5.5 Experiment of Exploration on Gaussian Noise Reduction Capacity of Neural Network in Phase Retrieval

5.5.1 Group of Experiments for Exploration on Gaussian Noise Reduction Capacity of Neural Network in Phase Retrieval

Trained Network	Noise Level(PPSNR)	Number of Density(s) involved in Training Data	Shape(s) involved in Training Data
Pattern 1			
F	6dB	1	ellipsoid and paraboloid
G	12dB	1	ellipsoid and paraboloid
H	24dB	1	ellipsoid and paraboloid
Pattern 5			
I	6dB	4	ellipsoid and paraboloid
J	12dB	4	ellipsoid and paraboloid
K	24dB	4	ellipsoid and paraboloid

Table 5.8: Overview on Experiments of Exploration on Gaussian Noise Reduction Capacity of Neural Network in Phase Retrieval

5.5.2 Single density

We first look at the single density case.

5.5.2.1 Testing Error of Trained Network for Noisy Phase Contrast Images as Input

Trained Network Applied	Noise Level & Index	Average NMSE	Average MSE	Average SSIM	Average PSNR
F	6dB Attenuation	0.18625505	9.64809178e-08	0.99980136	76.33654605
G	12dB Attenuation	0.12128208	3.16732764e-08	0.99993679	79.95842970
H	24dB Attenuation	0.07363655	6.10145421e-09	0.99998857	84.98196115
F	6dB Phase	0.1862549	0.20748354	0.51857784	61.14193157
G	12dB Phase	0.12128206	0.06811384	0.45310704	64.76380831
H	24dB Phase	0.07363655	0.01312127	0.80683493	69.78734031

Table 5.9: Testing Error of Trained Network for Noisy Phase Contrast Images as Input

Comparing with Table 5.4, the quality of attenuation and phase projection reconstruction performed by mixed-scale dense network from noisy phase contrast images become worse, because we have noise added, it causes more uncertainty to data mapping relationship between phase contrast images and original projection images.

The reconstructions performed by mixed-scale dense network become better when noise level decreases from 6dB (PPSNR) to 24dB (PPSNR) in terms of all the evaluation metrics.

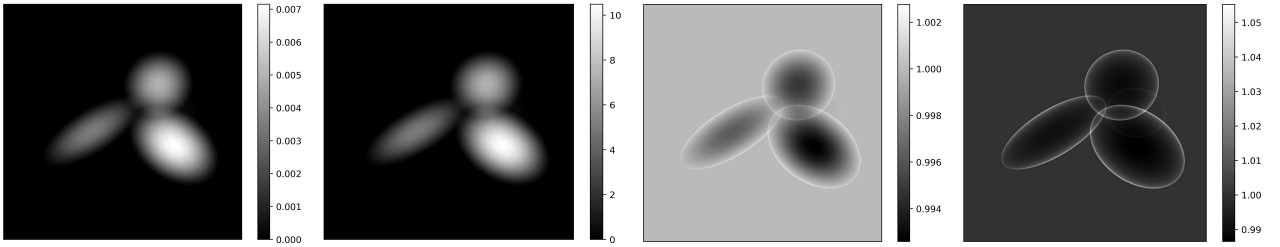
5.5.2.2 Testing Error of Contrast Transfer Function Method on Same Testing Datasets

Noise Level & Index	Average NMSE	Average MSE	Average SSIM	Average PSNR
6dB Attenuation	30.71029125	0.00224931	0.68889577	34.41506506
12dB Attenuation	15.67296973	0.00059158	0.86140637	39.98685879
24dB Attenuation	0.19890280	3.79288196e-06	0.99936463	60.60328414
6dB Phase	1.31512980	8.77216502	0.09293308	42.81042378
12dB Phase	1.20798503	7.72256197	0.13197457	43.42716402
24dB Phase	0.31067529	1.88051331	0.13751980	51.64779834

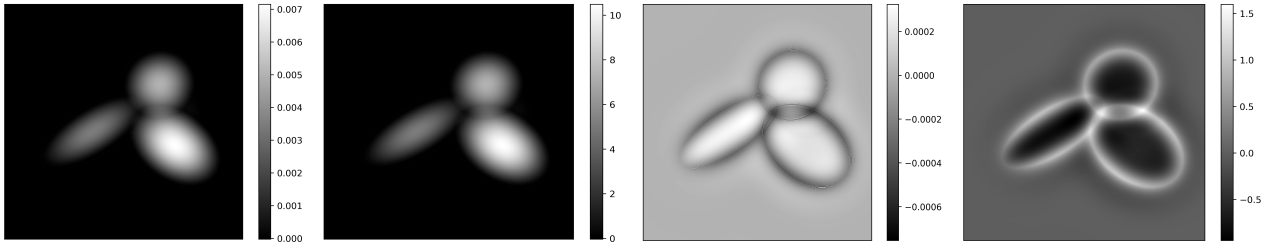
Table 5.10: Testing Error of Contrast Transfer Function Method on Same Testing Datasets for Noisy Phase Contrast Images as Input

The reconstructions performed by contrast transfer function become better when noise level decreases from 6dB (PPSNR) to 24dB (PPSNR) in terms of all the evaluation metrics, but it behaves worse than mixed-scale dense network for each noise level.

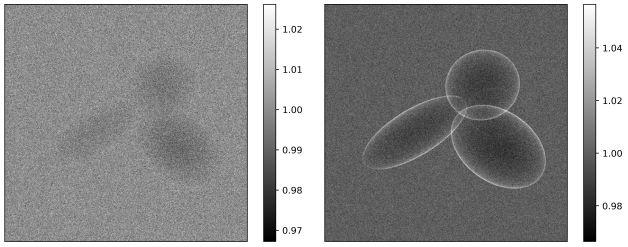
5.5.2.3 Best Case of Single Density Noise Model Phase Retrieval



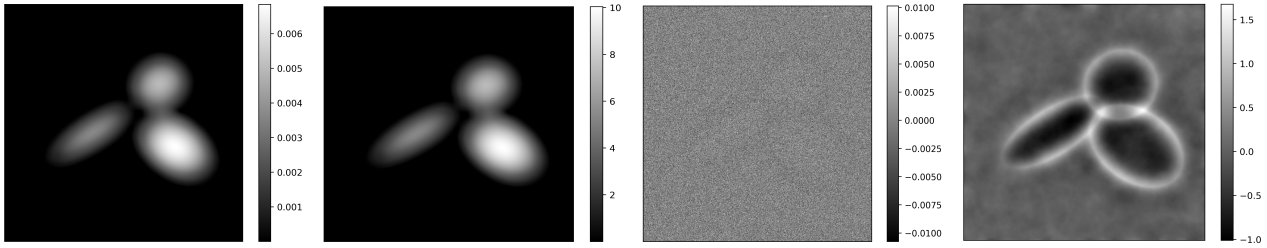
(a) Attenuation Projection (b) Phase Projection (c) Non-noisy Phase Contrast Image for Shortest Distance (d) Non-noisy Phase Contrast Image for Longest Distance



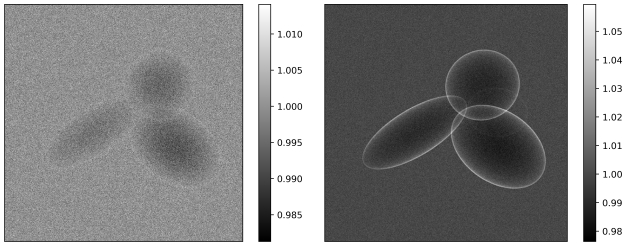
(e) Attenuation Retrieval Based on Non-noisy Phase Contrast Images (f) Phase Retrieval Based on Non-noisy Phase Contrast Images (g) Corresponding Attenuation Retrieval by CTF (h) Corresponding Phase Retrieval by CTF



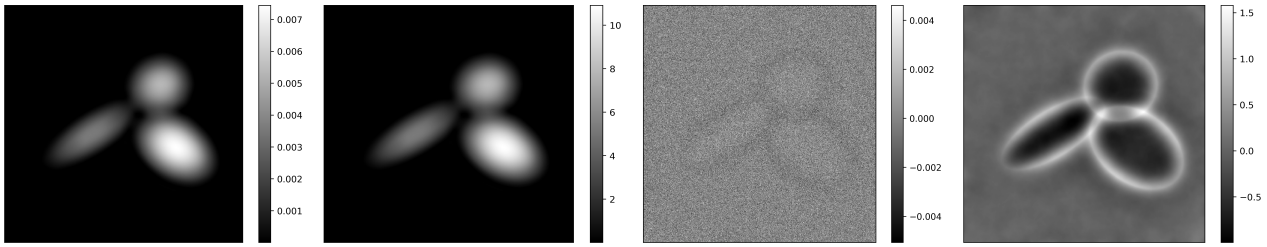
(i) 6dB Noise Level Phase Contrast Image for Shortest Distance (j) 6dB Noise Level Phase Contrast Image for Longest Distance



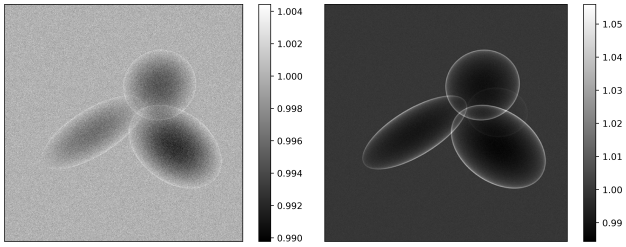
(k) 6dB Attenuation Retrieval (l) 6dB Phase Retrieval (m) CTF Attenuation Retrieval (n) CTF Phase Retrieval



(o) 12dB Noise Level Phase Contrast Image for Shortest Distance (p) 12dB Noise Level Phase Contrast Image for Longest Distance

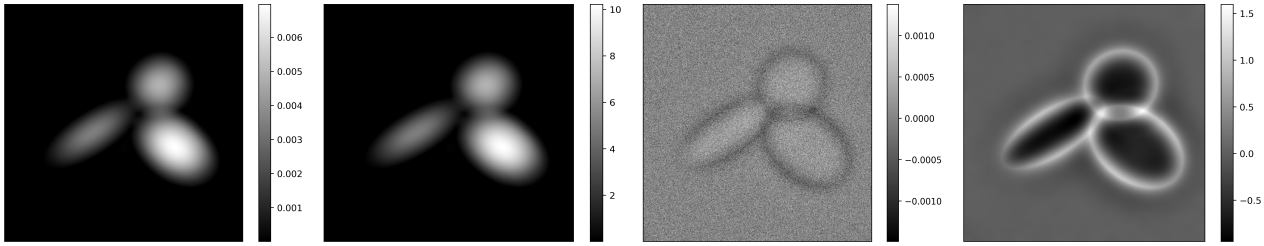


(q) 12dB Attenuation Retrieval (r) 12dB Phase Retrieval (s) CTF Attenuation Retrieval (t) CTF Phase Retrieval



(u) 24dB Noise Level Phase Contrast Image for Shortest Distance

(v) 24dB Noise Level Phase Contrast Image for Longest Distance



(w) 24dB Attenuation Retrieval

(x) 24dB Phase Retrieval

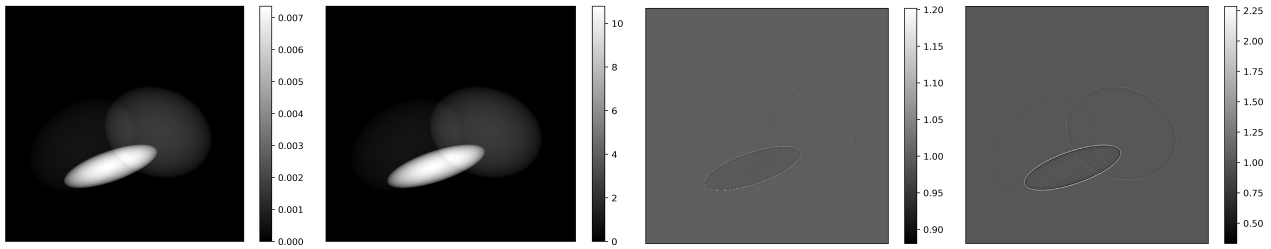
(y) CTF Attenuation Retrieval

(z) CTF Phase Retrieval

Figure 5.5: Best Case of Single Density Noise Model Reconstruction Performance and Corresponding CTF Performance In Comparison

The visual qualities of attenuation and phase reconstructions performed by mixed-scale dense network is maintained for all noise levels. And the visual quality of reconstructions performed by contrast transfer function become better when noise level decreases from 6dB (PPSNR) to 24dB (PPSNR), but all of its reconstructions behave worse than the ones obtained with mixed-scale dense network for each noise level if we take the original projection as reference without considering any image enhancement effect.

5.5.2.4 Worst Case of Single Density Noise Model Phase Retrieval

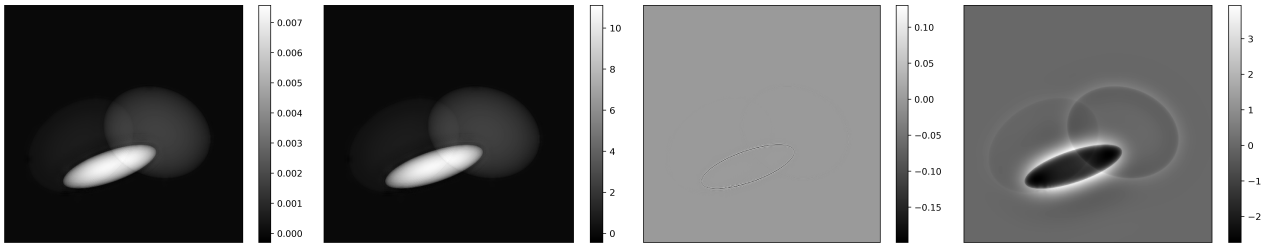


(a) Attenuation Projection

(b) Phase Projection

(c) Non-noisy Phase Contrast Image for Shortest Distance

(d) Non-noisy Phase Contrast Image for Longest Distance

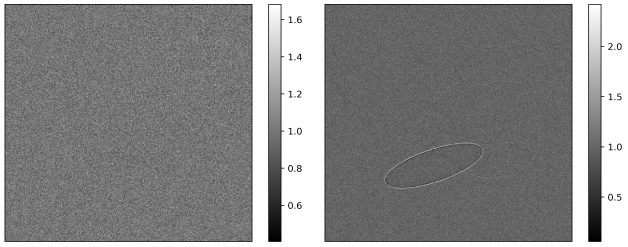


(e) Attenuation Retrieval Based on Non-noisy Phase Contrast Images

(f) Phase Retrieval Based on Non-noisy Phase Contrast Images

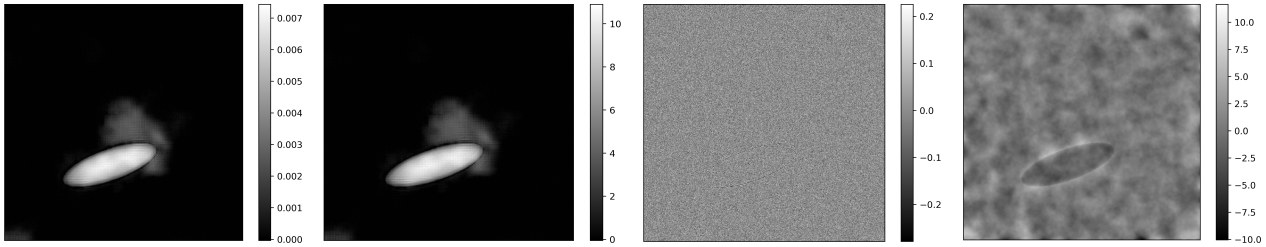
(g) Corresponding Attenuation Retrieval by CTF

(h) Corresponding Phase Retrieval by CTF



(i) 6dB Noise Level Phase Contrast Image for Shortest Distance

(j) 6dB Noise Level Phase Contrast Image for Longest Distance

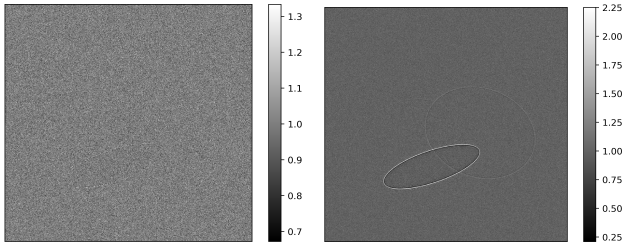


(k) 6dB Attenuation Retrieval

(l) 6dB Phase Retrieval

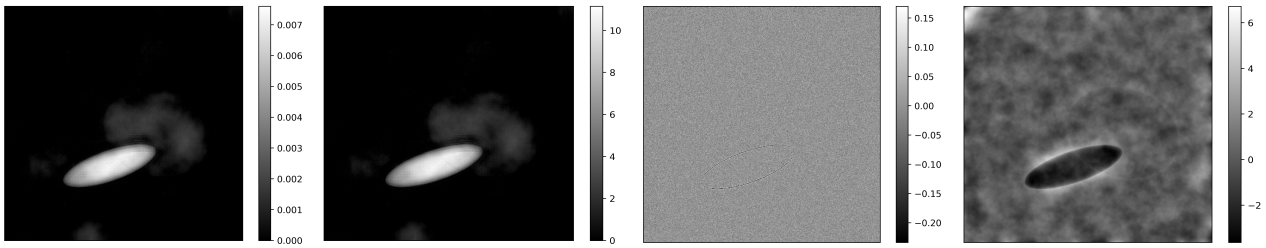
(m) CTF Attenuation Retrieval

(n) CTF Phase Retrieval



(o) 12dB Noise Level Phase Contrast Image for Shortest Distance

(p) 12dB Noise Level Phase Contrast Image for Longest Distance

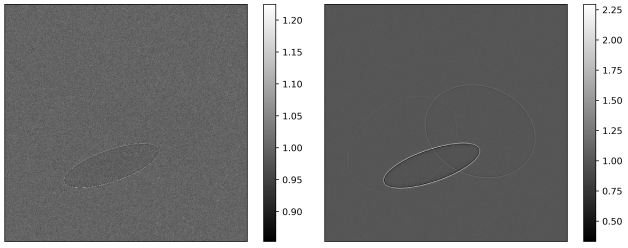


(q) 12dB Attenuation Retrieval

(r) 12dB Phase Retrieval

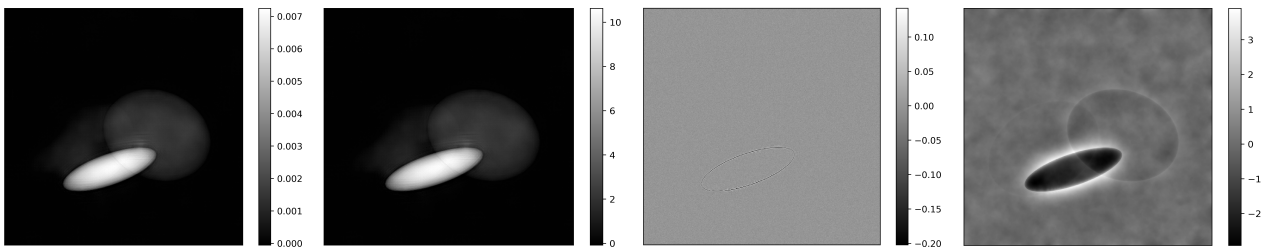
(s) CTF Attenuation Retrieval

(t) CTF Phase Retrieval



(u) 24dB Noise Level Phase Contrast Image for Shortest Distance

(v) 24dB Noise Level Phase Contrast Image for Longest Distance



(w) 24dB Attenuation Retrieval

(x) 24dB Phase Retrieval

(y) CTF Attenuation Retrieval

(z) CTF Phase Retrieval

Figure 5.6: Worst Case of Single Density Noise Model Reconstruction Performance and Corresponding CTF Performance In Comparison