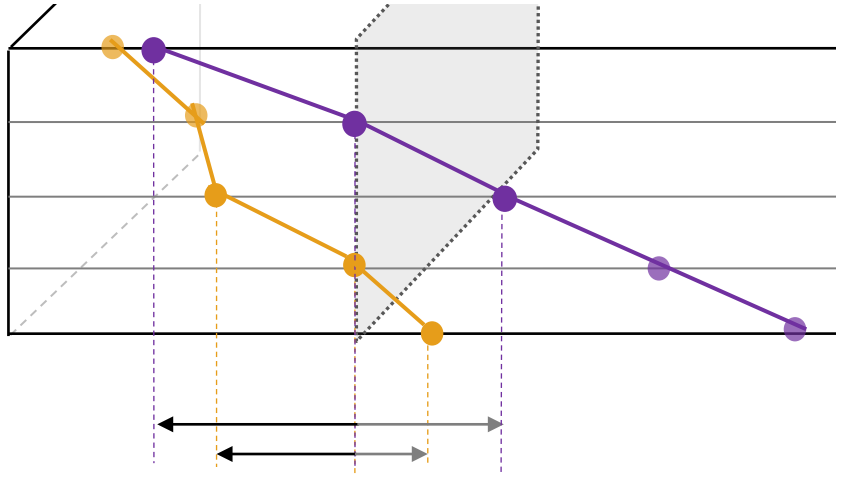
- **Observation:** No transport issues -> backward disparity = forward disparity.
  Transport issues -> backward disparity ≠ forward disparity.



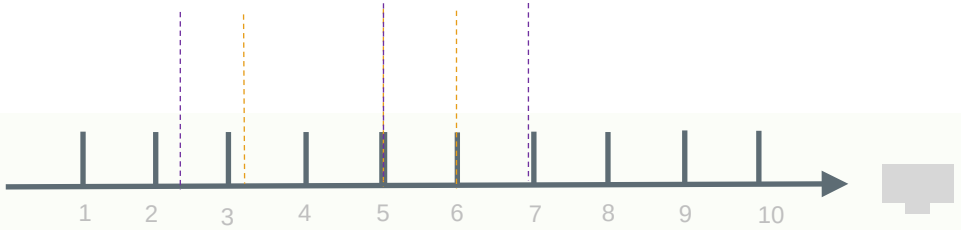




can be calculated anywhere

AIT ICI light field



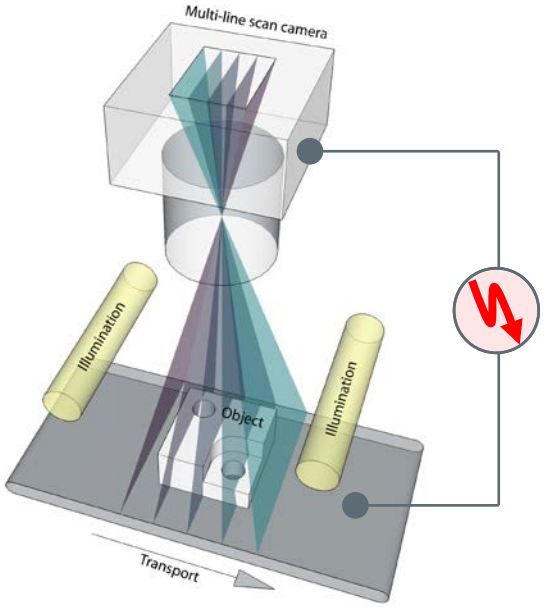
$d \neq \underline{d}$

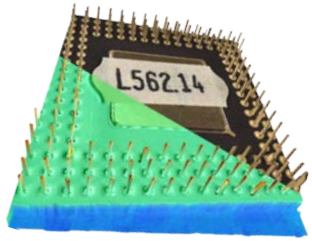



$\tilde{x} \neq x$ ….. transport index in light field image stack [integer indices]

# **Version 2:** Balanced fore- & background disparities

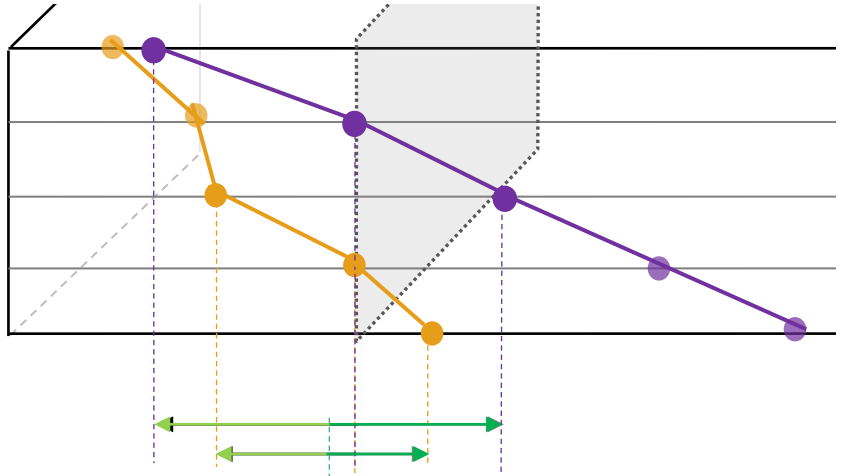
- **Compensation:** Enforce backward disparity = forward disparity.



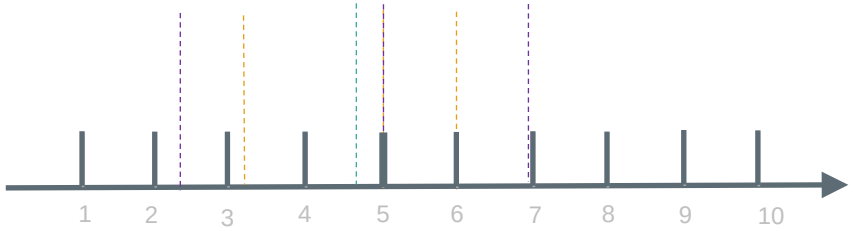

can be calculated anywhere

AIT ICI light field



$d \neq \underline{d}$

**Optimization:**
finds indices $\tilde{x}$




x ..... transport index in light field image stack [integer indices]
$\tilde{x}$ .... transport index in light field image stack [sub-pixel indices]

# **Motion artefact compensation**: Overview

- **Step 1:** Determine true sub-pixel transport indices




True x-indices ($\tilde{x}_i$) are recovered in an optimization & by constraining them according to *disparities.*
-> Two different approaches: Version 1 & Version 2.

- **Step 2:** Warp light field views accordingly

  Re-sample views at initially assumed integer indices (uniformly spaced)

# **Motion artefact compensation**: Results

**Dataset:** Coin
**Sync:** Off
**PS:** Off

Motion artefacts

Compensation Version 2

Transport direction

# **Motion artefact compensation**: Results

**Dataset:** Note
**Sync:** Off
**PS:** Off

Motion artefacts

Compensation Version 2

Transport direction

# **Motion artefact compensation**: Results

**Dataset:** PCB
**Sync:** Off
**PS:** Off

Motion artefacts

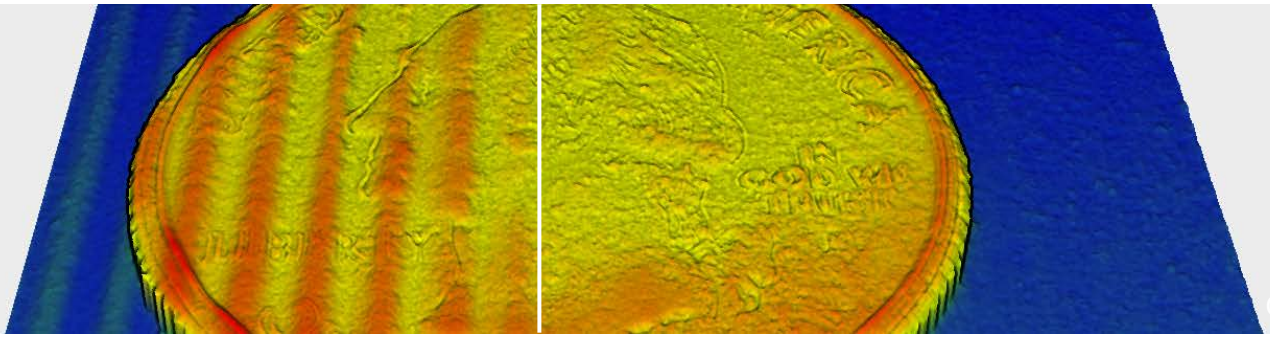
Compensation Version 2

Transport direction

# Take-home messages

The AIT Inline Computational Imaging system allows multi-line scan light field imaging …

- …. even in cases where the transport cannot be controlled with high precision.
- … at large magnification with correct resolution in the transport direction.
- …. can be used as a motion sensor itself and does not require additoinal hardware to compensate for motion artefacts.



Motion artefacts

Corrected acquisitions

# Thank you for your attention!

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