High-Quality Hyperspectral Reconstruction using a Spectral Prior

SIGGRAPH Asia 2017
Supplemental Material

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Comparison of Results

Our High-Resolution Dataset

List of Compared Methods:

TwIST: Bioucas-Dias and Figueiredo, “Two-Step Algorithms for Linear Inverse Problems with Non-Quadratic Regularization”, ICIP 2007

SpaRSA: Wright et al., “Sparse Reconstruction by Separable Approximation”, IEEE TSP 2009

SC: Lin et al., “Spatial-Spectral Encoded Compressive Hyperspectral Imaging”, ACM TOG 2014

Setup for Our Hyperspectral Dataset

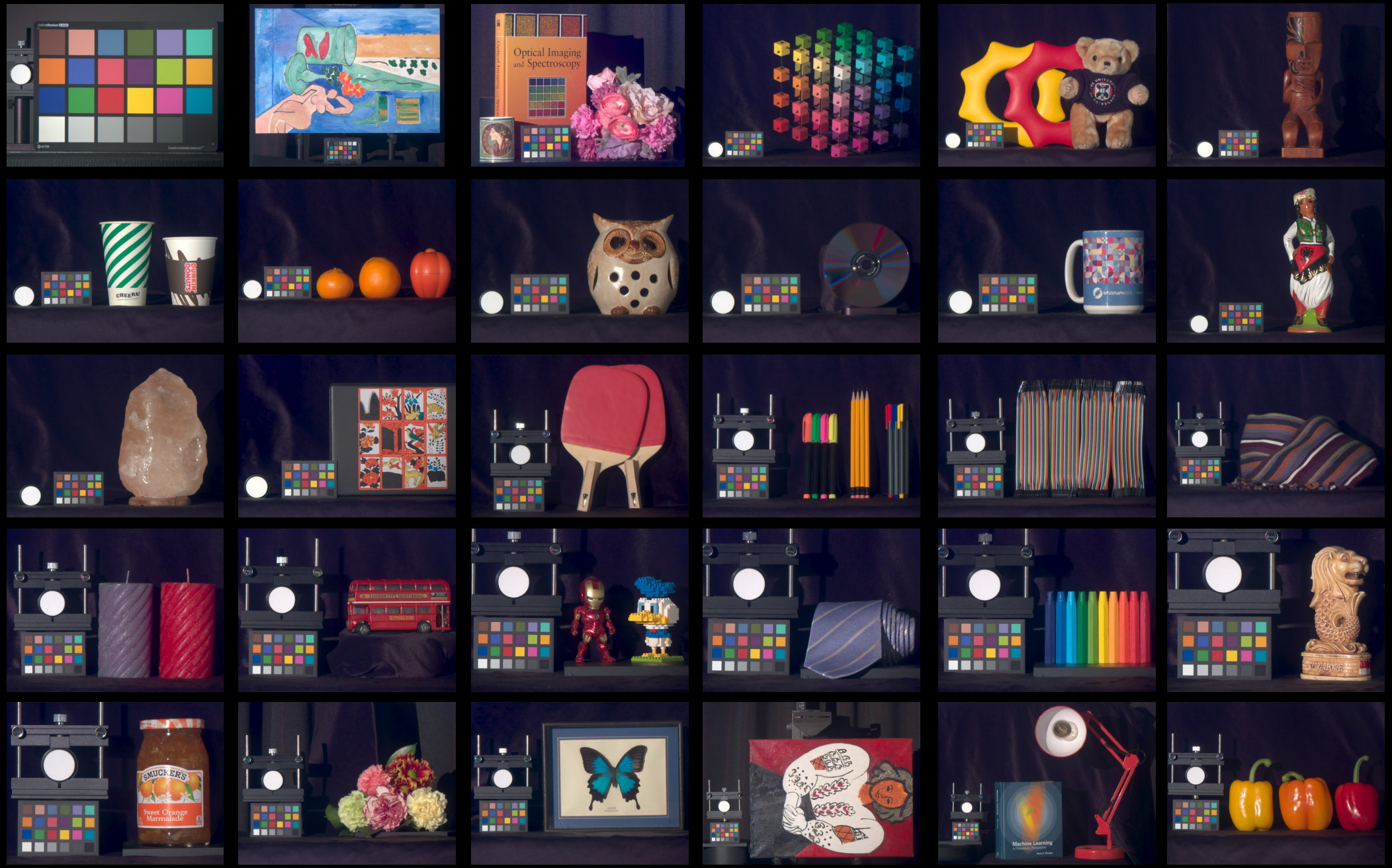
Parts	Specification
Filter	VeriSpec VIS LCTF (effective spectral range: 420 nm - 720 nm)
Objective lens	Coastal Optics 60 mm apochromatic lens
Camera	Monochromatic PointGrey Grasshopper (GS3-PGE-91S6M-C) Resolution: 3376 x 2704 Pixel pitch: 3.69 μm
Illuminant	Solid-state plasma lamp (Thorlab HPLS-30-04)

Note that we capture hyperspectral information by scanning the spectrum along wavelengths, so no reconstruction is needed.

Ground Truth: Our High-Resolution Dataset



Our Reconstruction: Our High-Resolution Dataset



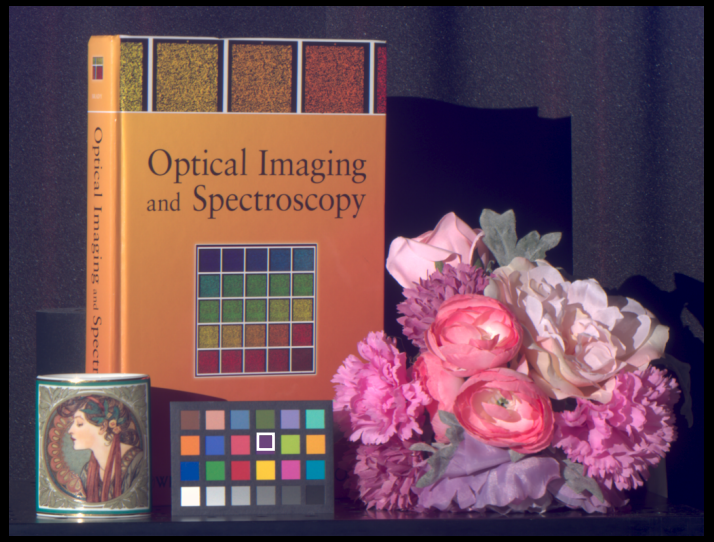
Our High-Resolution Dataset #1 (Figure 1)



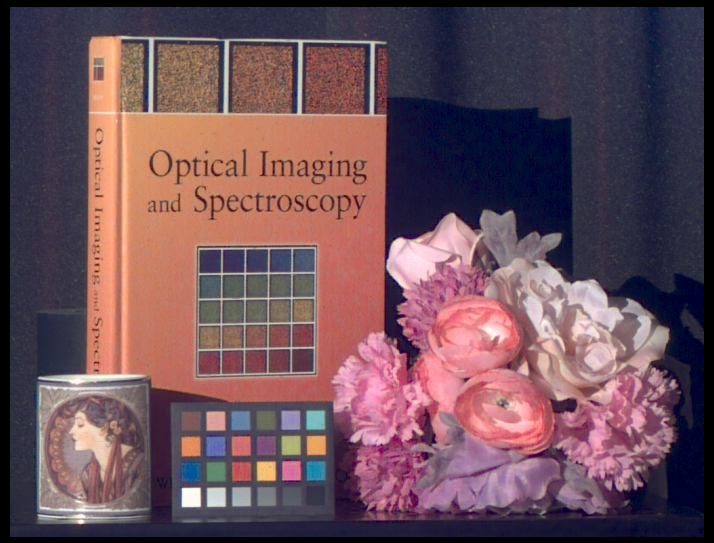
TwIST (22.22dB/SSIM:0.84)



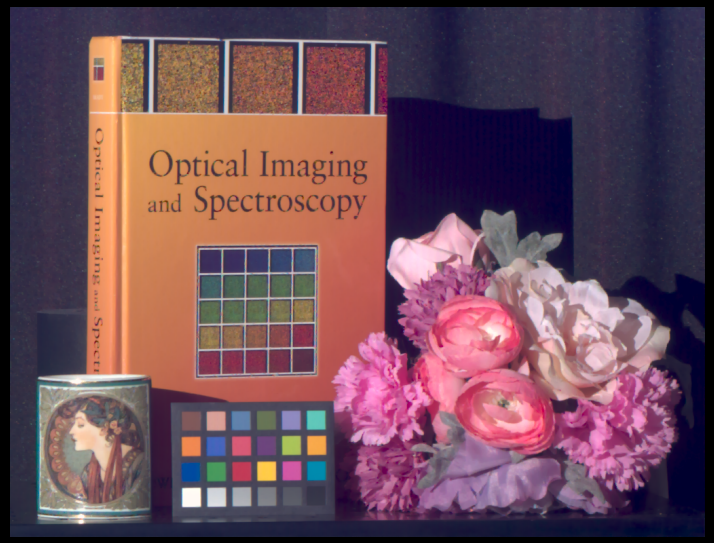
SpaRSA (24.27dB/SSIM:0.85)



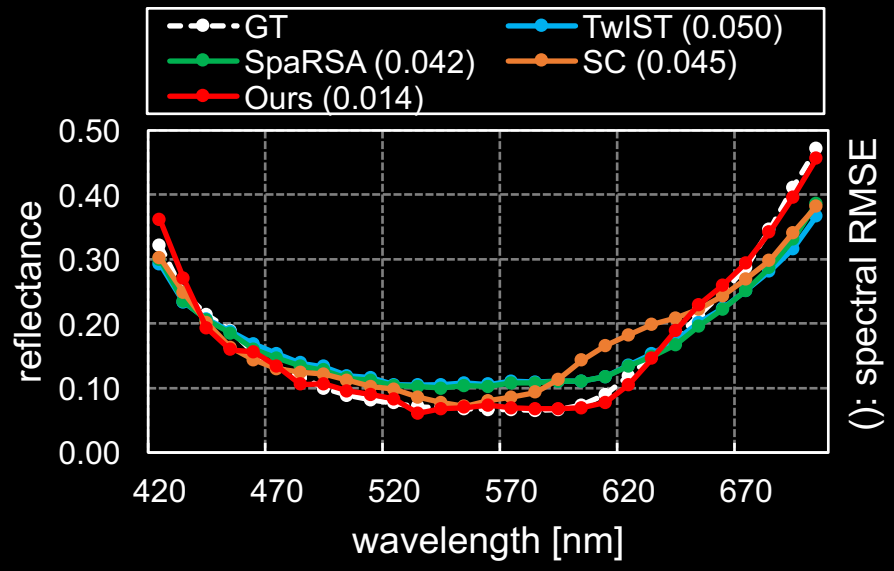
Ground truth



SC (28.36dB/SSIM:0.90)



Ours (32.23dB/SSIM:0.94)



Our High-Resolution Dataset #2 (Figure 11)



TwIST (22.29dB/SSIM:0.79)



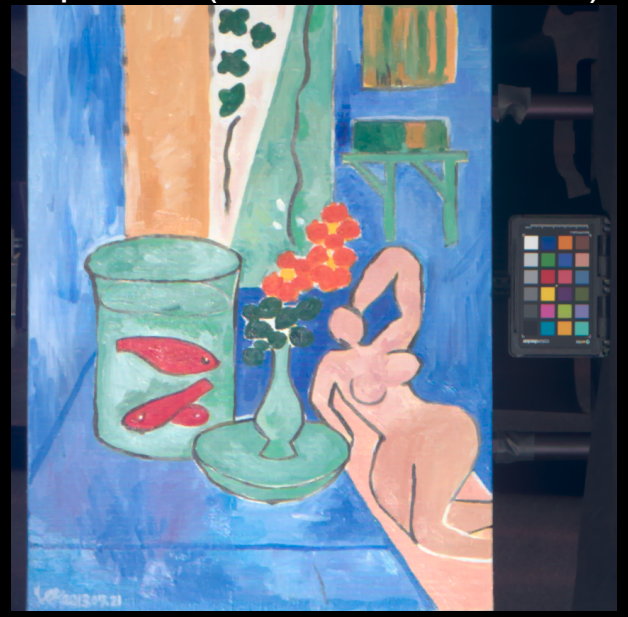
SpaRSA (23.63dB/SSIM:0.81)



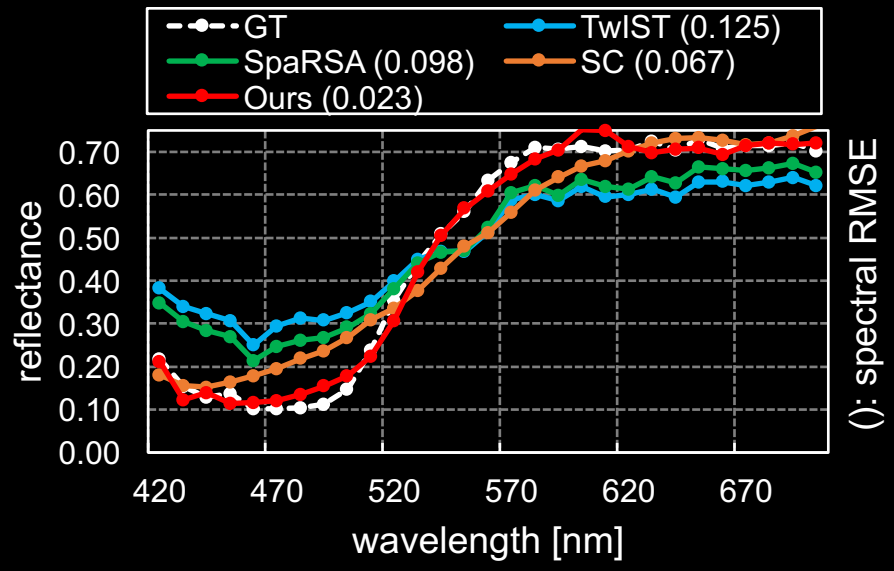
Ground truth



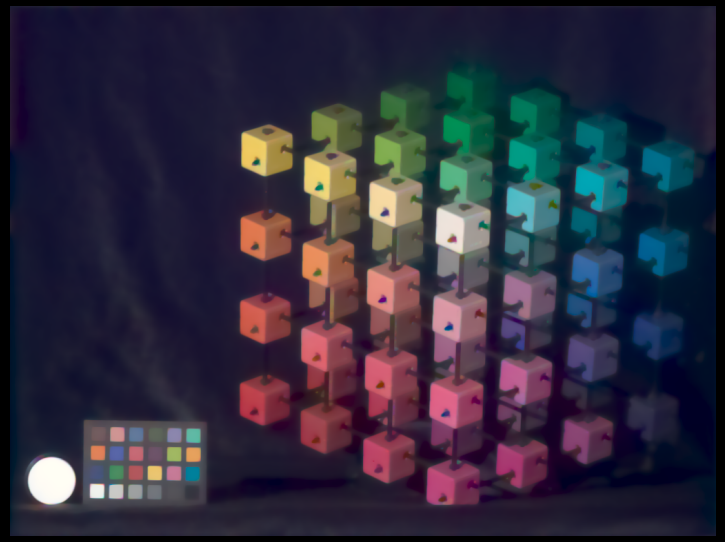
SC (25.74dB/SSIM:0.84)



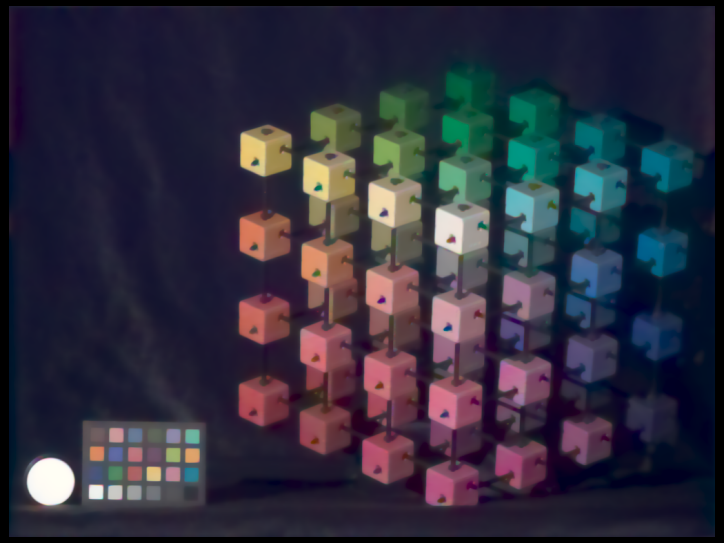
Ours (28.99dB/SSIM:0.90)



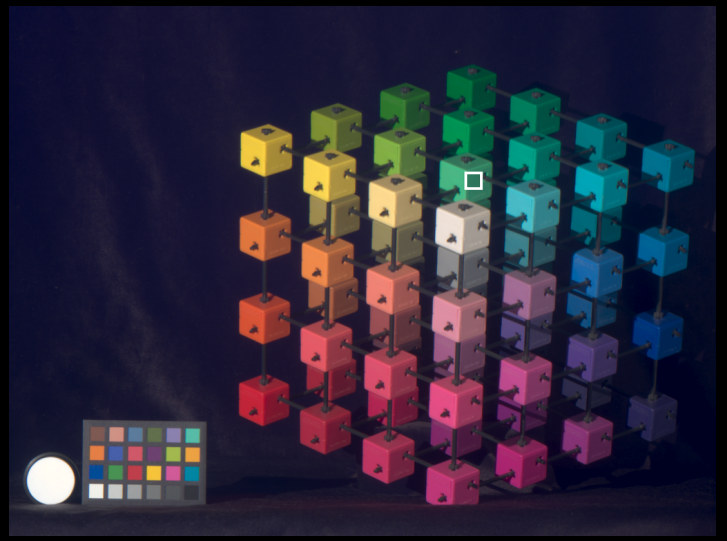
Our High-Resolution Dataset #3 (Figure 11)



TwIST (34.20dB/SSIM:0.95)



SpaRSA (32.03dB/SSIM:0.95)



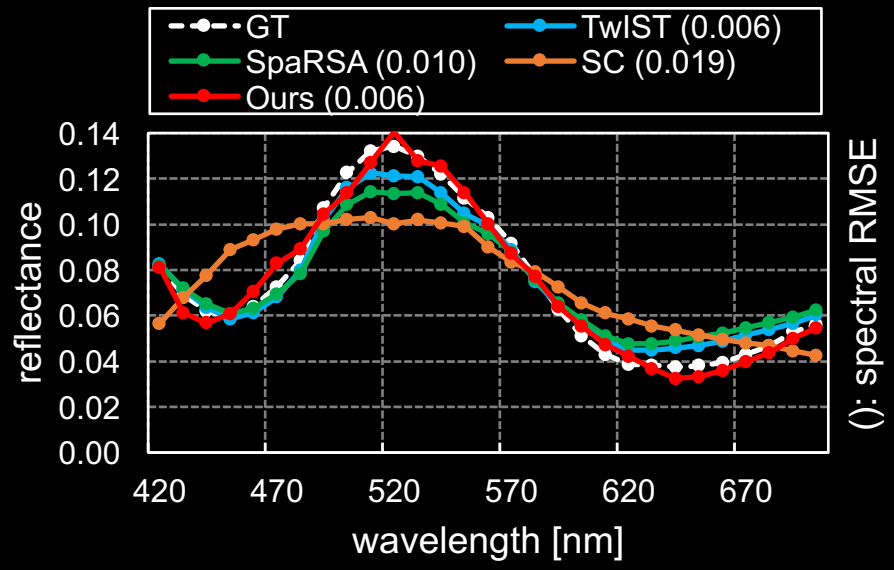
Ground truth



SC (32.29dB/SSIM:0.92)



Ours (39.21dB/SSIM:0.97)



Our High-Resolution Dataset #4



TwIST (30.76dB/SSIM:0.95)



SpaRSA (30.49dB/SSIM:0.95)



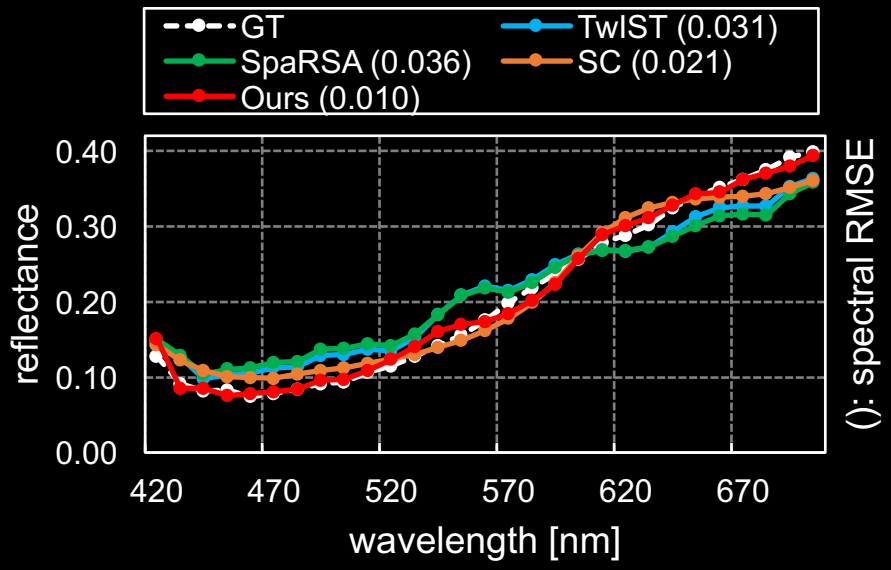
Ground truth



SC (33.97dB/SSIM:0.92)



Ours (37.76dB/SSIM:0.96)



Comparison of Results

with BPFA, Low-rank, Regression-based Reconstruction

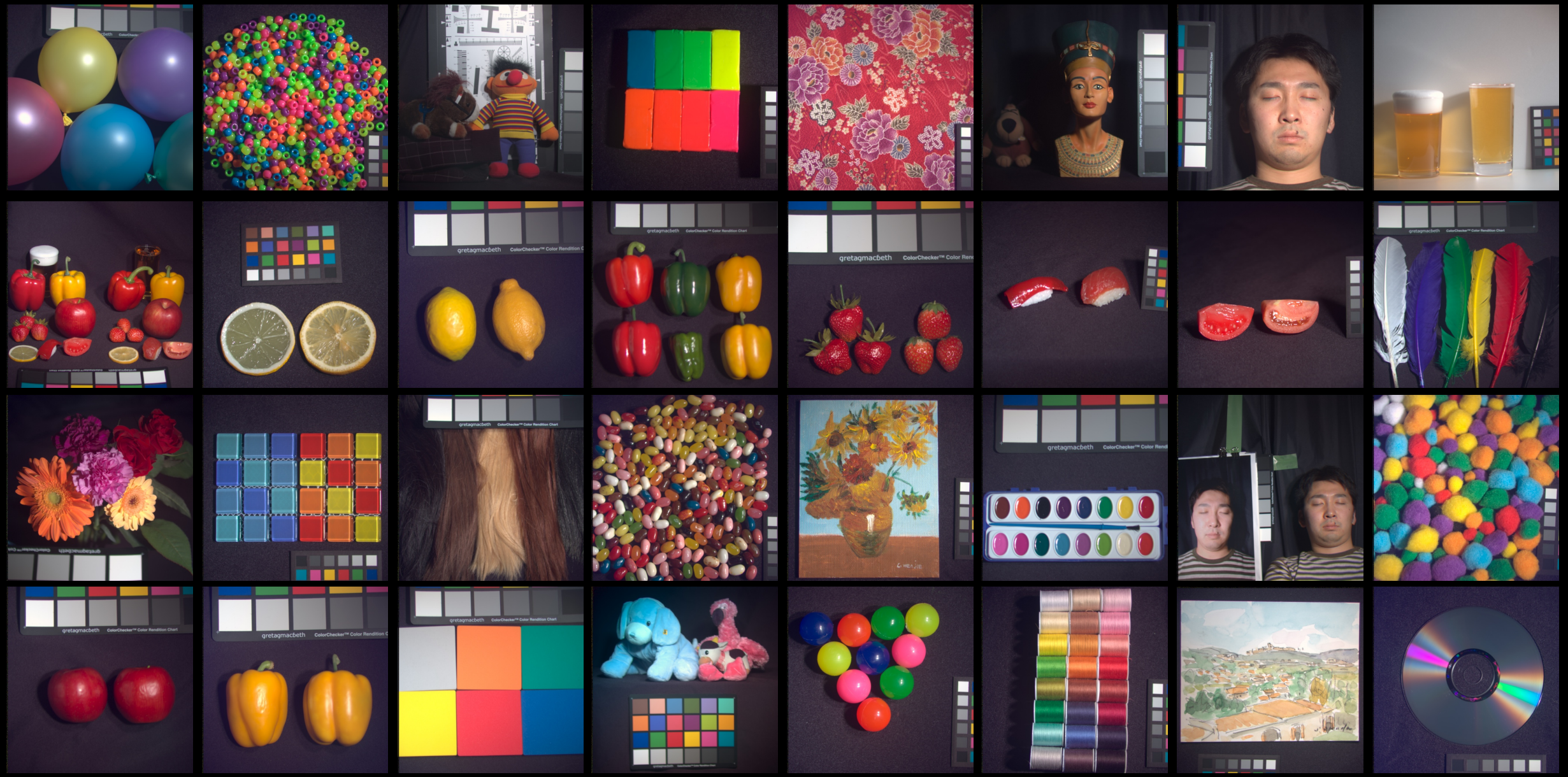
List of Compared Methods:

BPFA: Rajwade et al, “Coded Hyperspectral Imaging and Blind Compressive Sensing”, SIAM Journal on Imaging Sciences 2013

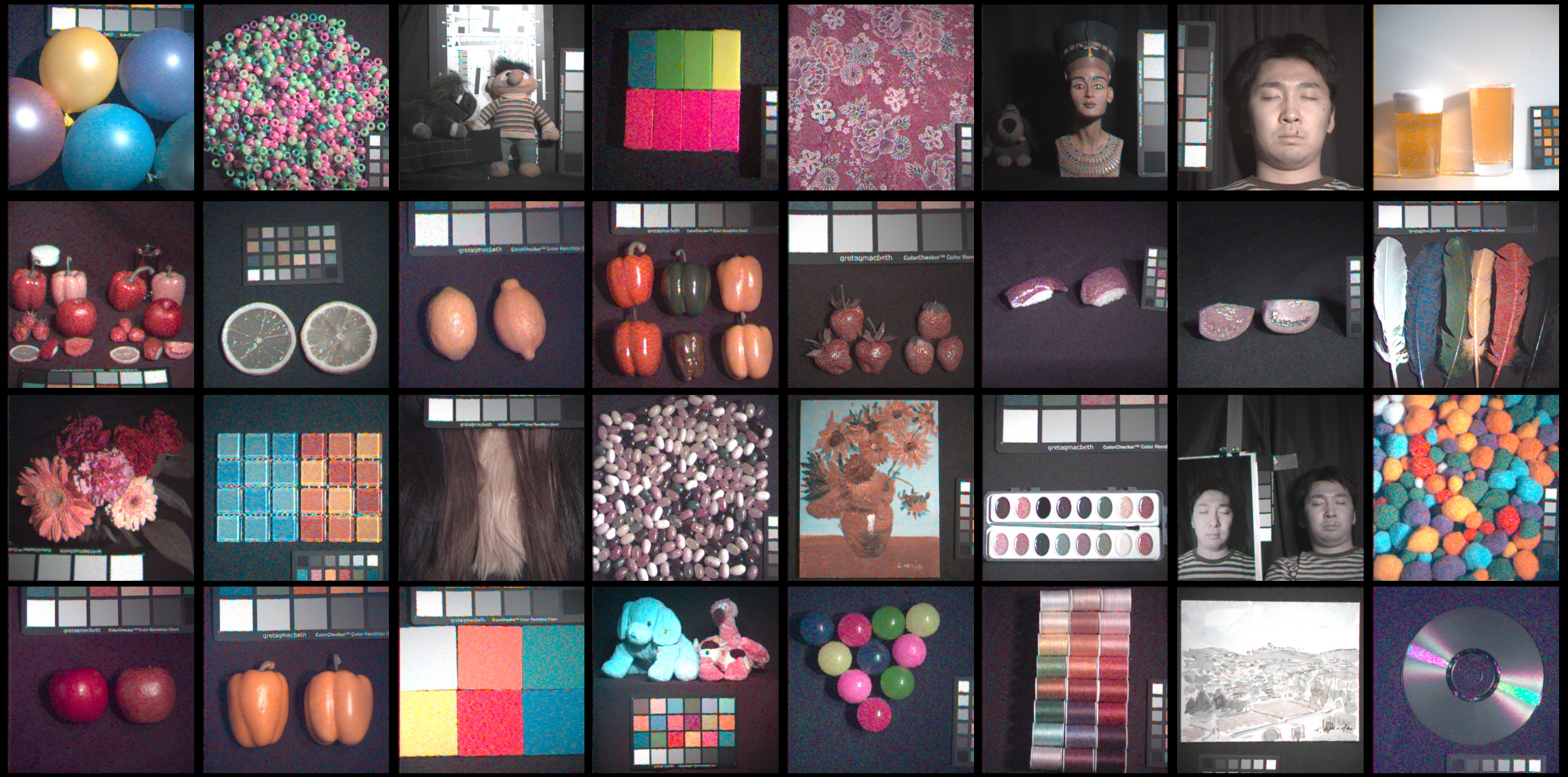
Low-rank: Fu et al., “Exploiting Spectral-Spatial Correlation for Coded Hyperspectral Image Restoration”, CVPR 2016

Regression: Kulkarni et al., “ReconNet: Non-Iterative Reconstruction of Images From Compressively Sensed Measurements”, CVPR 2016

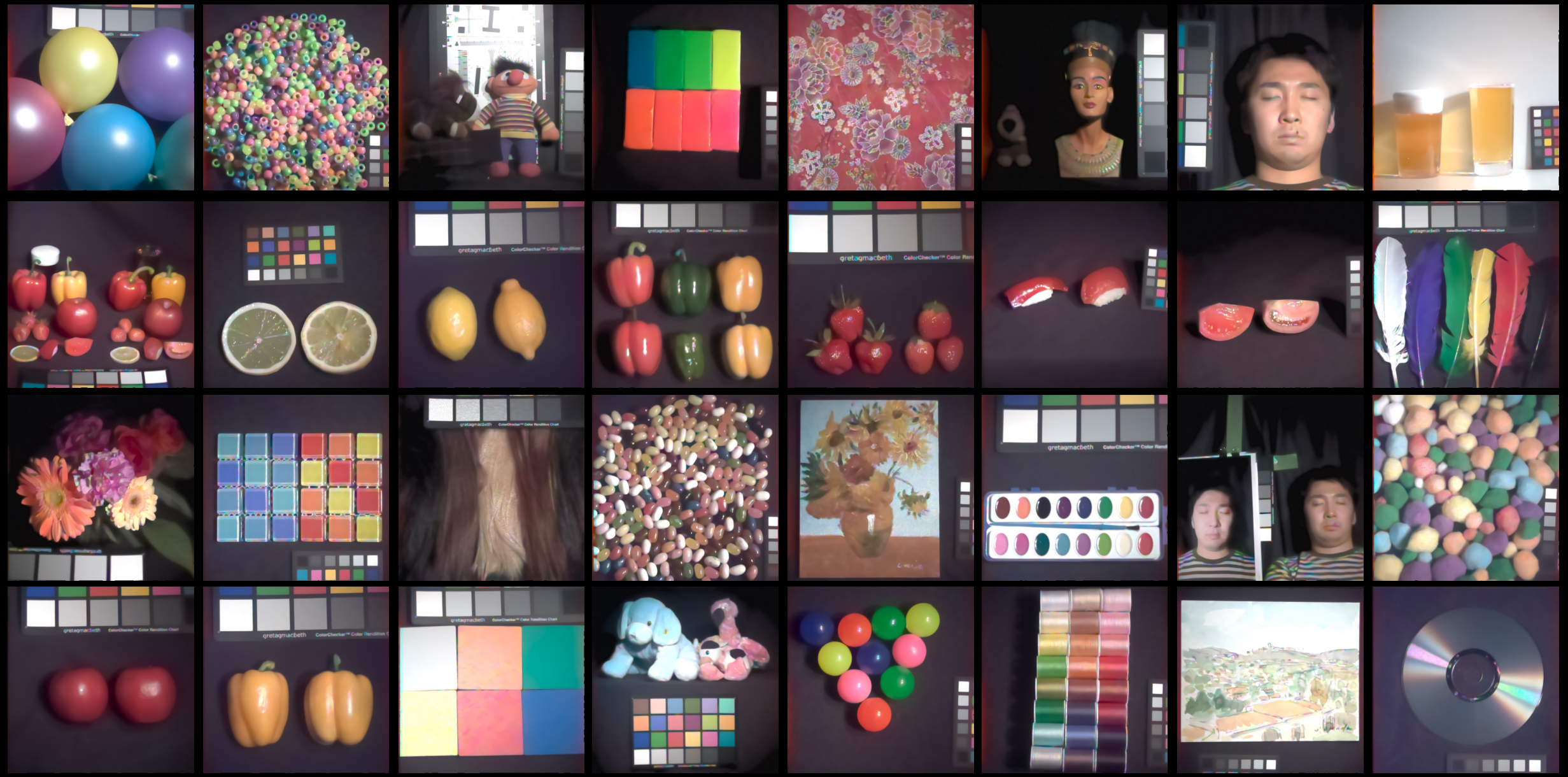
Ground Truth: Columbia Dataset



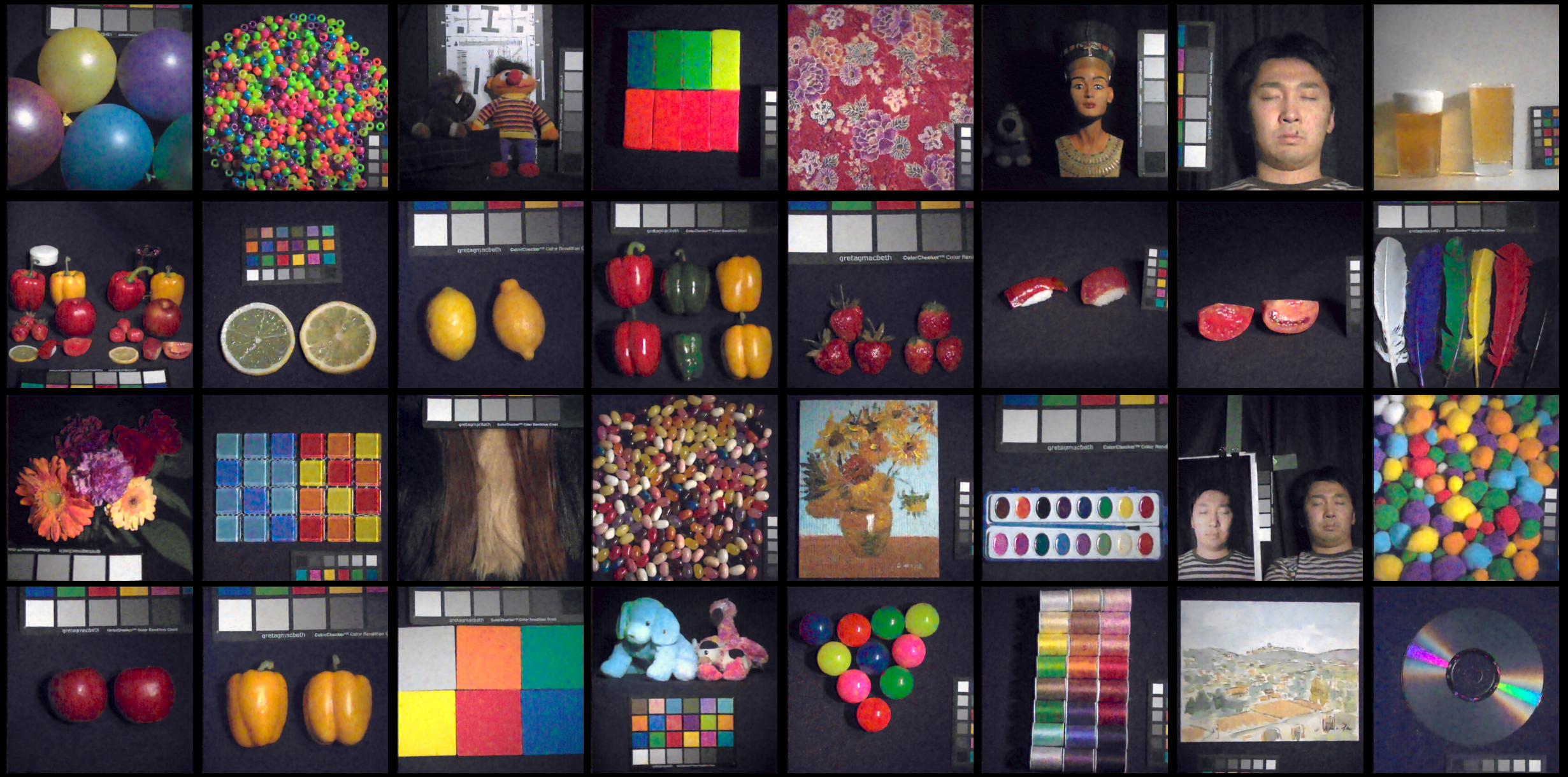
BPFA: Columbia Dataset



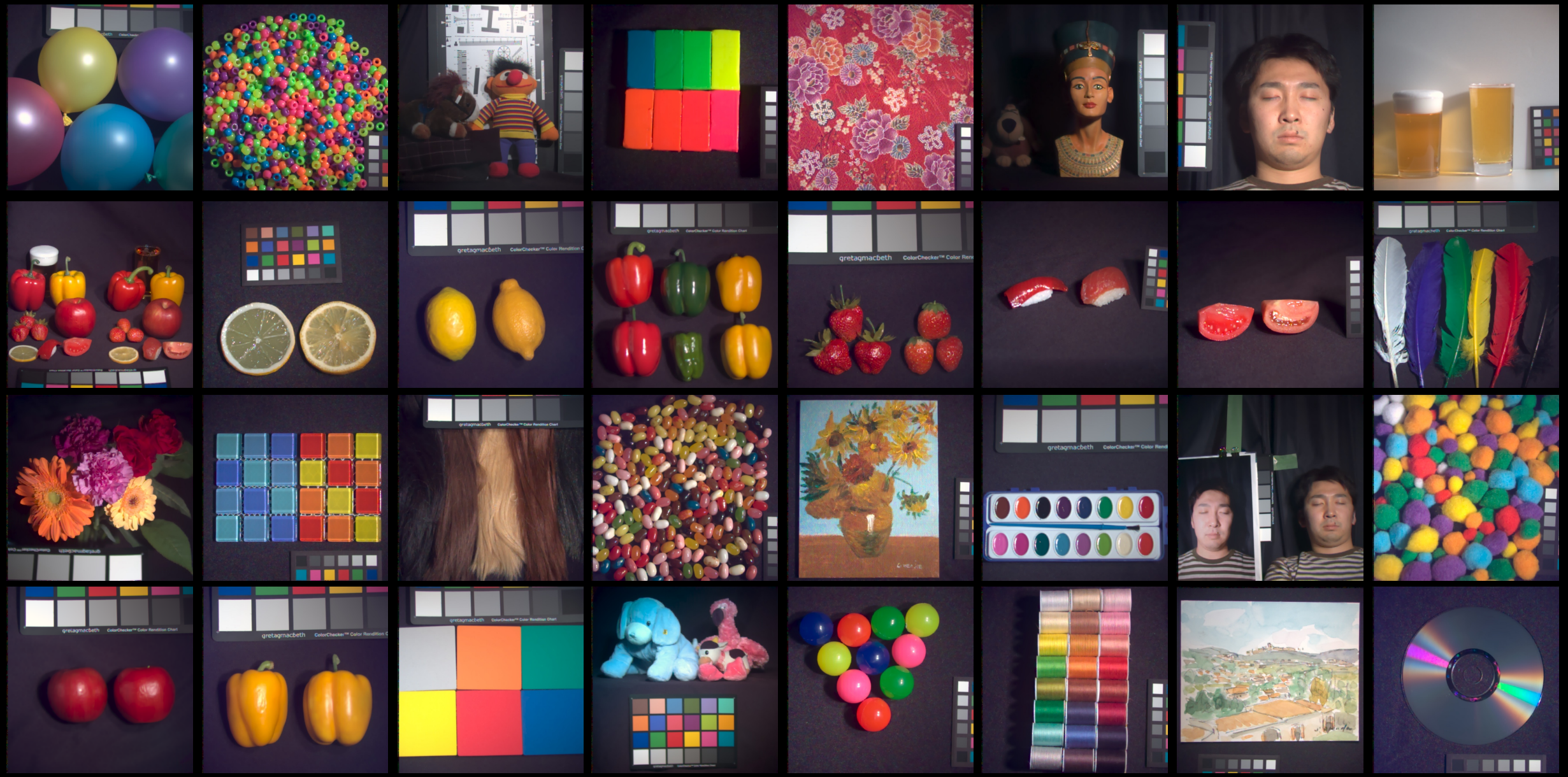
Low-rank: Columbia Dataset



Regression-based Reconstruction: Columbia Dataset



Our Reconstruction: Columbia Dataset



Comparison: Columbia Dataset #1 (Figure 13)



BPFA (22.45dB/SSIM:0.75)



Low-Rank (21.66dB/SSIM:0.88)



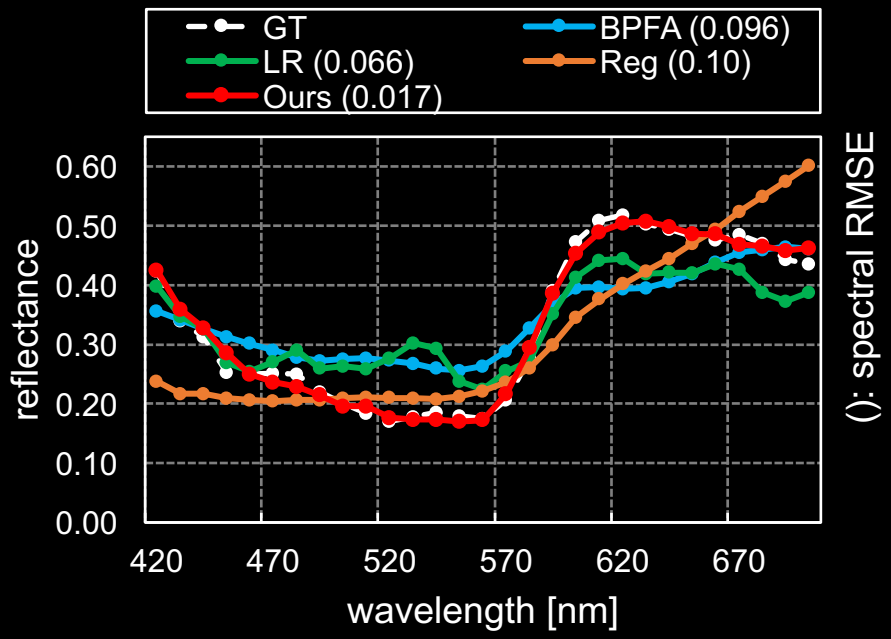
Ground truth



Regression (25.37dB/SSIM:0.86)



Ours (33.31dB/SSIM:0.97)



Comparison: Columbia Dataset #2 (Figure 13)



BPFA (23.85dB/SSIM:0.75)



Low-Rank (23.55dB/SSIM:0.69)



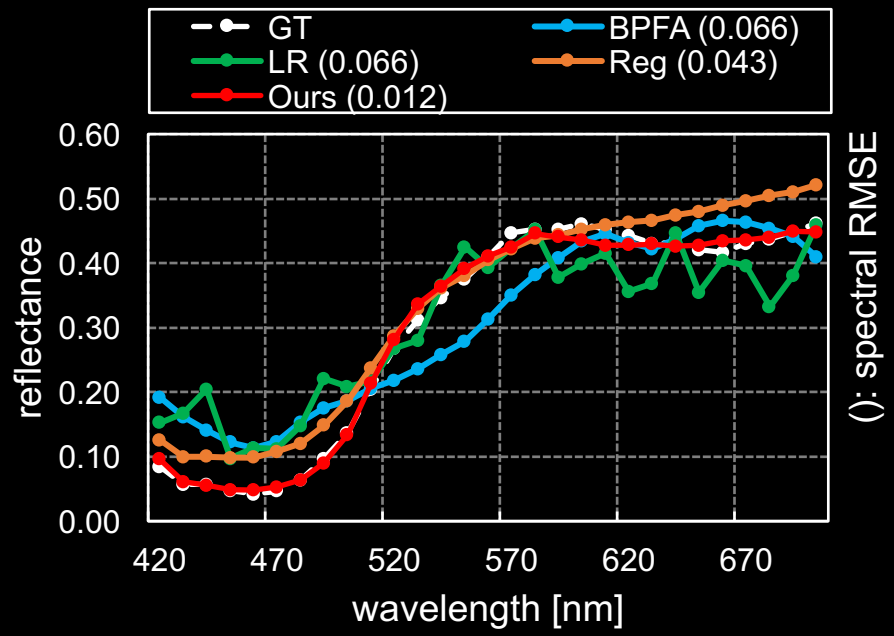
Ground truth



Regression (25.69dB/SSIM:0.78)



Ours (28.74dB/SSIM:0.85)



Comparison: Columbia Dataset #3 (Figure 13)



BPFA (24.73dB/SSIM:0.73)



Low-Rank (28.15dB/SSIM:0.90)



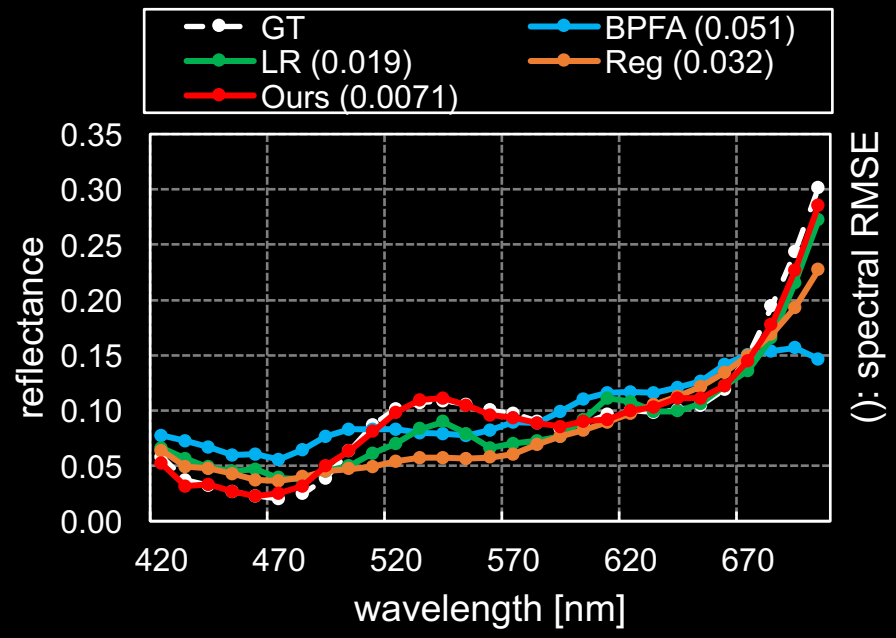
Ground truth



Regression (31.21dB/SSIM:0.91)

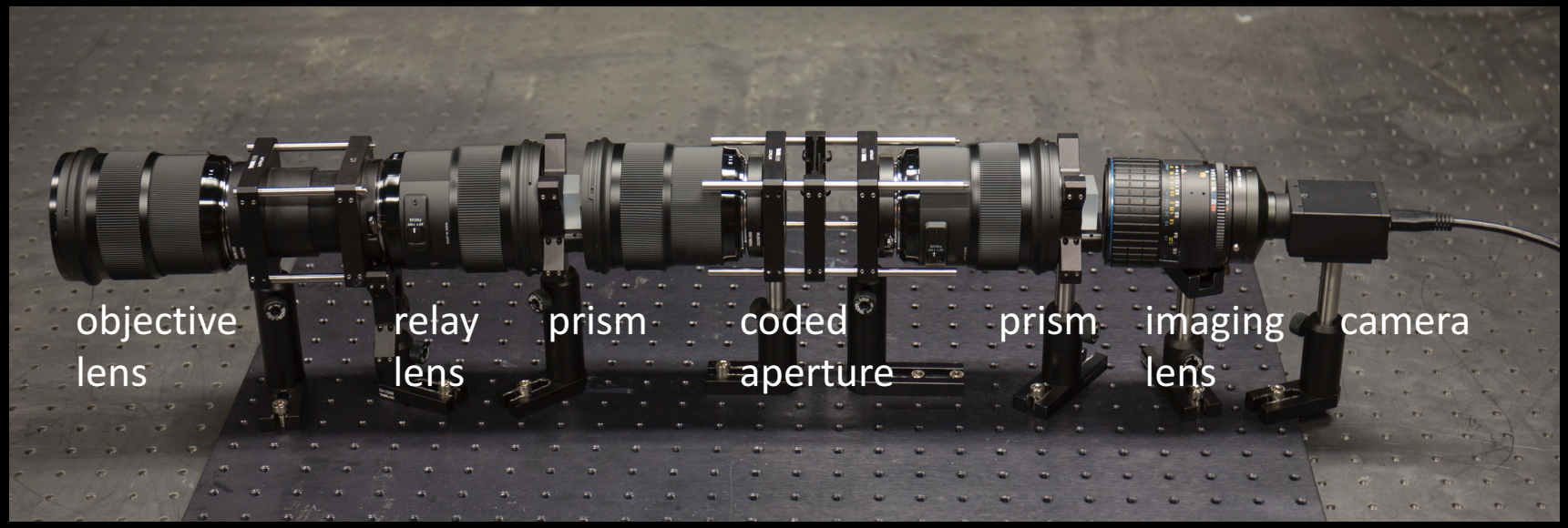


Ours (34.68dB/SSIM:0.96)



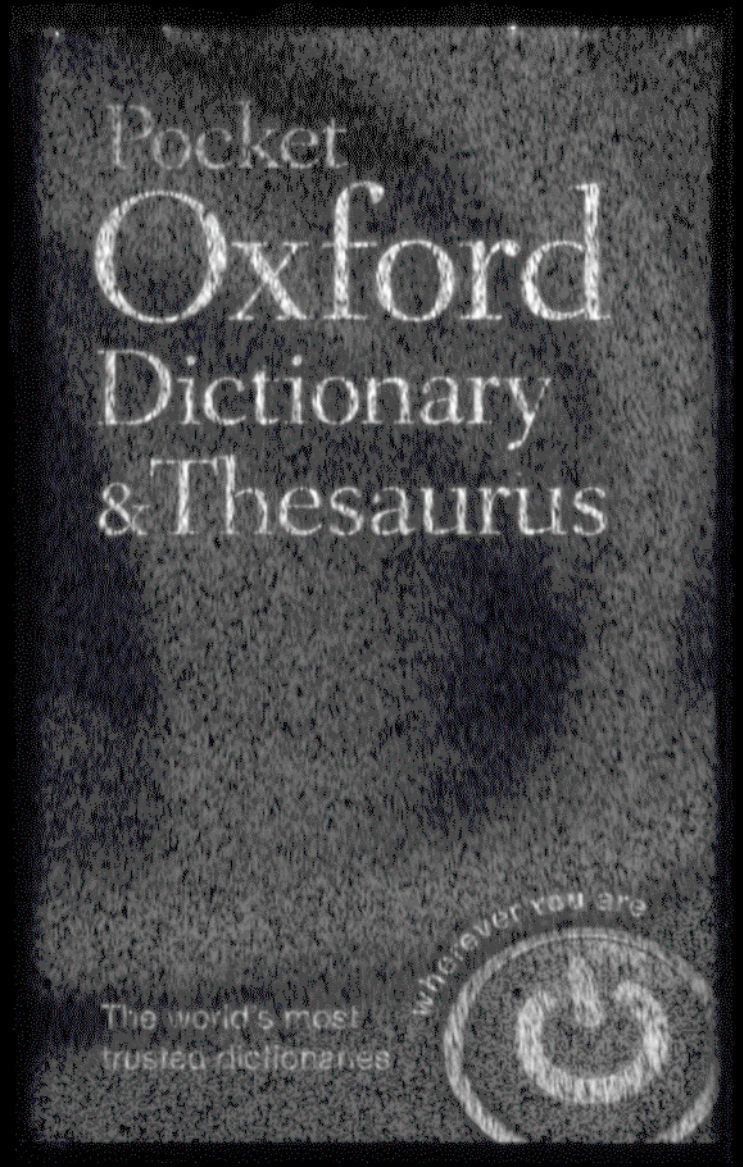
Our Reconstruction with Real Imager

Our Hyperspectral Imager (DD-CASSI)

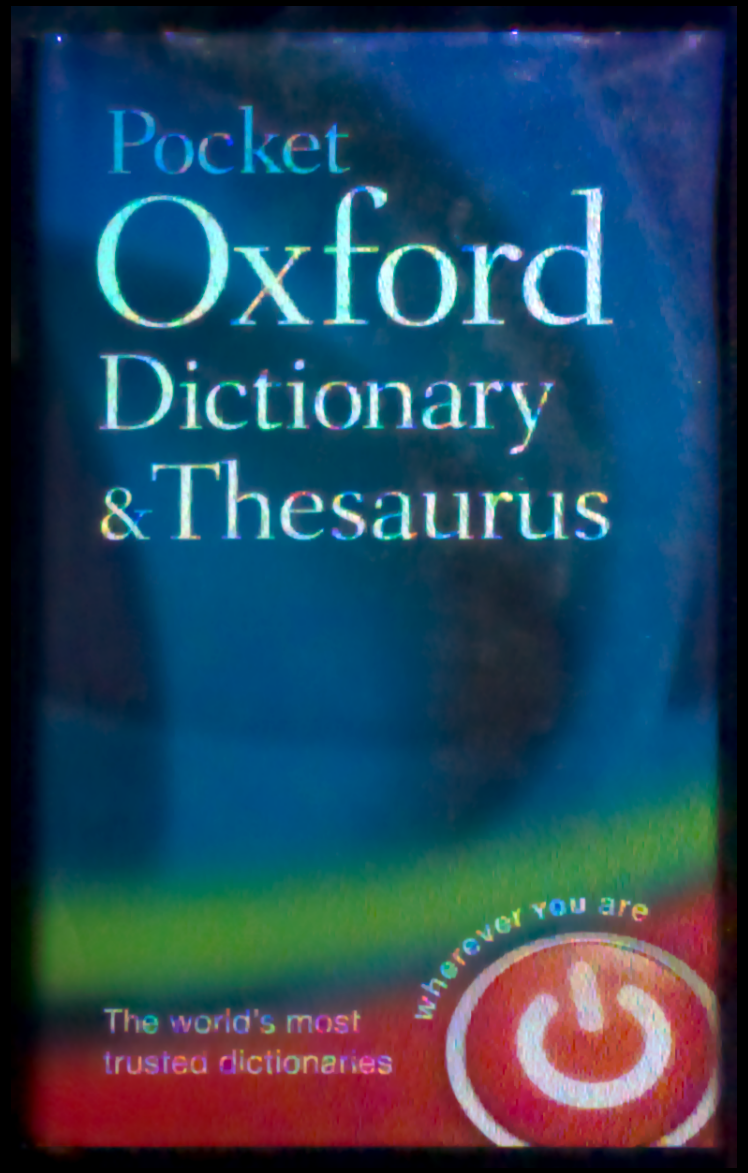


Parts	Specification
Objective lens / Relay lens	Sigma 60 mm Art lens
Prism	Right angle prism (2-degree angle, NBK-7)
Coded aperture	Lithographic chrome etching on a quartz plate Pixel pitch: 7.40 µm
Imaging lens	Coastal Optics 60 mm apochromatic lens
Camera	Monochromatic PointGrey Grasshopper (GS3-PGE-91S6M-C) Resolution: 3376 x 2704 Pixel pitch: 3.69 µm

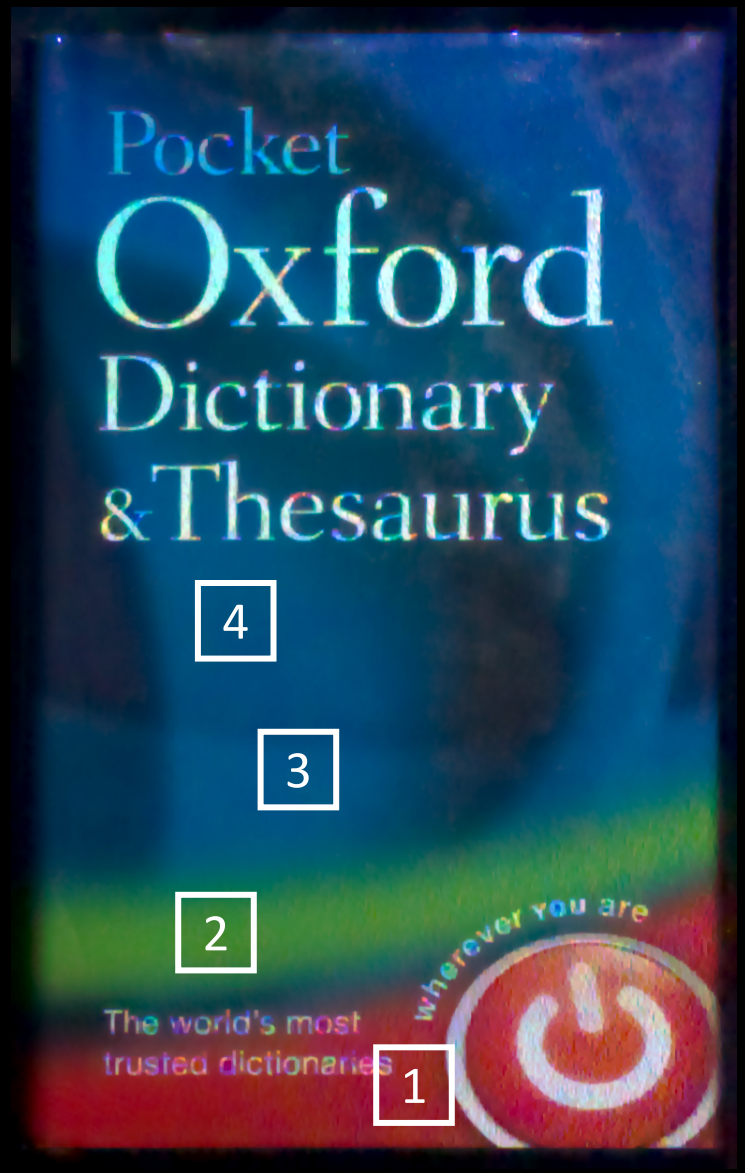
Compressive Input Image for Our Reconstruction (Figure 15)

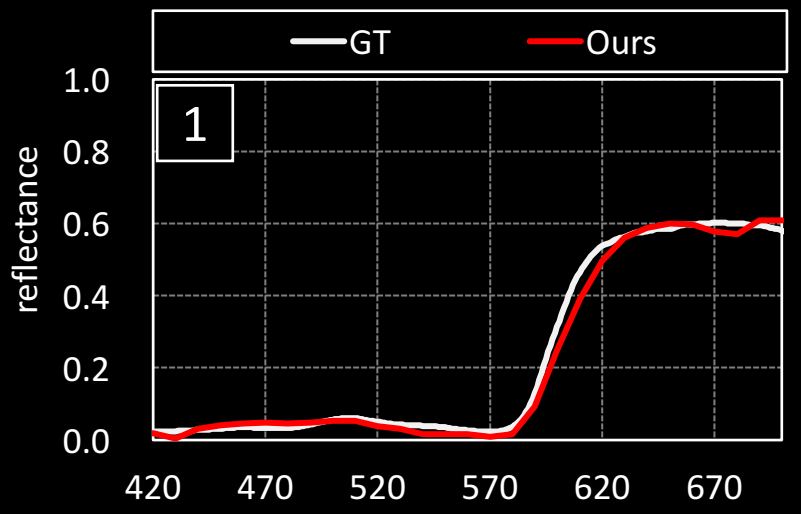


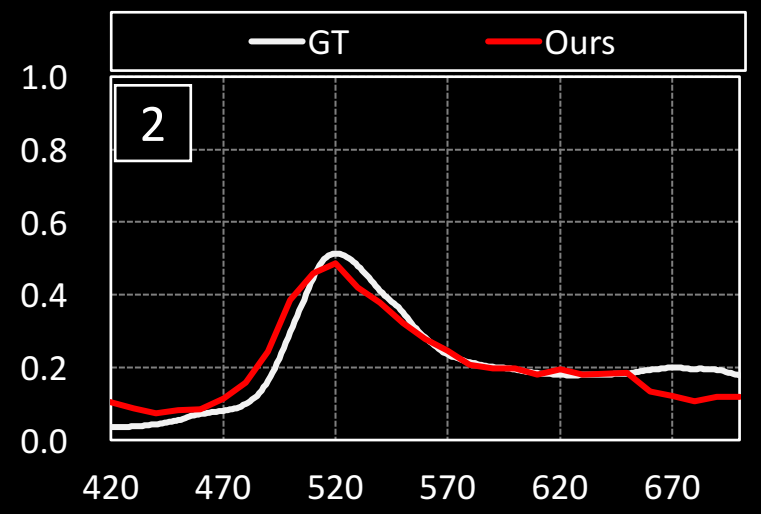
Our Reconstruction (Figure 15)

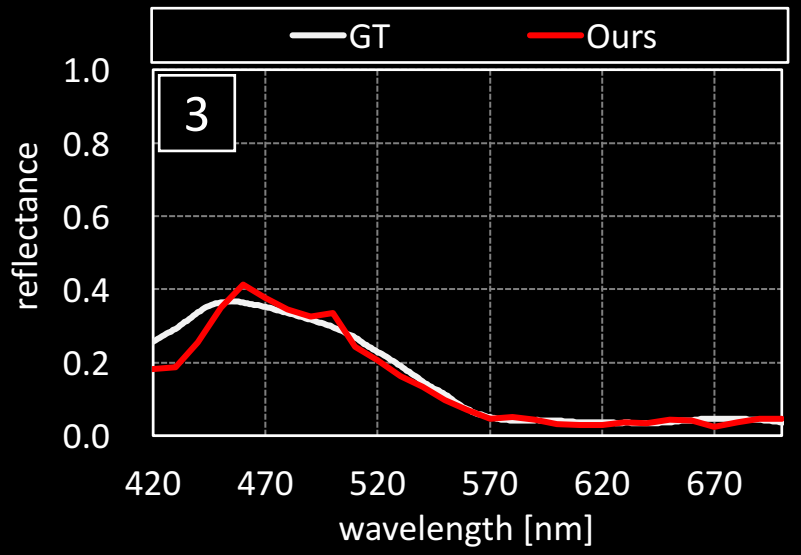


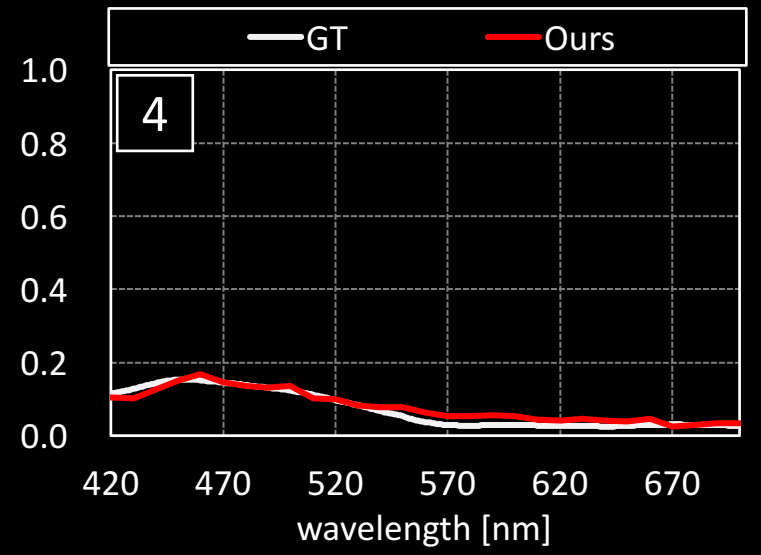
Our Reconstruction (Figure 15)



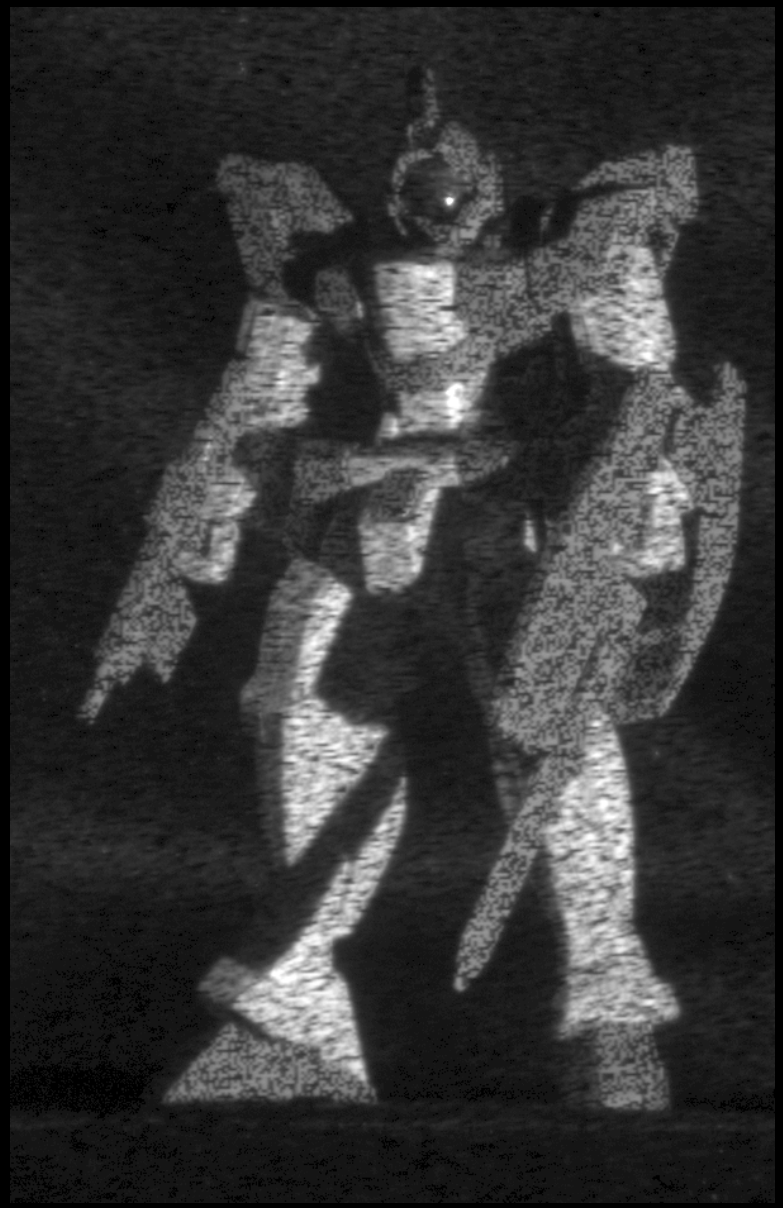








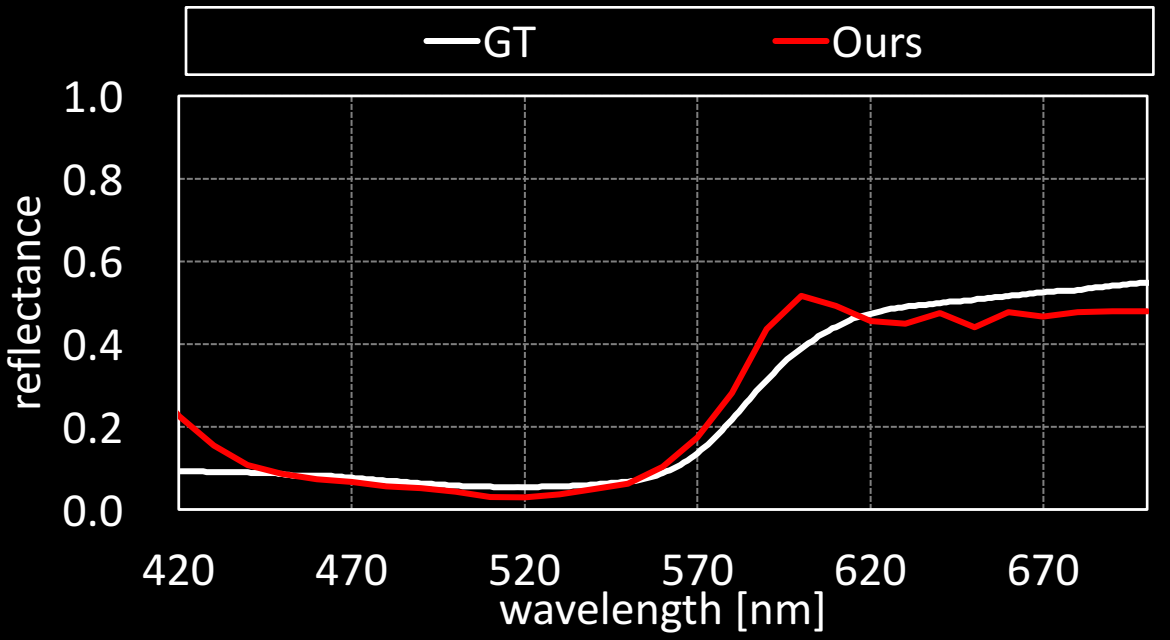
Compressive Input Image for Our Reconstruction



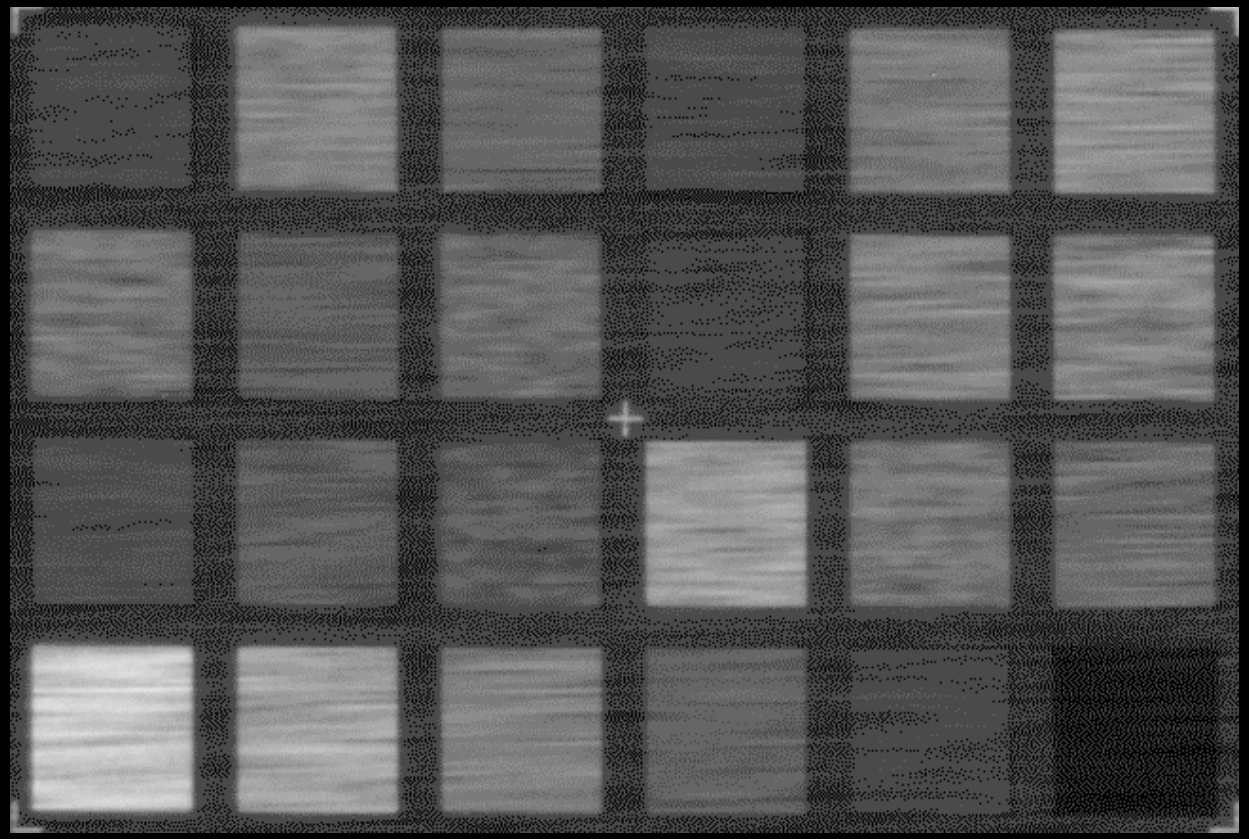
Our Reconstruction





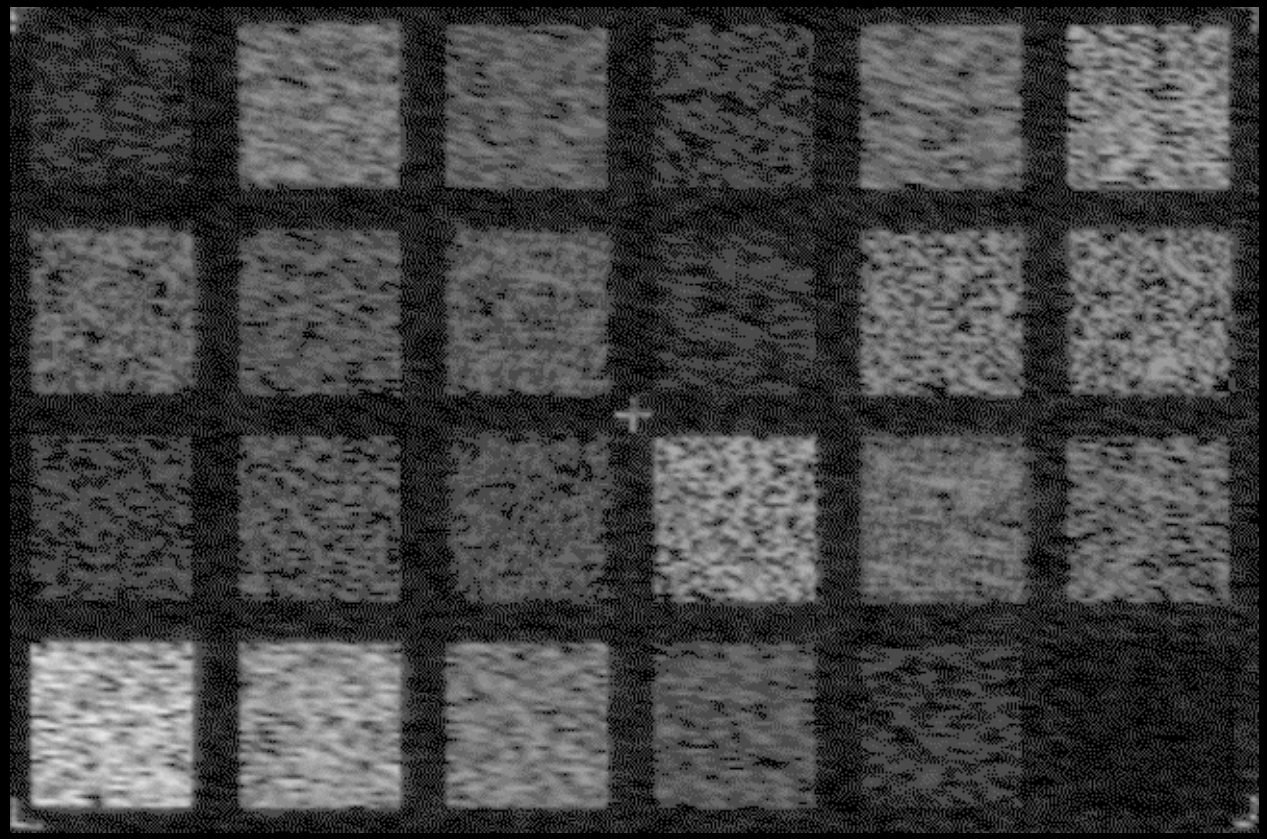

GT
Ours
1.0
0.8
0.6
0.4
0.2
0.0
reflectance
420
470
520
570
620
670
wavelength [nm]

Compressive Input Image for TwIST

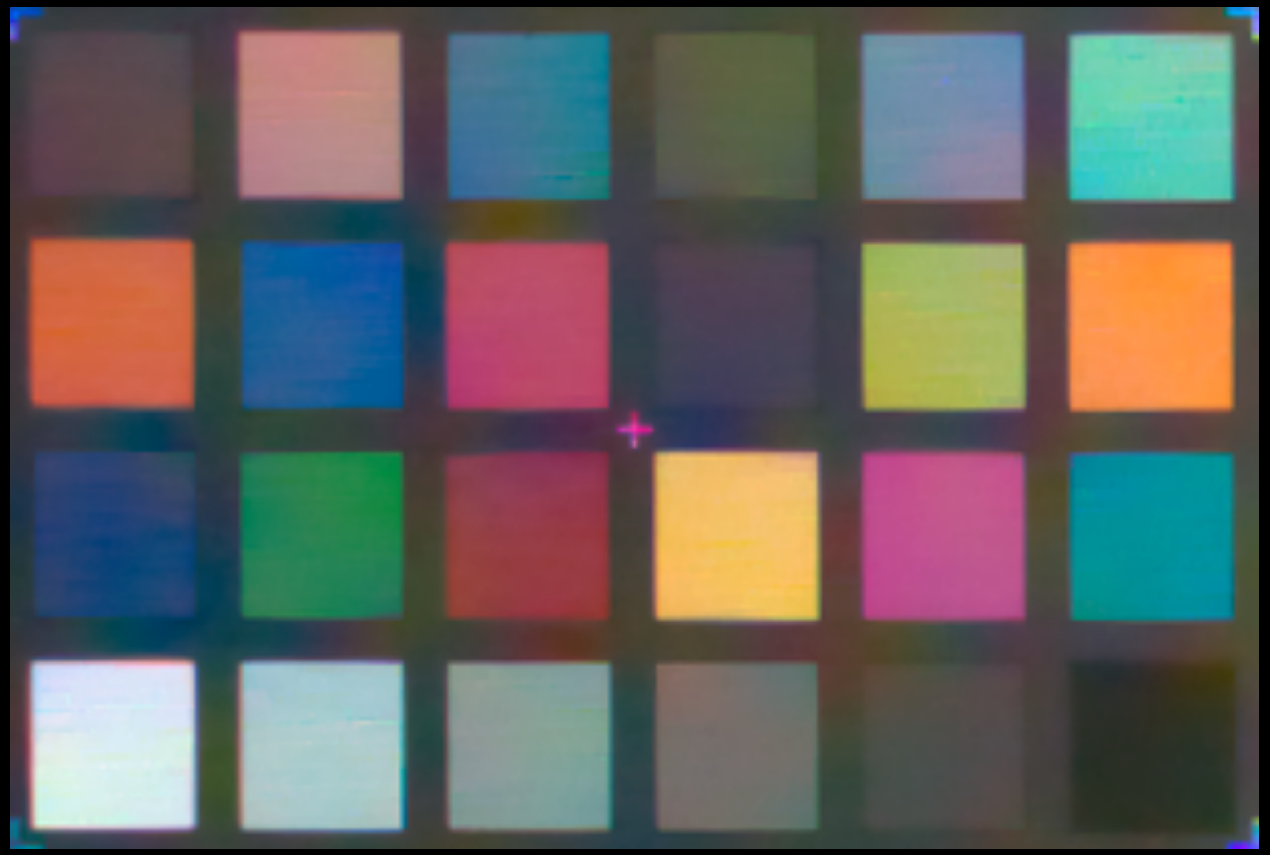


Since TwIST without any spectral prior requires a wider dispersion than our prior-based approach, we use 15-degree prisms to disperse light for TwIST in 89 pixels to provide a fair comparison.

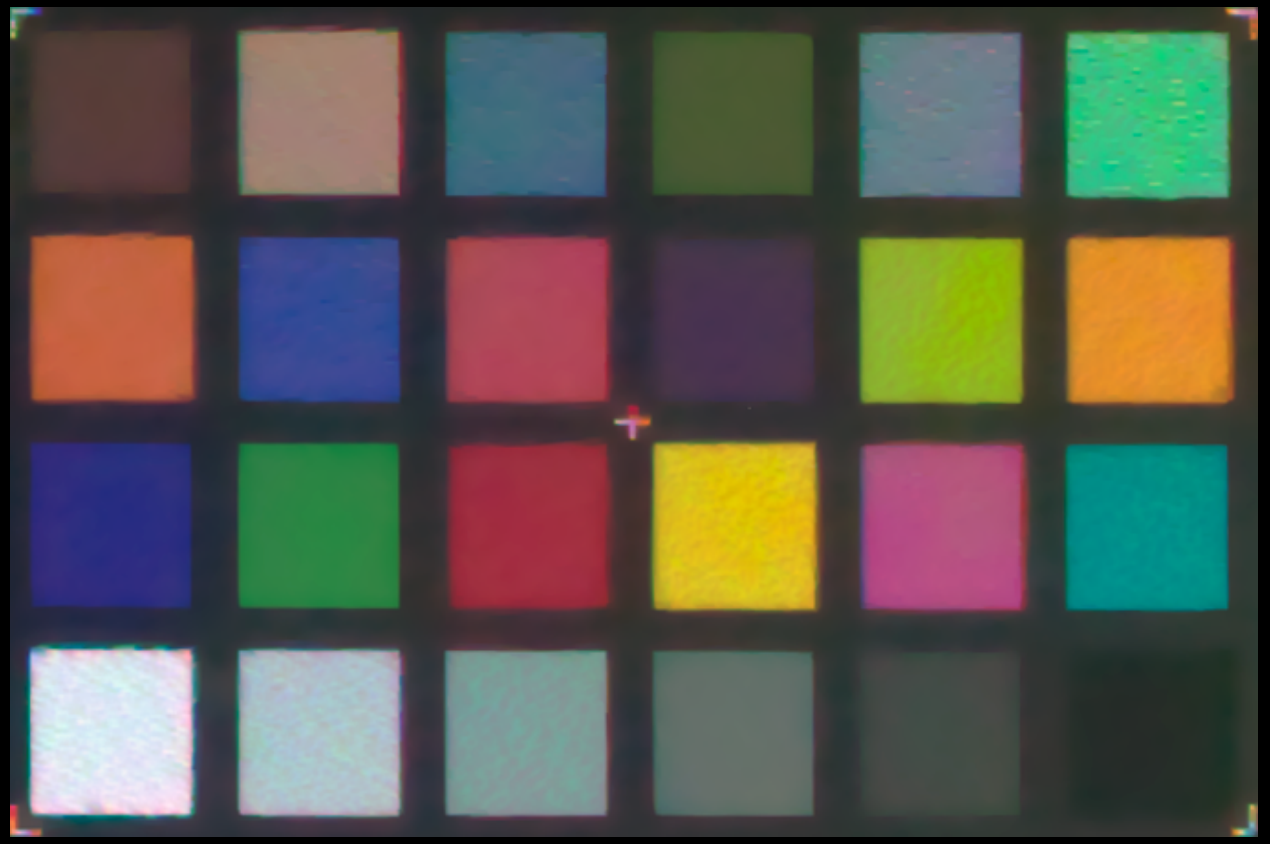
Compressive Input Image for Our Reconstruction



TwIST (Figure 15)

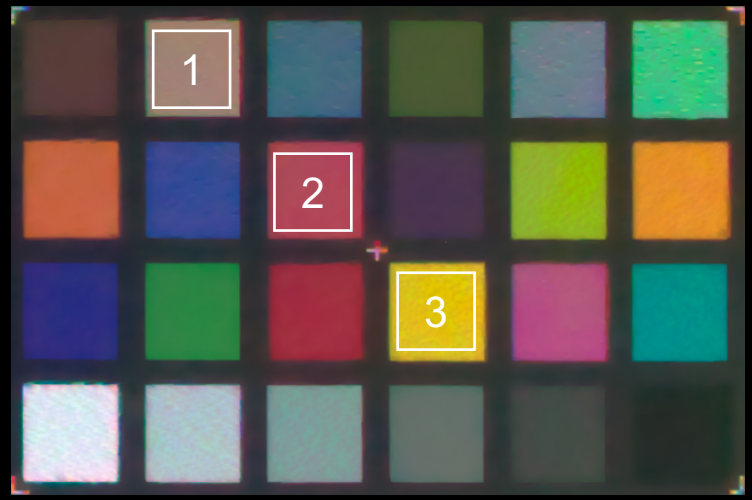


Our Reconstruction (Figure 15)

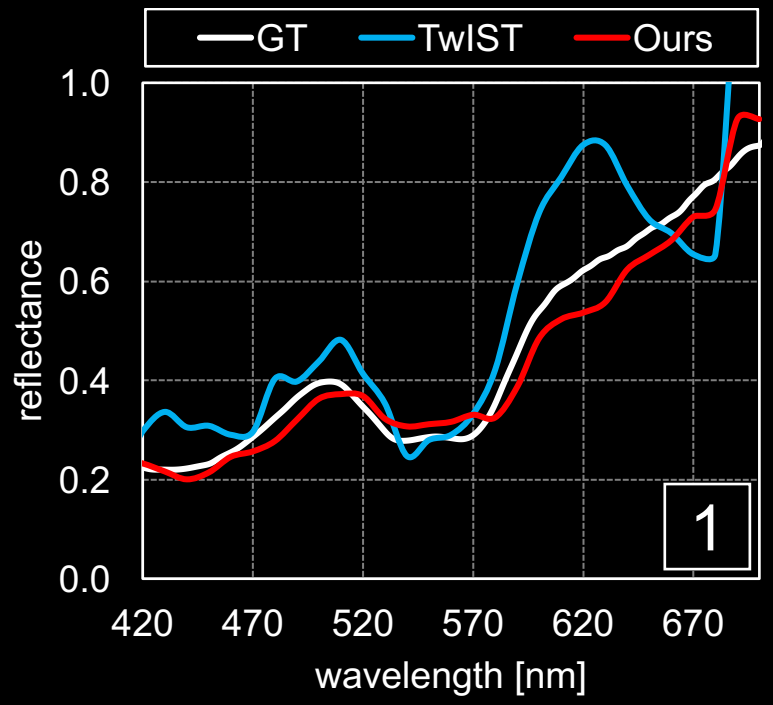


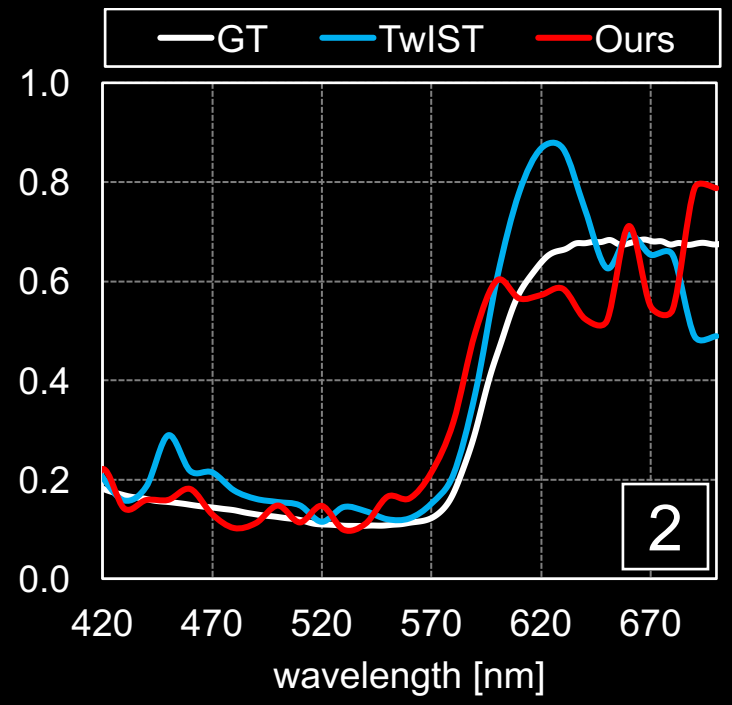


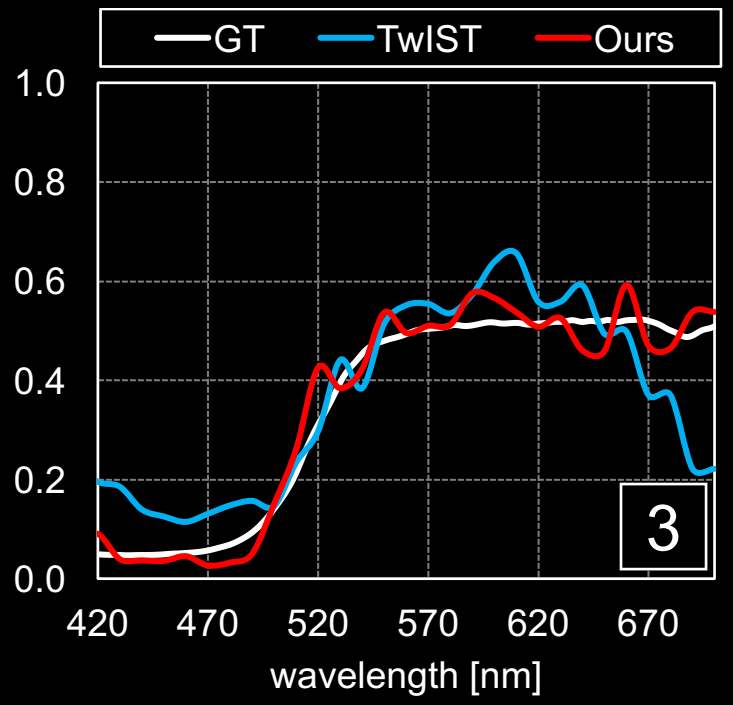
TwIST



Our Reconstruction

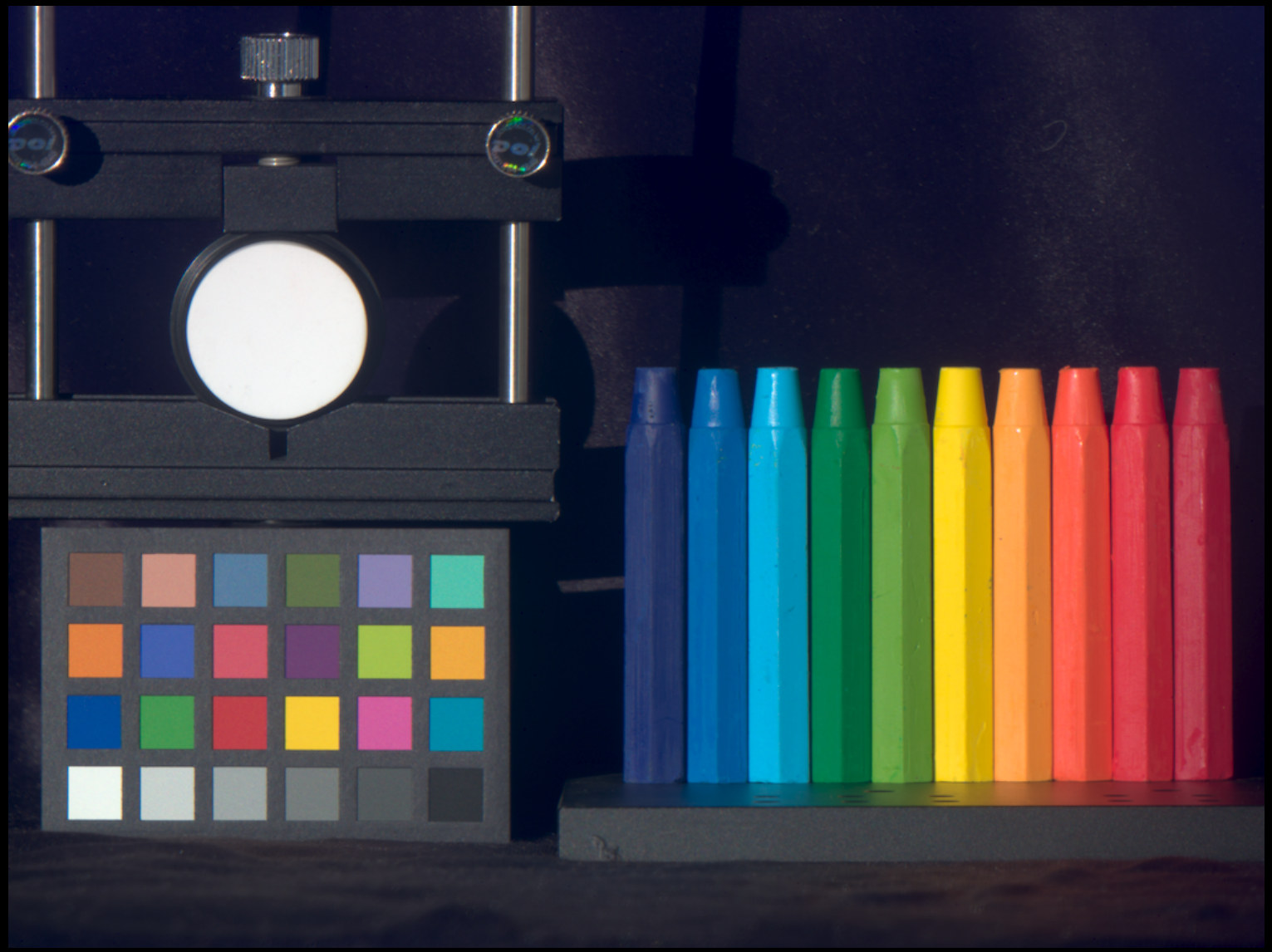




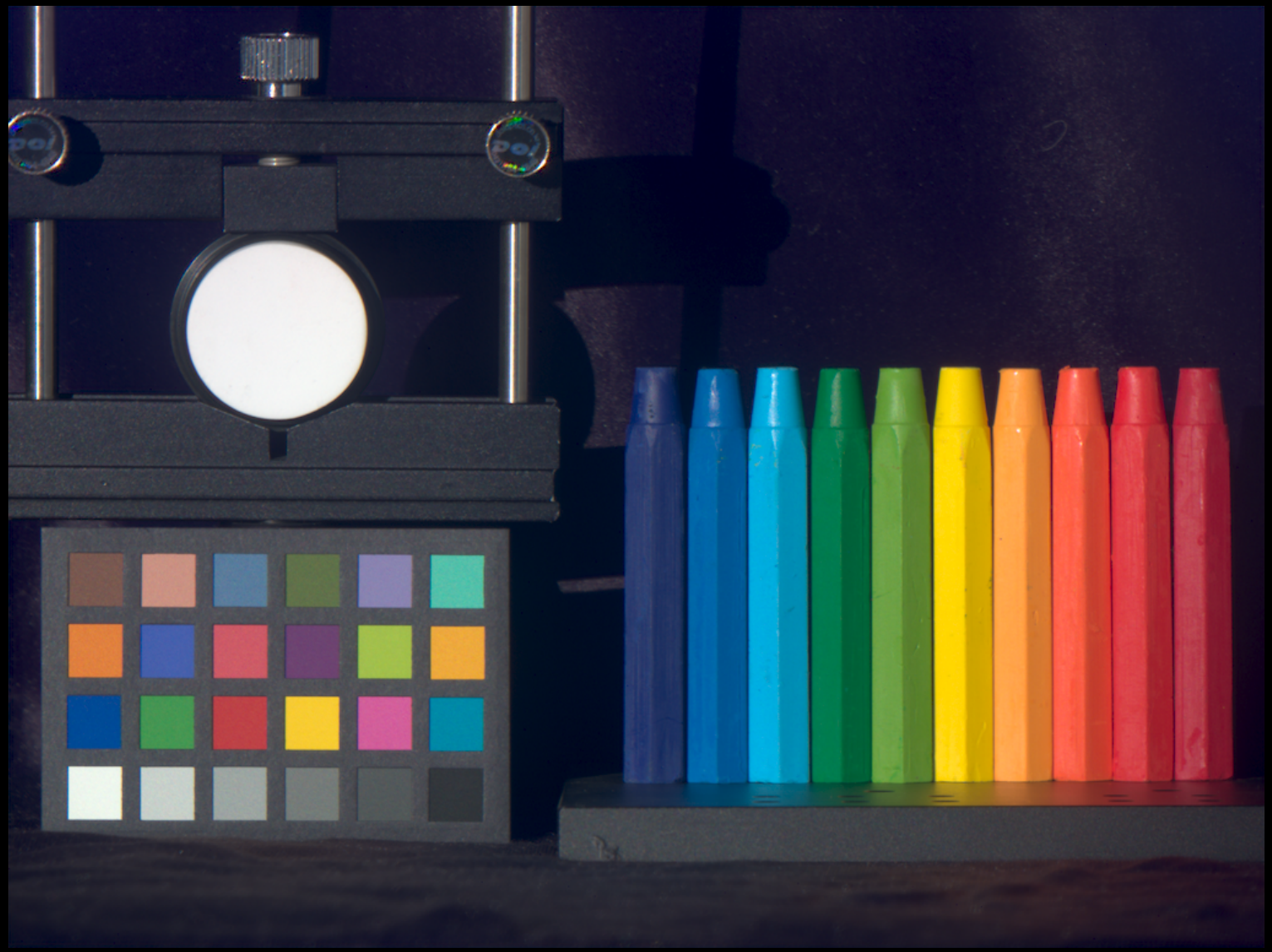


Application
Hyperspectral Interpolation

Ground truth (Figure 16(a))

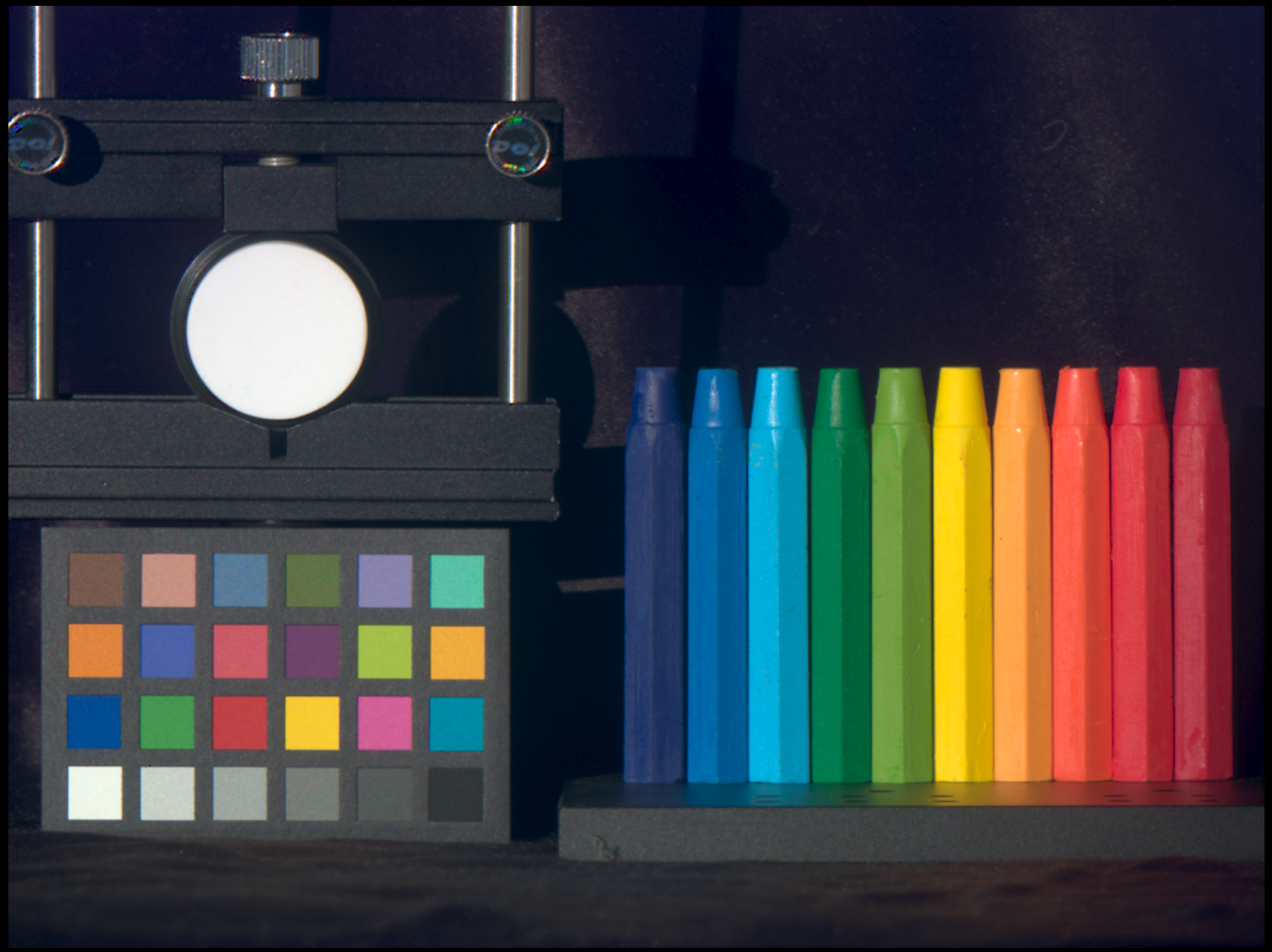


52 % compressed input (Figure 16(a))



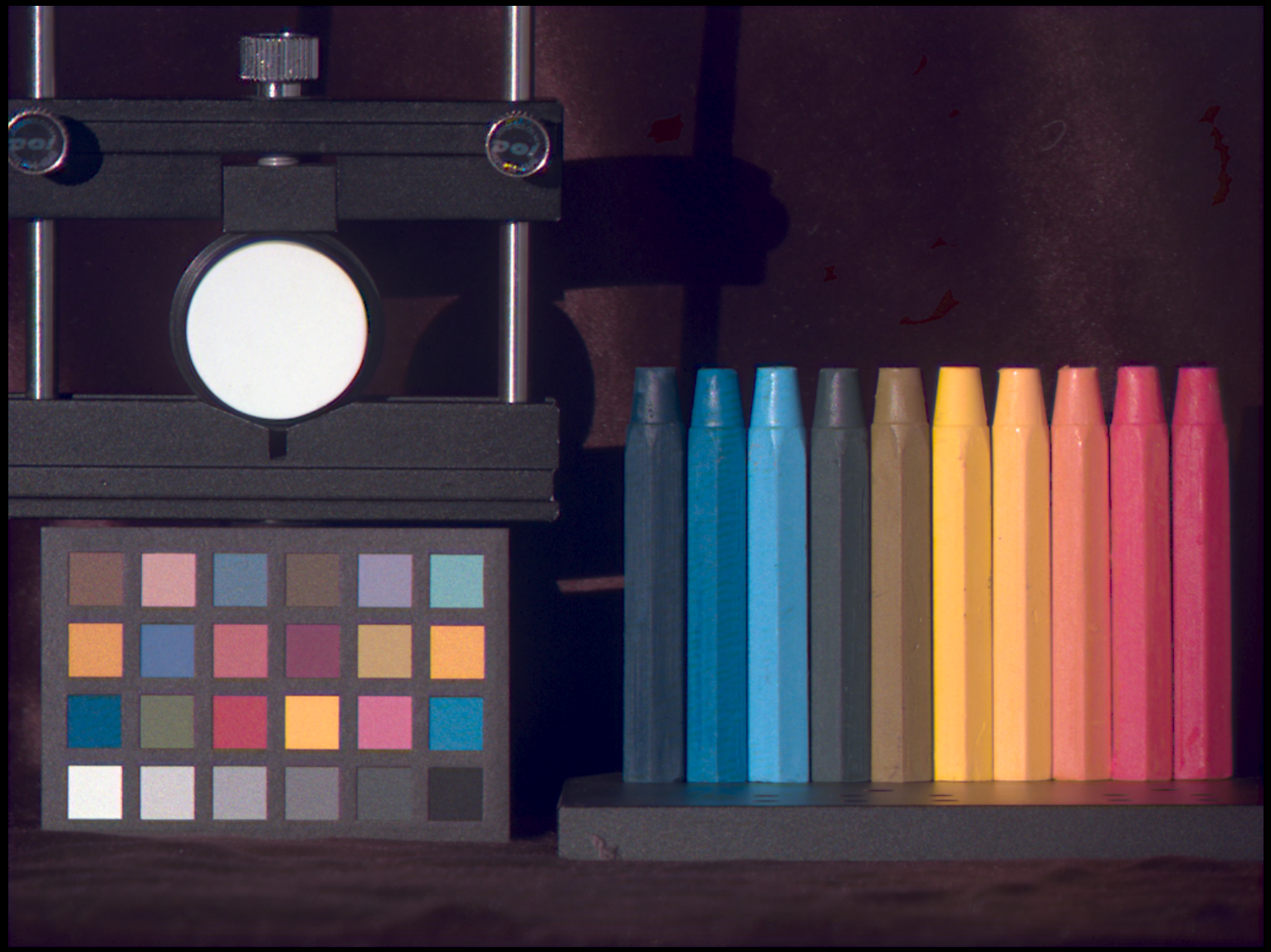
(40.12dB/SSIM:0.97)

26 % compressed input (Figure 16(a))

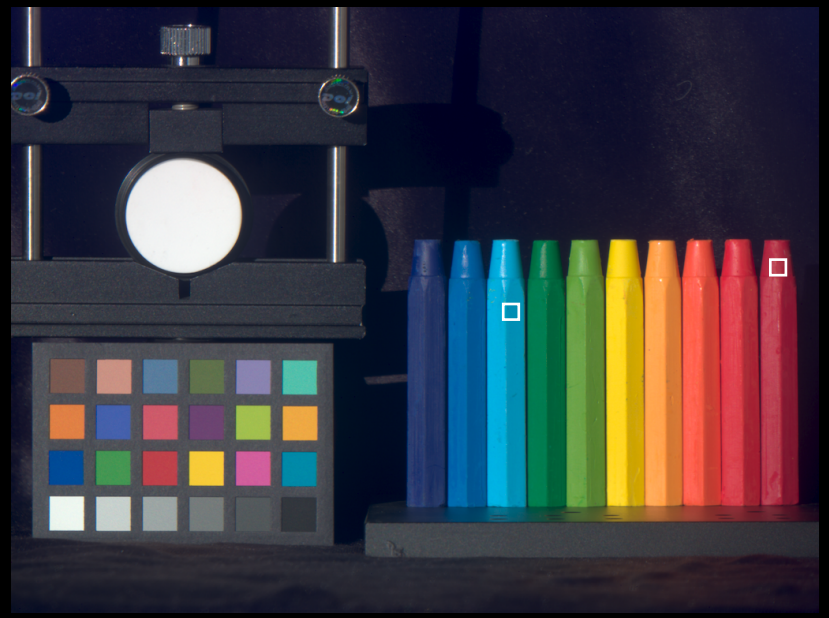


(38.09dB/SSIM:0.95)

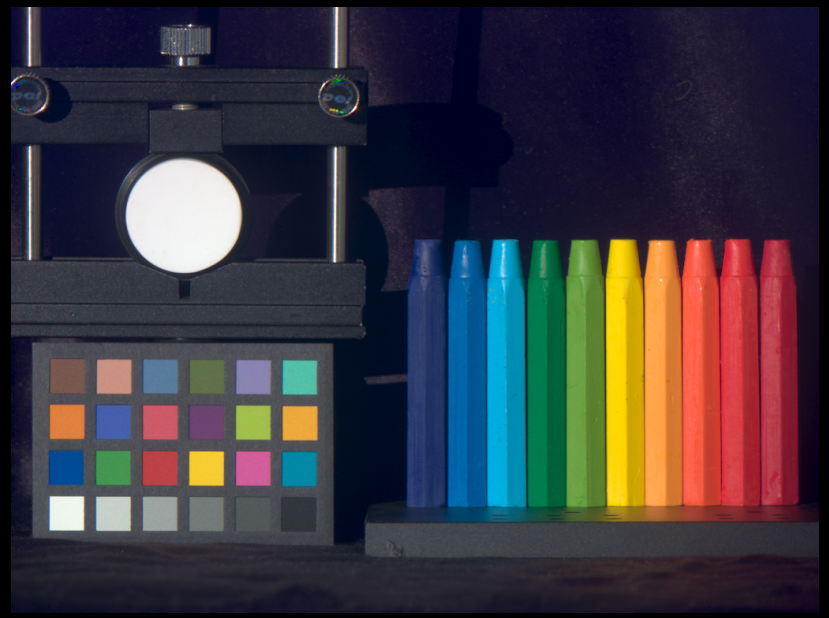
10 % compressed input (Figure 16(a))



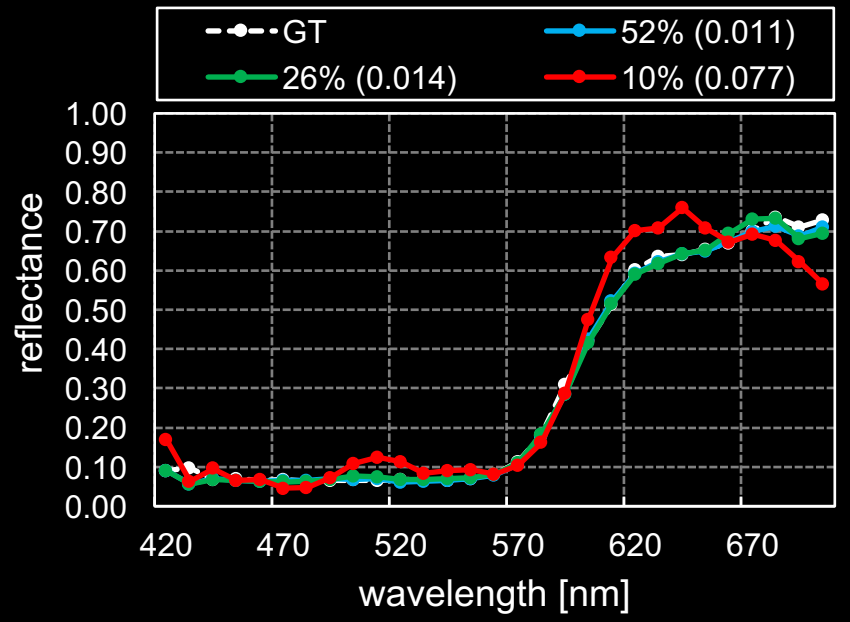
(29.68dB/SSIM:0.86)

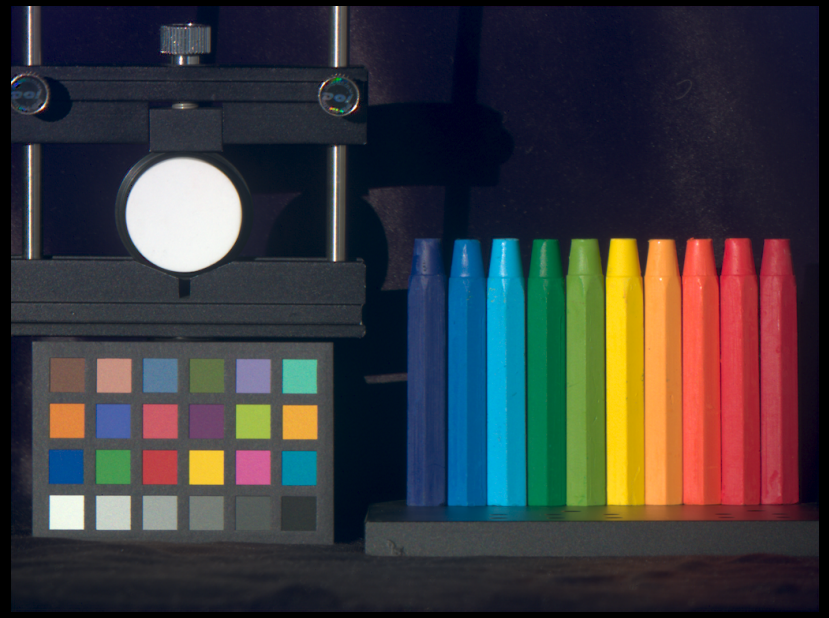


Ground truth

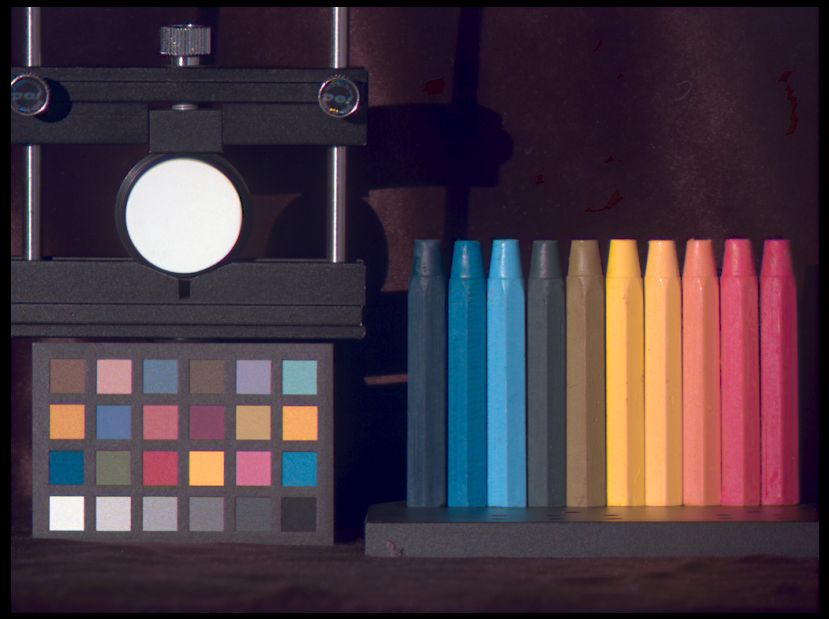


52 % (40.12dB/SSIM:0.97)

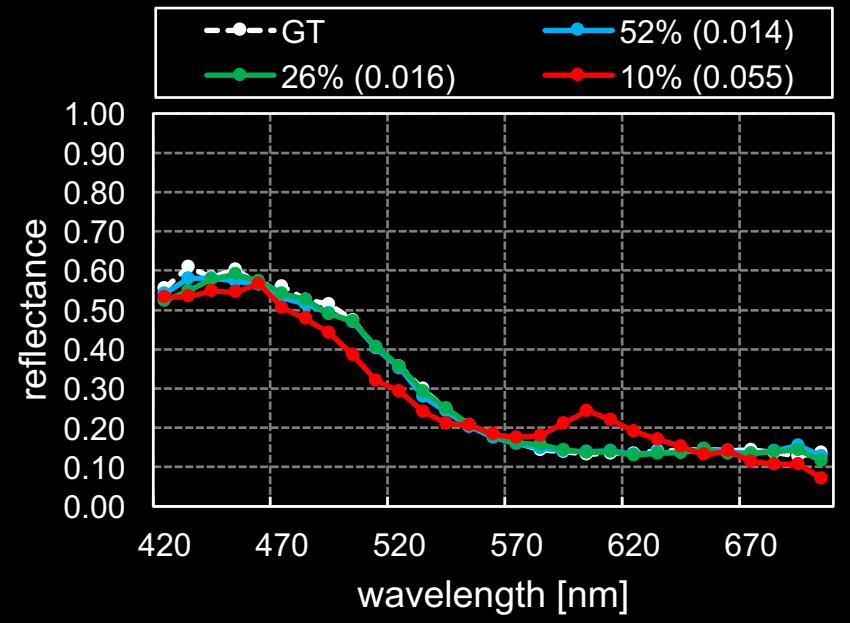




26 % (38.09dB/SSIM:0.95)



10 % (29.68dB/SSIM:0.86)



Application
Hyperspectral Demosaicing

Ground truth (Figure 16(b))



Bayer-Patterned Multispectral Image of four different wavelengths (450nm, 520nm, 580nm, and 650nm)



Demosaiced Hyperspectral Image (Figure 16(b))



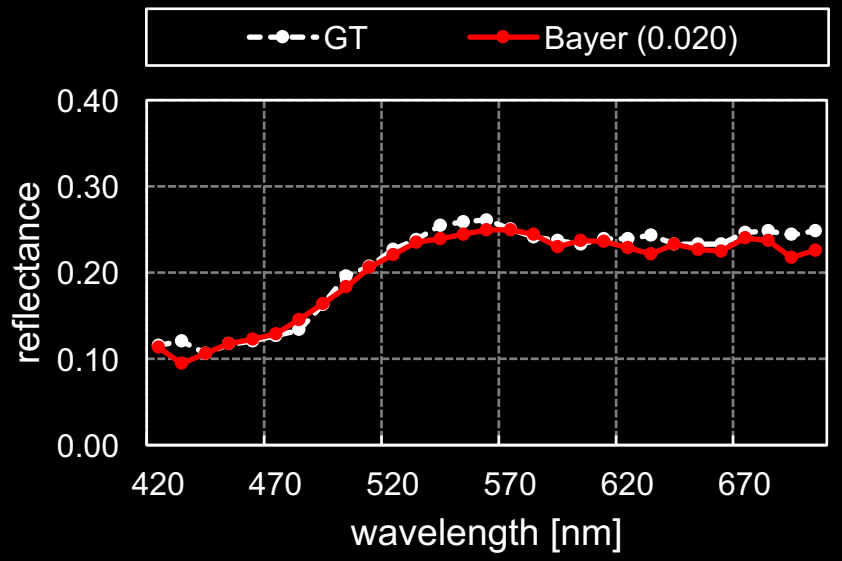
(31.04dB/SSIM:0.89)

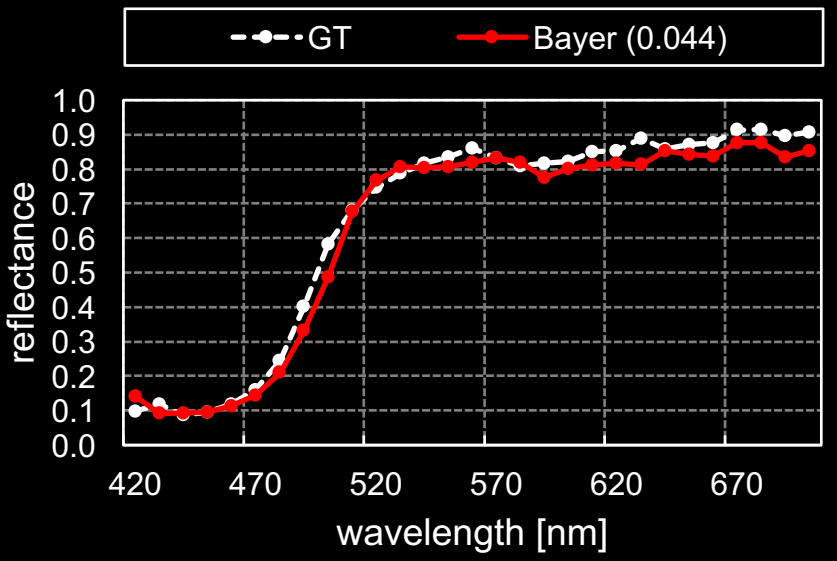




Ground truth

Demosaiced Hyperspectral Image (31.04dB/SSIM:0.89)





Comparison of Results

Columbia Dataset

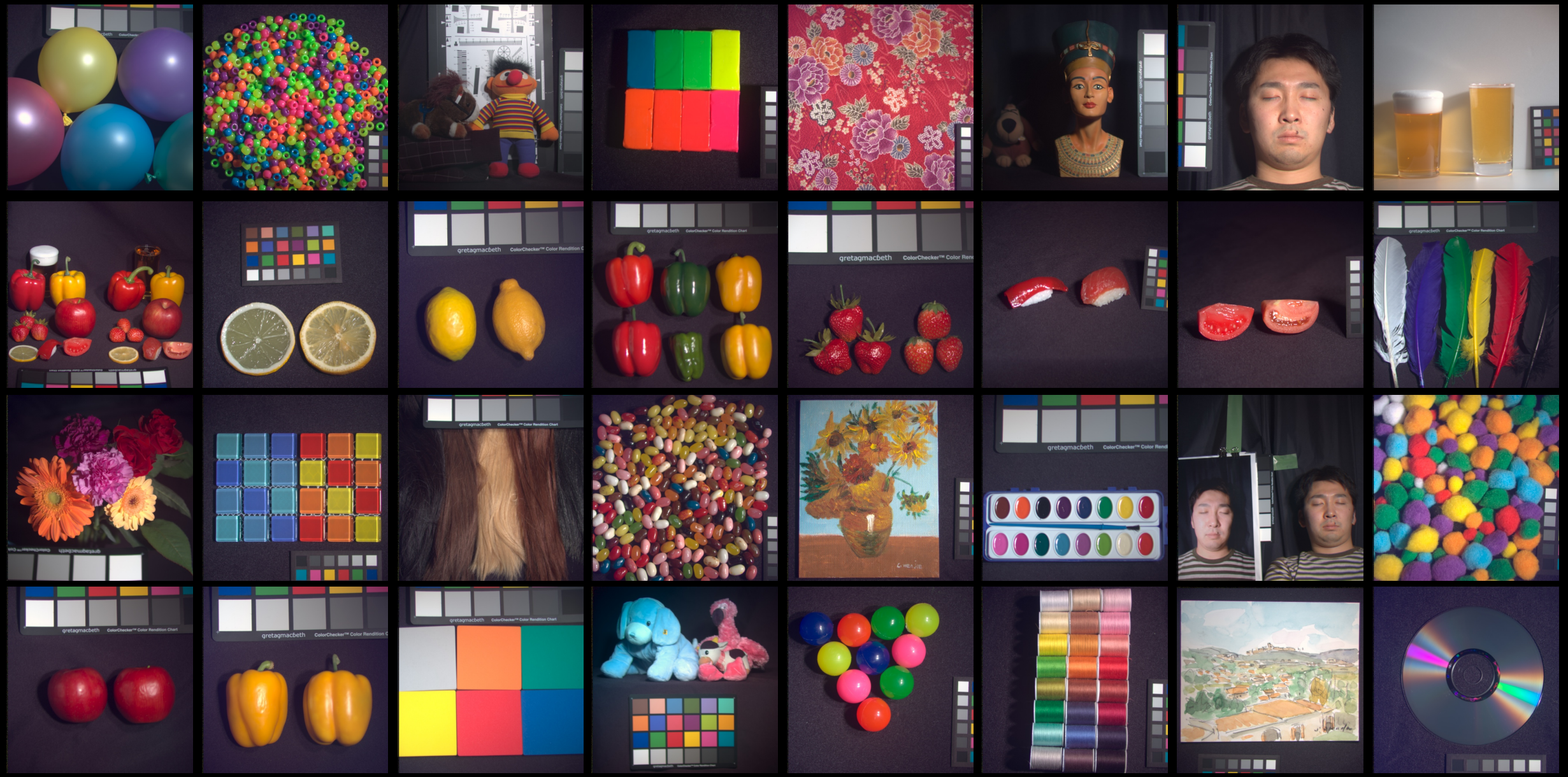
List of Compared Methods:

TwIST: Bioucas-Dias and Figueiredo, “Two-Step Algorithms for Linear Inverse Problems with Non-Quadratic Regularization”, ICIP 2007

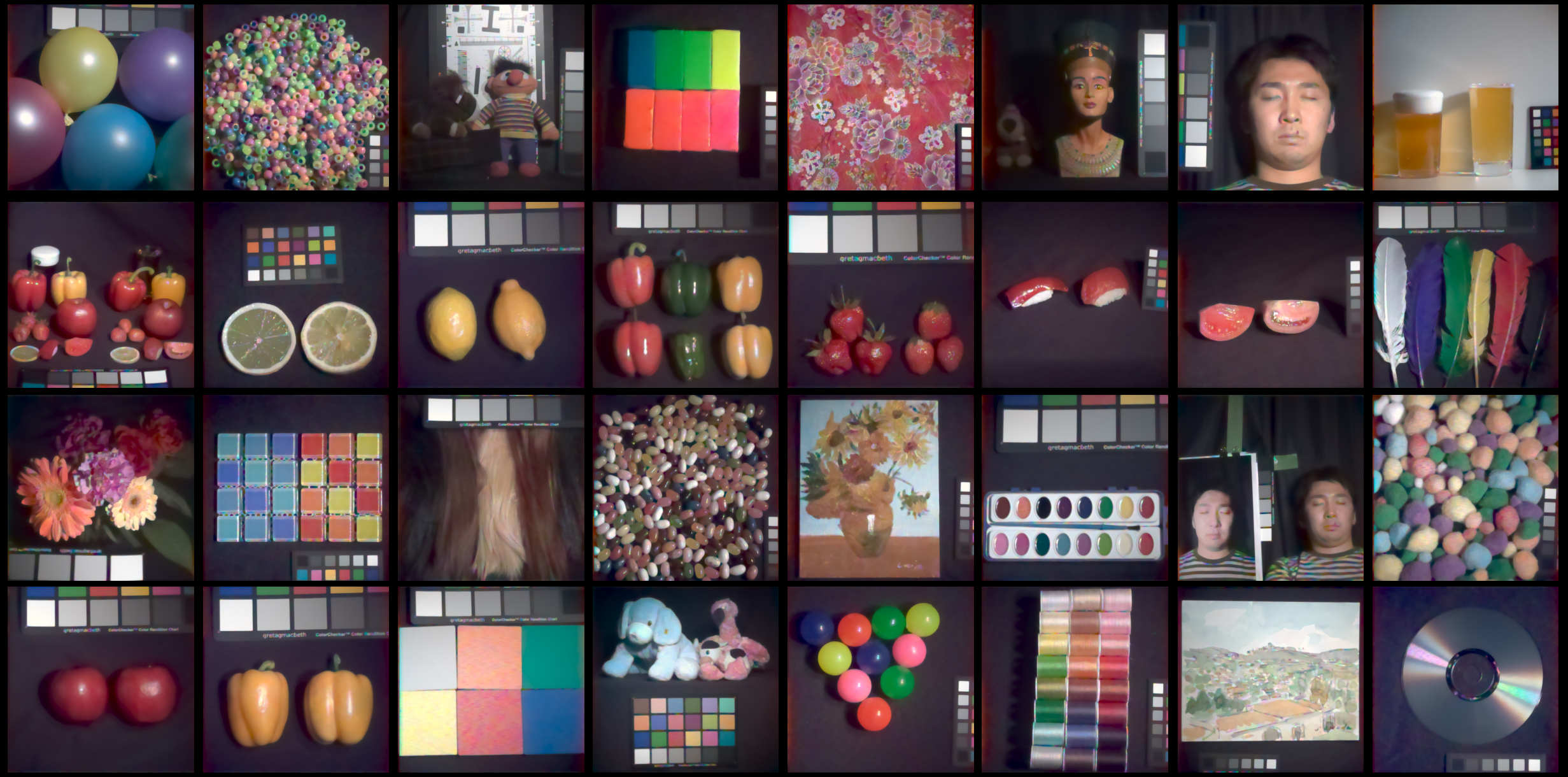
SpaRSA: Wright et al., “Sparse Reconstruction by Separable Approximation”, IEEE TSP 2009

SC: Lin et al., “Spatial-Spectral Encoded Compressive Hyperspectral Imaging”, ACM TOG 2014

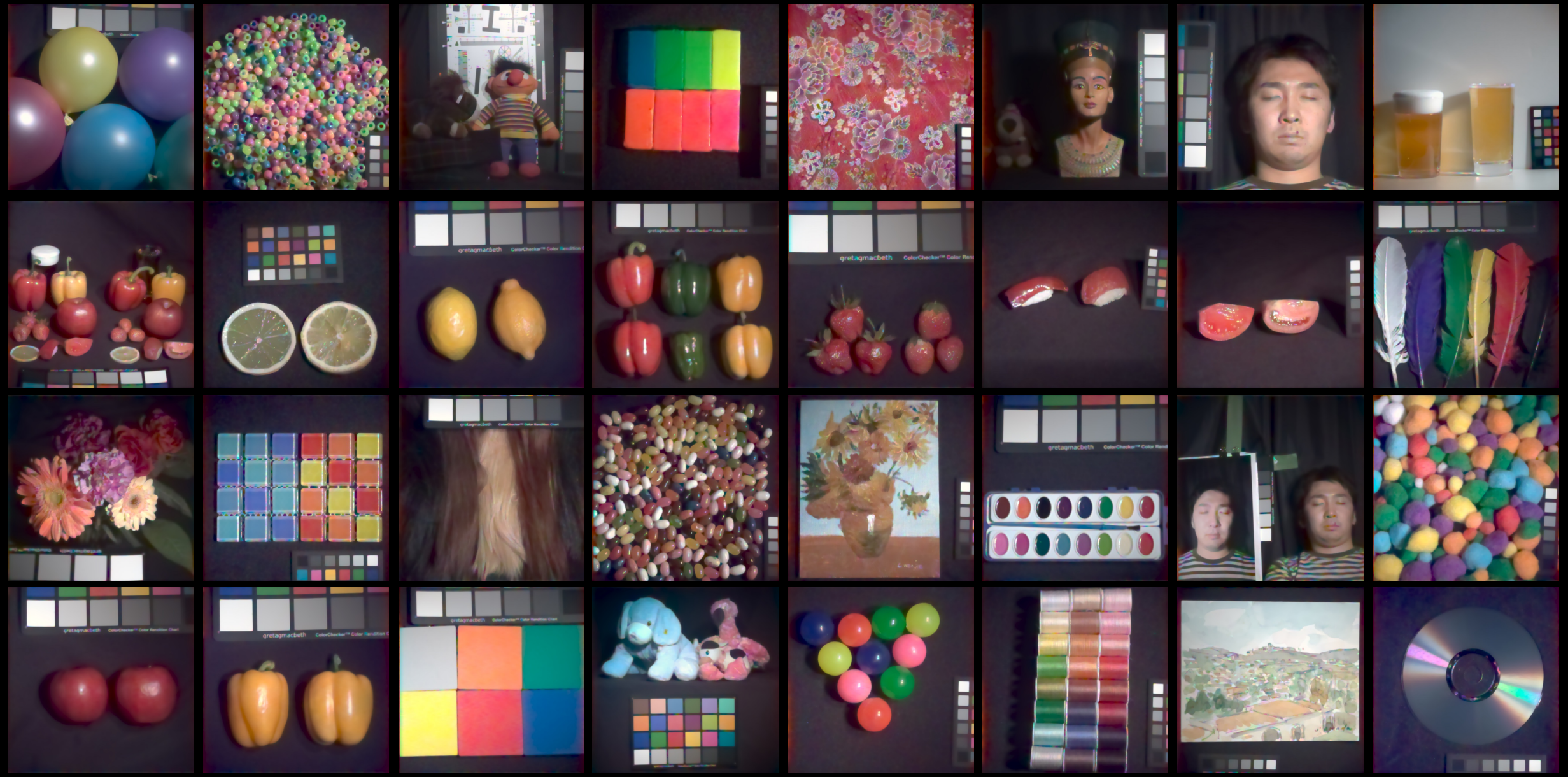
Ground Truth: Columbia Dataset



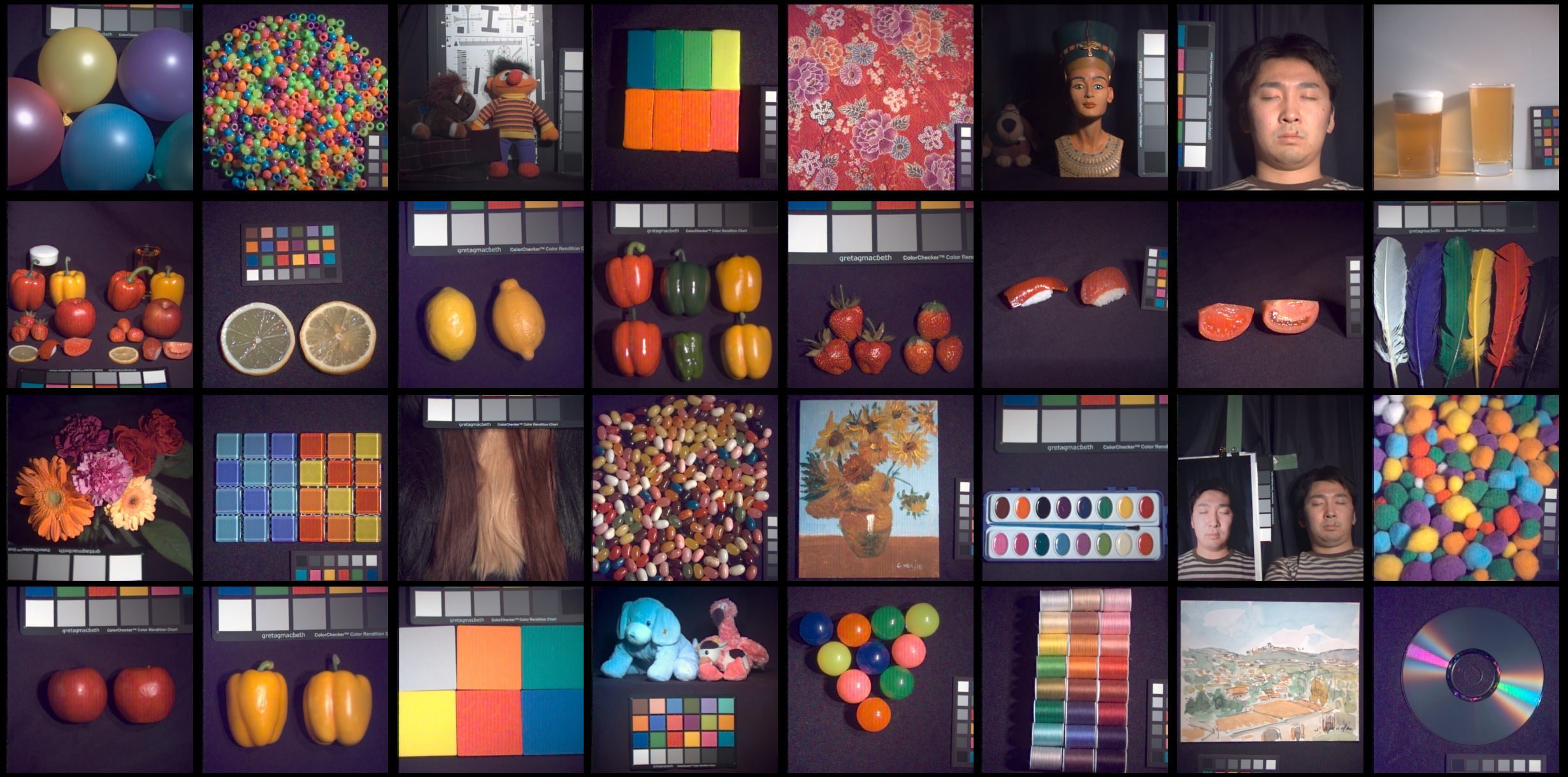
TwIST Reconstruction: Columbia Dataset



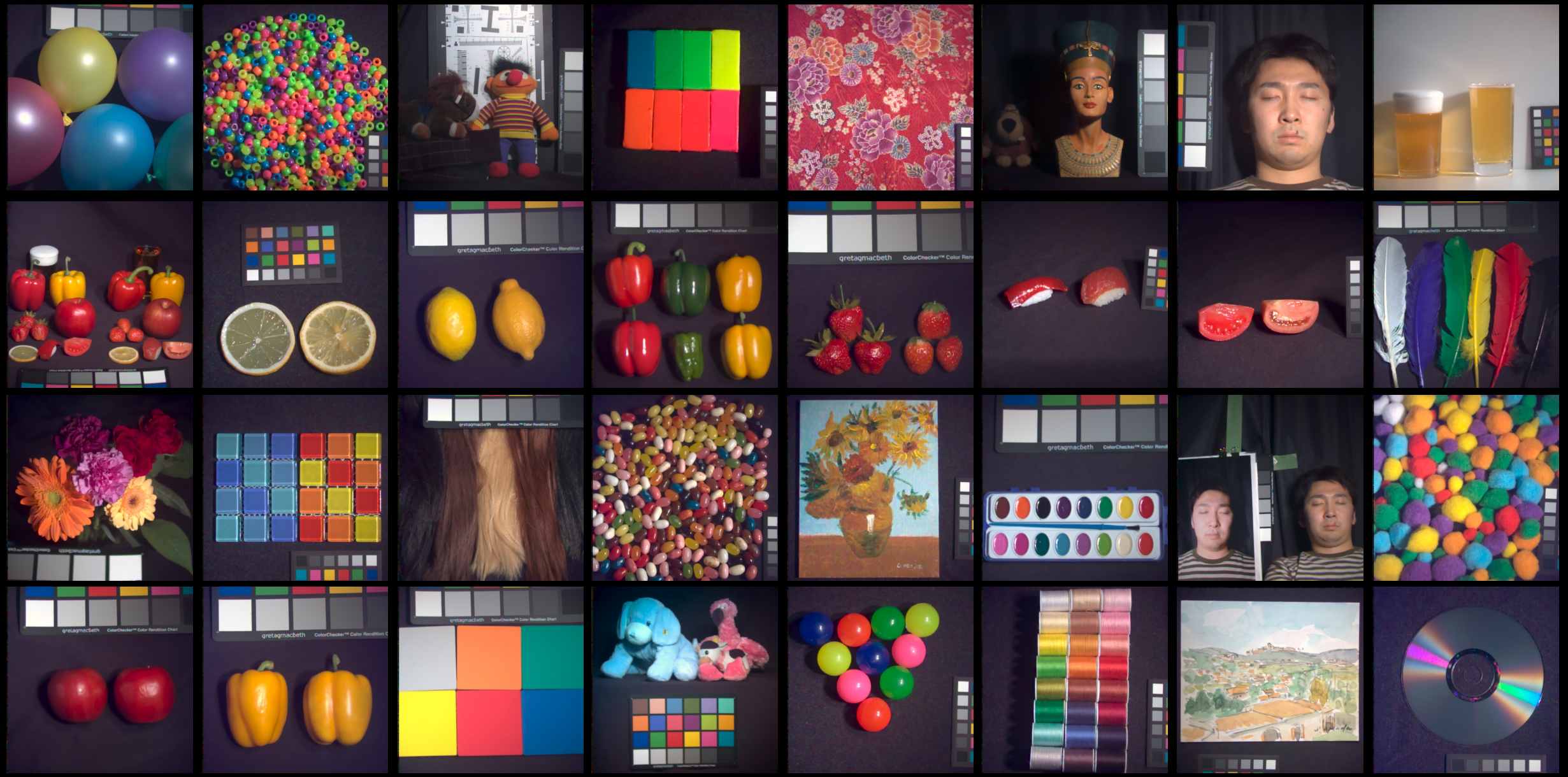
SpaRSA Reconstruction: Columbia Dataset



Sparse Coding Reconstruction: Columbia Dataset



Our Reconstruction: Columbia Dataset



Columbia Dataset #1



TwIST (20.80dB/SSIM:0.84)



SpaRSA (20.12dB/SSIM:0.84)



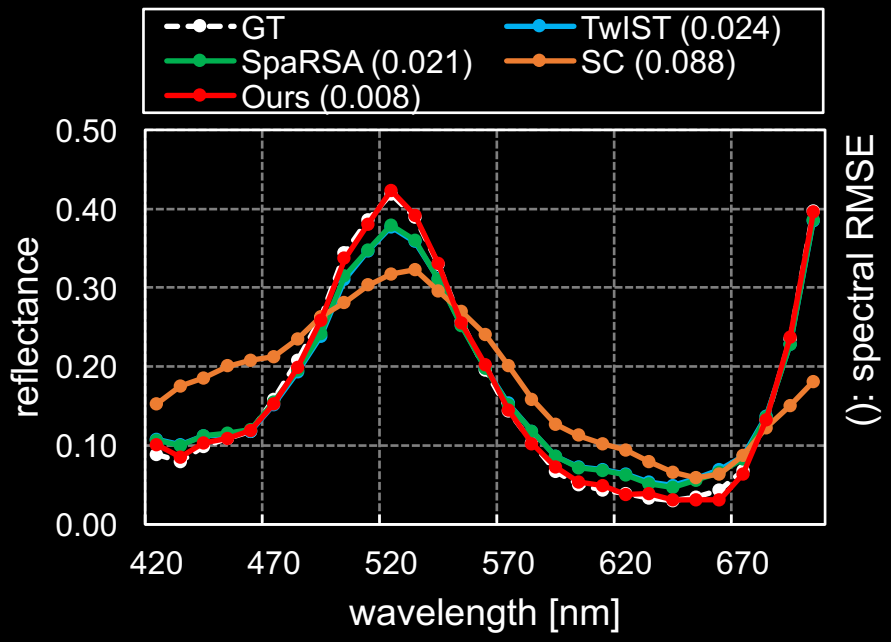
Ground truth



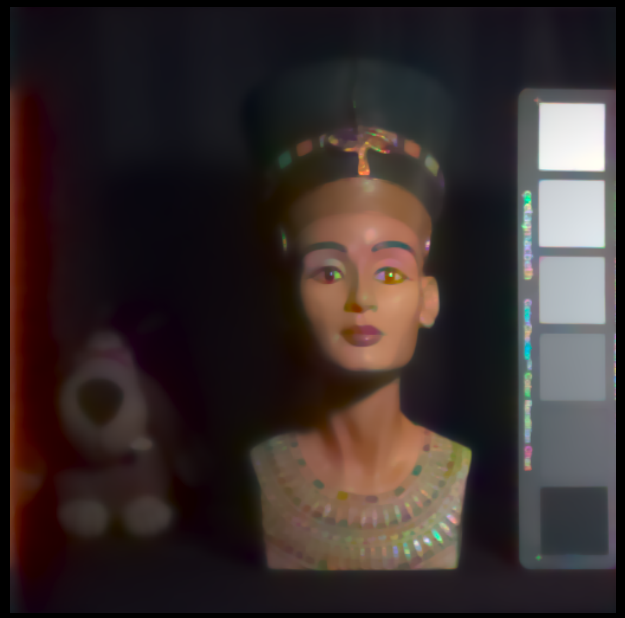
SC (24.07dB/SSIM:0.85)



Ours (29.20dB/SSIM:0.95)



Columbia Dataset #2 (Figure 11)



TwIST (28.42dB/SSIM:0.91)



SpaRSA (28.57dB/SSIM:0.92)



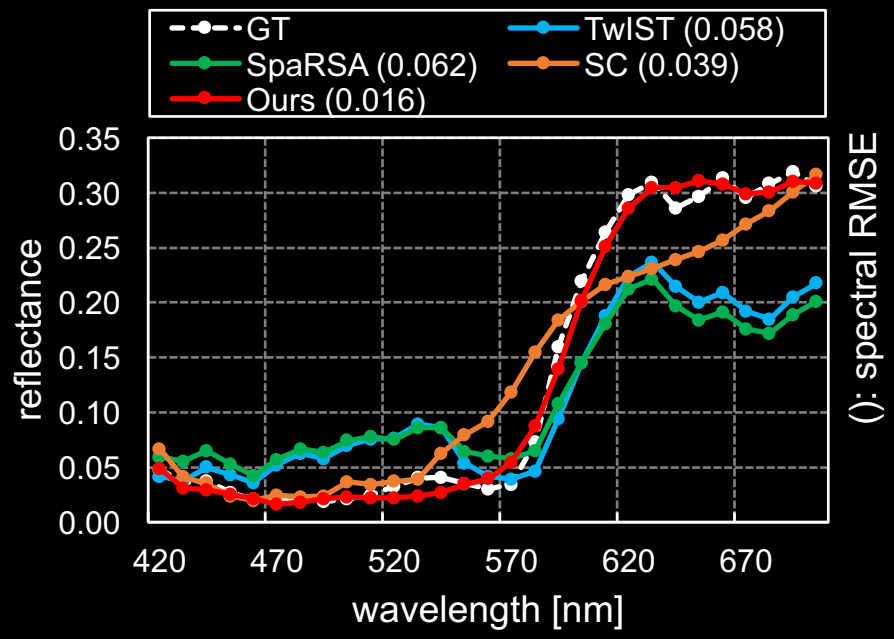
Ground truth



SC (34.89dB/SSIM:0.96)



Ours (35.40dB/SSIM:0.97)



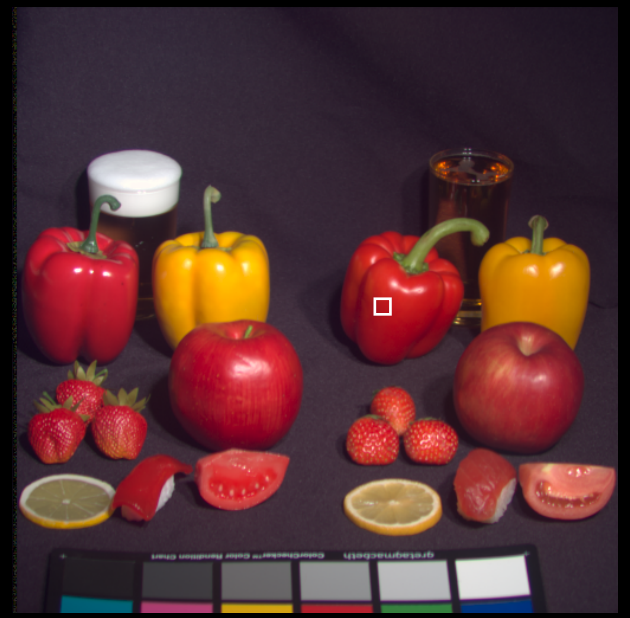
Columbia Dataset #3 (Figure 11)



TwIST (23.11dB/SSIM:0.81)



SpaRSA (22.64dB/SSIM:0.80)



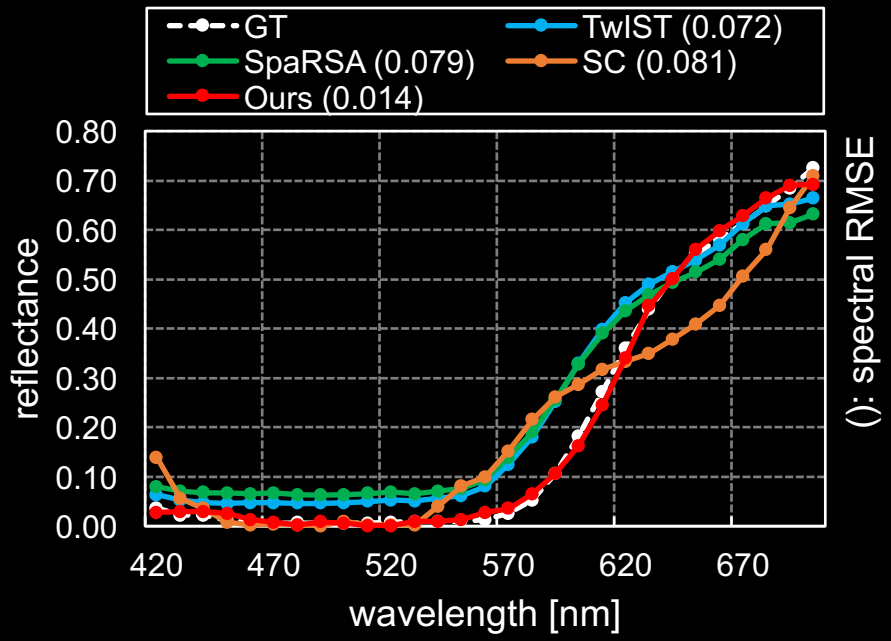
Ground truth



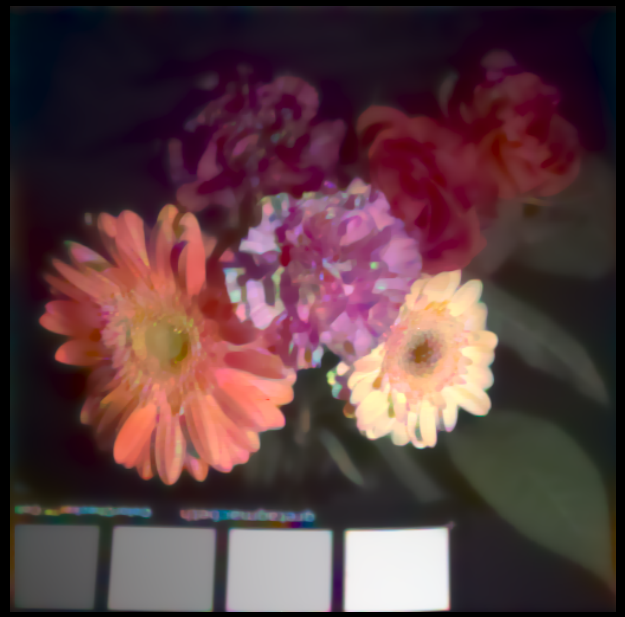
SC (27.96dB/SSIM:0.88)



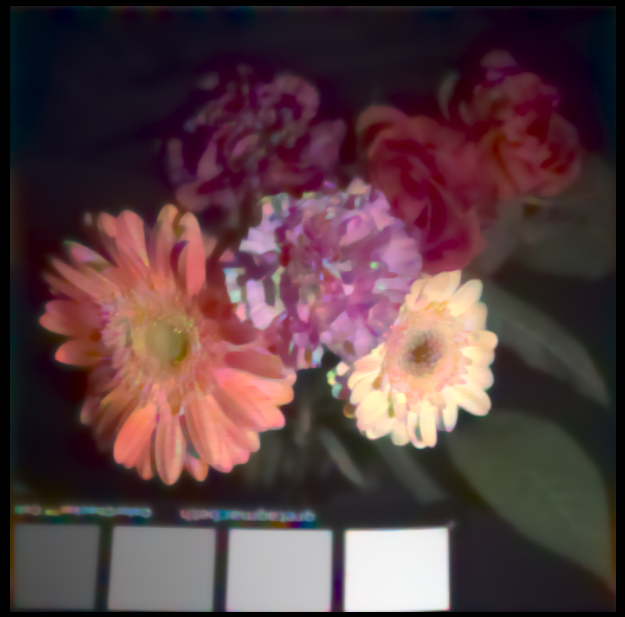
Ours (33.71dB/SSIM:0.96)



Columbia Dataset #4



TwIST (23.11dB/SSIM:0.81)



SpaRSA (22.64dB/SSIM:0.80)



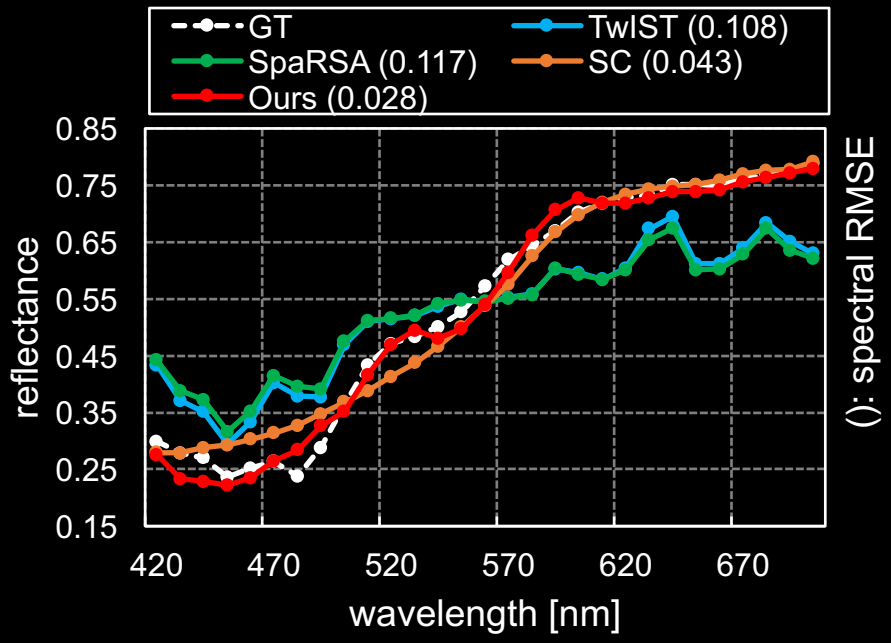
Ground truth



SC (27.96dB/SSIM:0.88)



Ours (33.71dB/SSIM:0.96)



Comparison of Results

Harvard Dataset

List of Compared Methods:

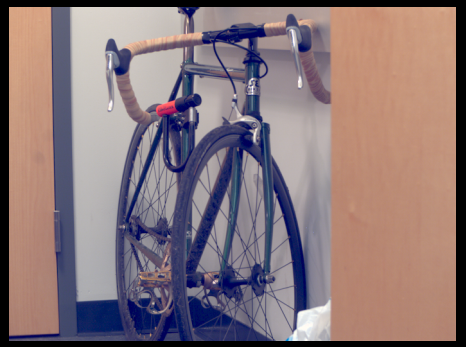
TwIST: Bioucas-Dias and Figueiredo, “Two-Step Algorithms for Linear Inverse Problems with Non-Quadratic Regularization”, ICIP 2007

SpaRSA: Wright et al., “Sparse Reconstruction by Separable Approximation”, IEEE TSP 2009

SC: Lin et al., “Spatial-Spectral Encoded Compressive Hyperspectral Imaging”, ACM TOG 2014

Ground Truth: Harvard Dataset




















TwIST Reconstruction: Harvard Dataset



SpaRSA Reconstruction: Harvard Dataset



Sparse Coding Reconstruction: Harvard Dataset





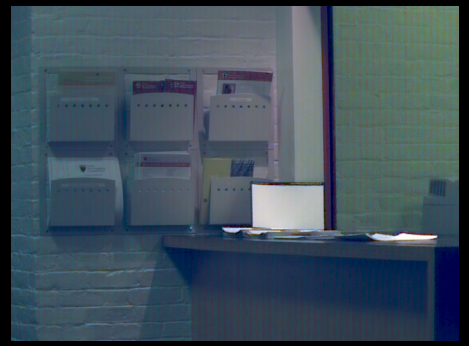















Our Reconstruction: Harvard Dataset











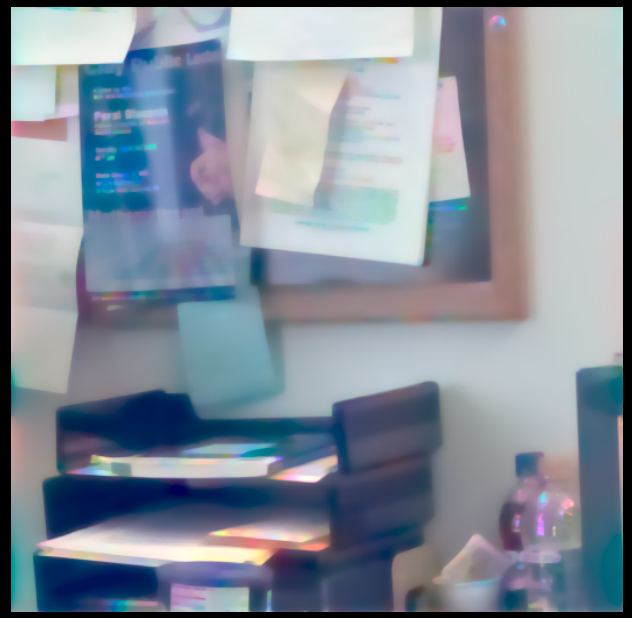




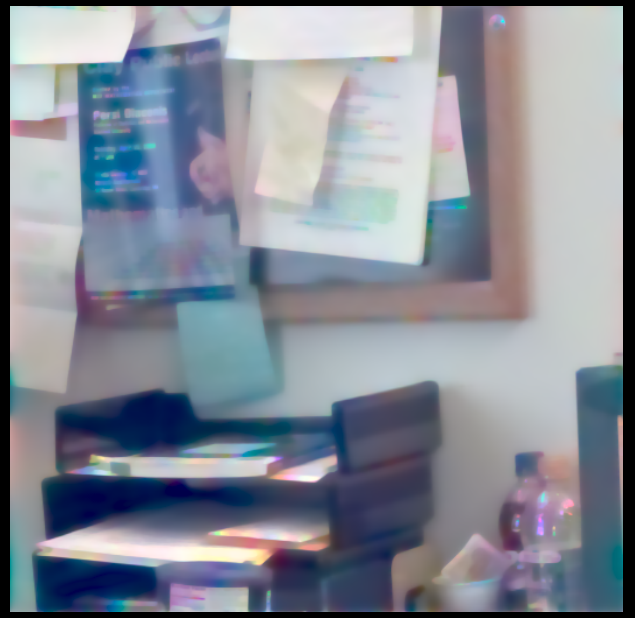





Harvard Dataset #1 (Figure 11)



TwIST (19.71dB/SSIM:0.68)



SpaRSA (19.74dB/SSIM:0.68)



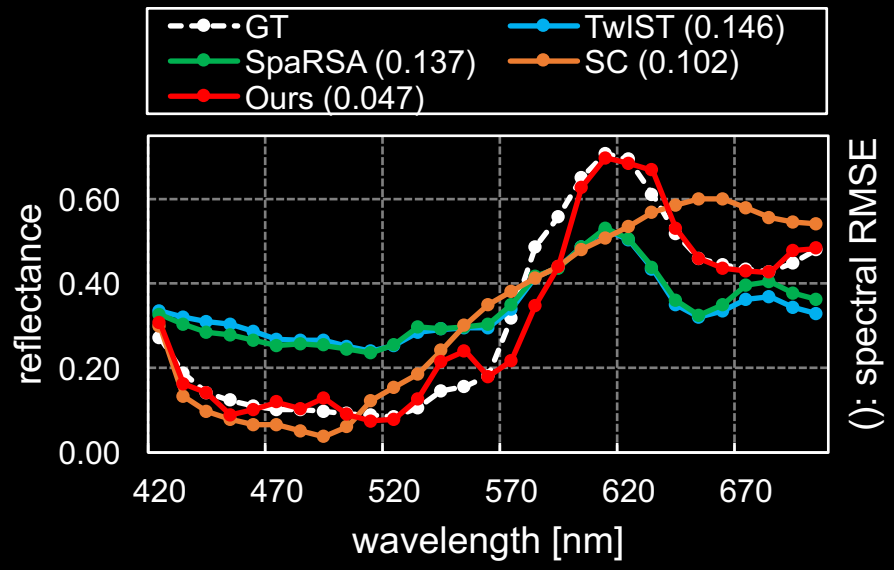
Ground truth



SC (20.30dB/SSIM:0.62)



Ours (25.49dB/SSIM:0.82)



Harvard Dataset #2 (Figure 11)



TwIST (20.36dB/SSIM:0.84)



SpaRSA (20.58dB/SSIM:0.84)



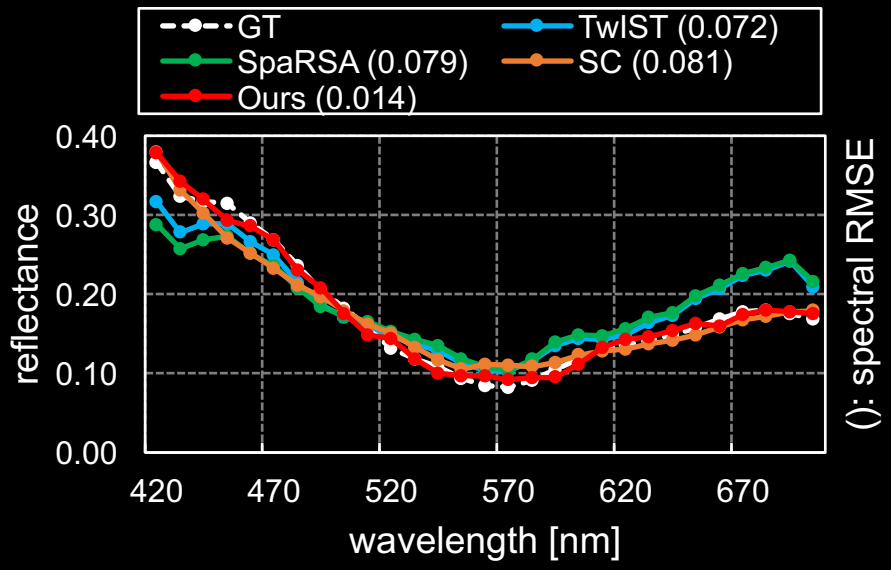
Ground truth



SC (28.24dB/SSIM:0.93)



Ours (29.66dB/SSIM:0.95)



Harvard Dataset #3 (Figure 17)



TwIST (17.28dB/SSIM:0.62)



SpaRSA (17.38dB/SSIM:0.62)



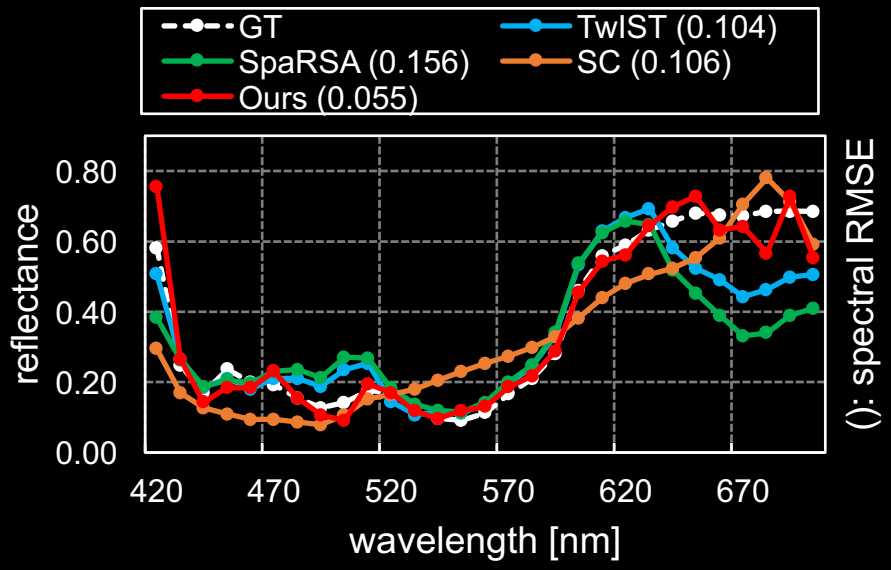
Ground truth



SC (19.16dB/SSIM:0.58)



Ours (21.80dB/SSIM:0.77)



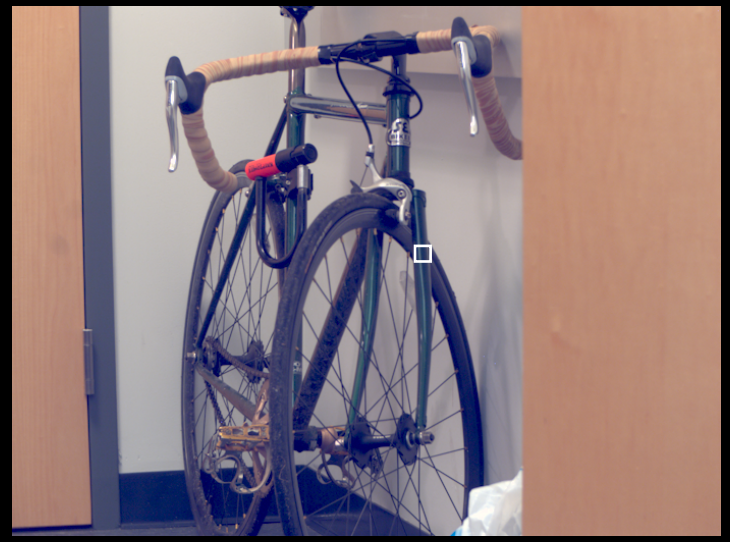
Harvard Dataset #4



TwIST (20.44dB/SSIM:0.70)



SpaRSA (20.67dB/SSIM:0.70)



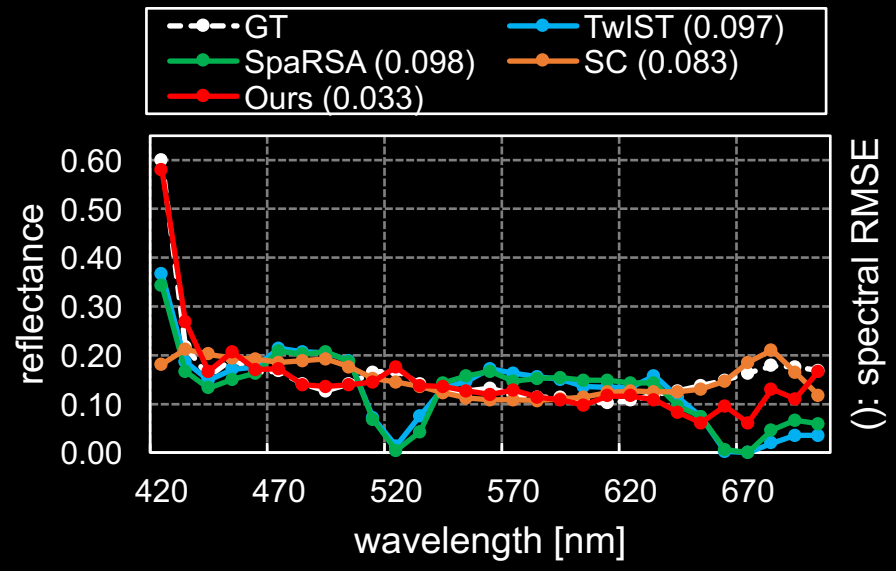
Ground truth



SC (22.94dB/SSIM:0.56)



Ours (23.16dB/SSIM:0.80)



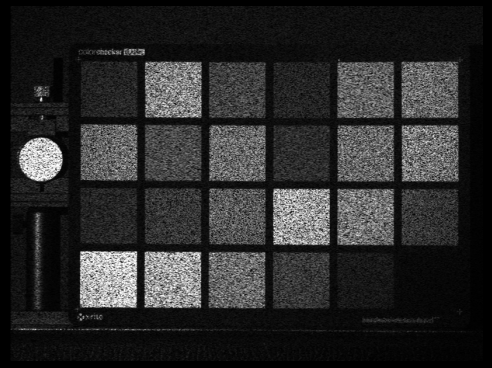
Our Reconstruction Results

Our High-Resolution Dataset

Our Reconstruction: Our High-Resolution Dataset #01



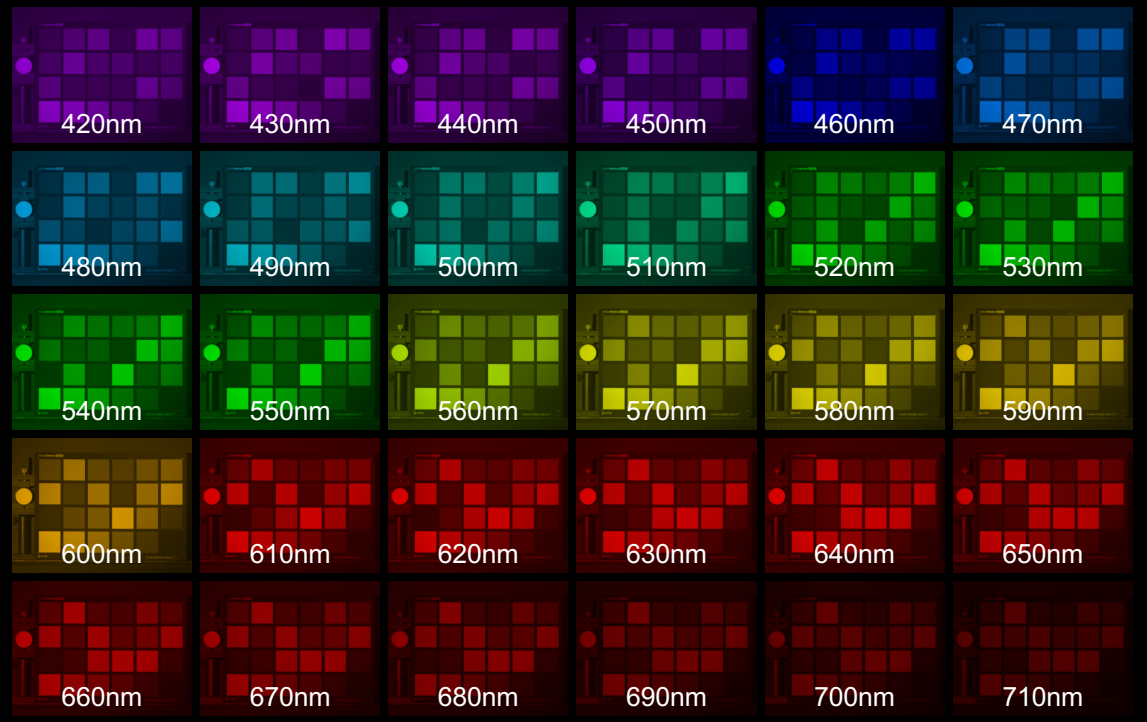
Ground truth



Compressive input



Our reconstruction



Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #02



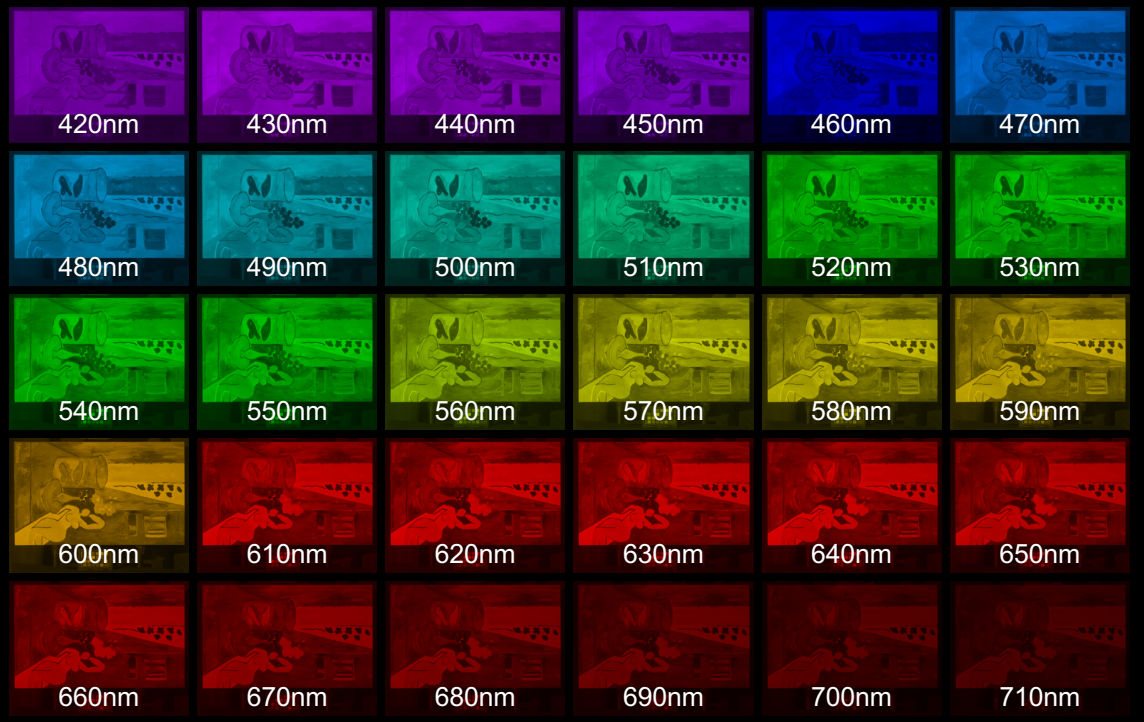
Ground truth



Compressive input

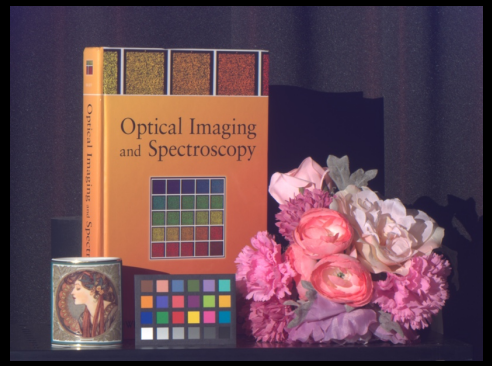


Our reconstruction

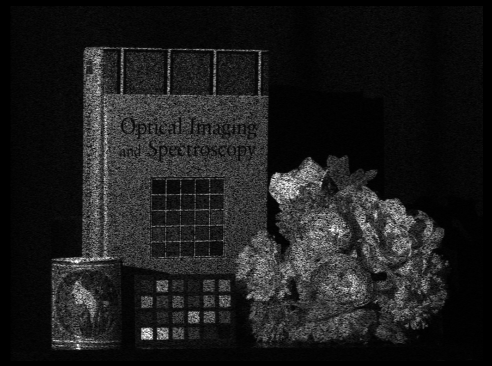


Our reconstructed spectral bands

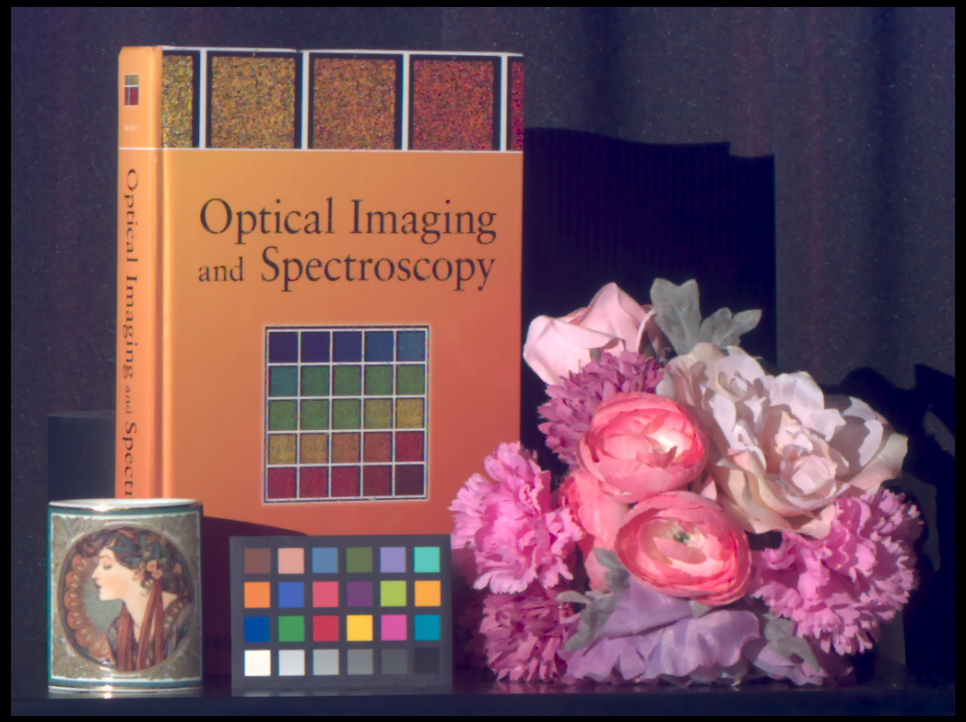
Our Reconstruction: Our High-Resolution Dataset #03



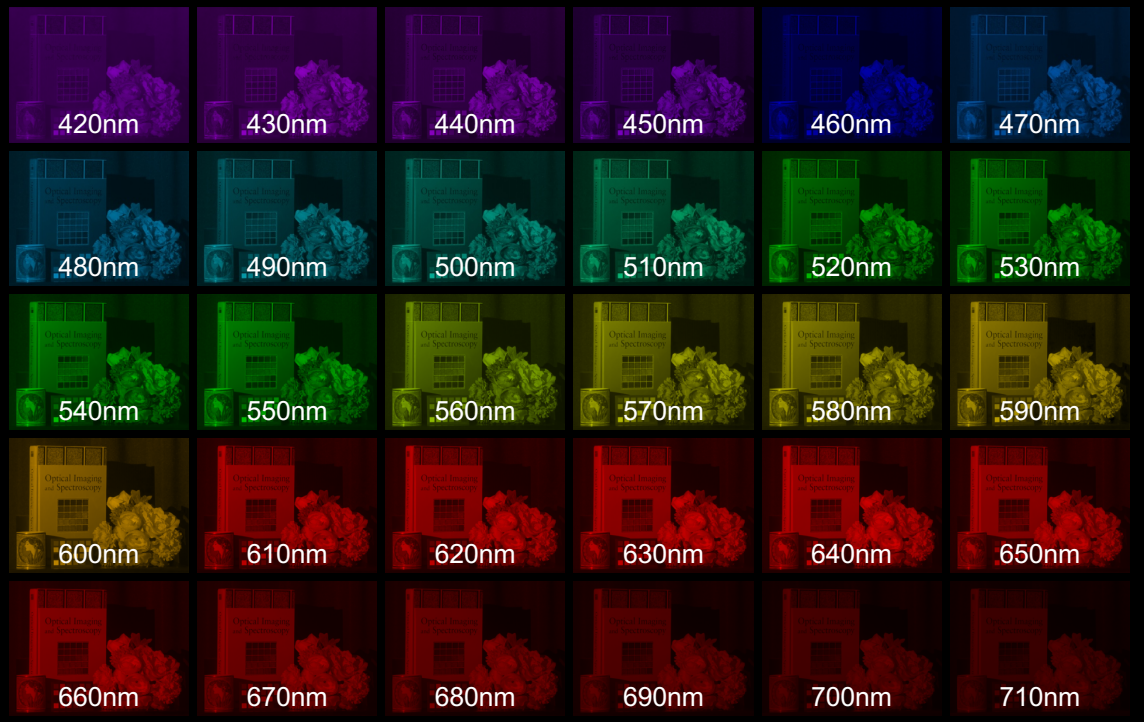
Ground truth



Compressive input

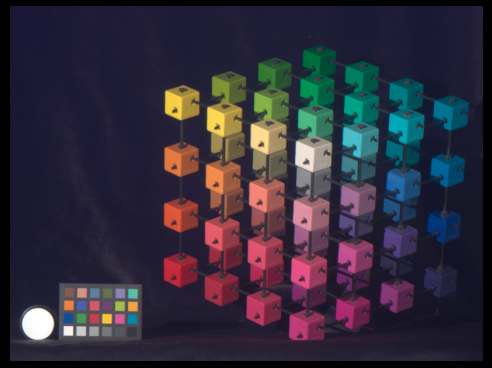


Our reconstruction

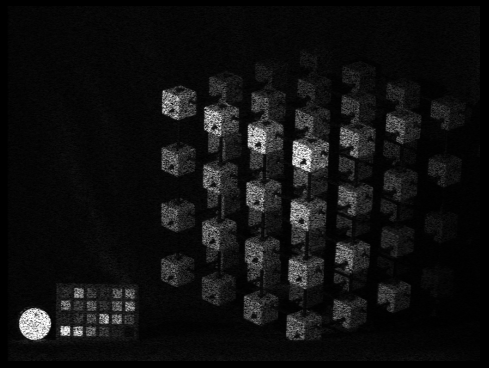


Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #04



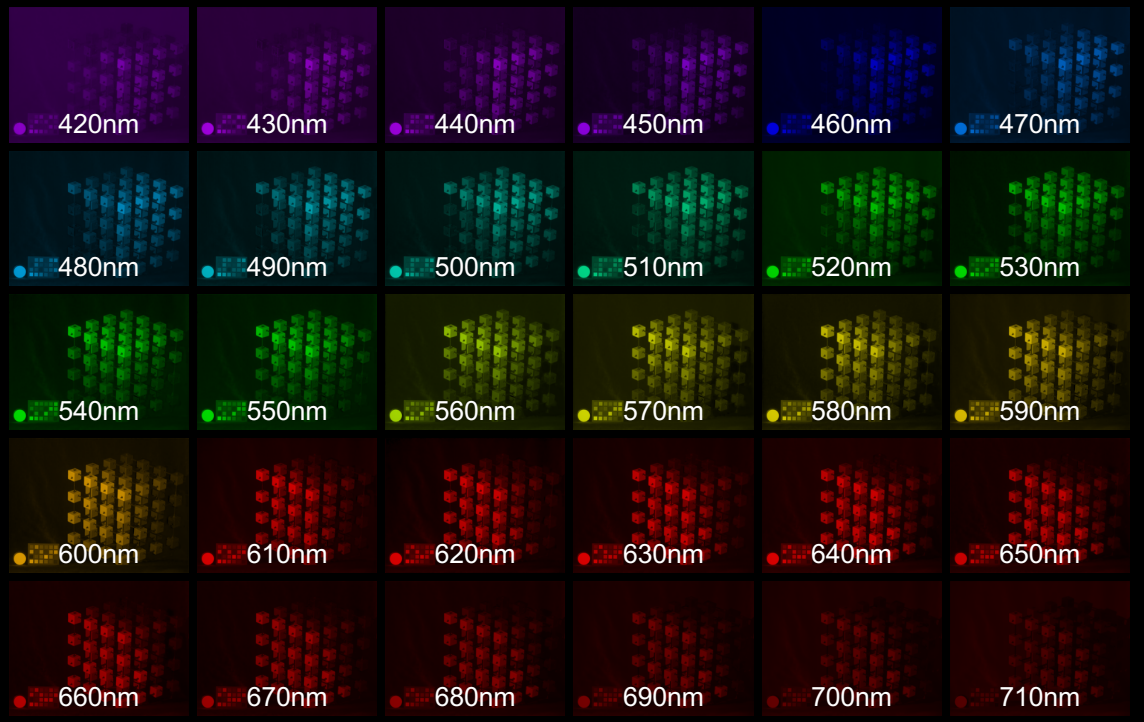
Ground truth



Compressive input



Our reconstruction

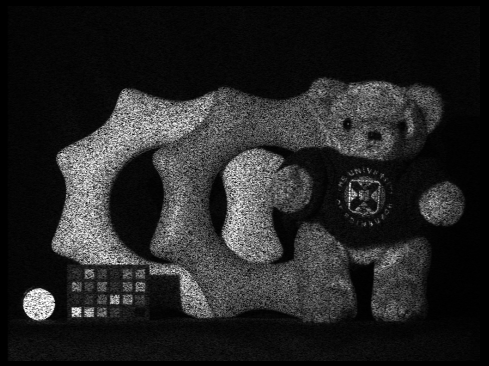


Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #05



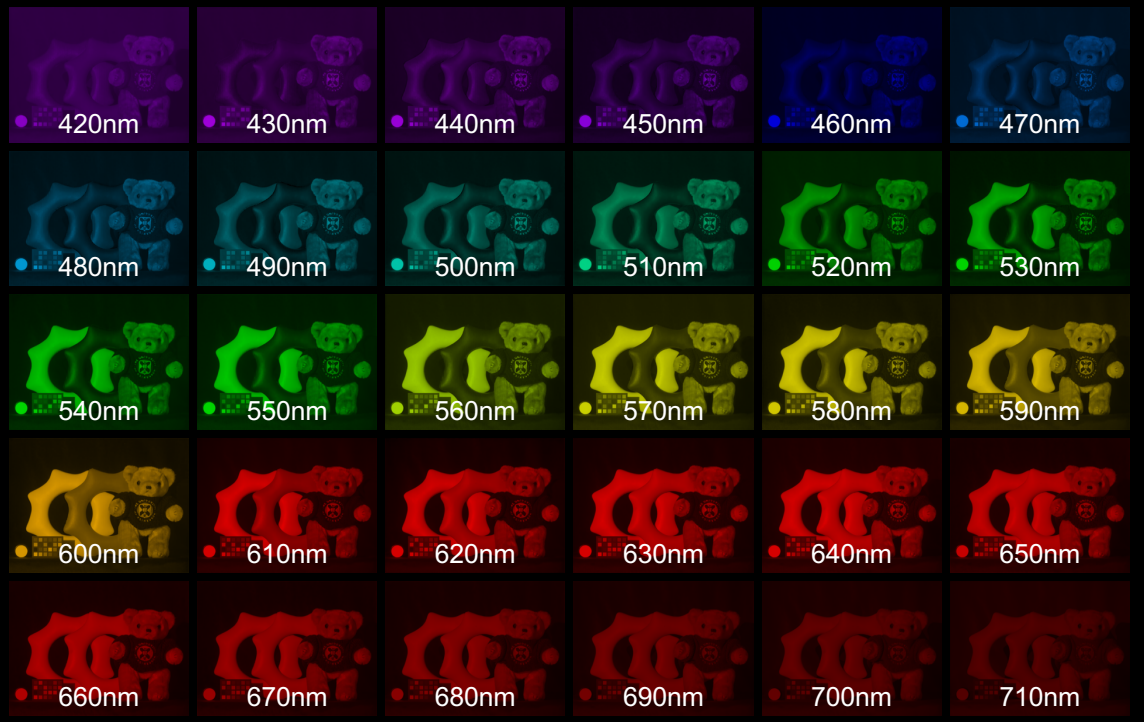
Ground truth



Compressive input



Our reconstruction



Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #06



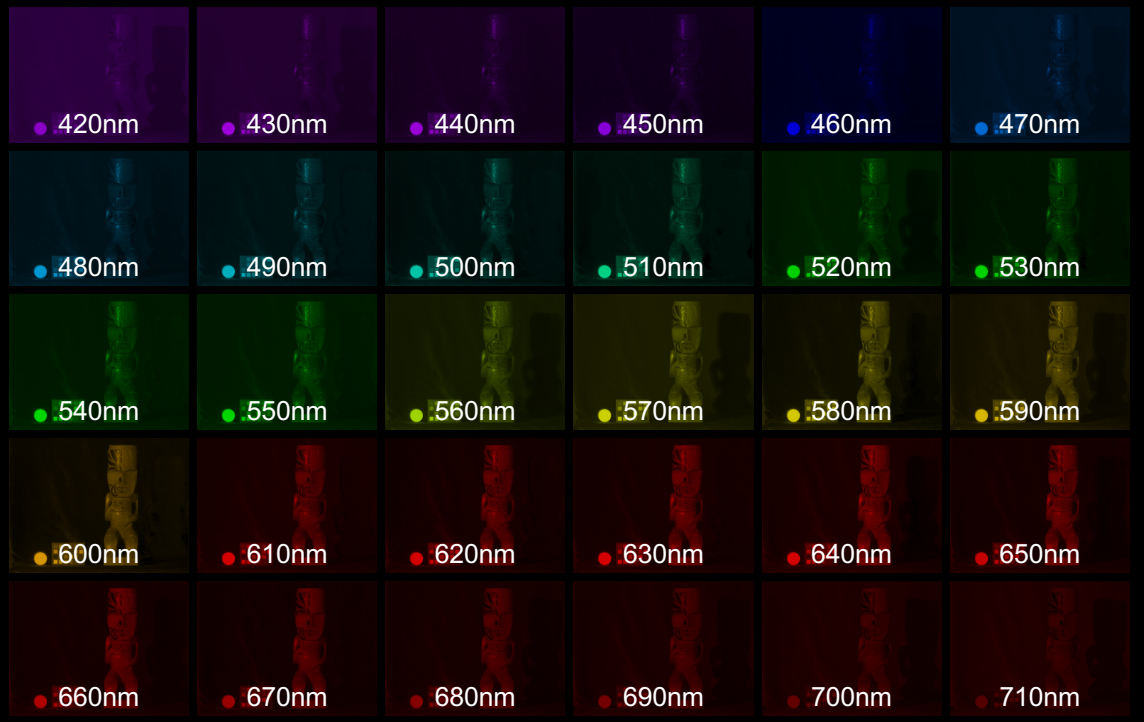
Ground truth



Compressive input



Our reconstruction



Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #07



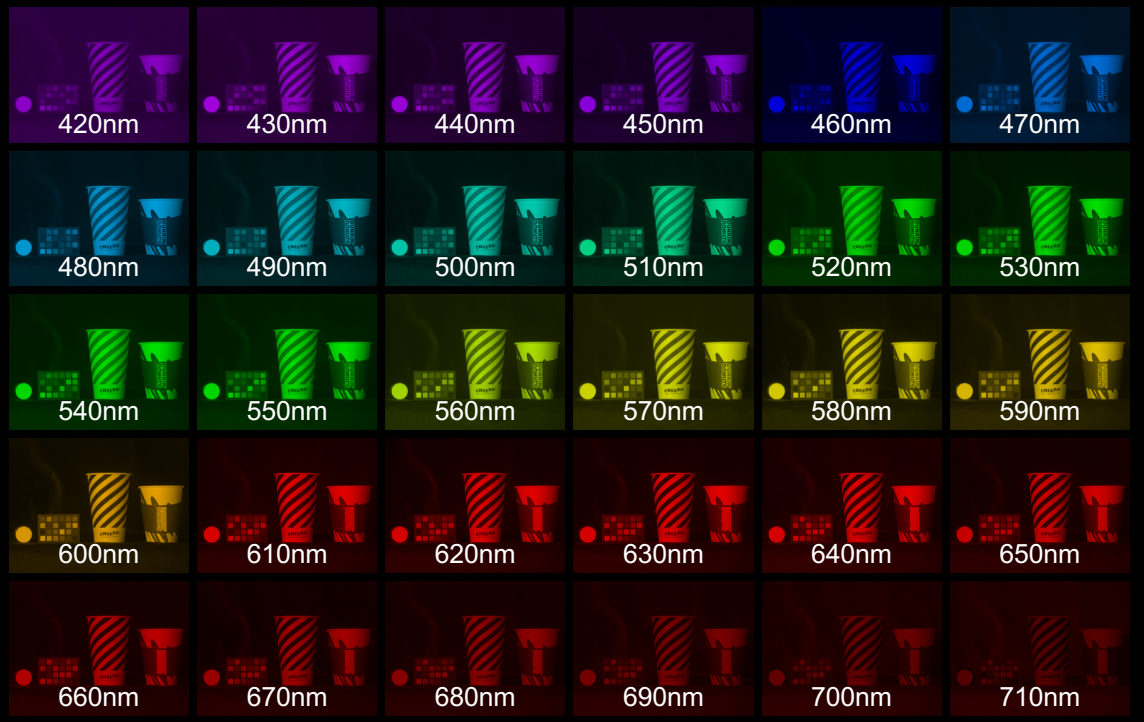
Ground truth



Compressive input



Our reconstruction

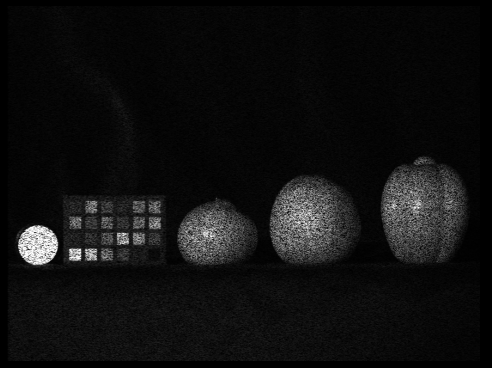


Our reconstructed spectral bands

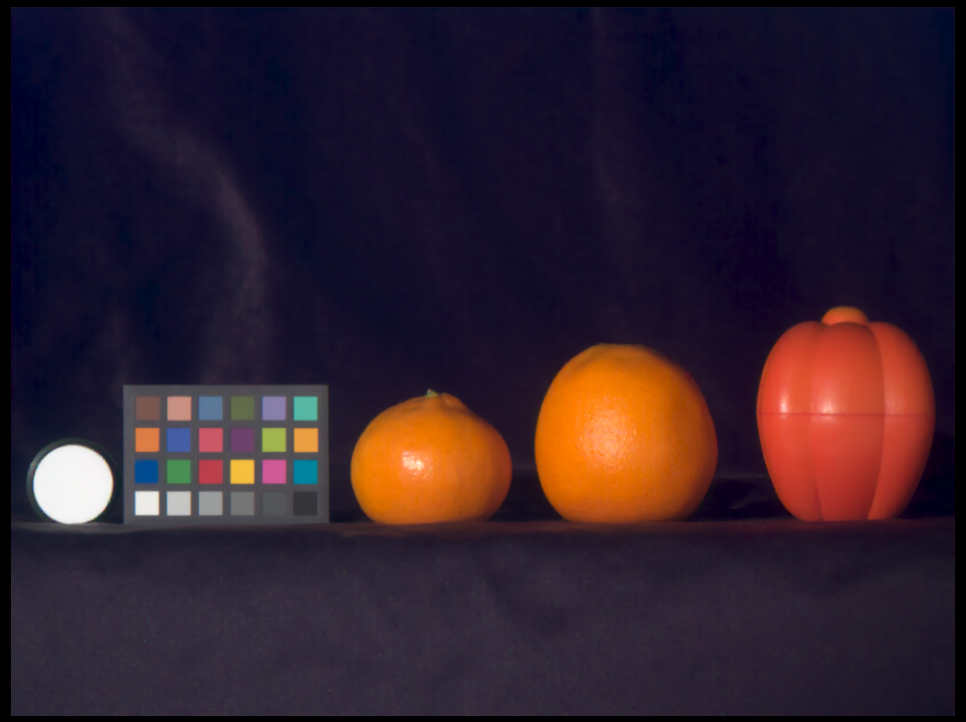
Our Reconstruction: Our High-Resolution Dataset #08



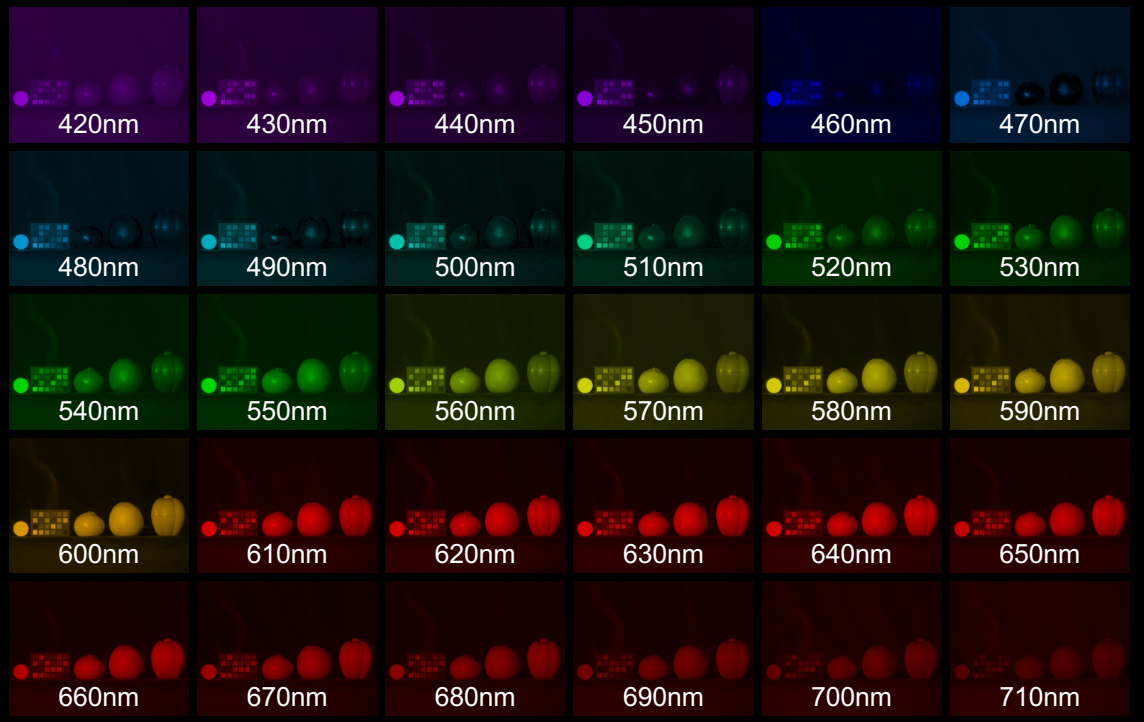
Ground truth



Compressive input



Our reconstruction

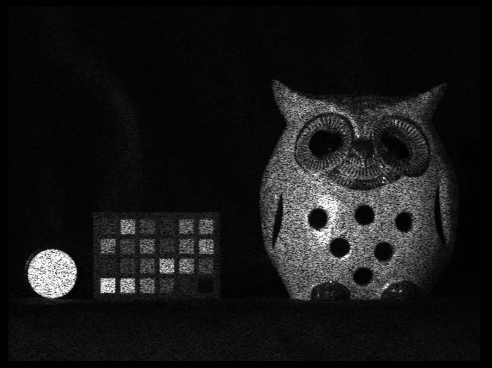


Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #09



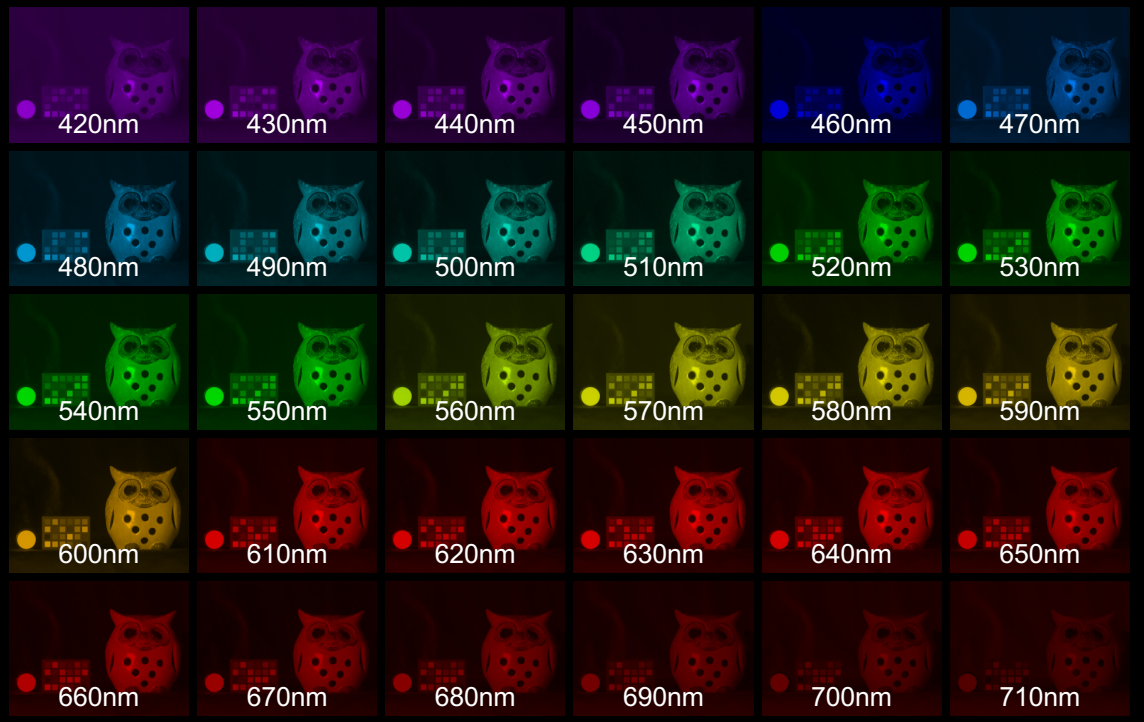
Ground truth



Compressive input



Our reconstruction

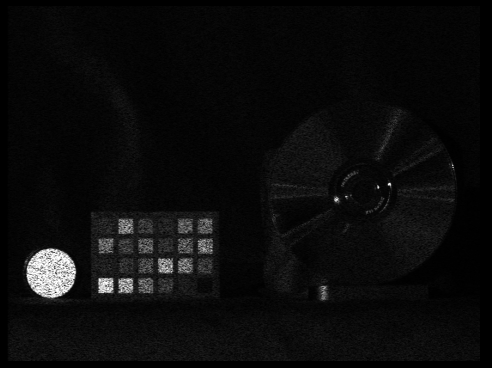


Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #10



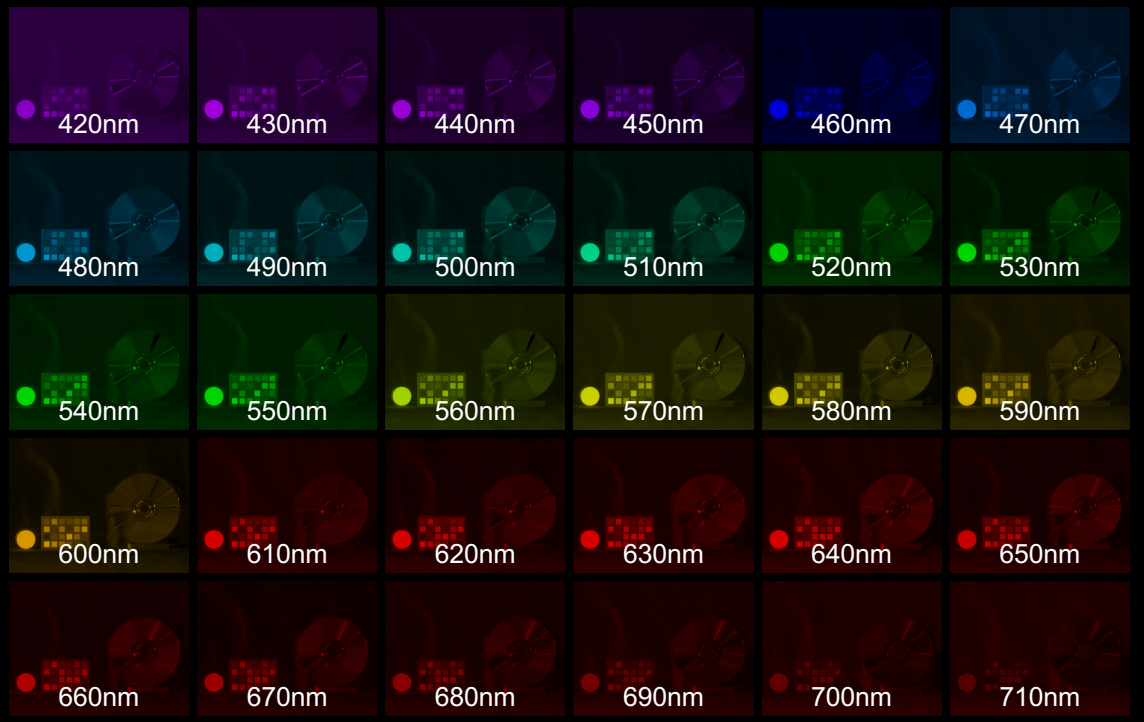
Ground truth



Compressive input



Our reconstruction

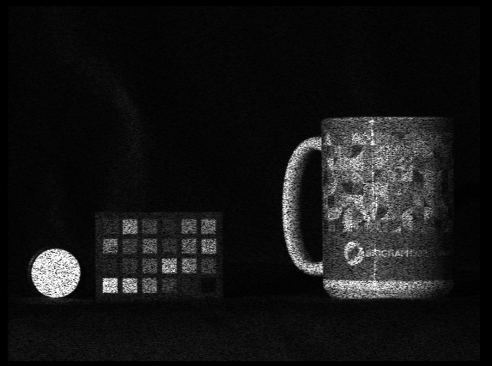


Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #11



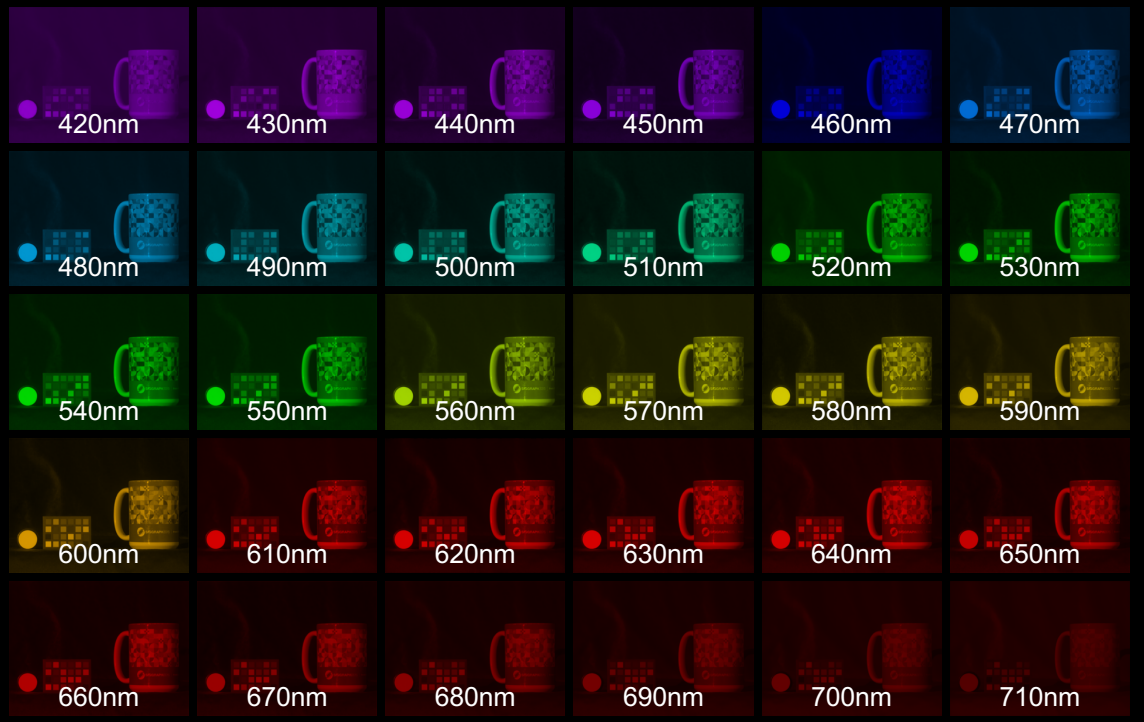
Ground truth



Compressive input



Our reconstruction



Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #12



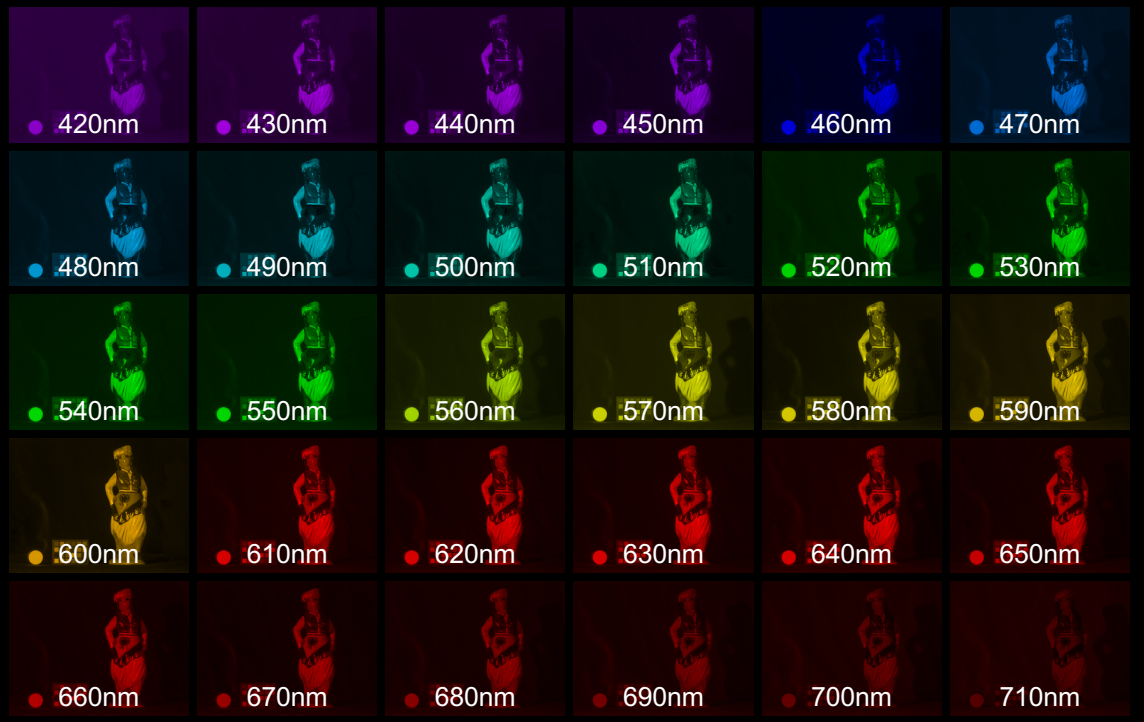
Ground truth



Compressive input



Our reconstruction

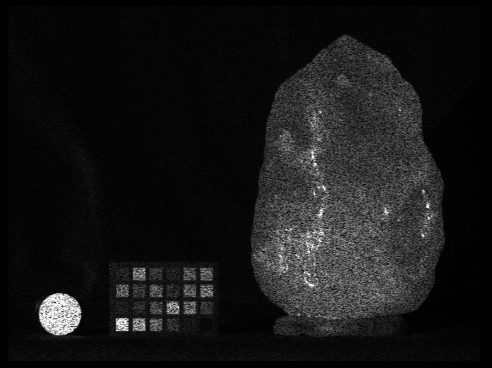


Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #13



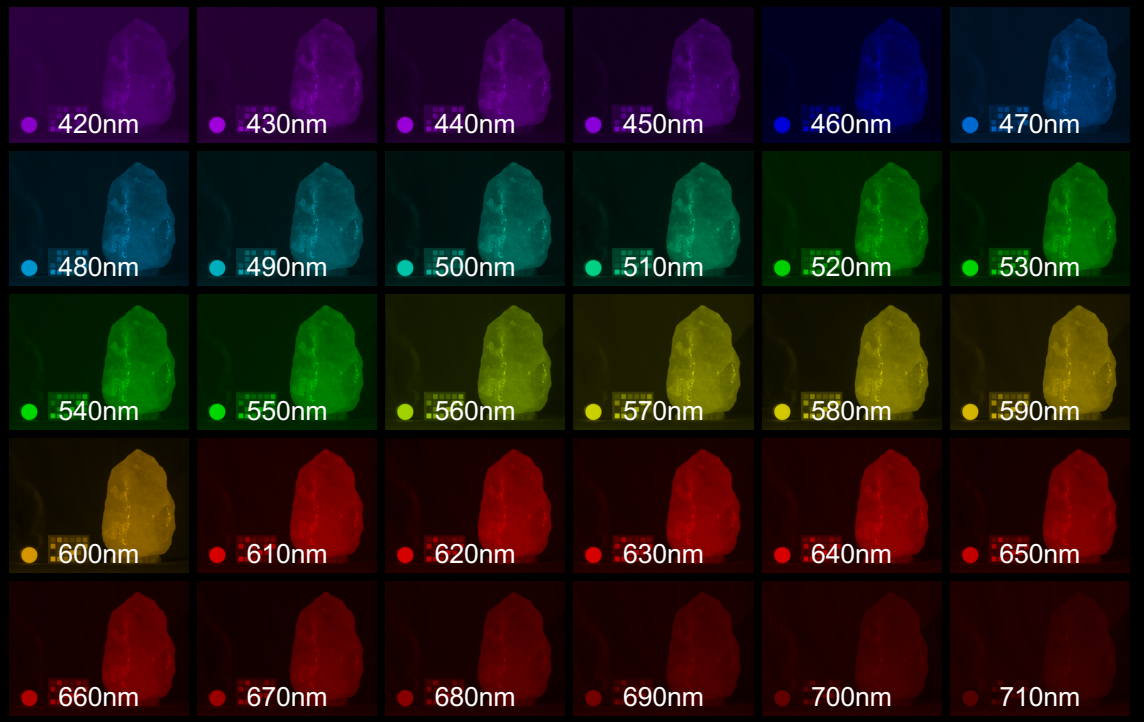
Ground truth



Compressive input



Our reconstruction

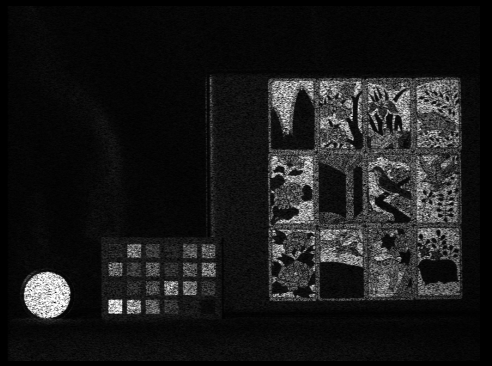


Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #14



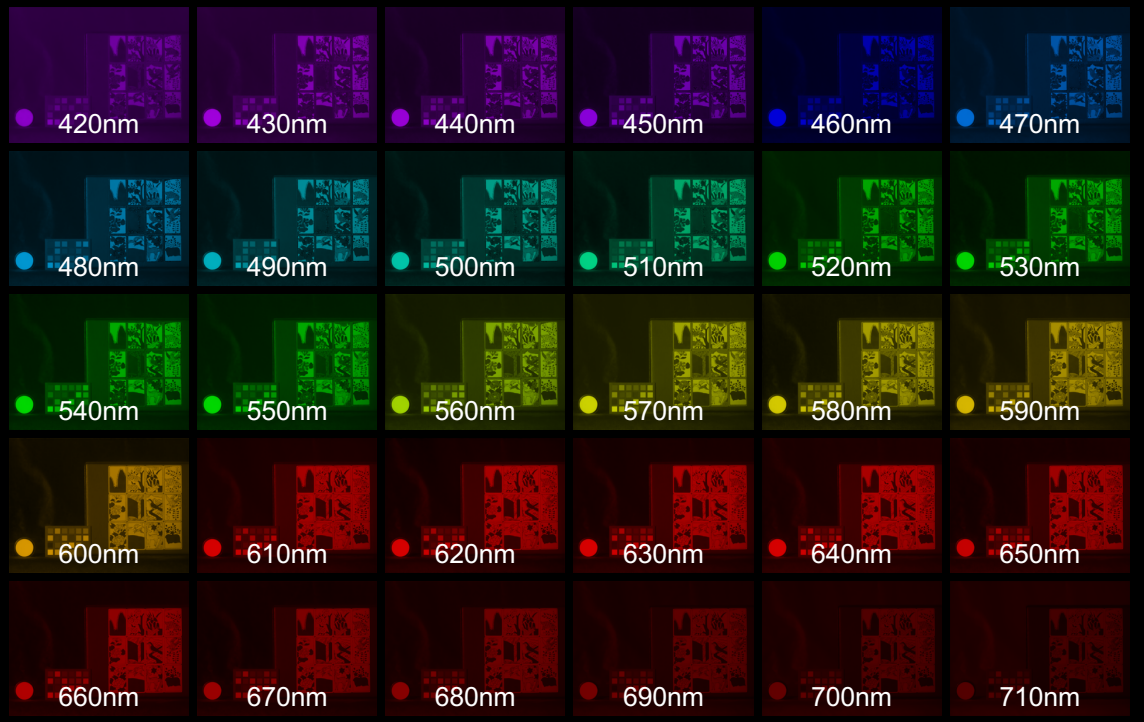
Ground truth



Compressive input



Our reconstruction

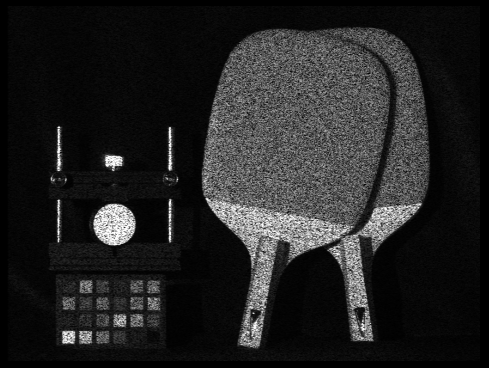


Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #15



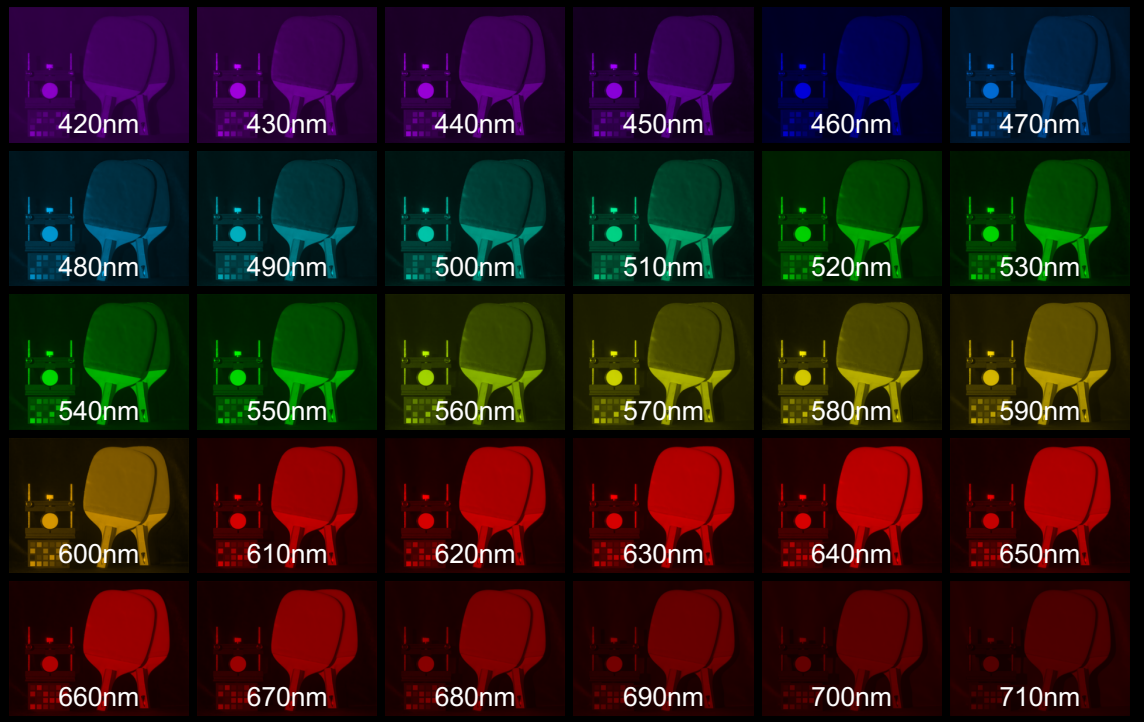
Ground truth



Compressive input



Our reconstruction

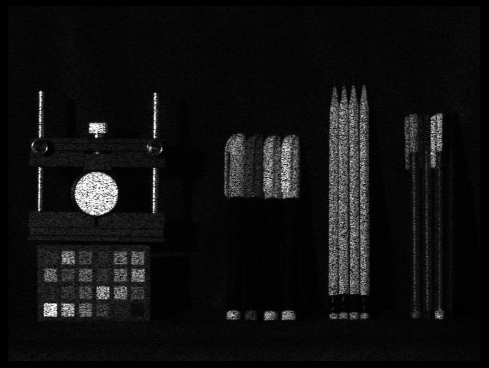


Our reconstructed spectral bands

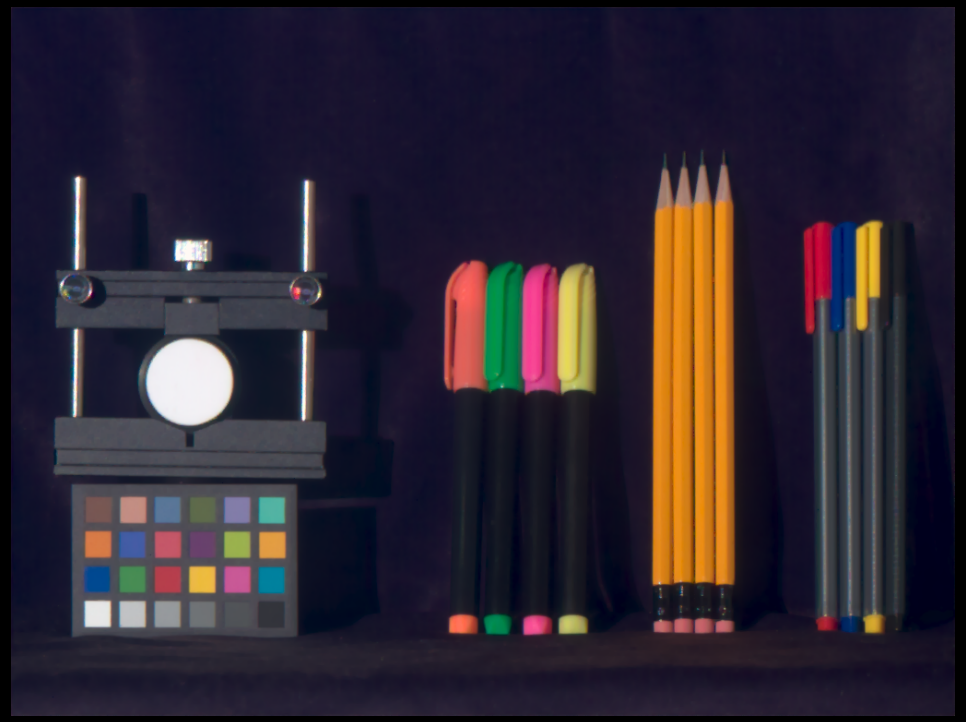
Our Reconstruction: Our High-Resolution Dataset #16



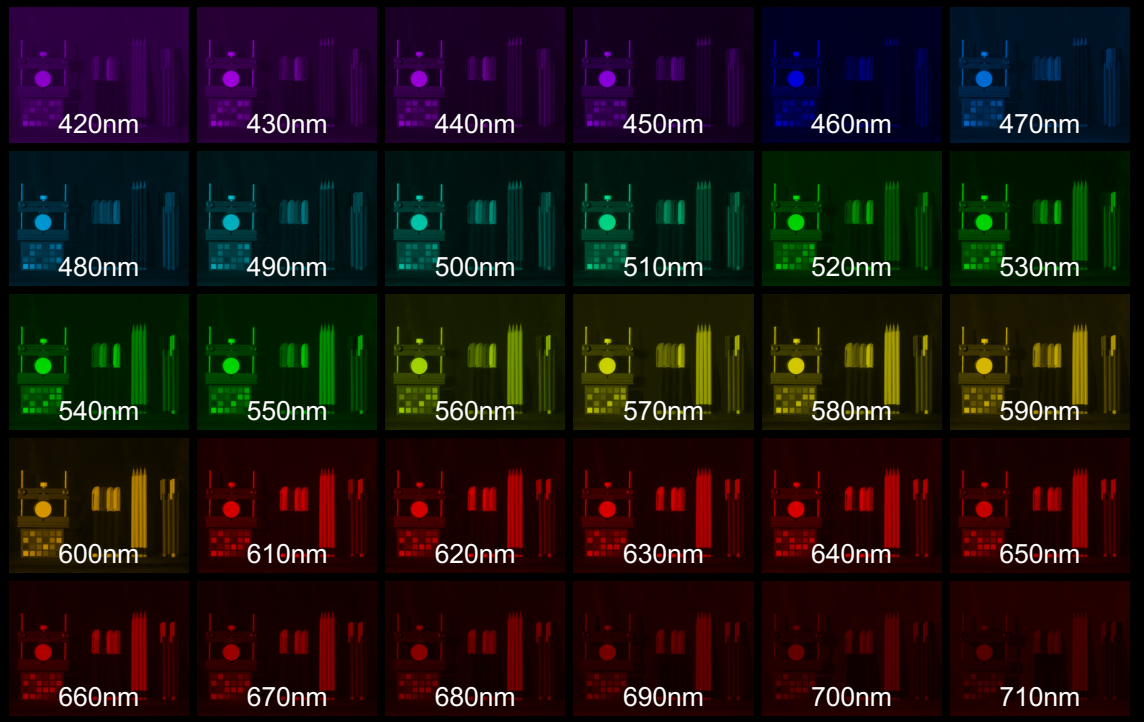
Ground truth



Compressive input

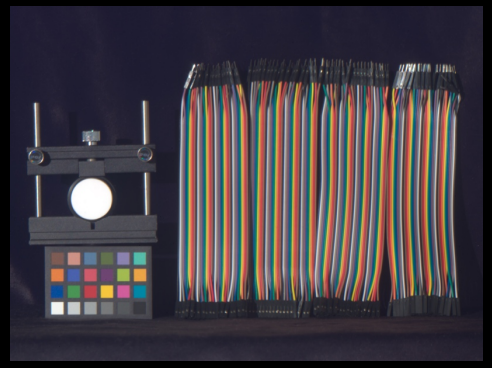


Our reconstruction

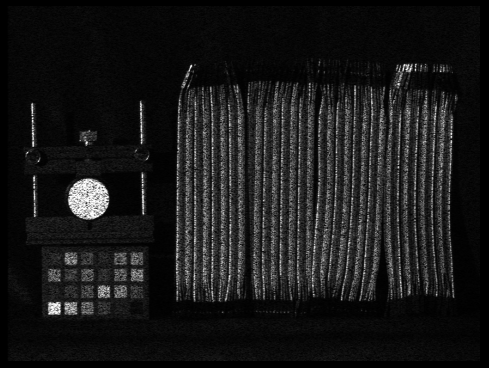


Our reconstructed spectral bands

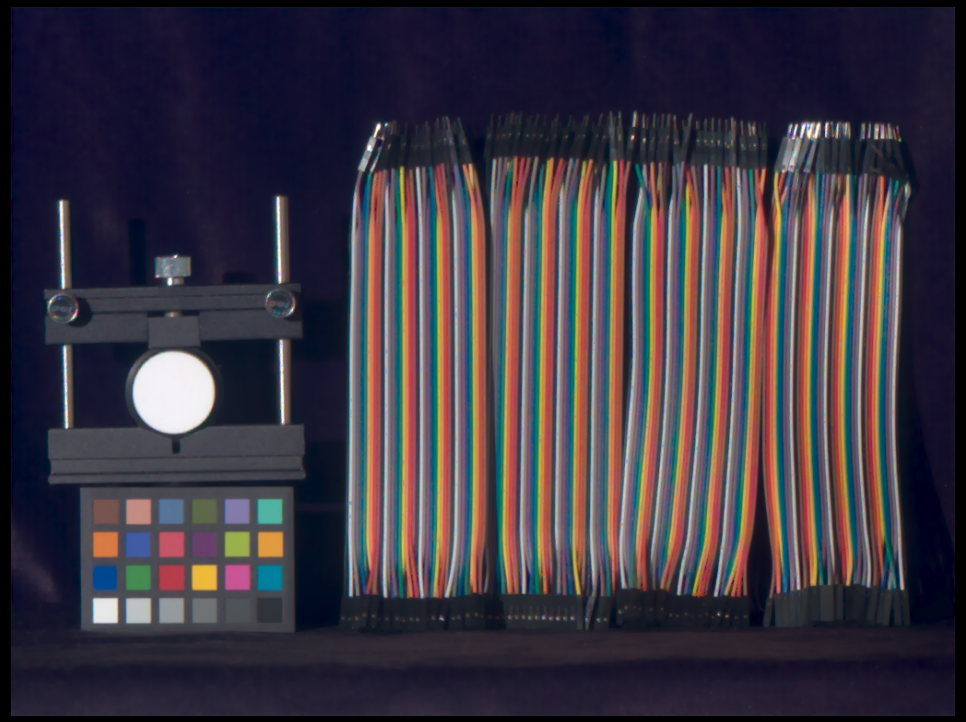
Our Reconstruction: Our High-Resolution Dataset #17



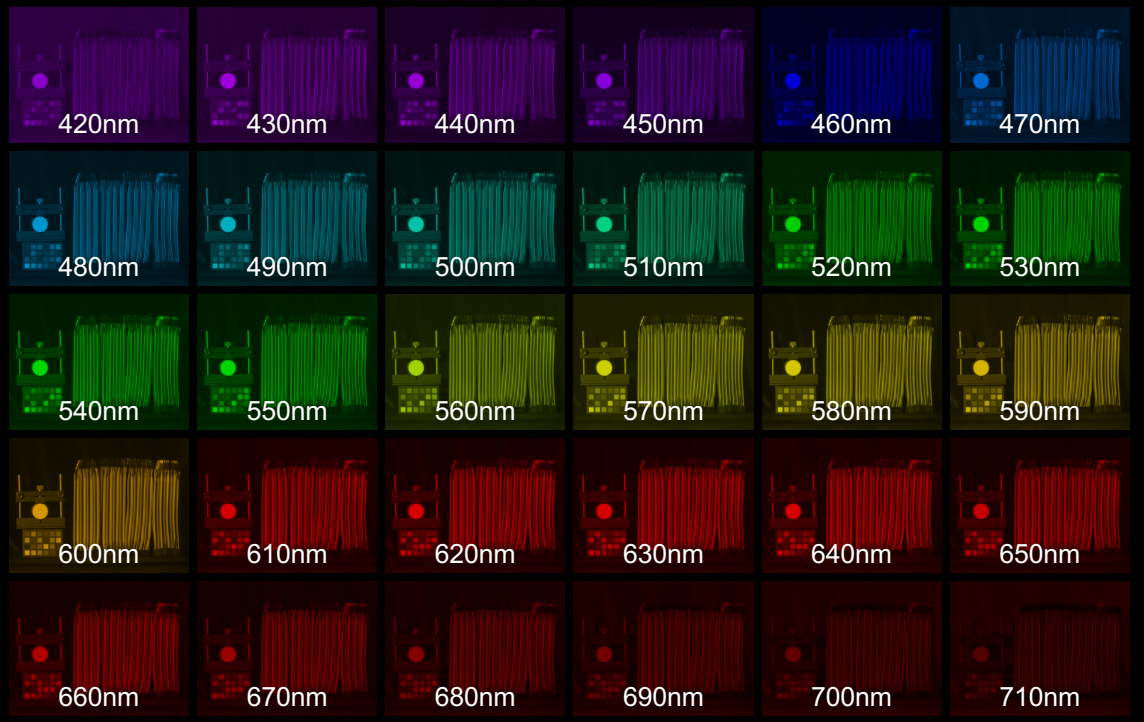
Ground truth



Compressive input



Our reconstruction



Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #18



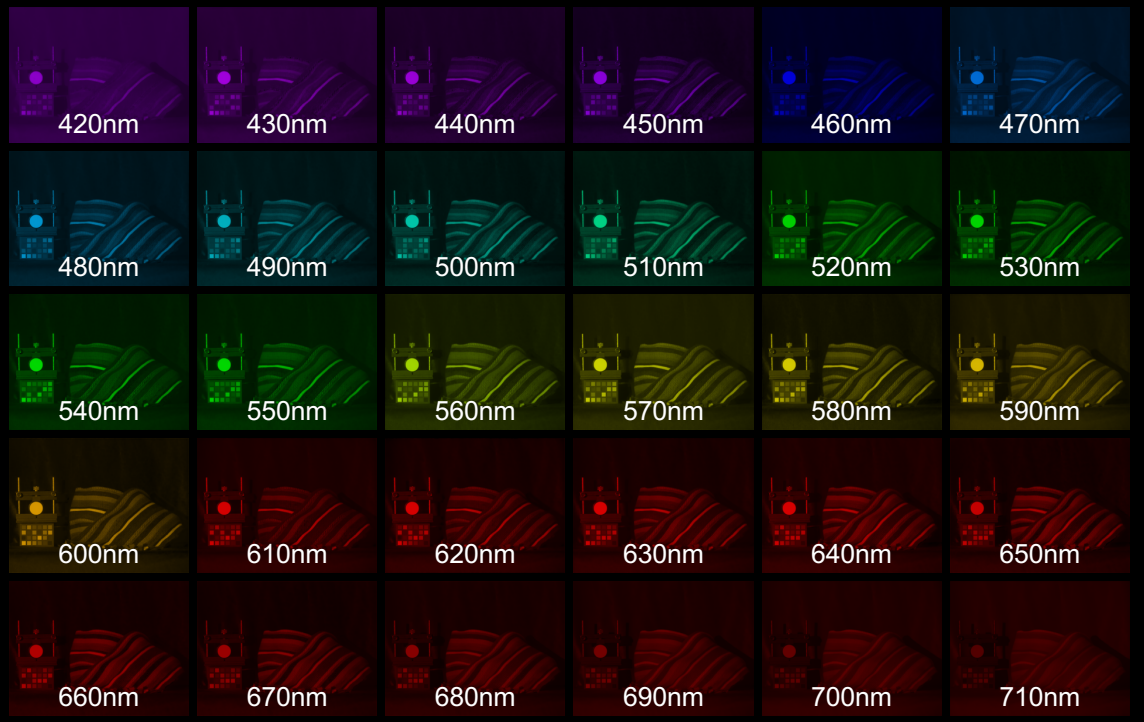
Ground truth



Compressive input



Our reconstruction

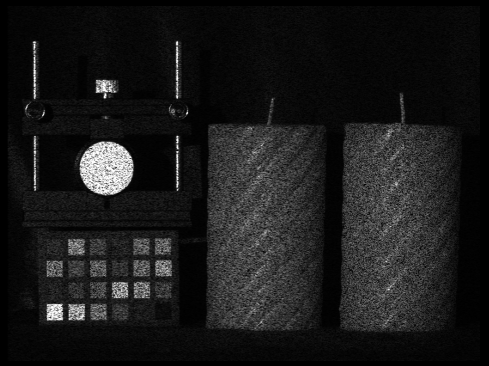


Our reconstructed spectral bands

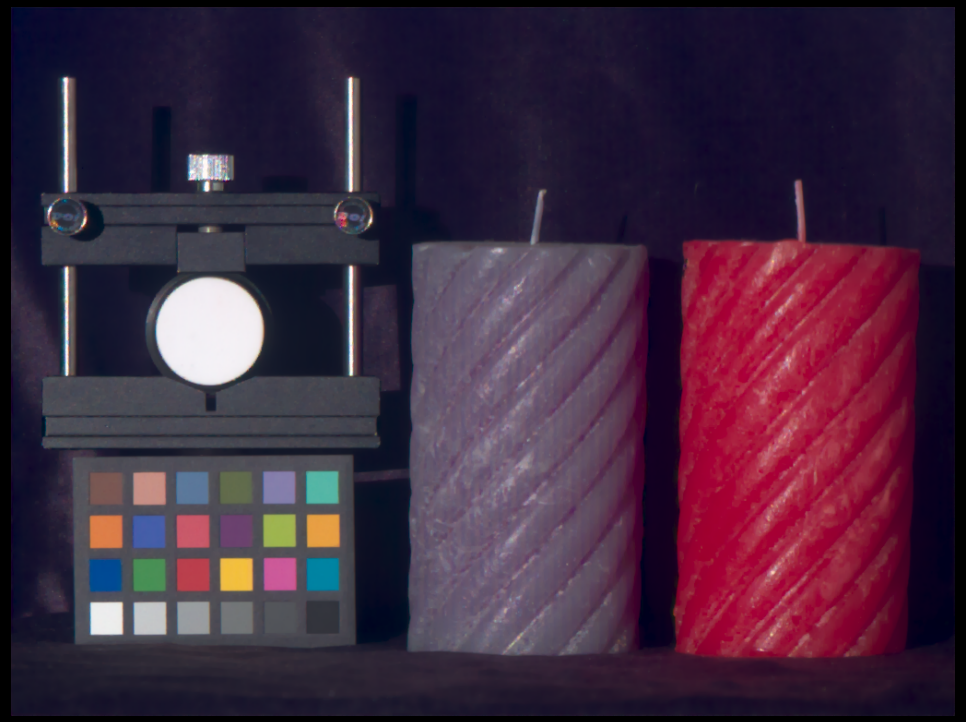
Our Reconstruction: Our High-Resolution Dataset #19



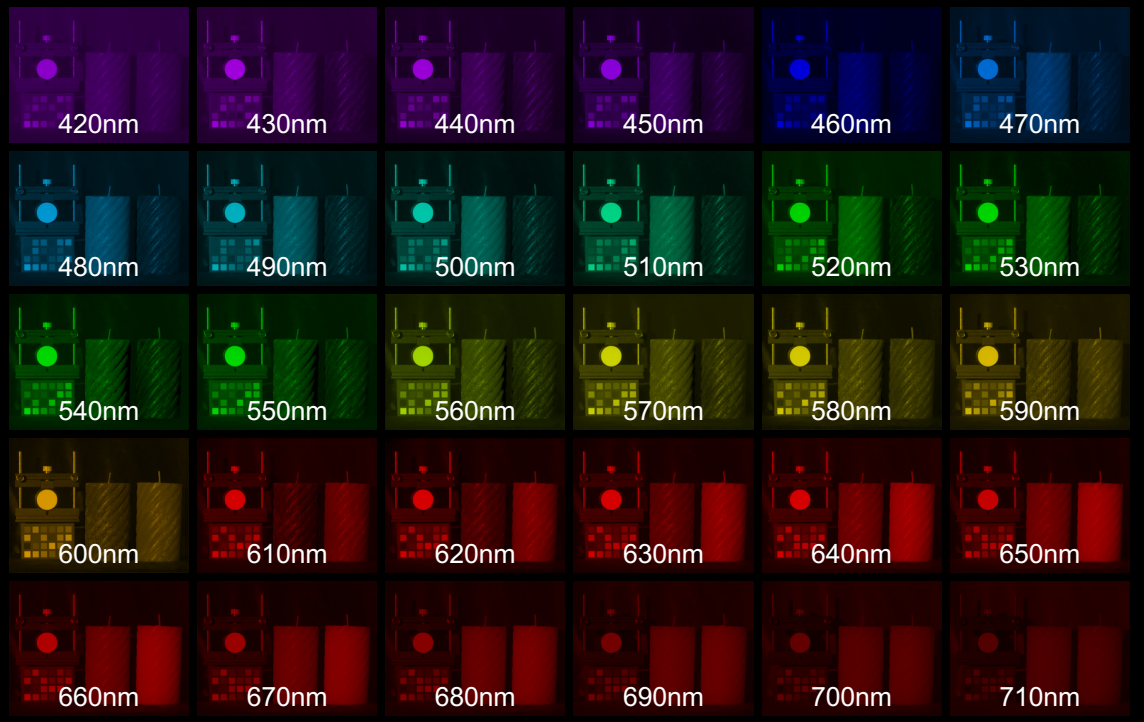
Ground truth



Compressive input



Our reconstruction

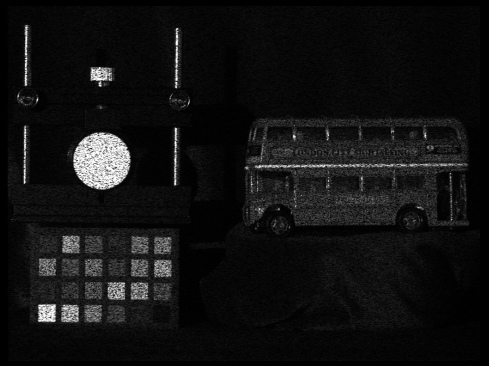


Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #20



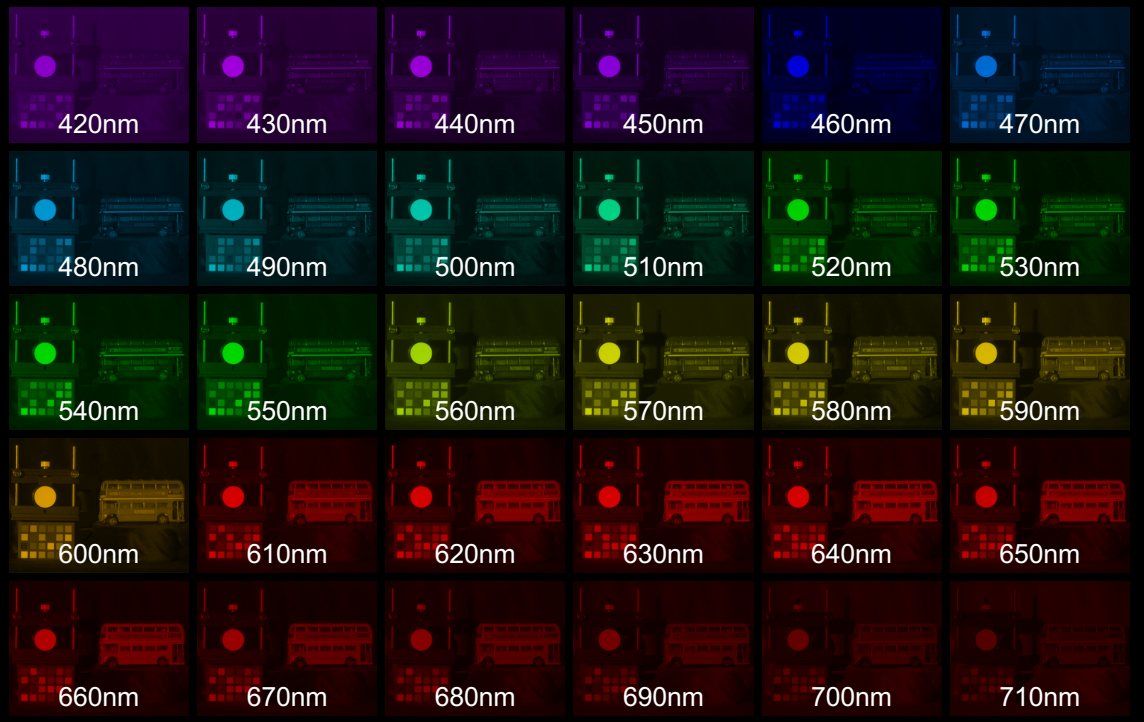
Ground truth



Compressive input



Our reconstruction

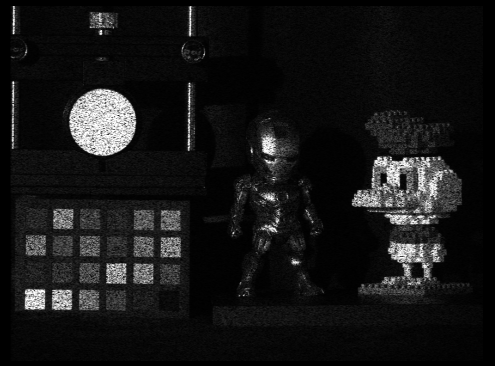


Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #21



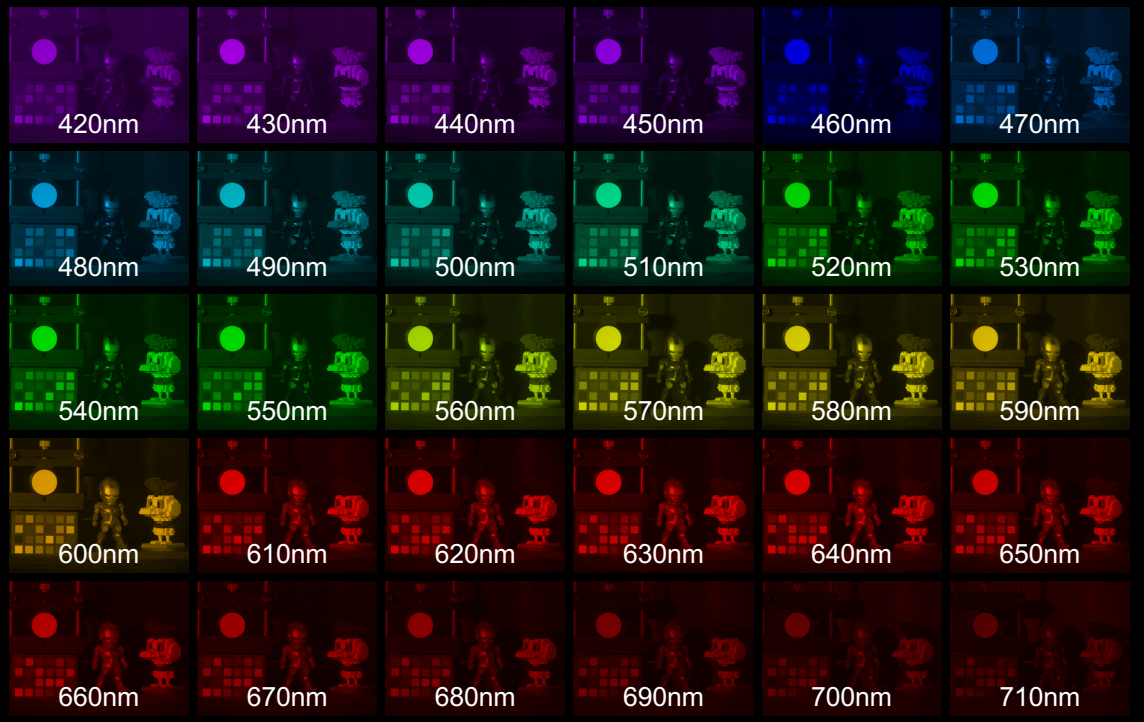
Ground truth



Compressive input

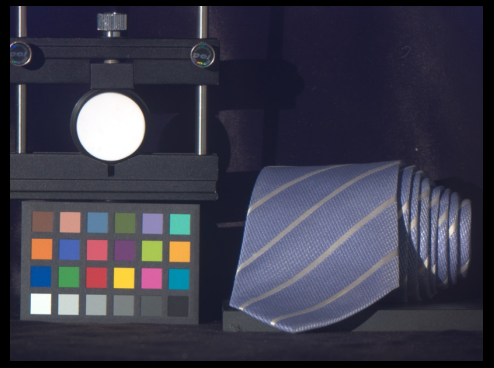


Our reconstruction

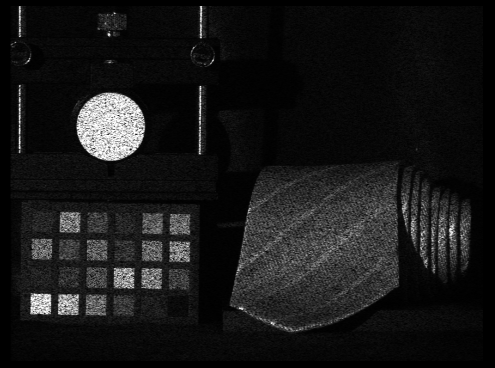


Our reconstructed spectral bands

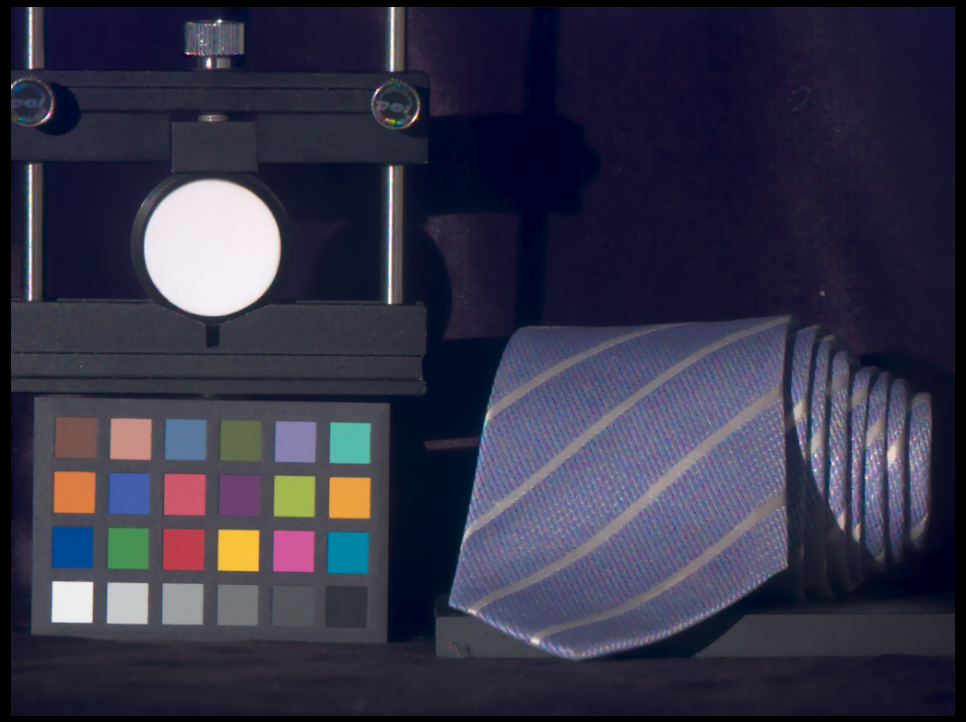
Our Reconstruction: Our High-Resolution Dataset #22



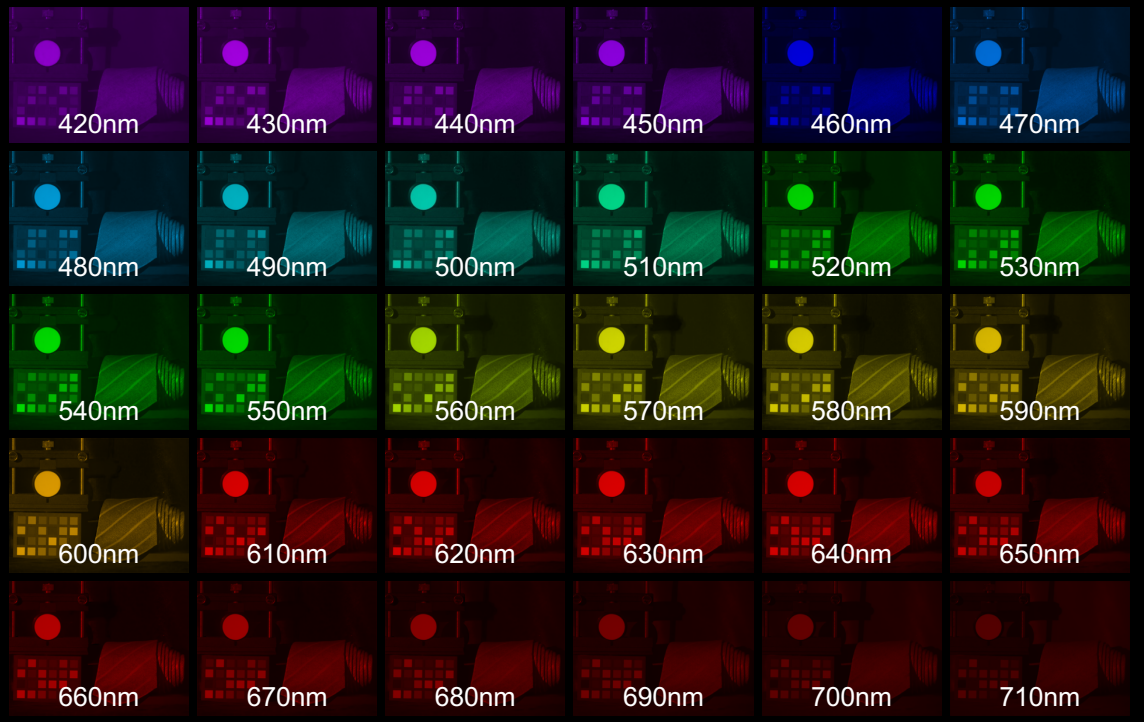
Ground truth



Compressive input

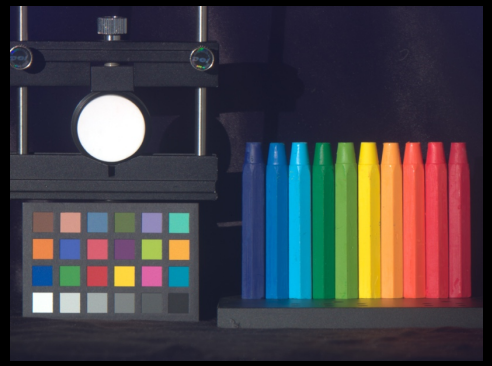


Our reconstruction

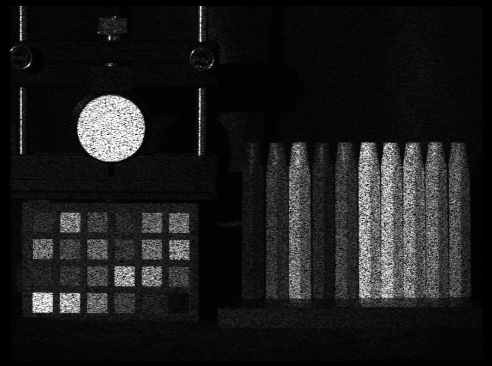


Our reconstructed spectral bands

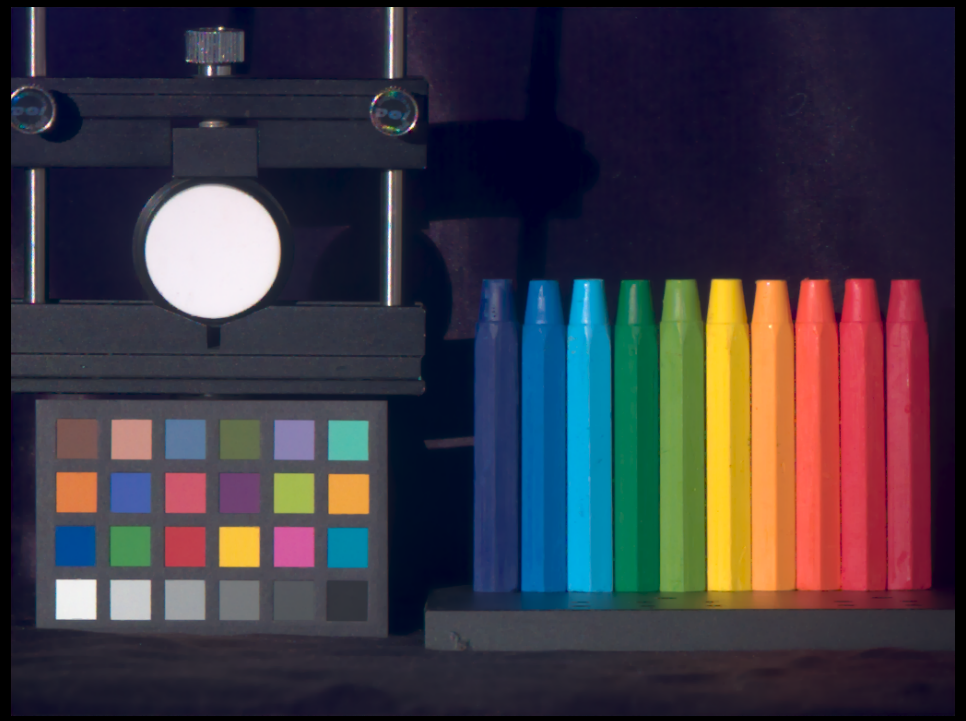
Our Reconstruction: Our High-Resolution Dataset #23



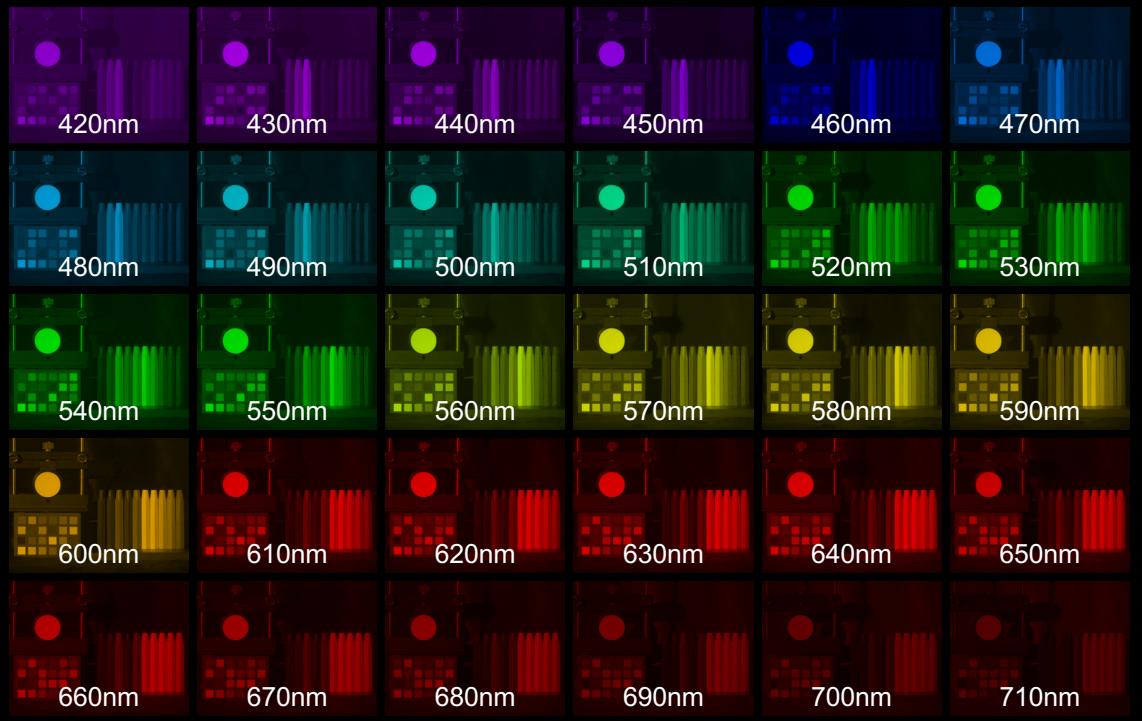
Ground truth



Compressive input



Our reconstruction

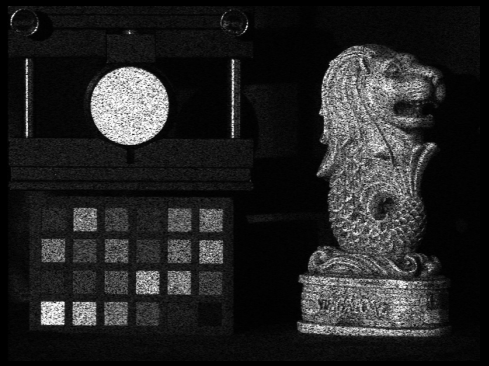


Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #24



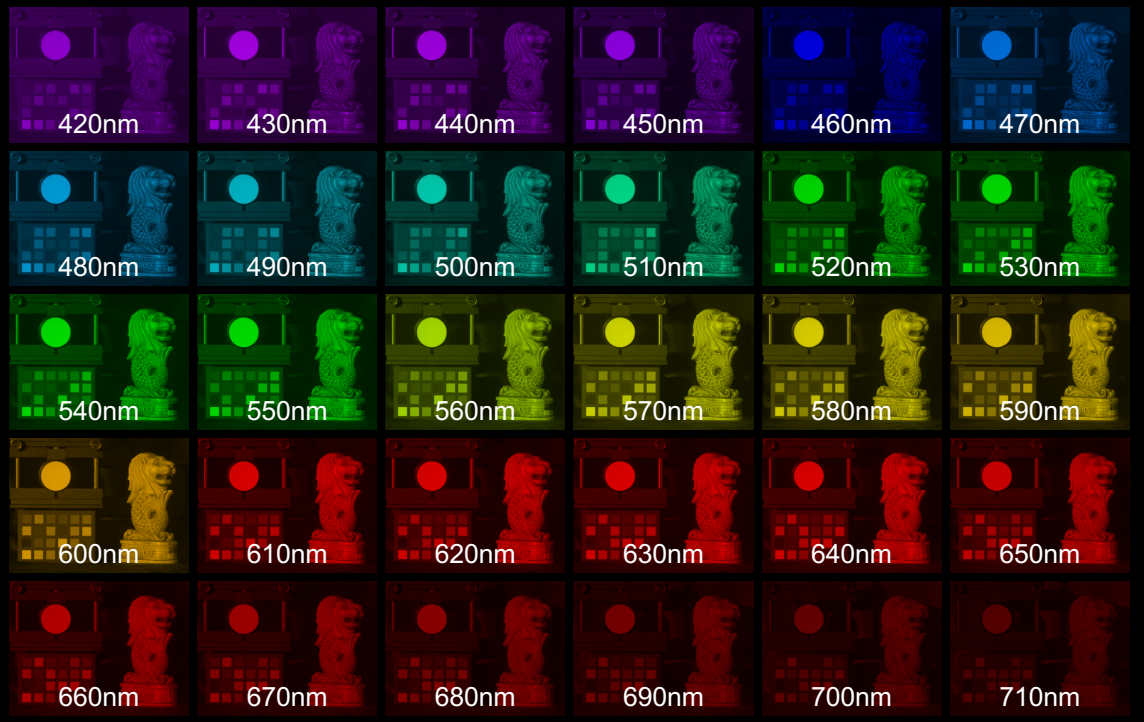
Ground truth



Compressive input



Our reconstruction

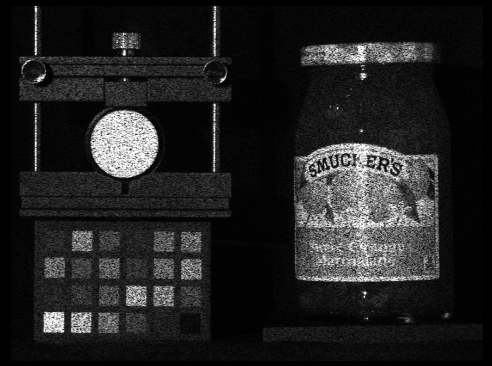


Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #25



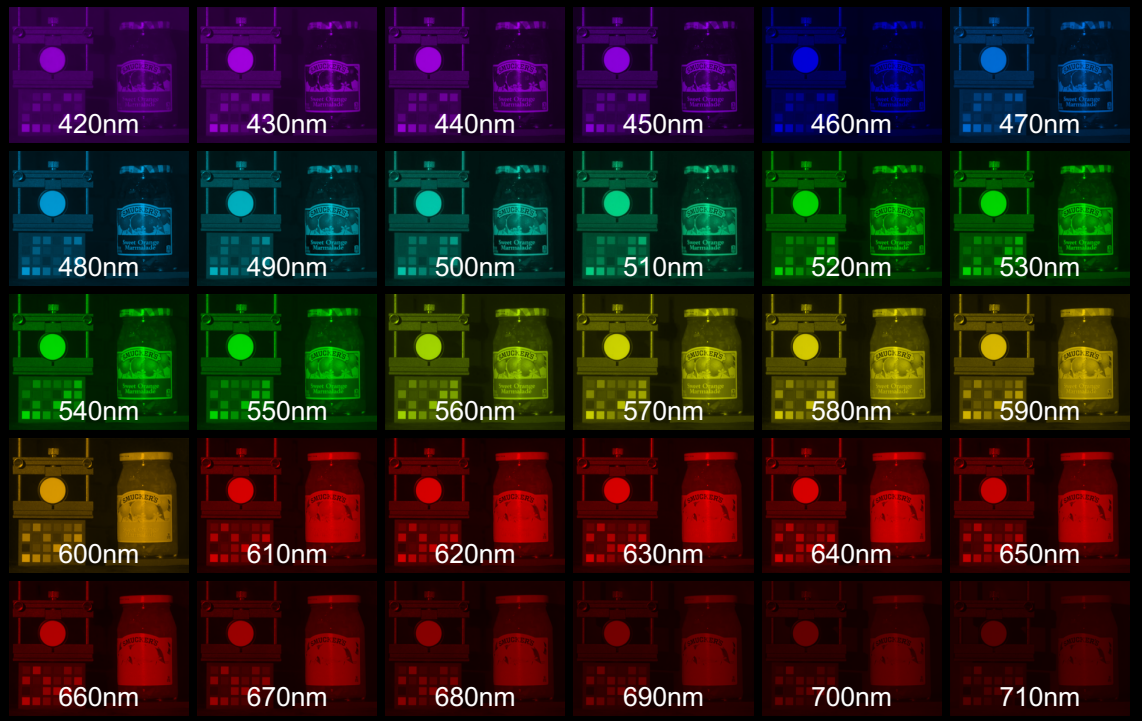
Ground truth



Compressive input



Our reconstruction

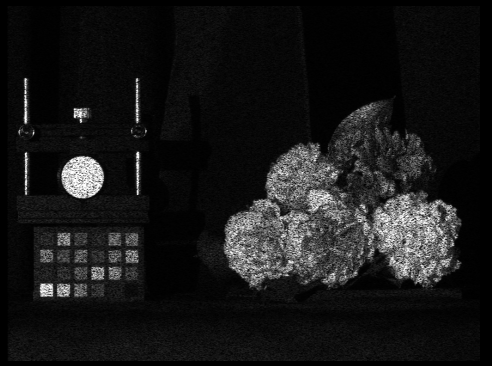


Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #26



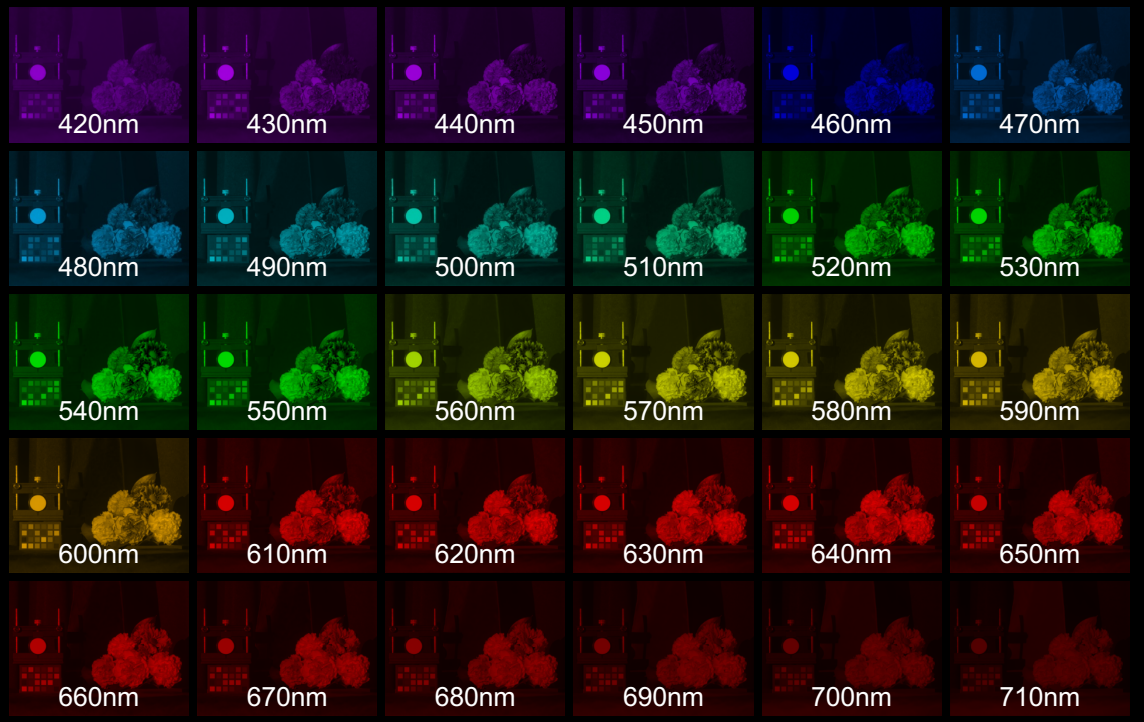
Ground truth



Compressive input



Our reconstruction



Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #27



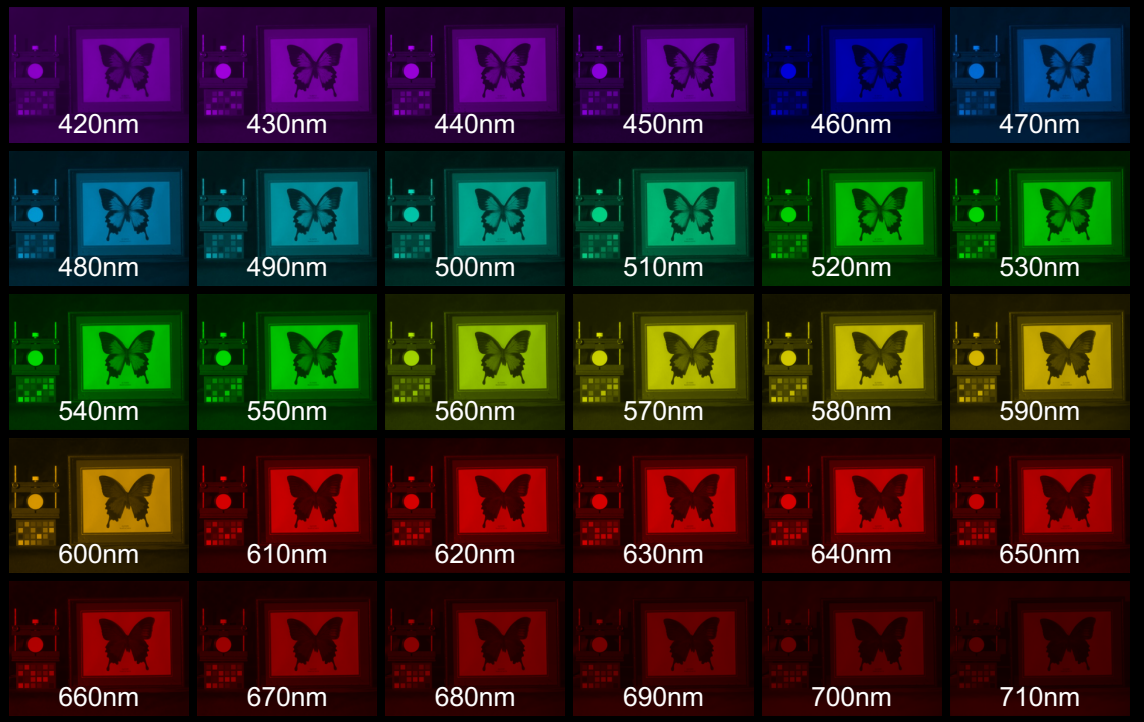
Ground truth



Compressive input



Our reconstruction



Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #28



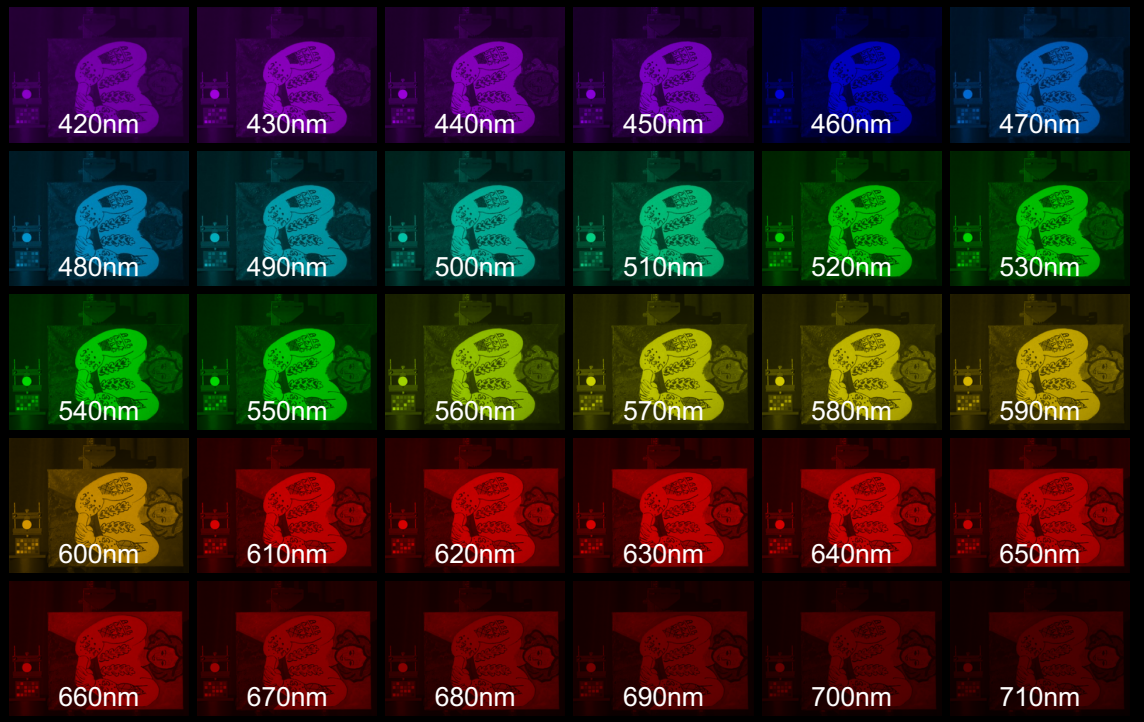
Ground truth



Compressive input



Our reconstruction

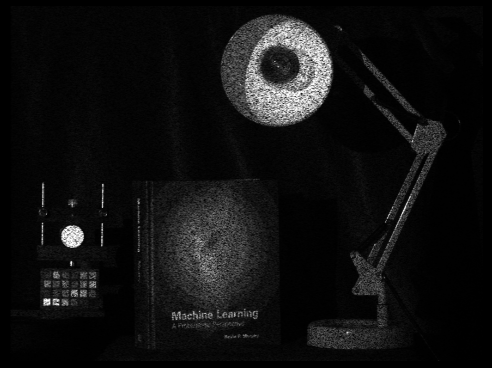


Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #29



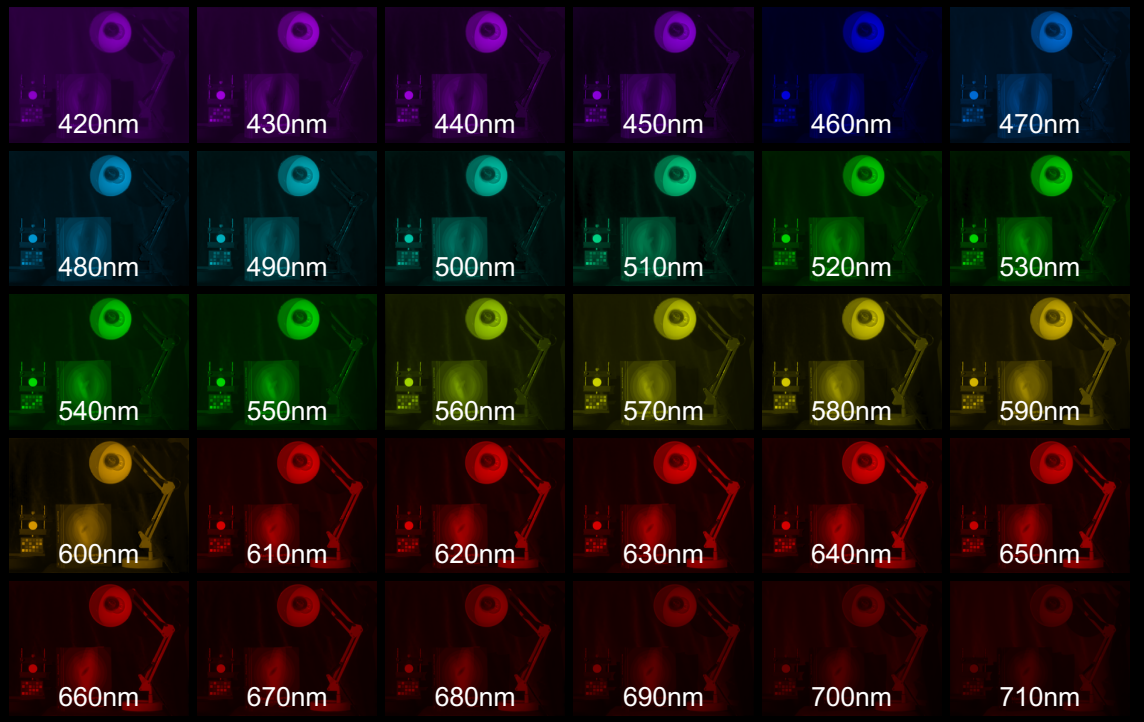
Ground truth



Compressive input

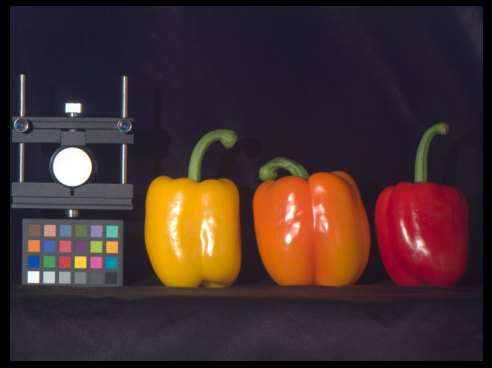


Our reconstruction



Our reconstructed spectral bands

Our Reconstruction: Our High-Resolution Dataset #30



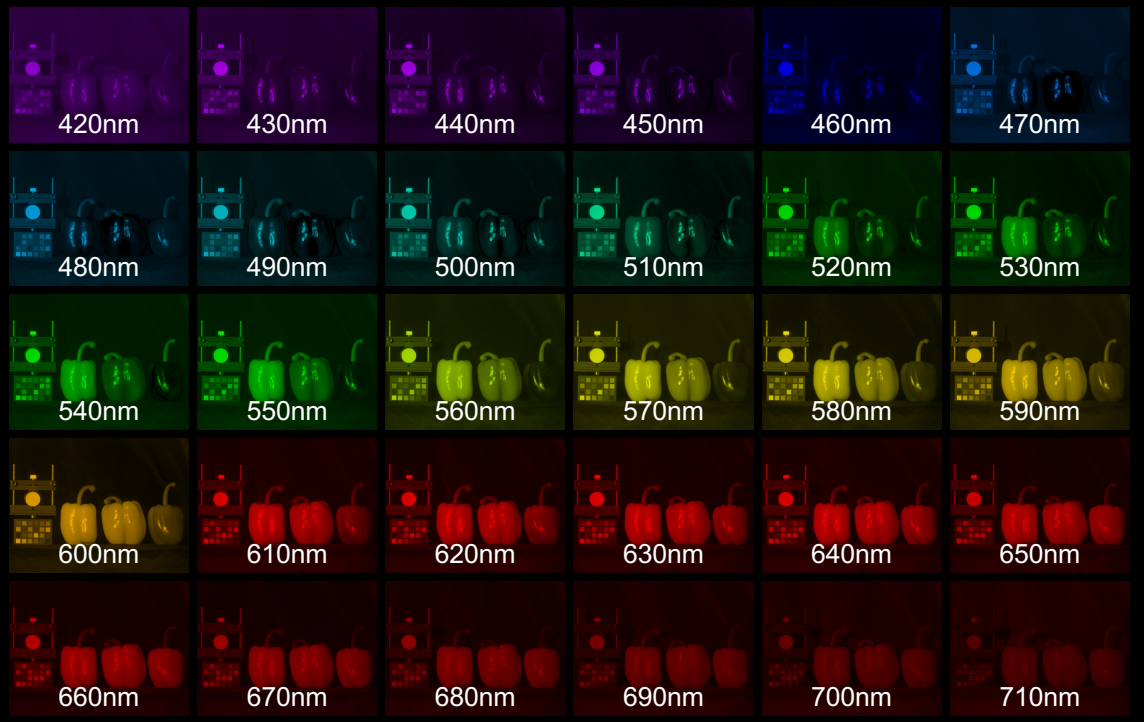
Ground truth



Compressive input



Our reconstruction



Our reconstructed spectral bands