# Compressive Sensing in Microscopy: a (P)review

Andrew Stevens

# Collaborators

- Duke: Xin Yuan, Yunchen Pu, Lawrence Carin
- SuperSTEM: Quentin Ramasse, Patricia Abellan
- IFW-Dresden: Sebastian Schneider, Bernd Rellinghaus
- LBNL: Hao Yang
- PNNL: Libor Kovarik, Nigel Browning

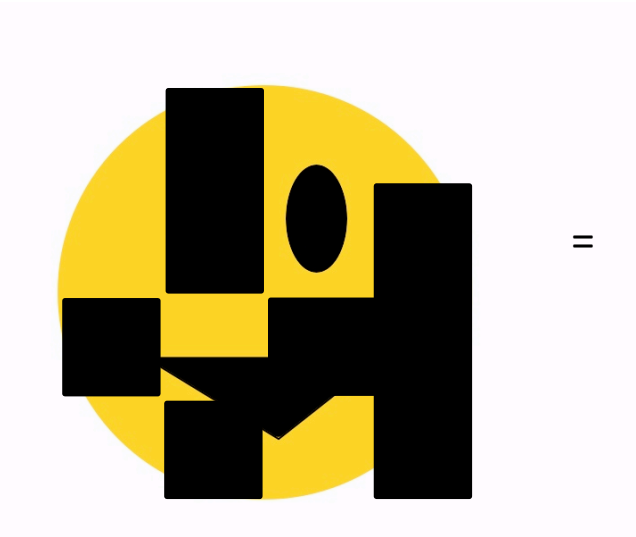
# Why CS?

## Reduce: Energy, Time, Noise, Data

- STEM: Collect fewer pixels → dose reduction
- TEM: 1 frame = 10 frames → dose, time, data
- EELS: 1 spectra = 10 spectra → noise, time

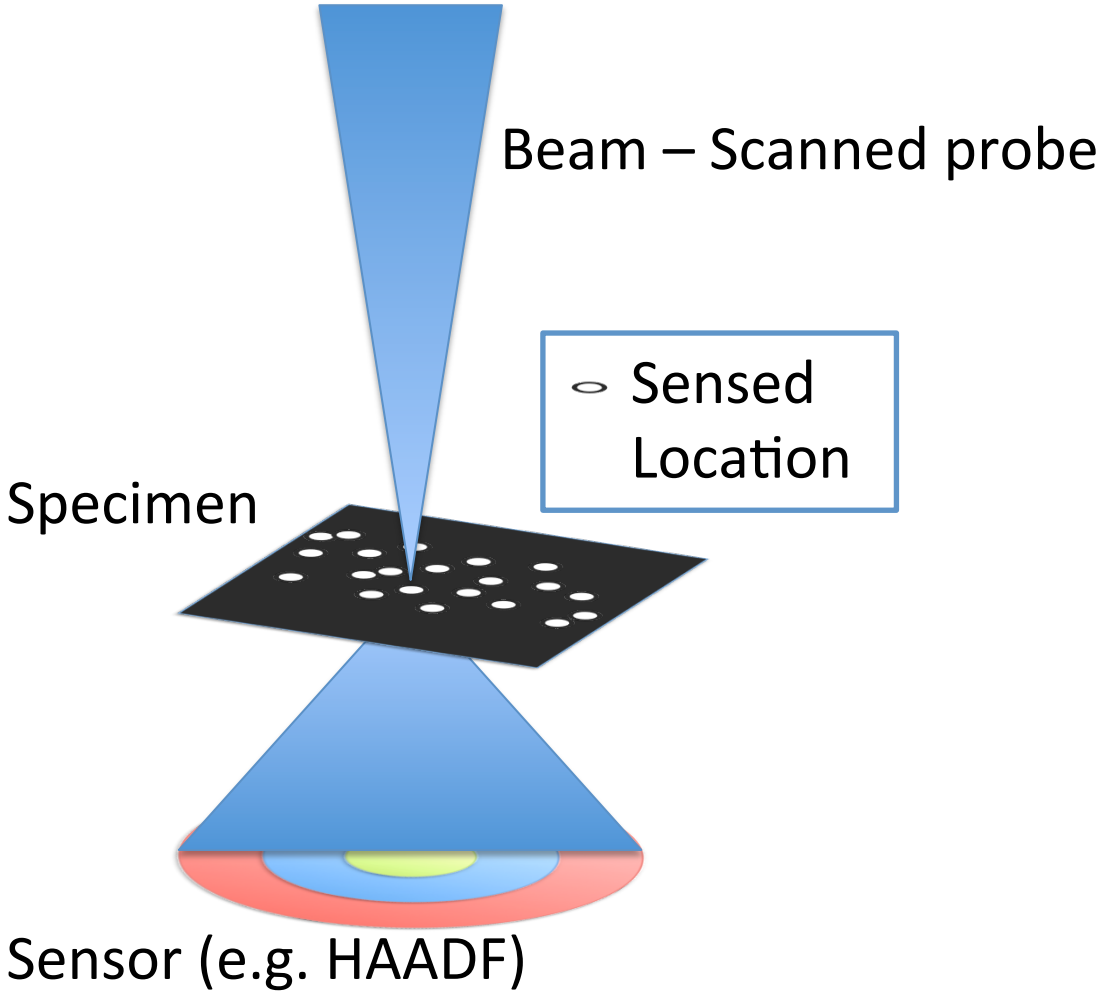
This film has been modified from its original version. It has been formatted to fit this screen and edited to run in the time allotted and for content.

# Inpainting

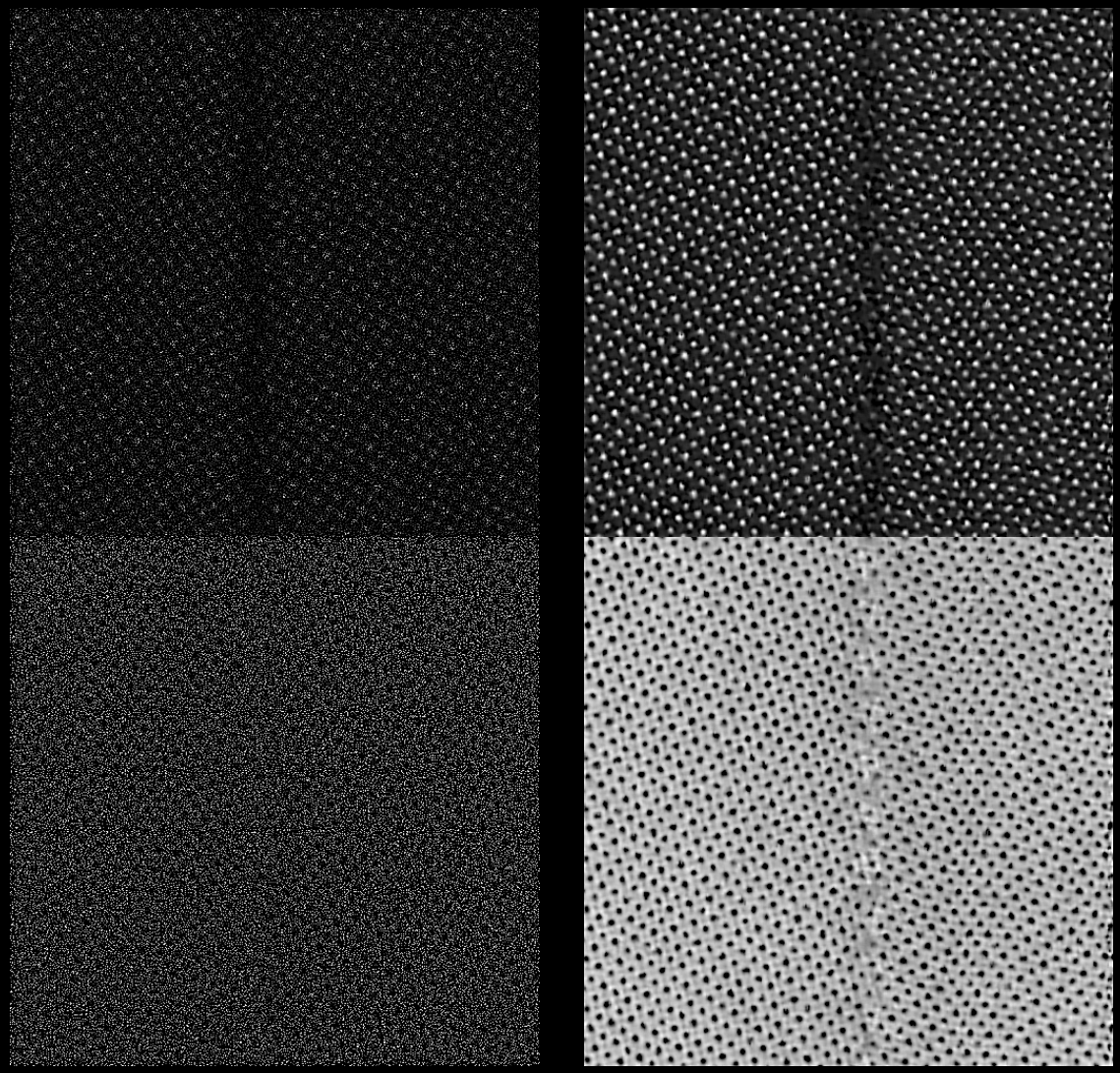


$$= \begin{bmatrix} 1 & 0 & 1 & 1 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \end{bmatrix} \circ$$

# Inpainting


Beam – Scanned probe
Sensed Location
Specimen
Sensor (e.g. HAADF)

# Inpainting – $SrTiO_3$ 20% missing



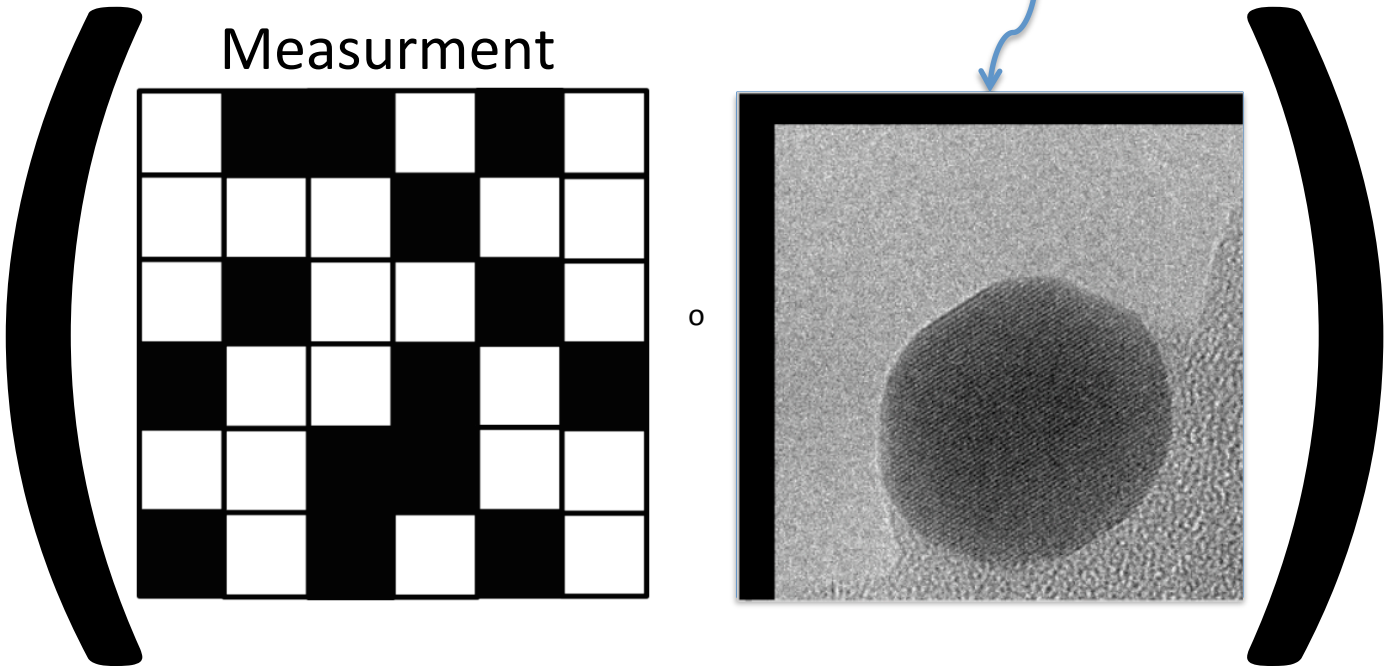
PSNR 20.66 dB
SSIM 0.9051
XCOR 0.8667

# Compressive Sensing (CS)

Compressd measurement

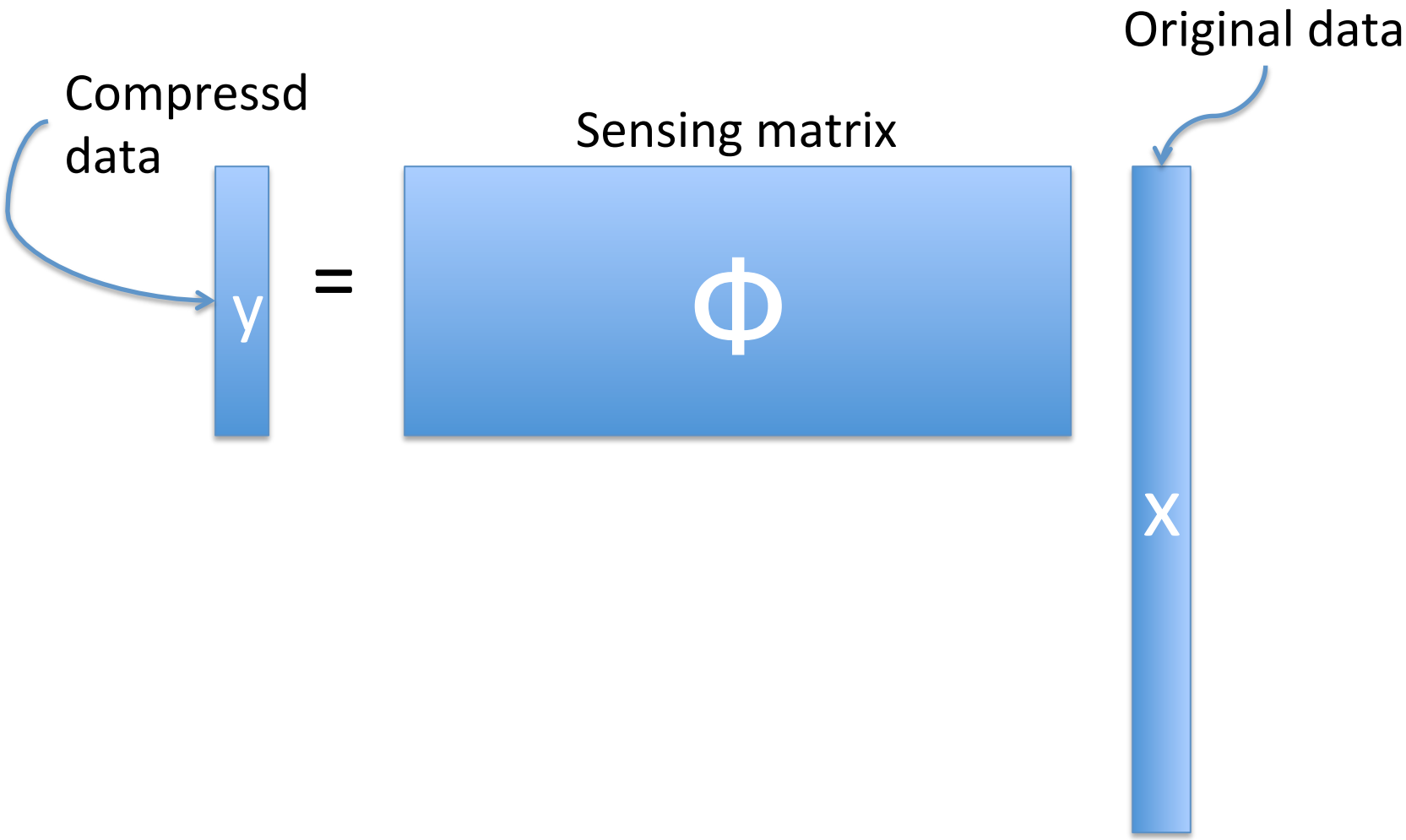
$y_i$ = SUM

Measurment

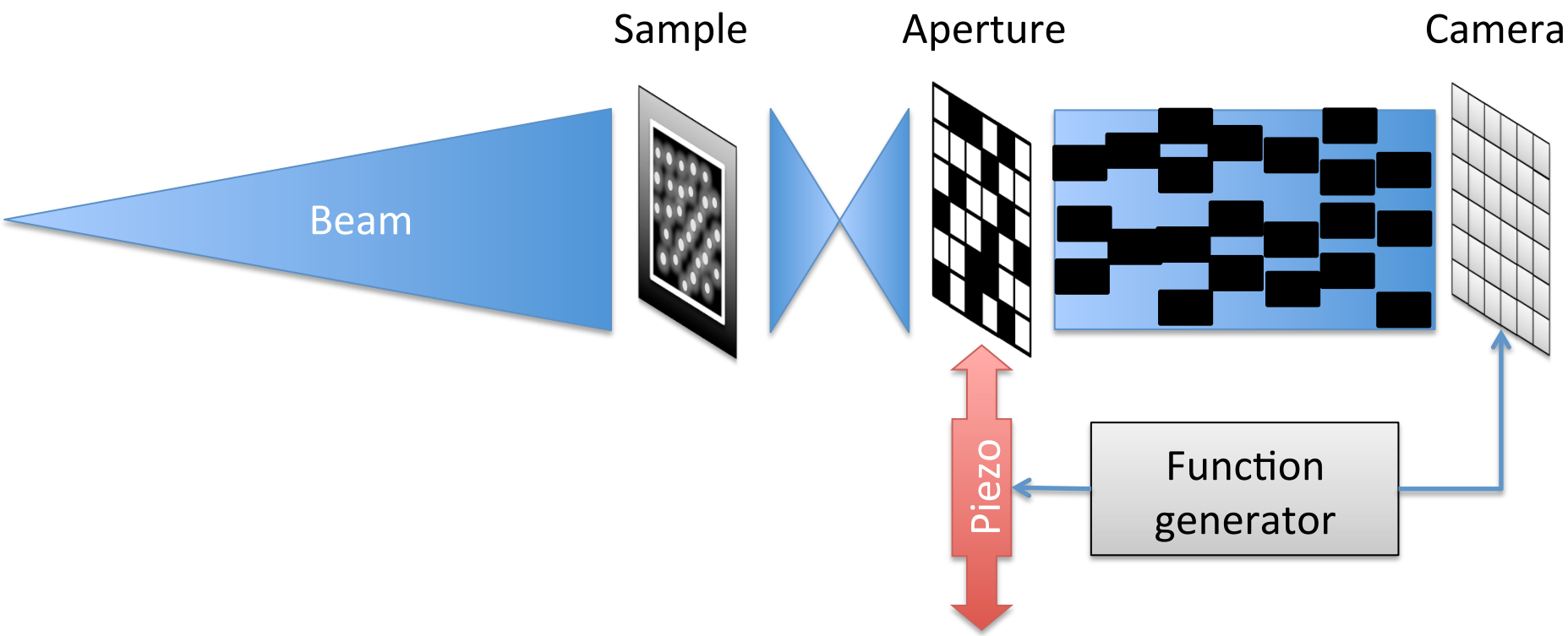



Original data

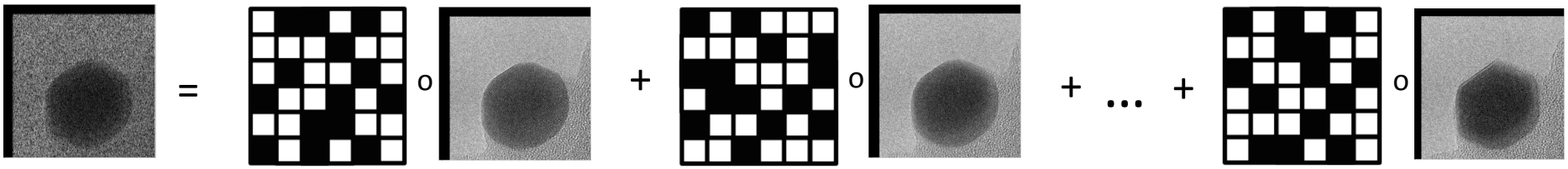
# Compressive Sensing



# Video CS

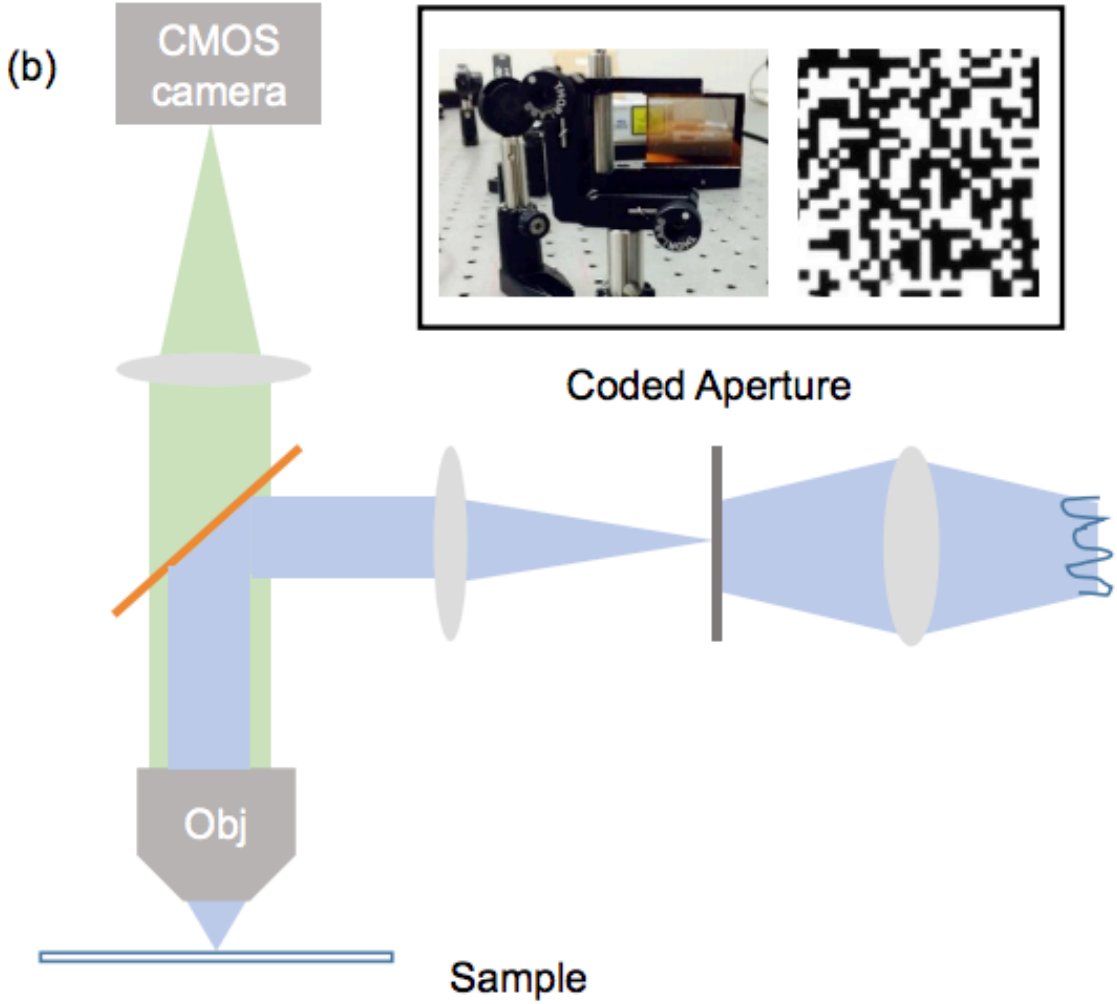


# Video CS

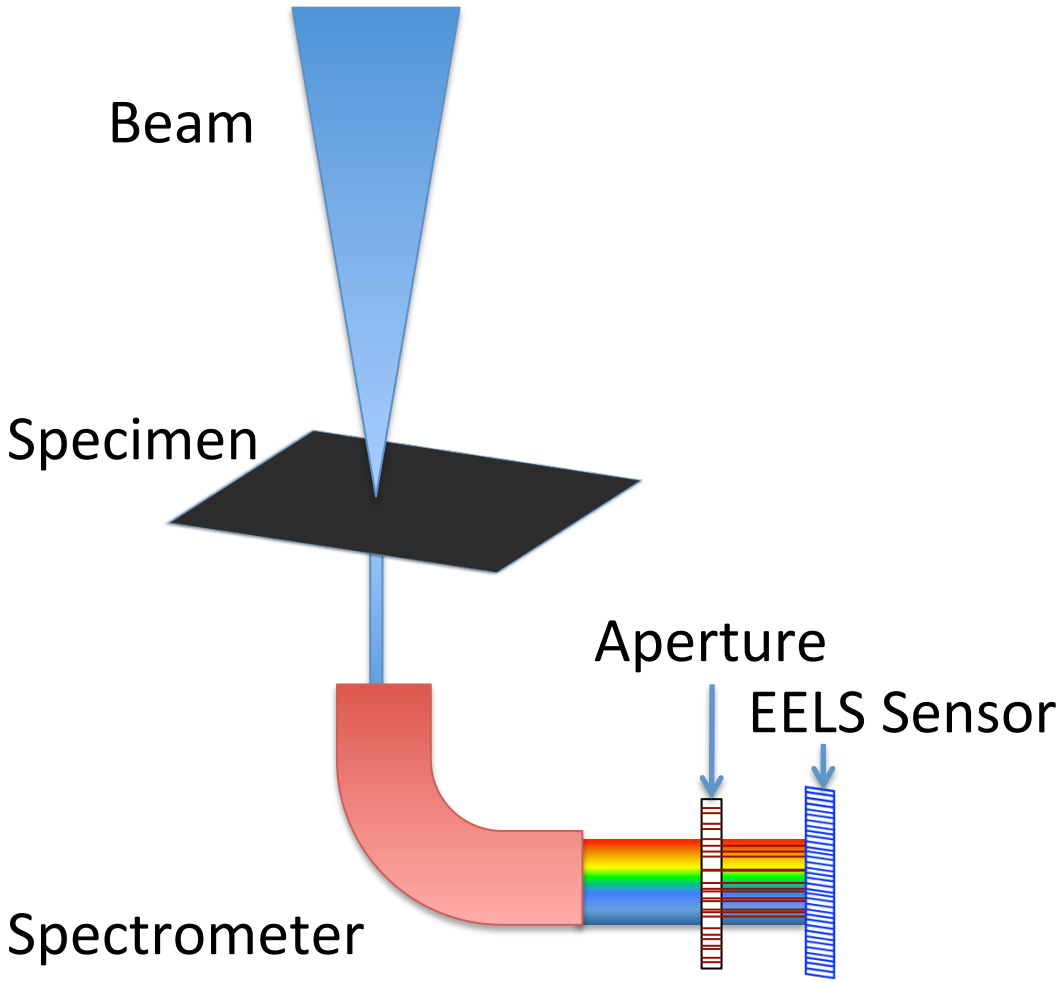



$$Y = H_1 \circ X_1 + H_2 \circ X_2 + \ldots + H_T \circ X_T$$

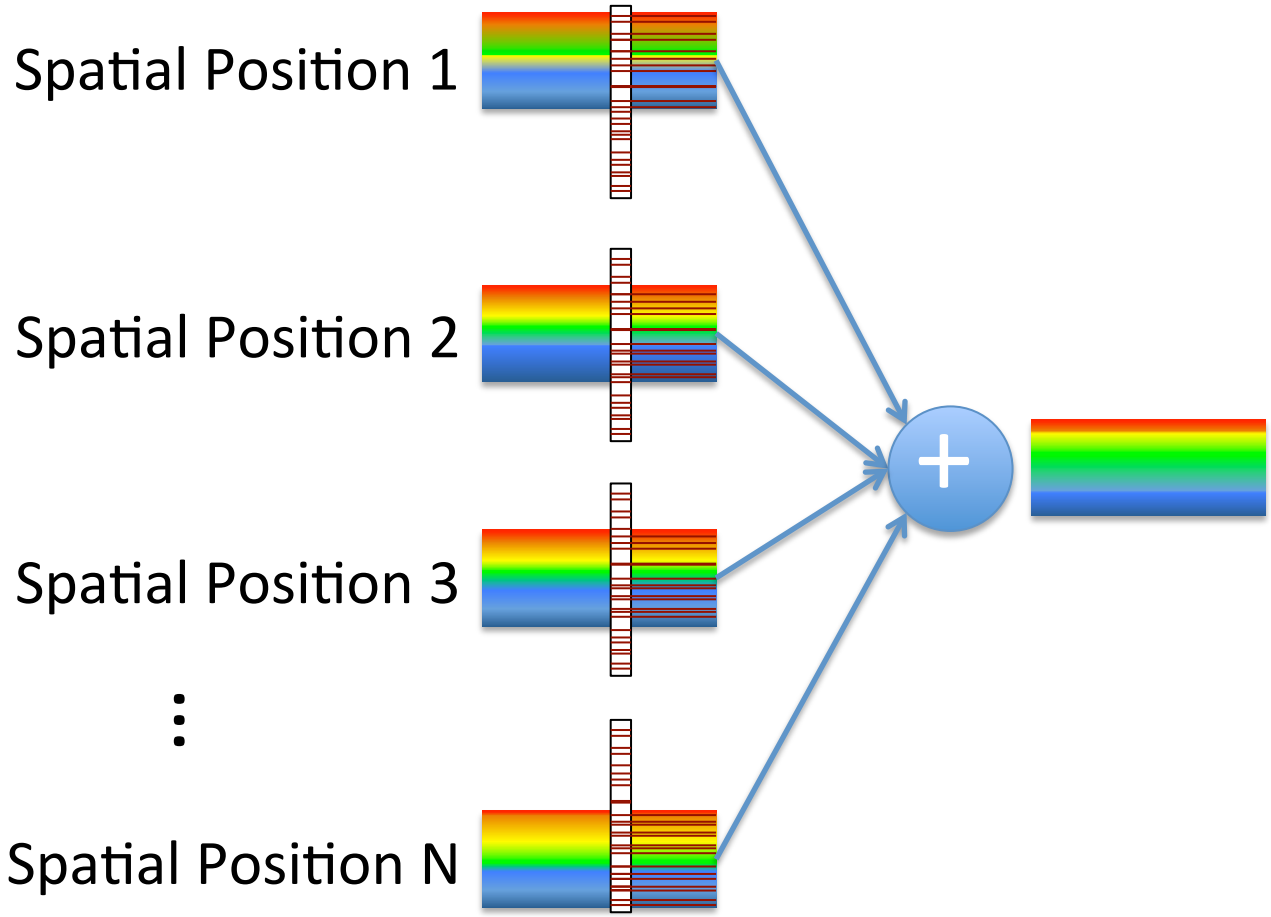
# Visible light video CS



# Electron energy loss spectroscopy CS

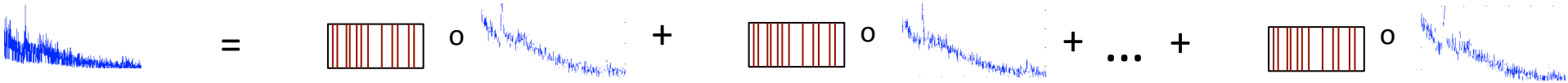


# Electron energy loss spectroscopy CS



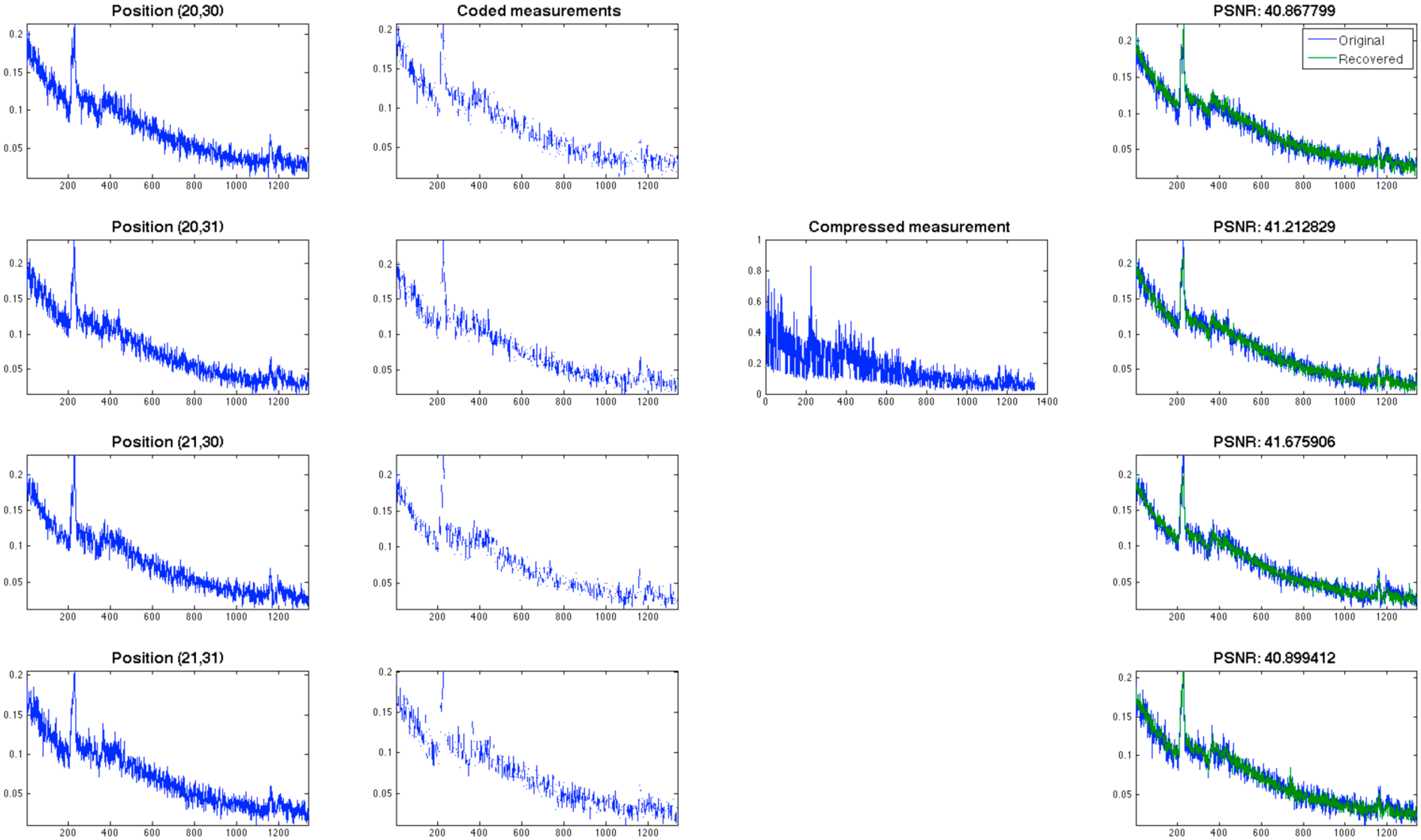

Compressive measurement: Sum of coded spectra

# Electron energy loss spectroscopy CS

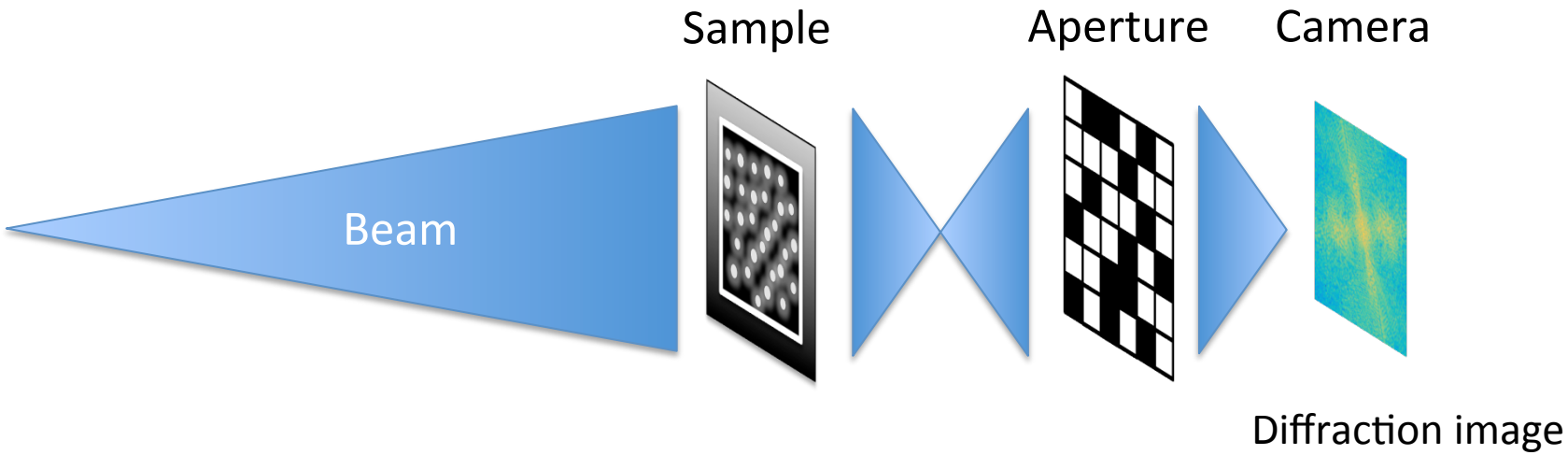


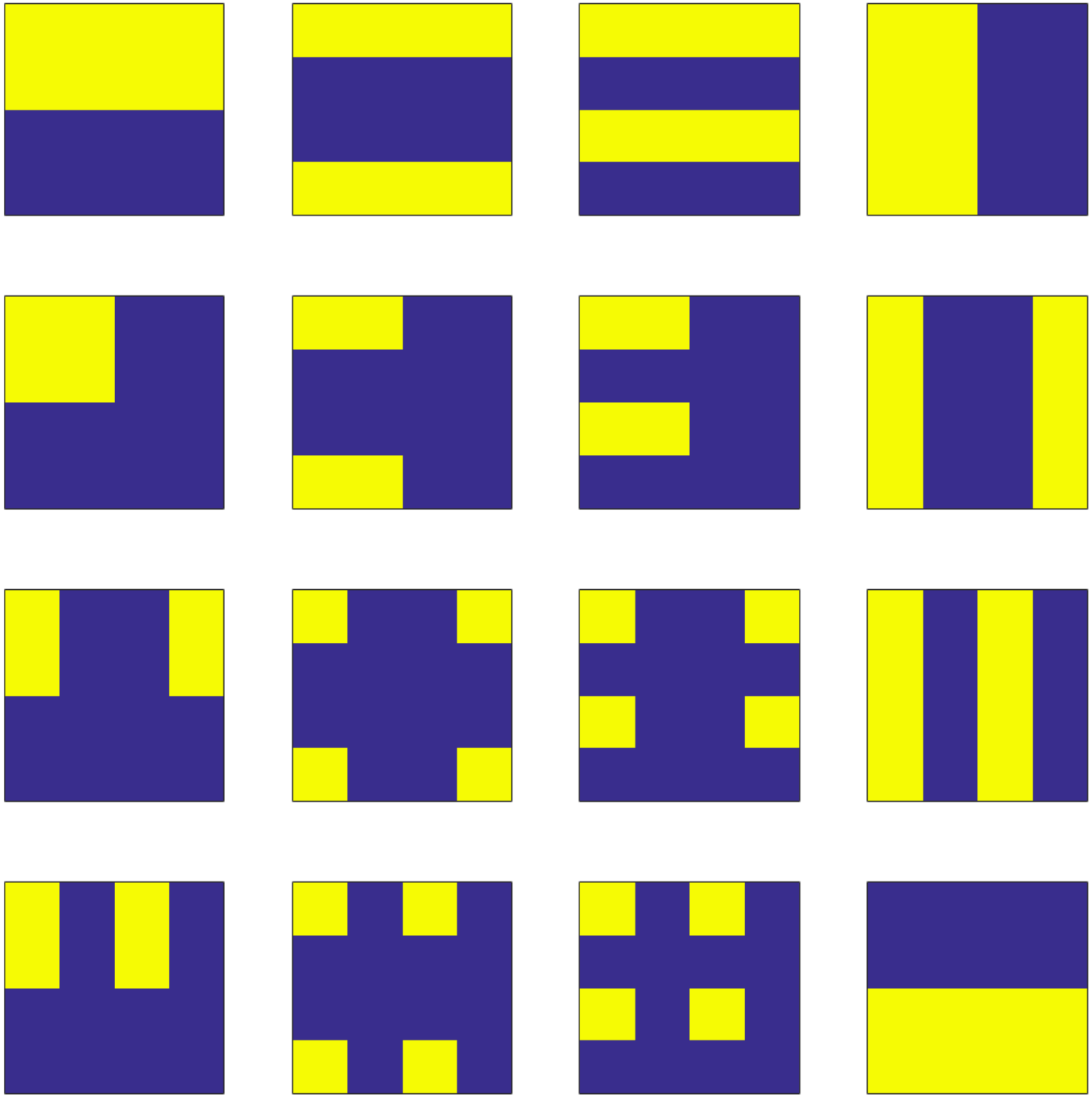

$$Y = H_1 \circ X_1 + H_2 \circ X_2 + \ldots + H_T \circ X_T$$

# Electron energy loss spectroscopy CS



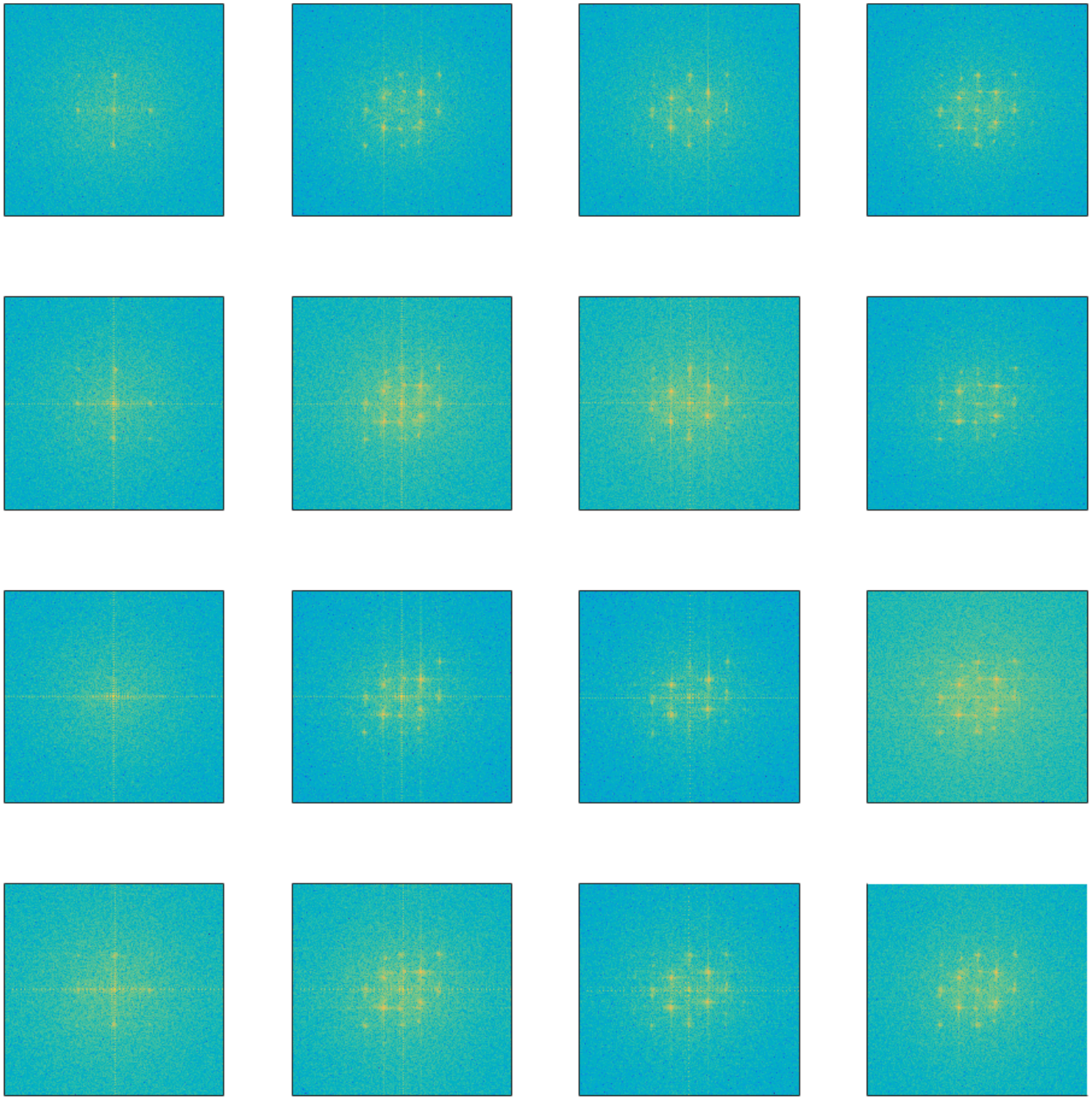
# Phase retreival





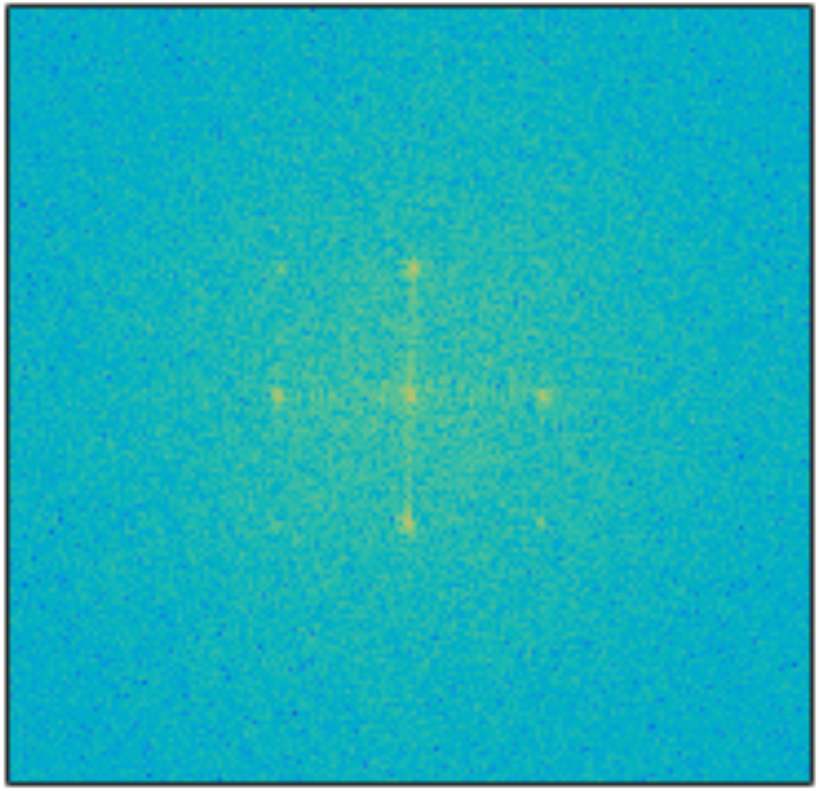
Masks
512x512

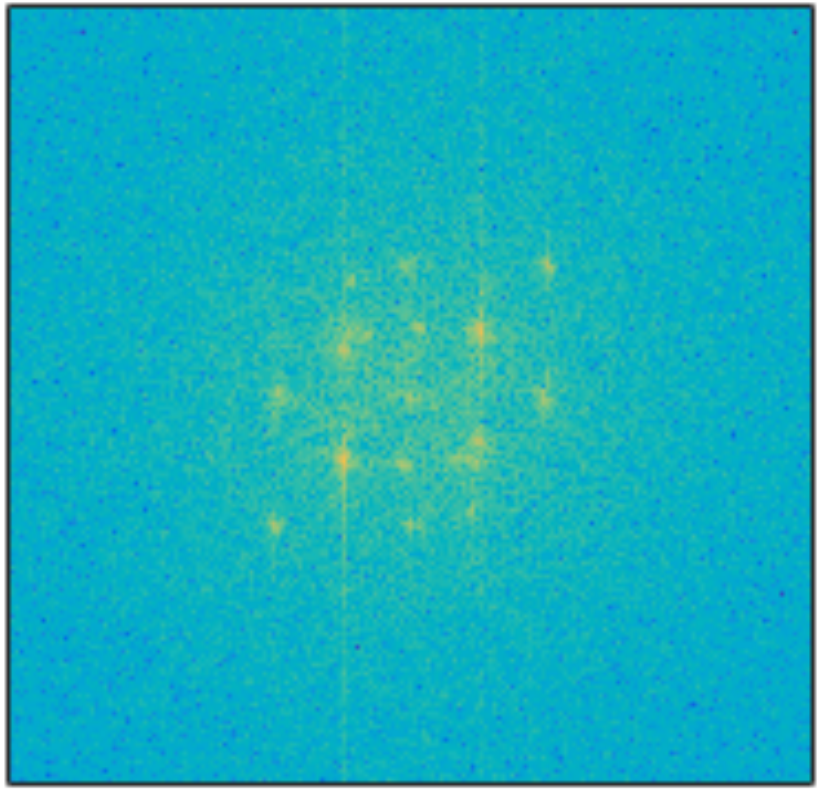
Yellow
transmissive



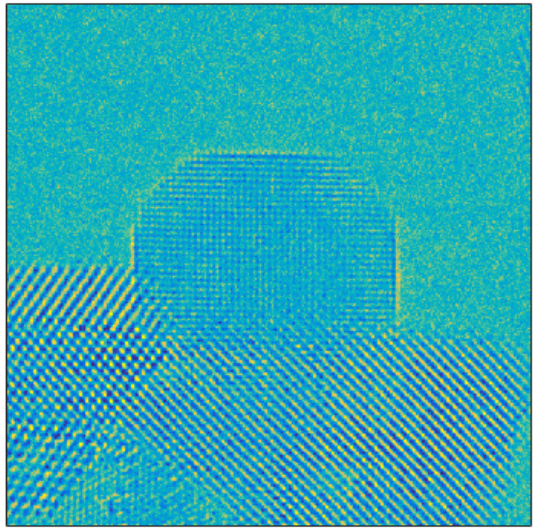
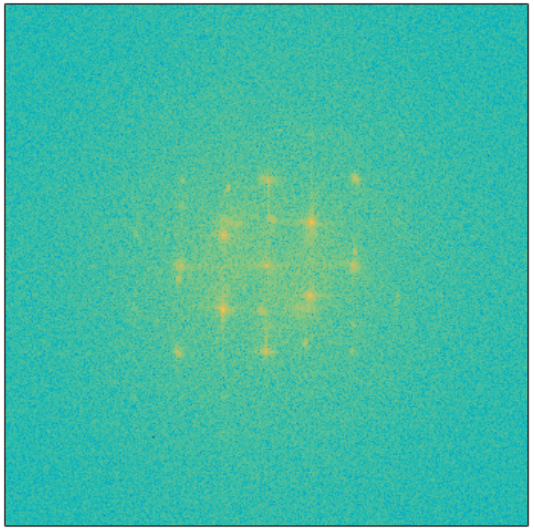
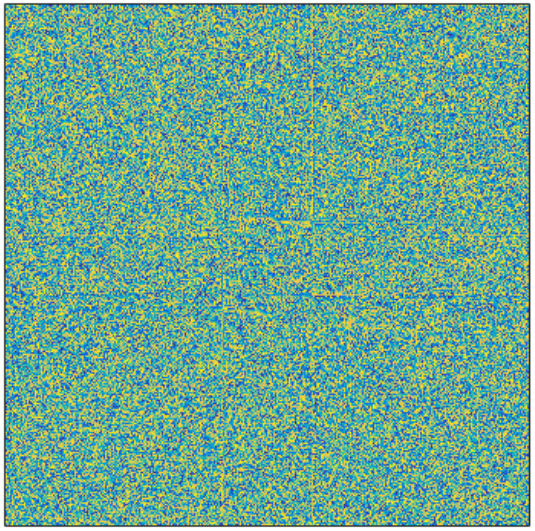
Diffraction of mask and specimen

Diffraction of mask and specimen

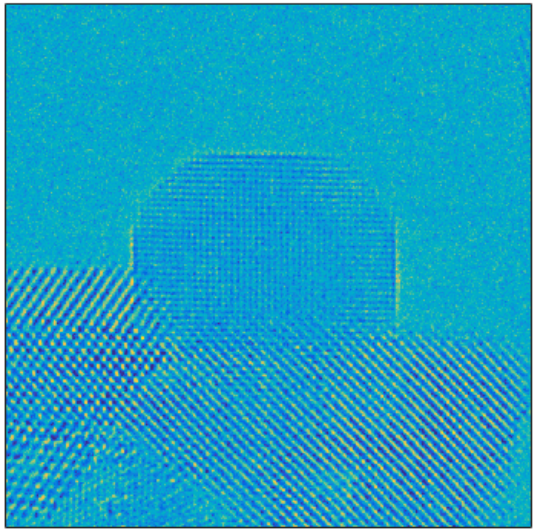
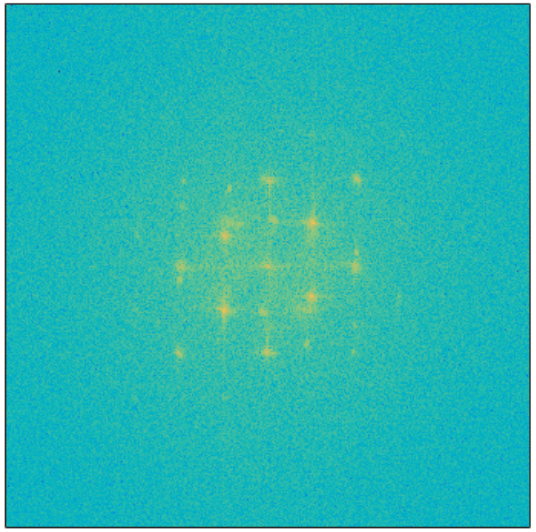
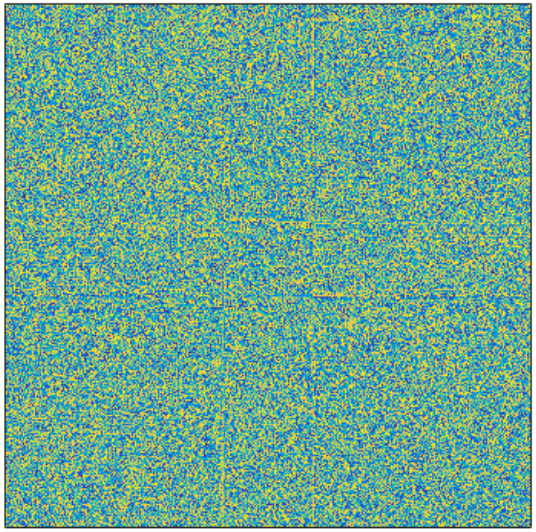




# Phase retrieval

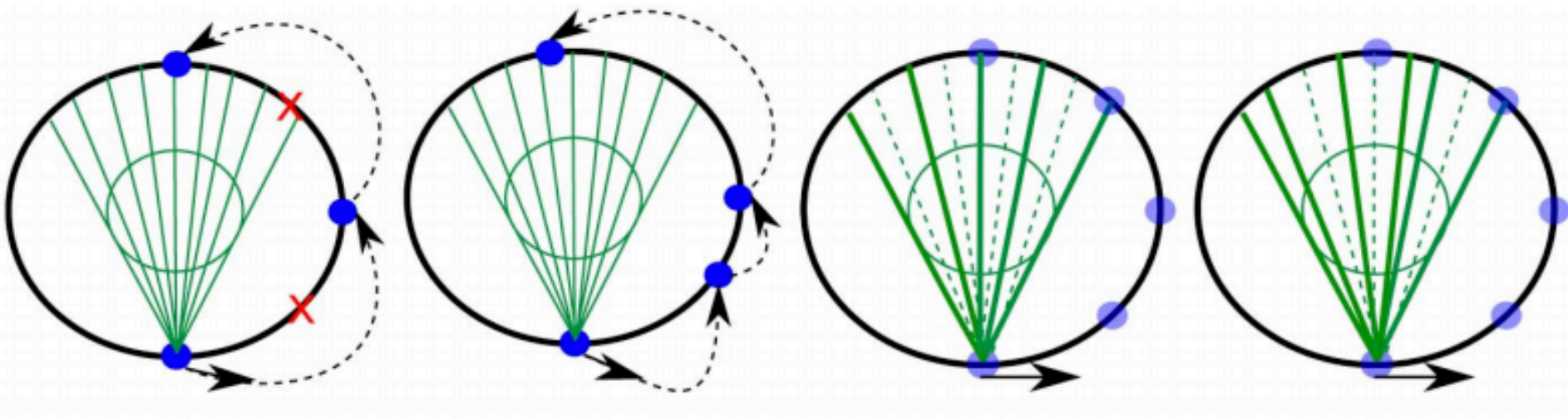
Top original, bottom reconstructed

# Tomography

Random tilts

Random pixel skipping



Tilts at angle increments

Collect all pixels

Kaganovsky et al.

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- Inpainting
- Video
- Spectroscopy
- Phase retrieval
- Tomography
- Single pixel
- Mix and match