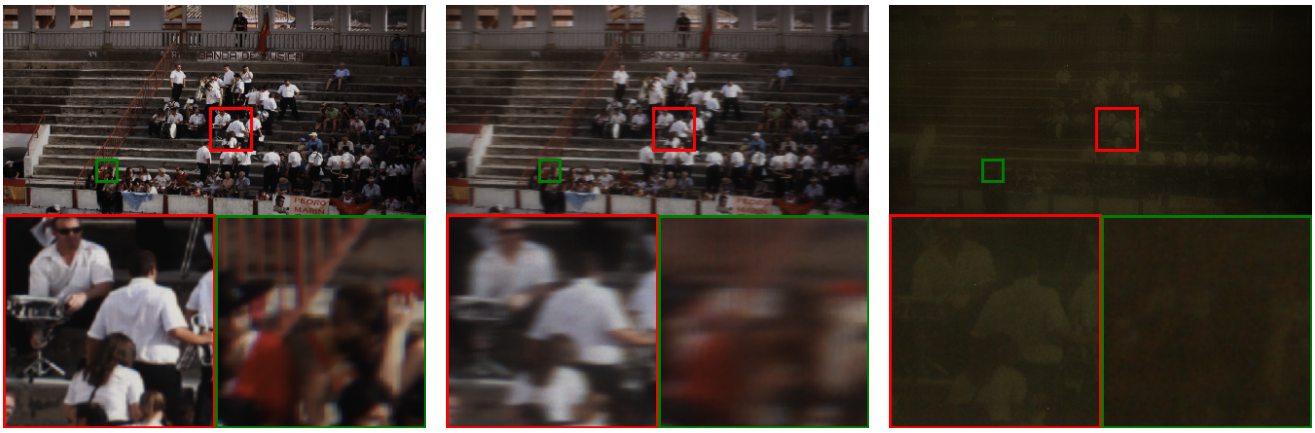
Supplementary Material:
Image Restoration for Under-Display Camera

Yuqian Zhou[1], David Ren[2], Neil Emerton[3], Sehoon Lim[3], Timothy Large[3]
[1]IFP, UIUC, [2]CIL, UC Berkeley, [3]Microsoft



(a) Display-free (b) T-OLED (c) P-OLED

Figure 1: More real data samples acquried by our MCIS set-up. (a) The image captured with camera covered by thin glass, (b)T-OLED, and (c) P-OLED.

1. Real Data

More examples in 8-bit RGB version in the UDC real dataset are shown in Fig. 1. Each image has a high resolution of $1024 \times 2048 \times 3$. Images captured by T-OLED demonstrate a blur effect along the horizontal direction. Some spatial frequencies (i.e. vertical bands) are missing due to diffraction effects. Images captured by P-OLED are yellow-shifted, dark, and noisy. We also stored the 16-bit raw sensor data, which is mainly used for training and testing in the paper.

2. Synthetic Data

We follow the image formation pipeline to synthesize the near-realistic data. Given only the display pattern, and some specific measurements of the cameras, we could generate the blur kernels as shown in Fig. 2 along with the degraded images for training. Fig. 3 compares the synthetic data with the real data. Perceptually, two sets of data samples have similar visual characteristics.

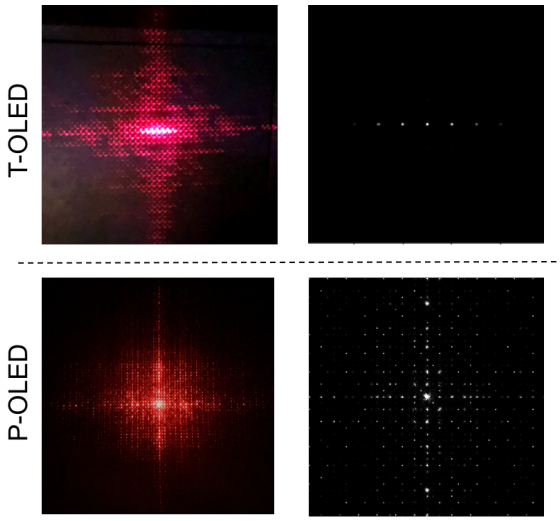
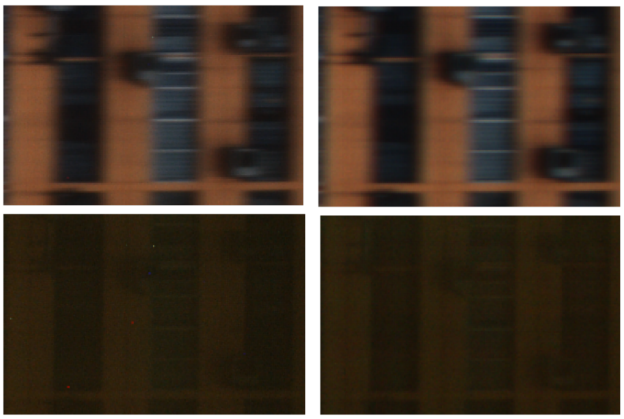
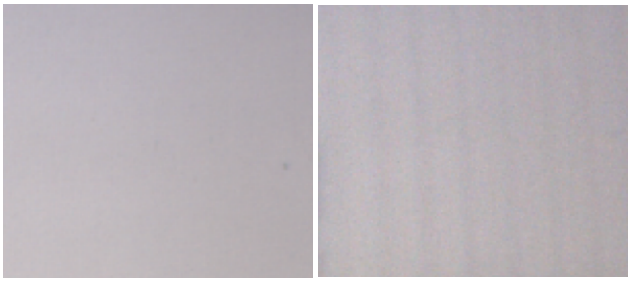


Figure 2: Real and the computed Point Spread Function (PSF).



(a) Real data samples. (b) Synthetic data samples.

Figure 3: Comparison of real data and synthetic data. First row: T-OLED. Second row: P-OLED.



(a) Synthetic data. (b) Real data with bands.

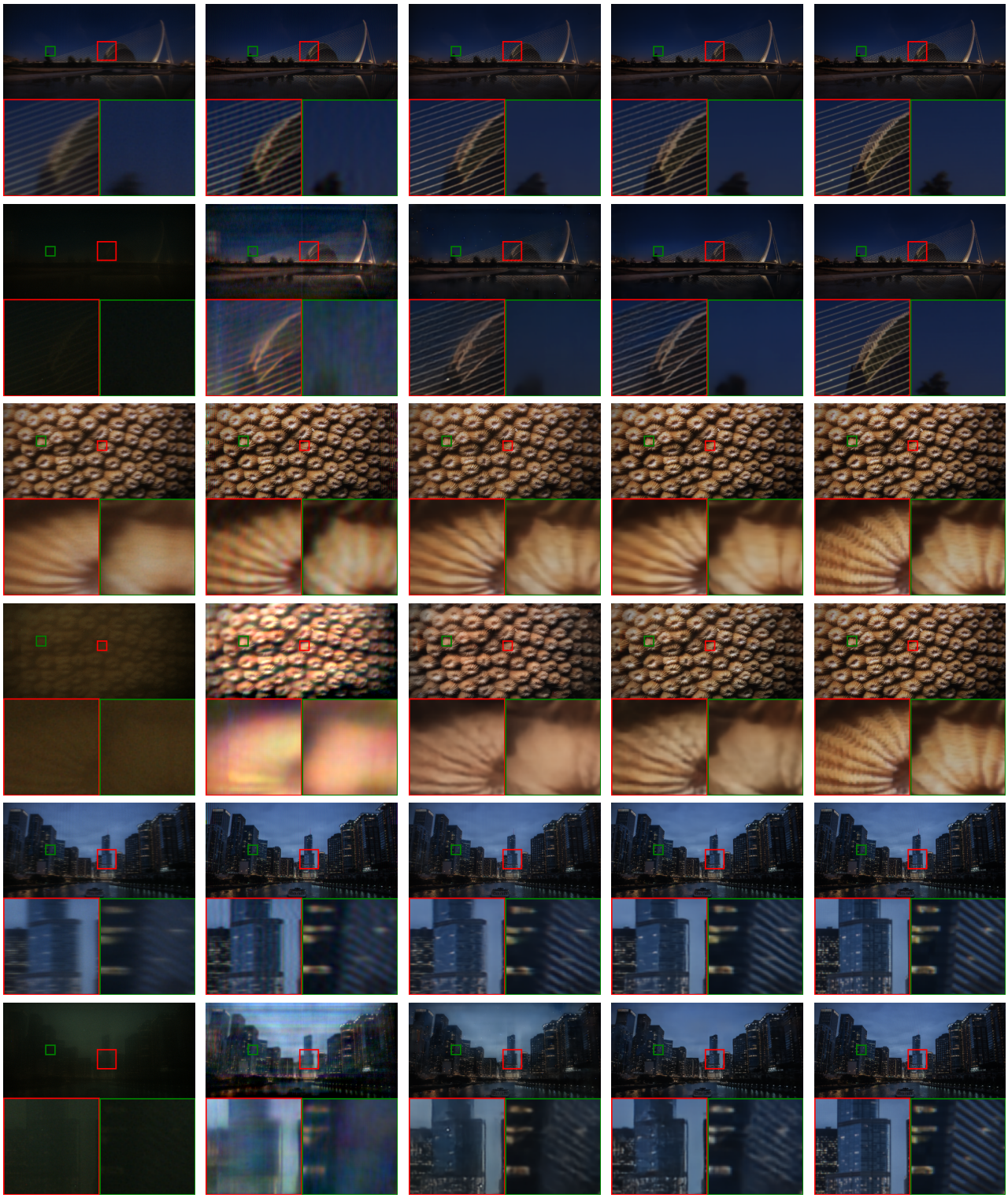
Figure 4: Visible bands in real data.

3. Visible Bands for T-OLED

In addition to the degradation formulated in the paper, there is another minor image artifact caused by the periodic grating-like pixel structure (i.e. T-OLED): superposition of periodic bands over the image at low to moderate visibility levels. As shown in the Fig. 4, periodic bands are visible in the real data, but not in the synthetic data. We regard it as the main gap of data synthesis. Those bands are caused by the imperfect adhesion of the display to the camera lens. In the degradation model, we assume the display pattern or objects are exactly placed against the lens, while in practical set-up of our experiments, there is still a small distance between them. We can consider the grating as being imaged very out-of-focus on the sensor plane. There will be an image on the image sensors consisting of the grating convoluted with the very-out-of-focus point spread function – a circle. This problem can be mitigated by real industrial manufacturing process, so we did not resolve it explicitly in the paper with experimental settings. However, it still forms an interesting problem regarding eliminating real periodic noises left for future works.

4. More Restoration Results

We show more restoration results in Fig. 5.



(a) Display (b) DeP (c) UNet(Syn) (d) UNet (e) GT

Figure 5: More restoration results. For each two-row group, the first row is for T-OLED, and the second one is for P-OLED.