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High Dynamic Range Image Reconstruction via Deep Explicit Polynomial Curve Estimation

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Paper: https://arxiv.org/abs/2307.16426

Project Page: https://github.com/jqtangust/EPCE-HDR

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Oral

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High Dynamic Range (HDR) Image Reconstruction

32-bits HDR image

Camera Pipeline

HDR
Reconstruction

8-bits SDR image

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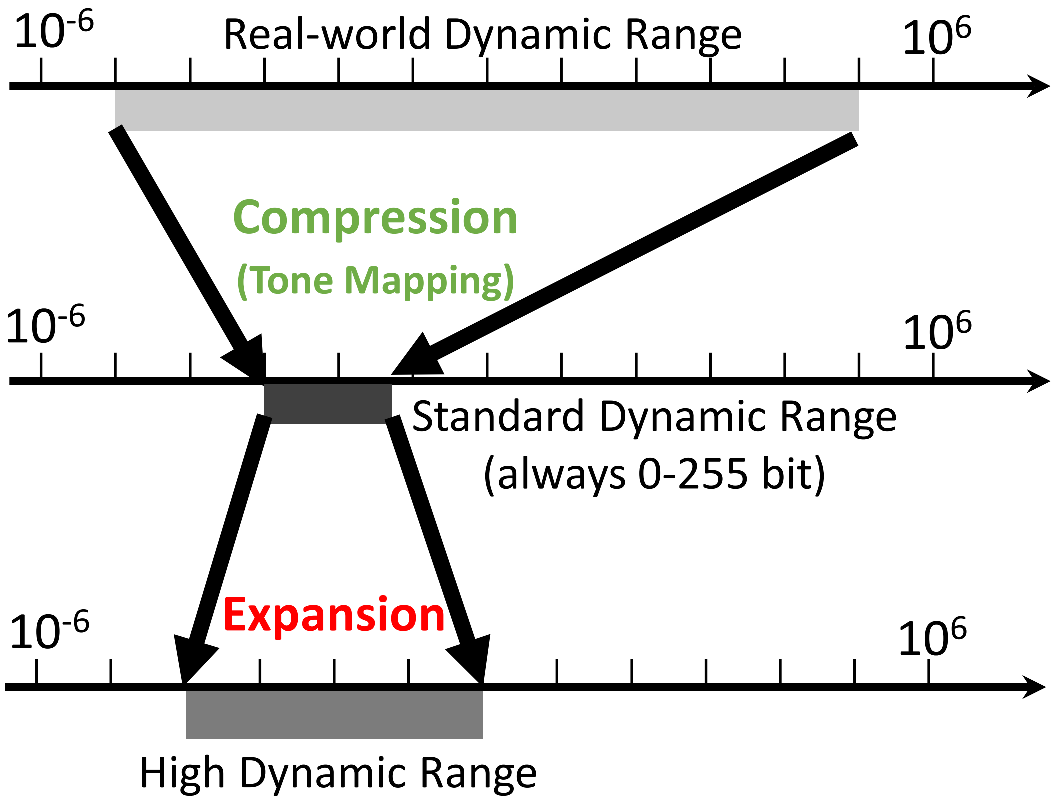
32-bits HDR image

Camera Pipeline

HDR Reconstruction

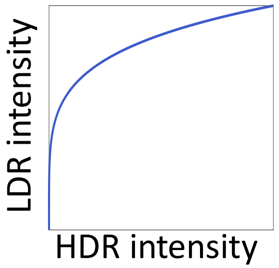
8-bits SDR image



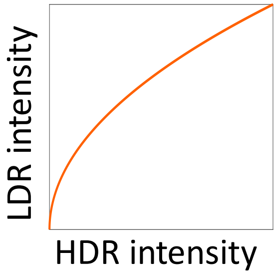
Practical Scenarios

One HDR

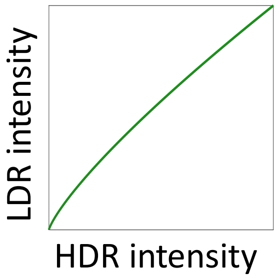
$\gamma = 0.2$



$\gamma = 0.5$



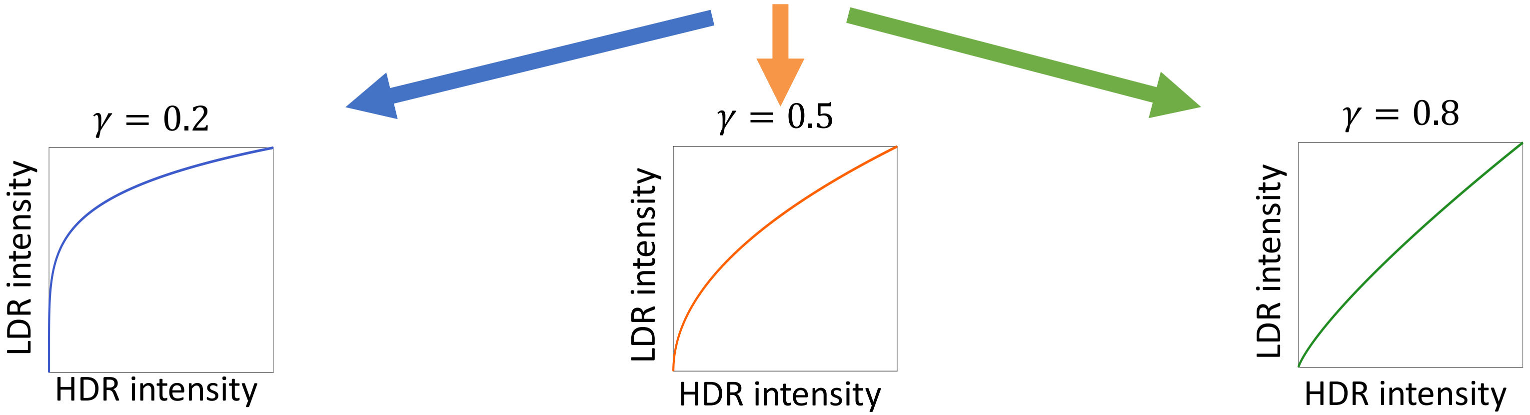
$\gamma = 0.8$



Different LDRs

Problems in Implicit Model: **Incorrect Tone Mapping**

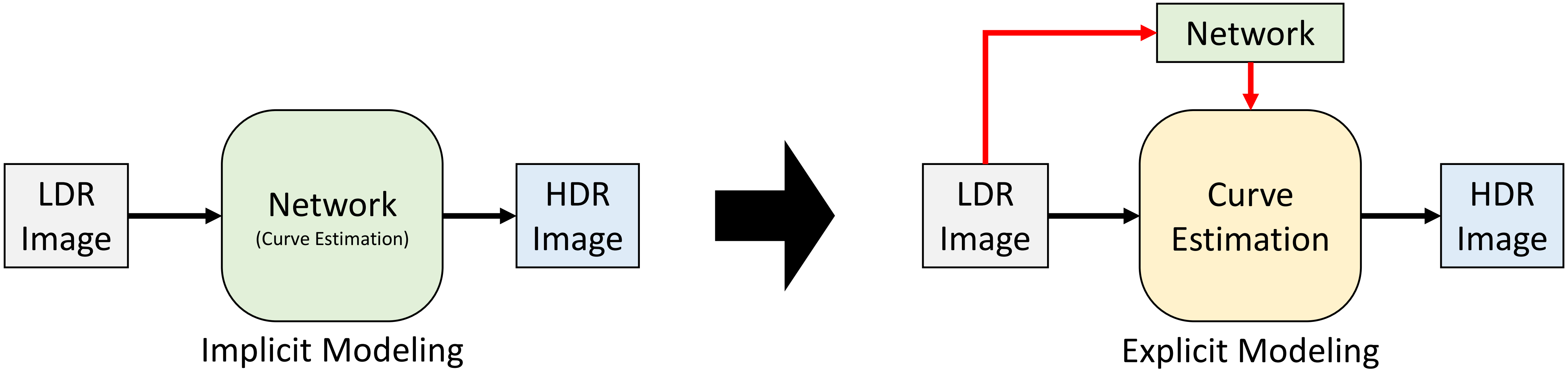
One HDR



Reconstruction With Implicit Modeling

Different LDRs

Implicit Model *vs.* Explicit Model

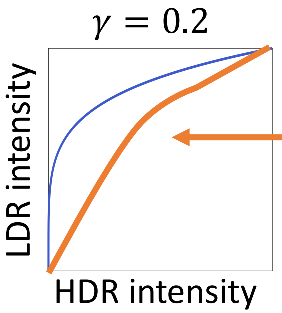


Implicit Model *vs.* Explicit Model

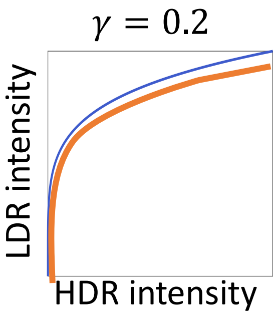
Reconstruction With Implicit Modeling

Our Reconstruction With **Explicit** Modeling

Implicit Model *vs.* Explicit Model



Reconstructed Tone Mapping Curve



Our Contributions

- **A new framework**

→ *for handling diverse tone-mapping functions.*

- **A new synthetic dataset**

→ *clear relationship between LDR images and corresponding tone functions.*

- **SOTA performance in *synthesis* and *real* datasets.**

Reversing the Tone-Mapping Function

- HDR-to-LDR conversion (Camera Pipeline):

$$L = \zeta(\tau(H))$$

LDR image | Other Degradations | Tone mapping | HDR image

- Reversing HDR-to-LDR conversion:

$$H = \tau^{-1}(\zeta^{-1}(L))$$

- Two Goals:
  - ➢Reversing tone mapping function (Key)
  - ➢Removing other degradations

Parameterizing the Tone-Mapping Function

- What is **structures** of Tone mapping function?

→ *Simple structure, monotonic or semi-monotonic curve.*

- To parameterizing it as a polynomial curve:

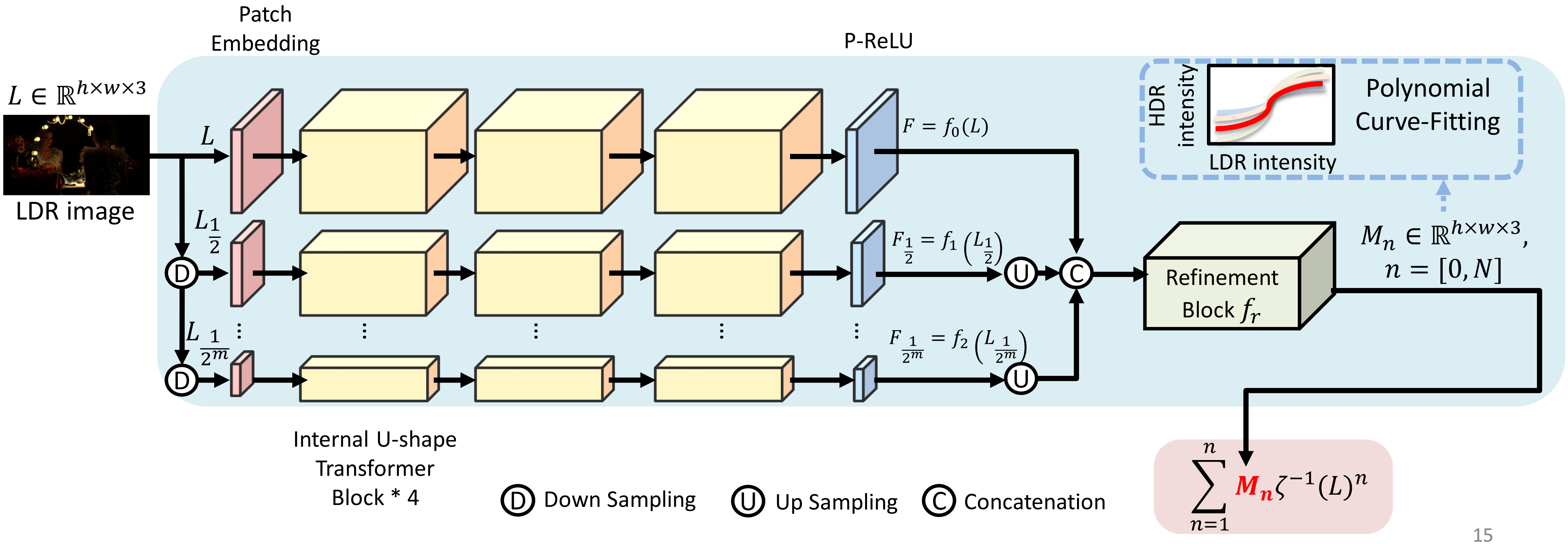
$$H = \tau^{-1}(\zeta^{-1}(L)) = \sum_{n=0}^{N} M_n \zeta^{-1}(L)^n$$

Polynomial
Coefficient Maps
(PCMs)

Learning the Polynomial Coefficient Maps

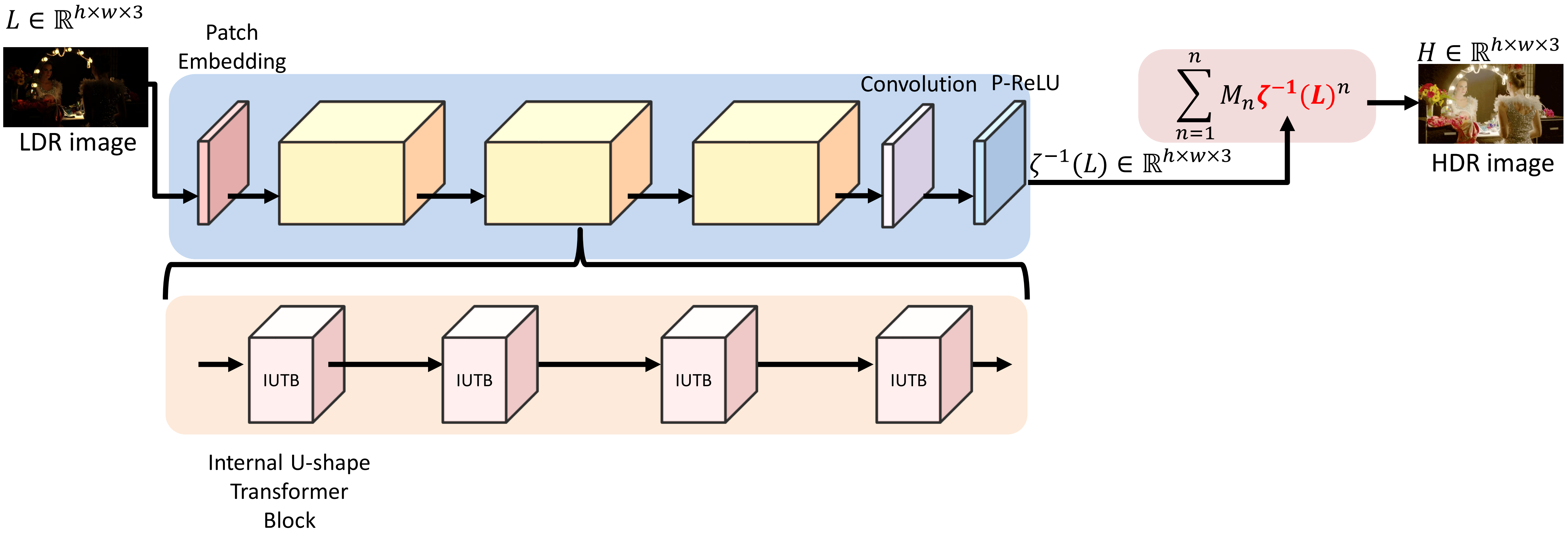
- **Pyramid-Path Vision Transformer (PPViT)**

  To fuse features from different scales.



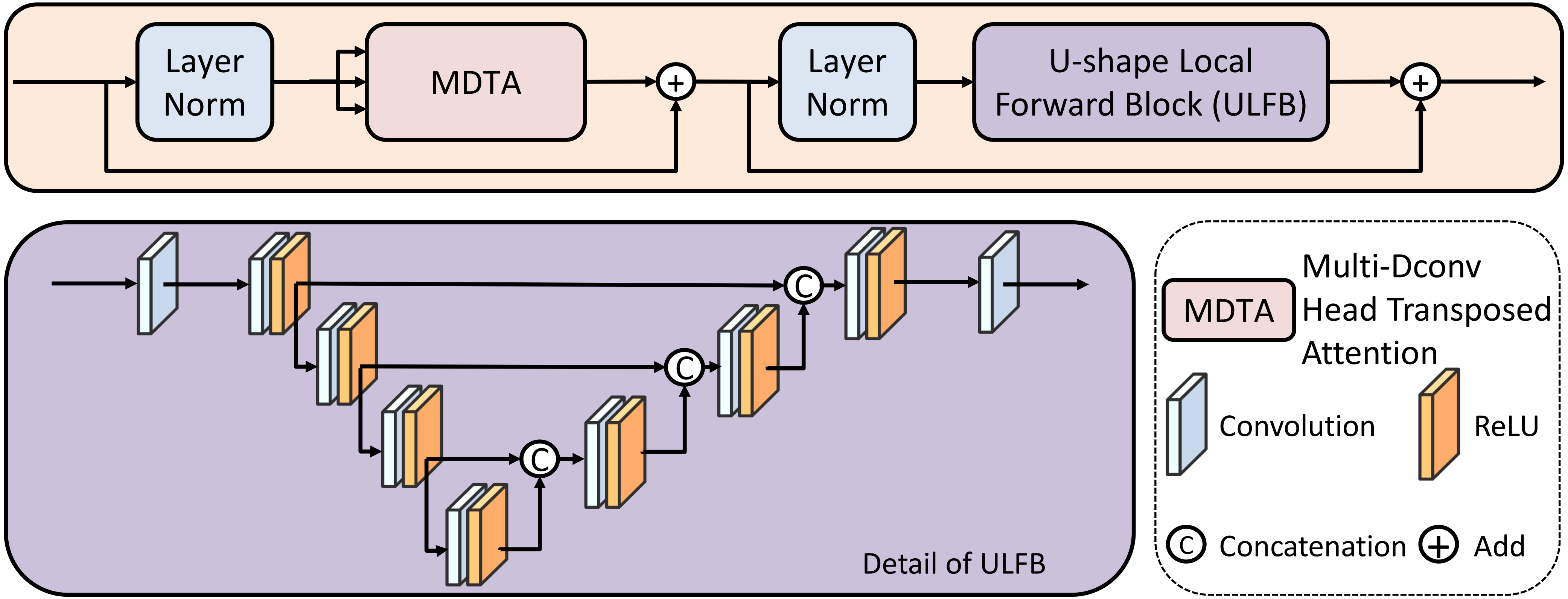
Removing other Degradations

- Learnable Pixel-Wise Element (LPE) to remove other degradations.



Internal U-shape Transformer Block

- Extracting local information for estimating tone-mapping functions.



Dataset

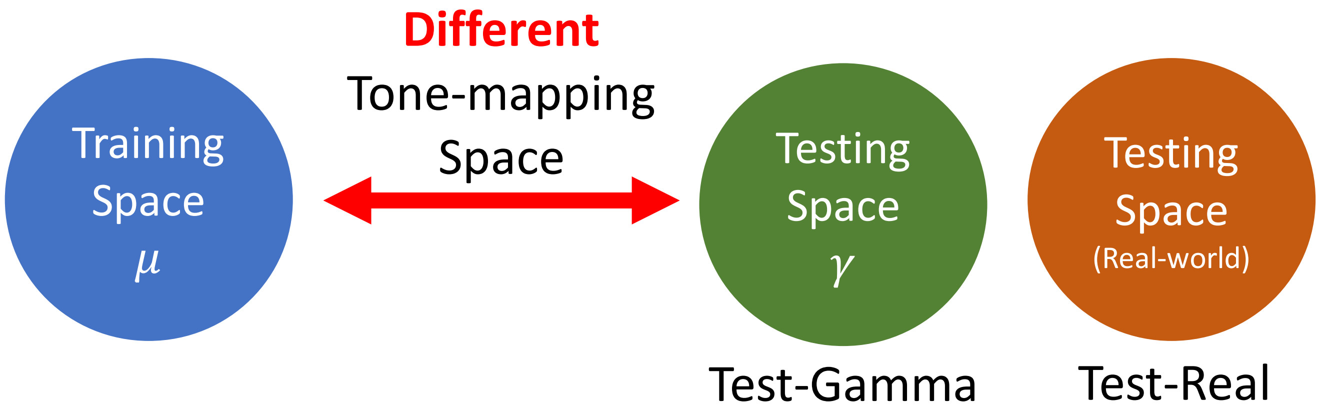
- Training at μ Space.

$$L = \frac{log(1+\mu H)}{log(1+\mu)}$$

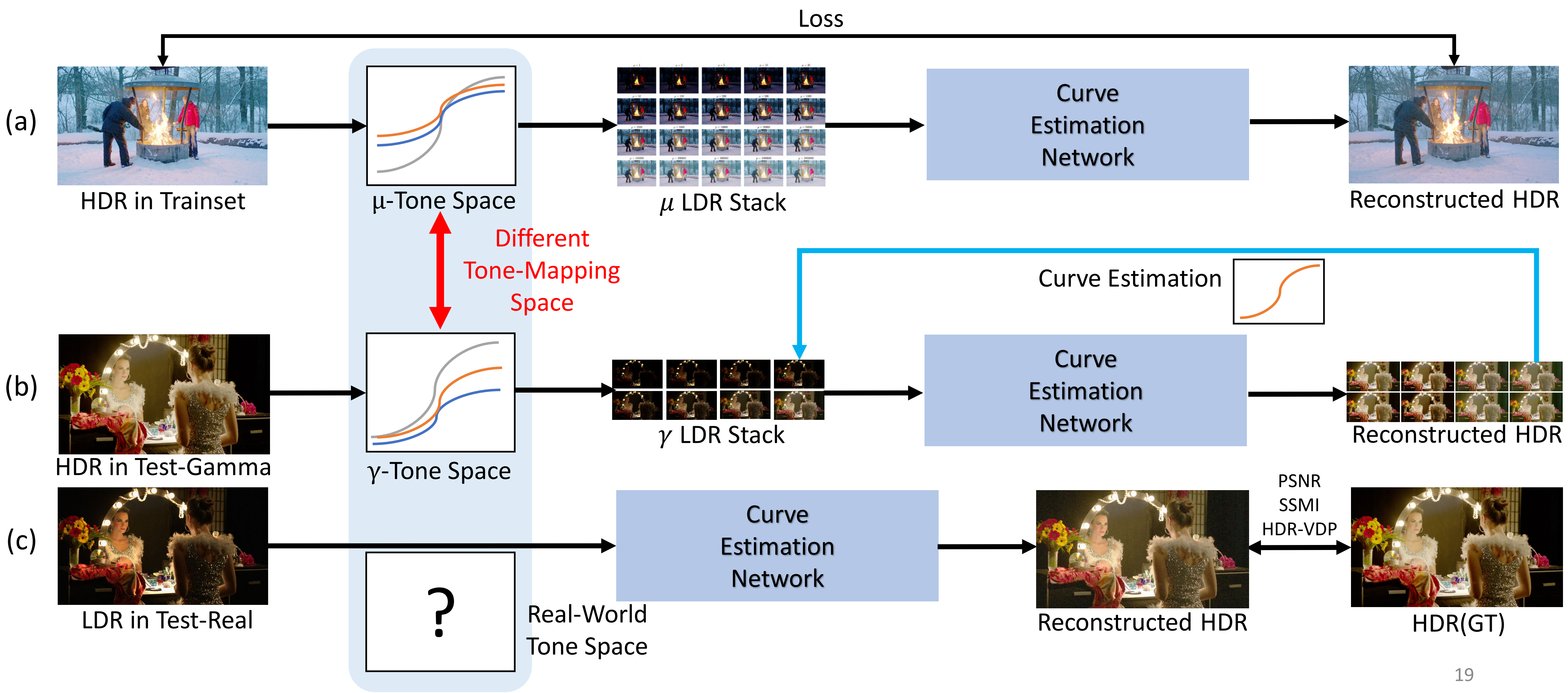
- Testing at γ Space.

Hyper-parameter

$$L = b \cdot H^{\gamma}$$

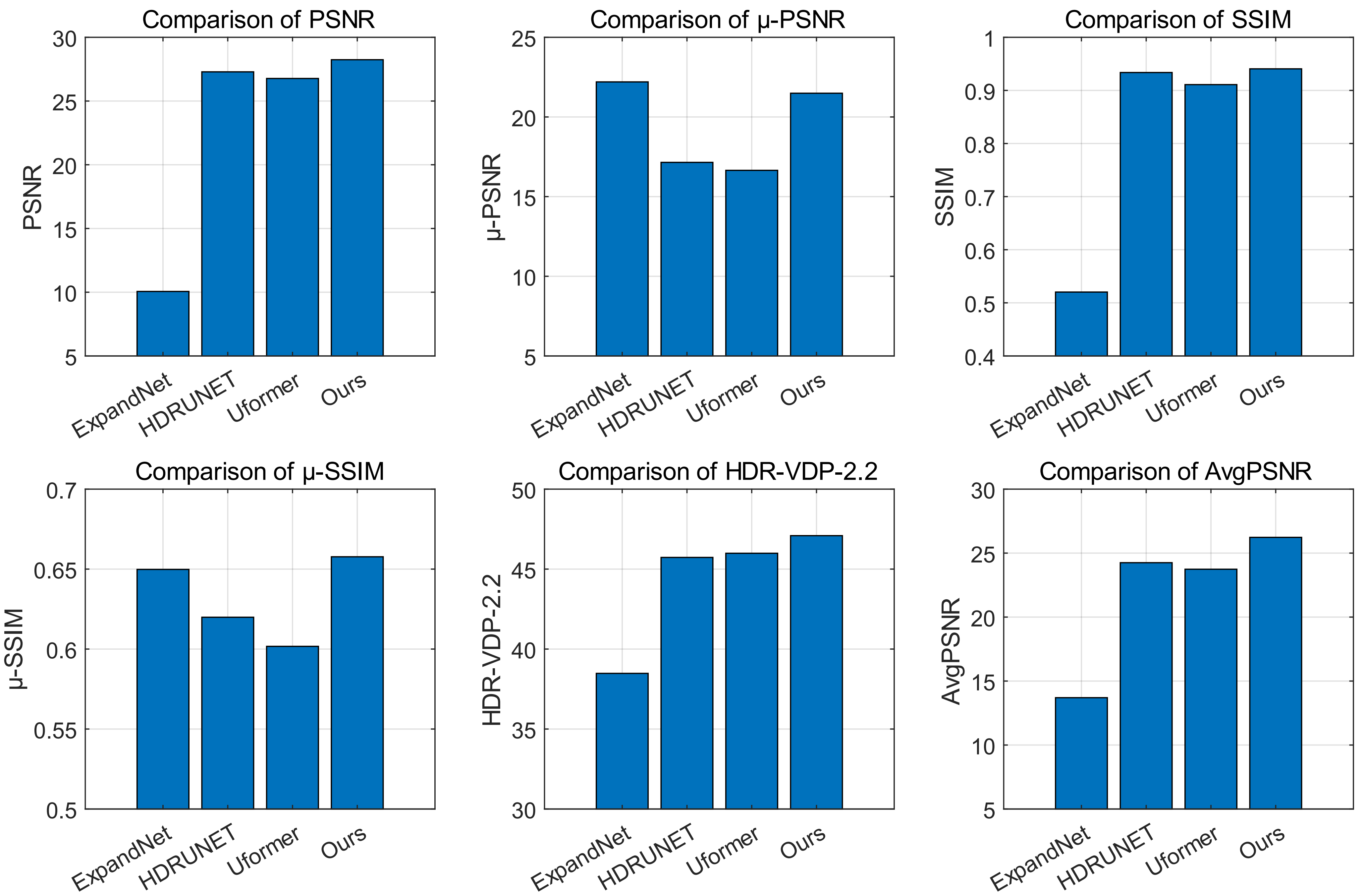


Training and Testing



Quantitative Comparison

In **Test-Real** dataset



Comparison of PSNR
PSNR
30
25
20
15
10
5
ExpandNet
HDRUNET
Uformer
Ours
Comparison of μ-PSNR
μ-PSNR
25
20
15
10
5
ExpandNet
HDRUNET
Uformer
Ours
Comparison of SSIM
SSIM
1
0.9
0.8
0.7
0.6
0.5
0.4
ExpandNet
HDRUNET
Uformer
Ours
Comparison of μ-SSIM
μ-SSIM
0.7
0.65
0.6
0.55
0.5
ExpandNet
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Uformer
Ours
Comparison of HDR-VDP-2.2
HDR-VDP-2.2
50
45
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ExpandNet
HDRUNET
Uformer
Ours
Comparison of AvgPSNR
AvgPSNR
30
25
20
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Uformer
Ours

Qualitative Comparison

In **Test-Real** dataset

LDR

ExpandNet

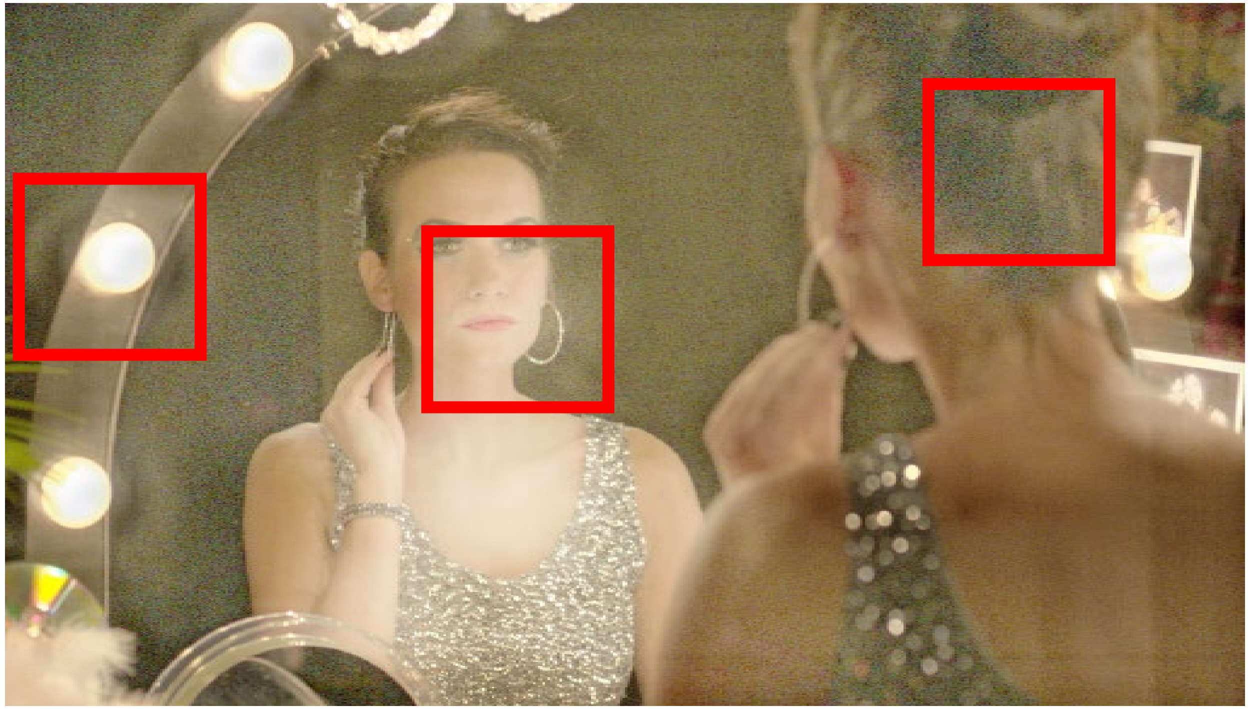
HDRUNET

Uformer

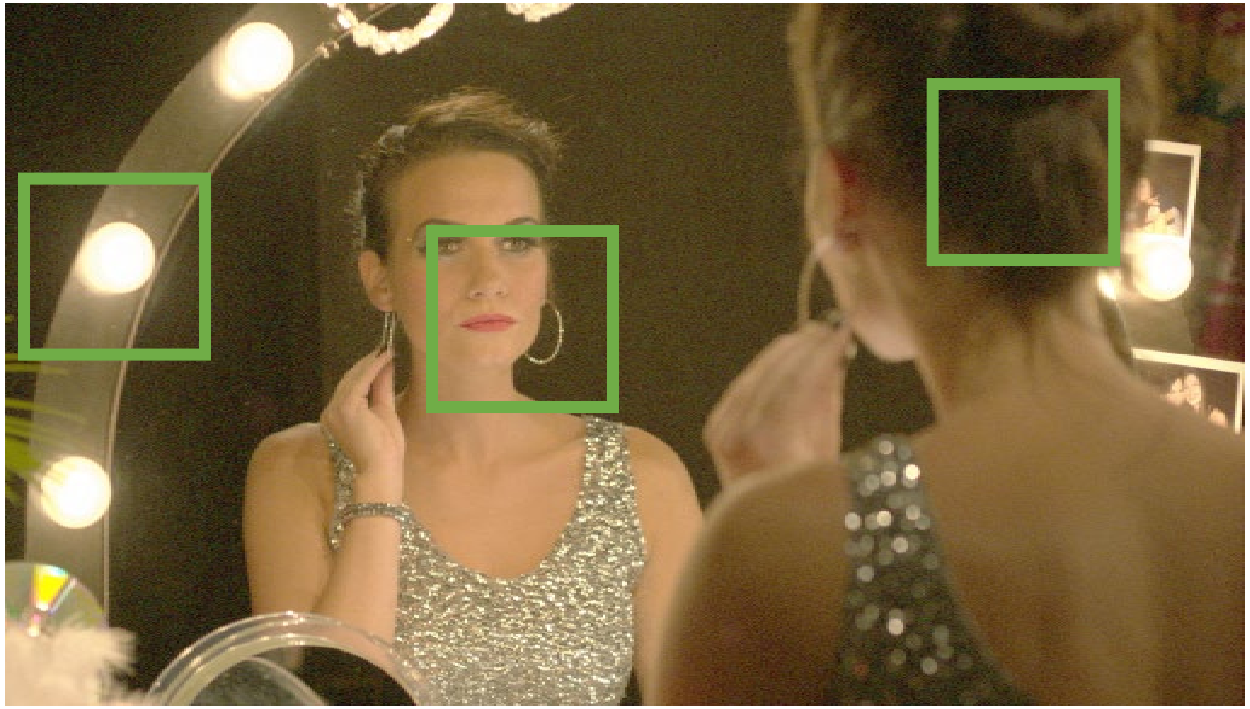
Ours

Ground Truth

Details in Color Consistency



HDRUNET



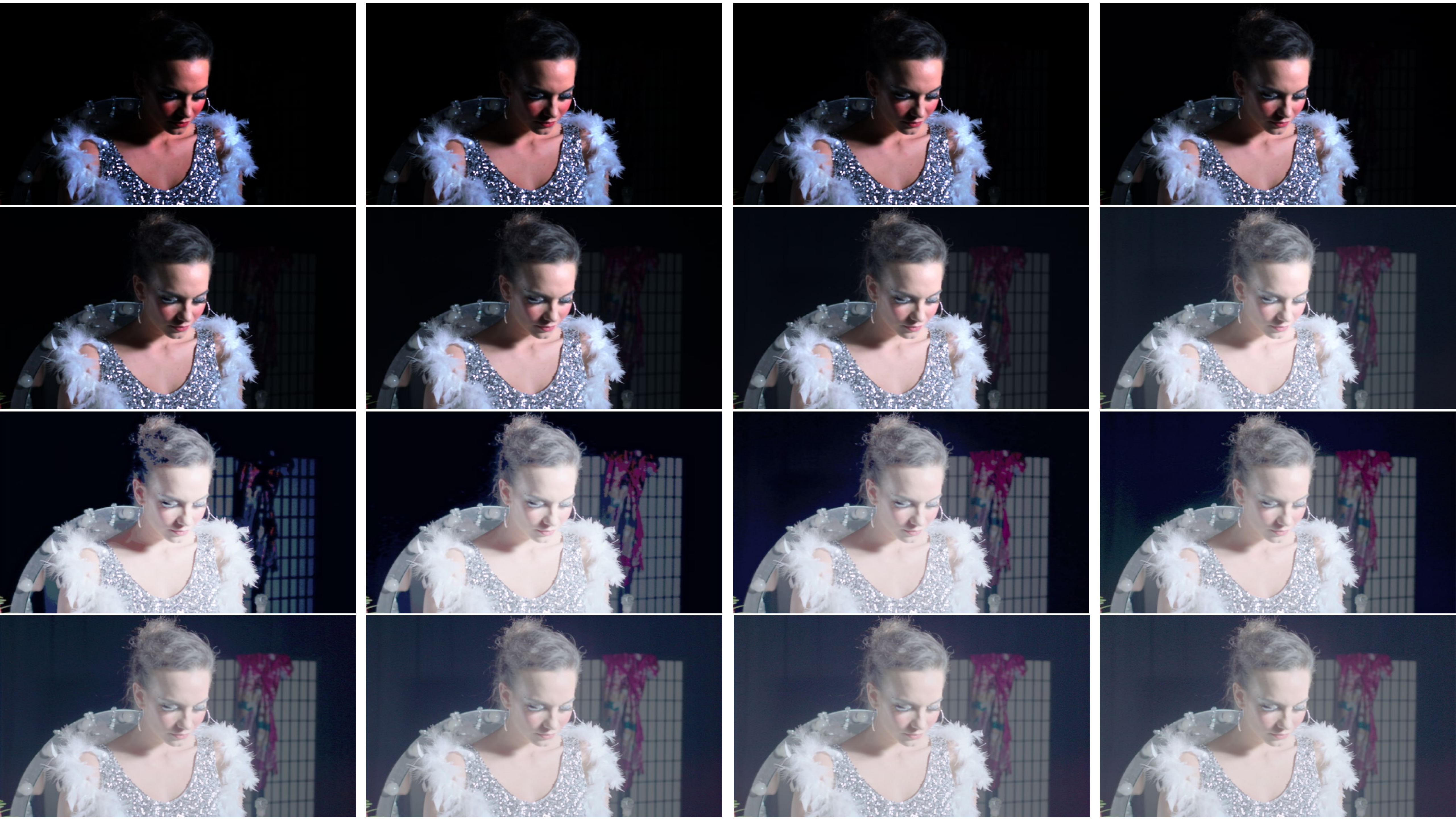
Ours

Qualitative Comparison

In **Test-Gamma** dataset

LDR image in Gamma Space

- The value of γ is from 0.2 to 1.



Comparison with HDRUNET

HDRUNET

Ours

Ground Truth

γ = 0.3

Comparison with HDRUNET

HDRUNET

Ours

Ground Truth

γ = 0.6

Comparison with HDRUNET

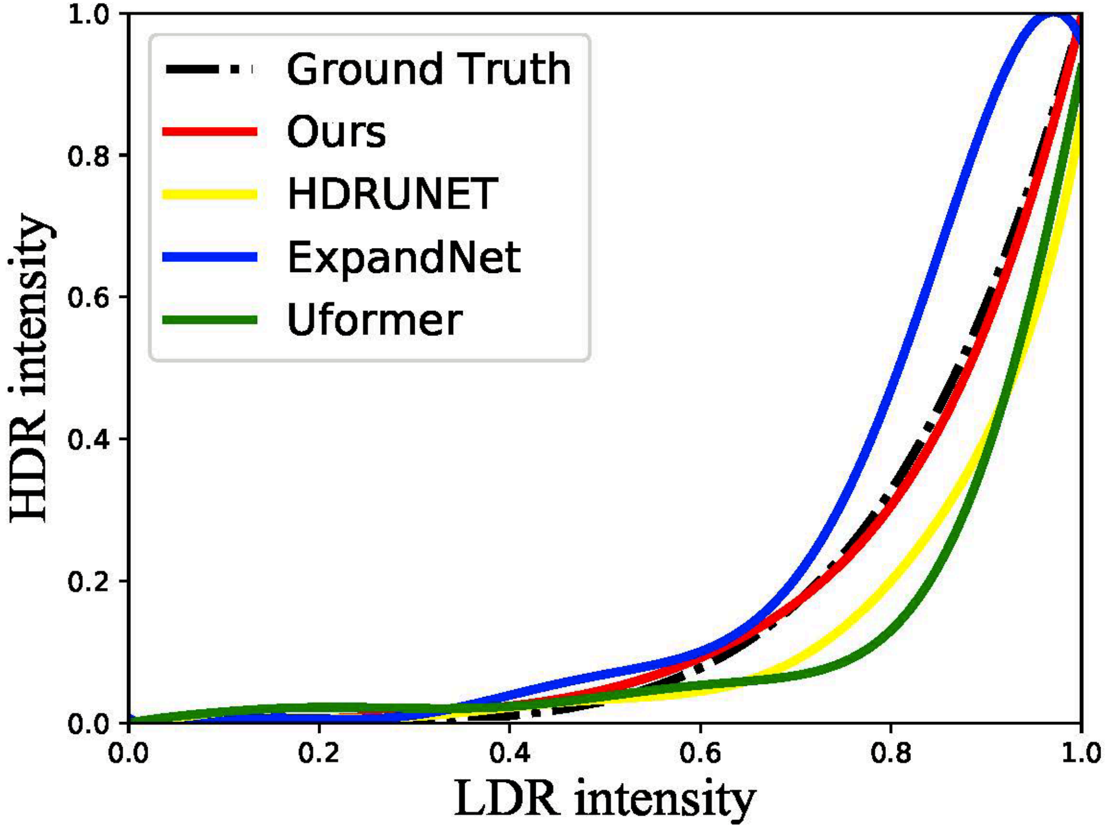
HDRUNET

Ours

Ground Truth

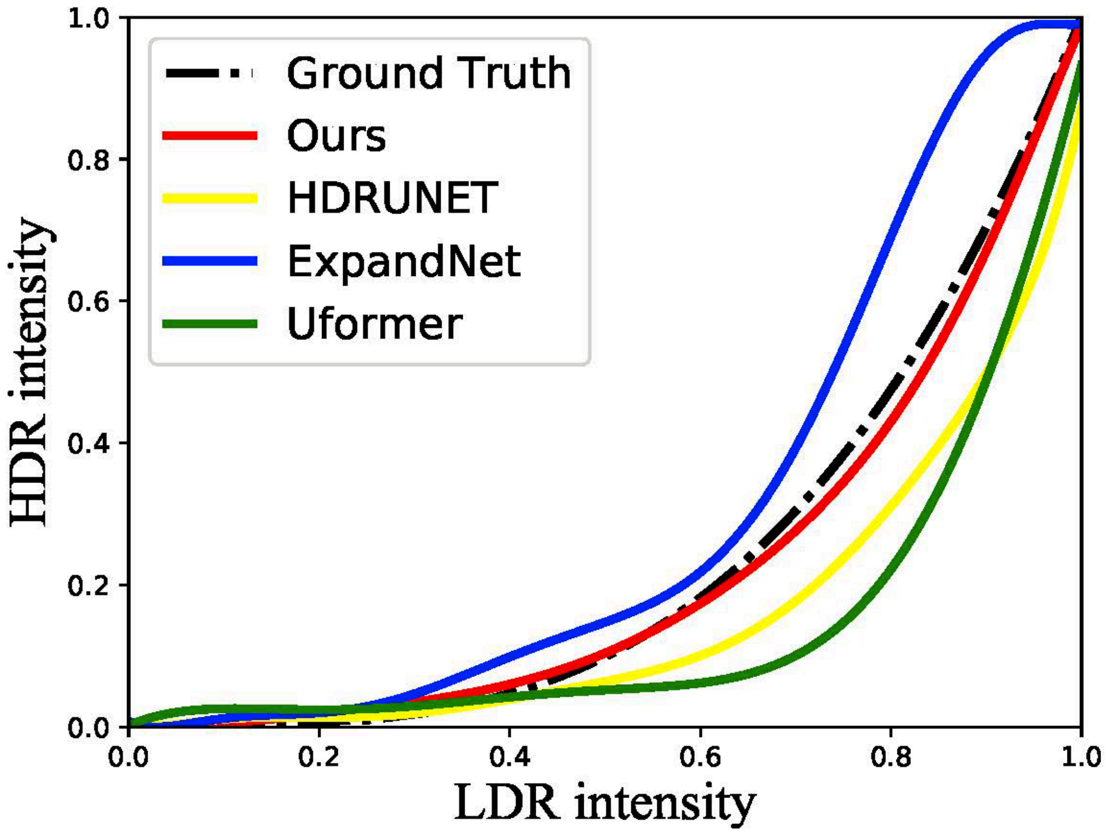
$\boldsymbol{\gamma} = \mathbf{0.8}$

Curve Estimation Evaluation



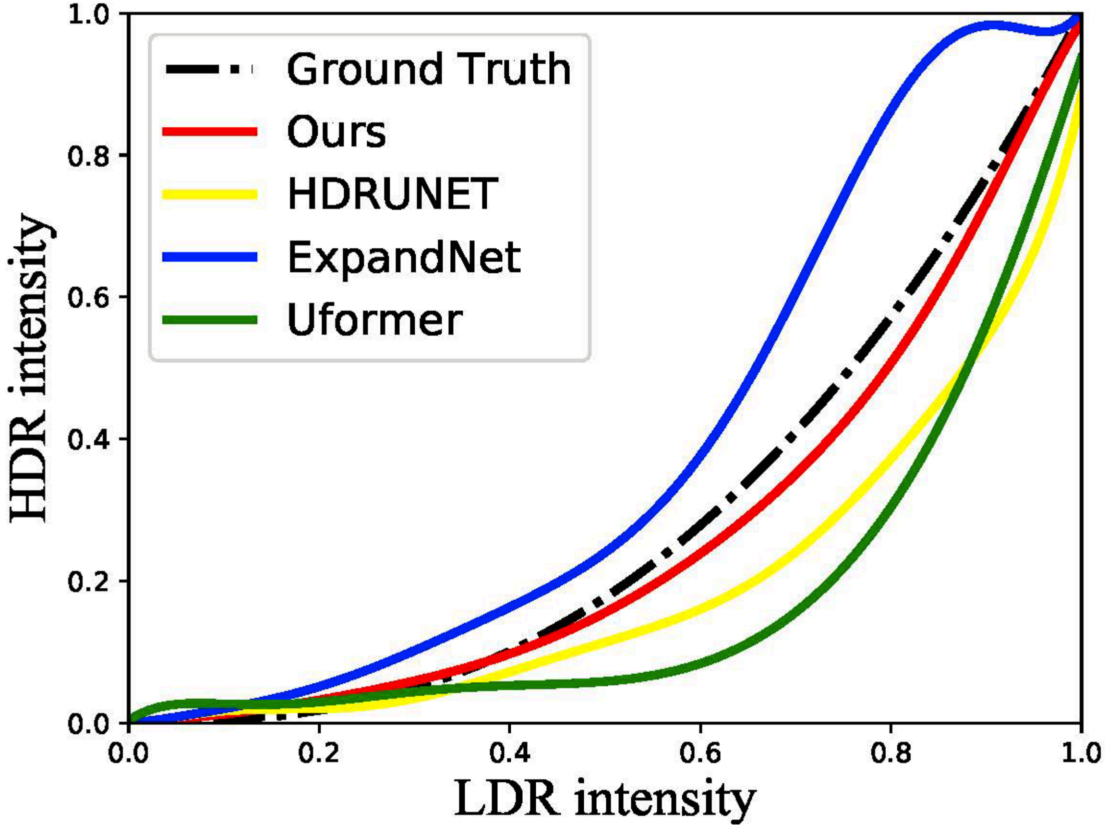
γ = 0.2

Curve Estimation Evaluation



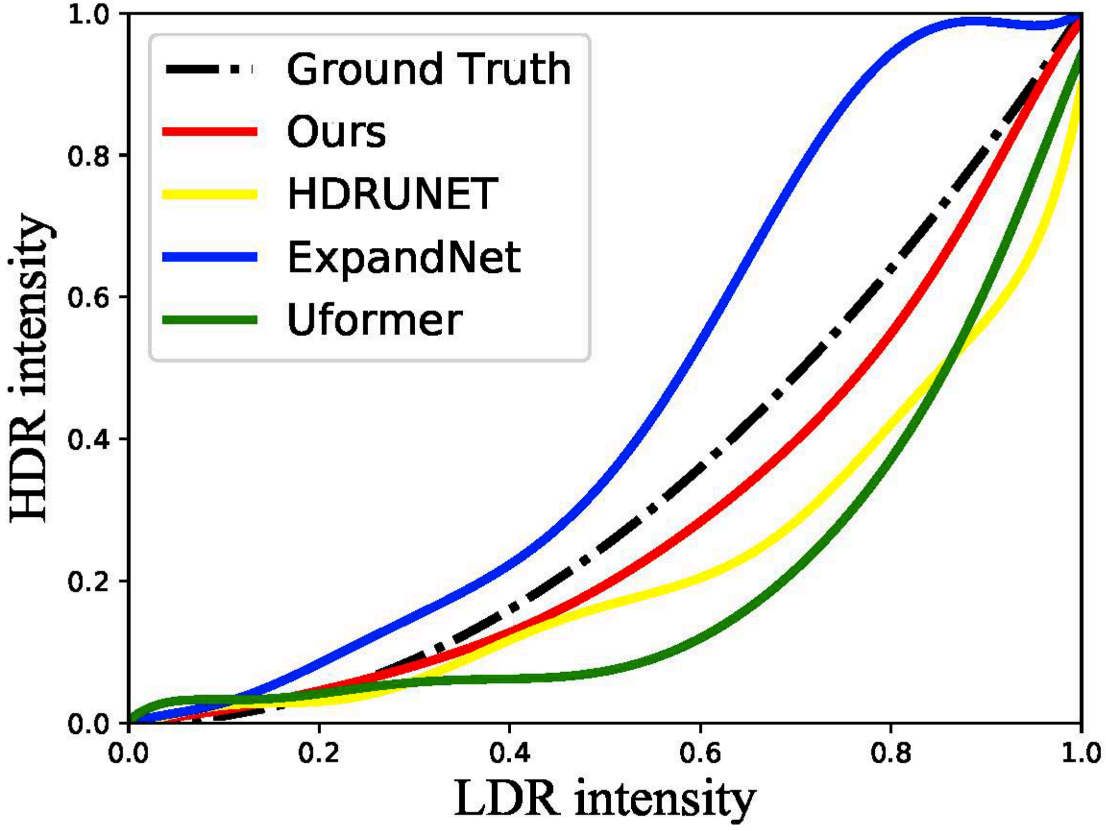
γ = 0.3

Curve Estimation Evaluation



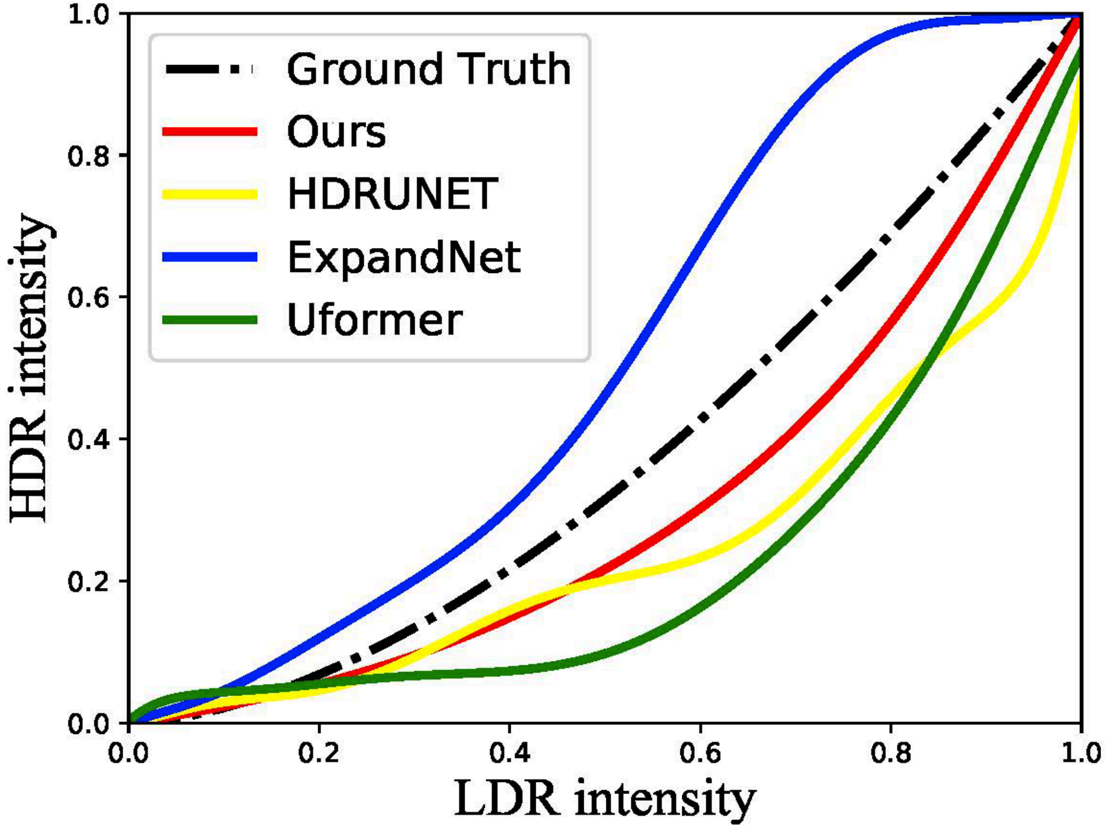
γ = 0.4

Curve Estimation Evaluation



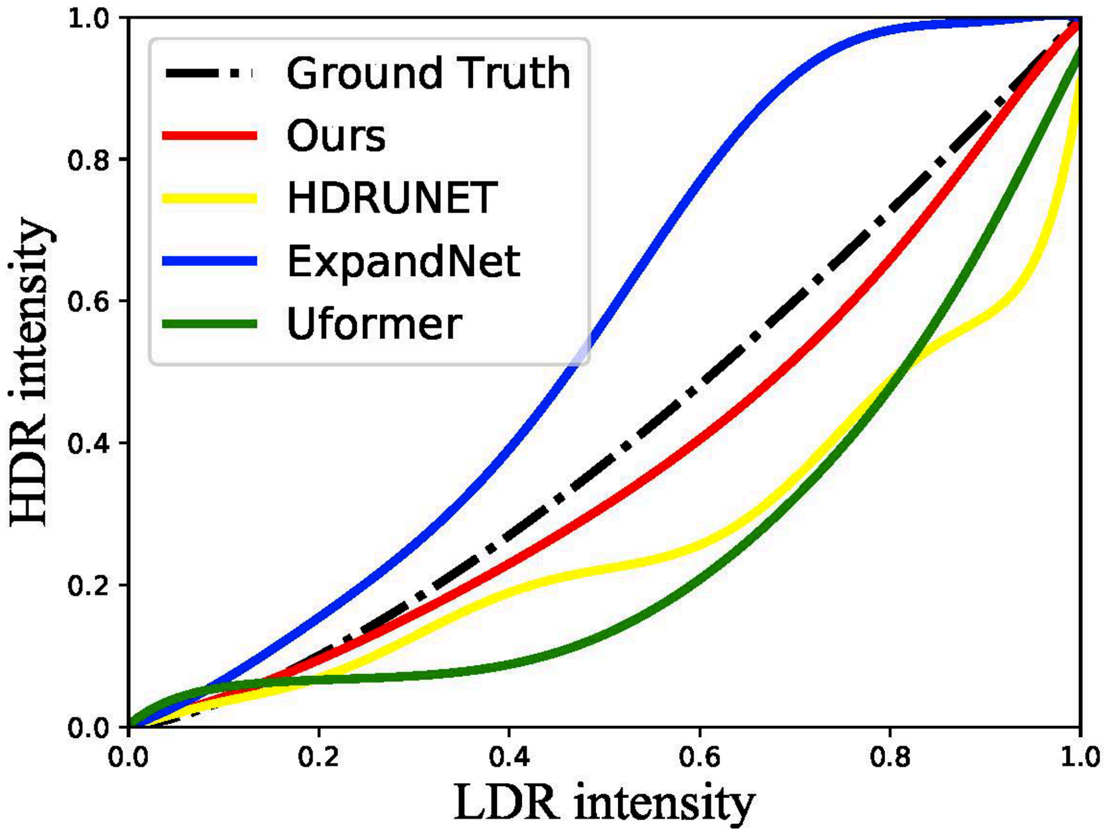
γ **= 0.5**

Curve Estimation Evaluation



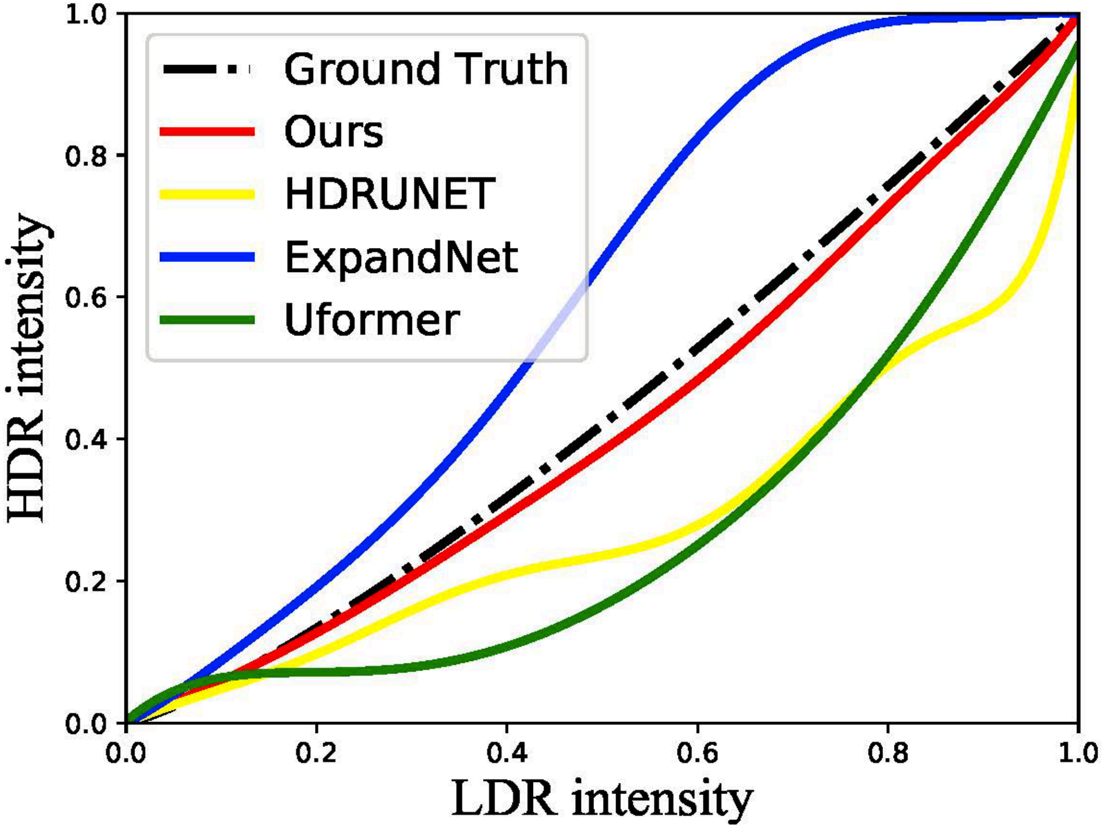
$\gamma = 0.6$

Curve Estimation Evaluation



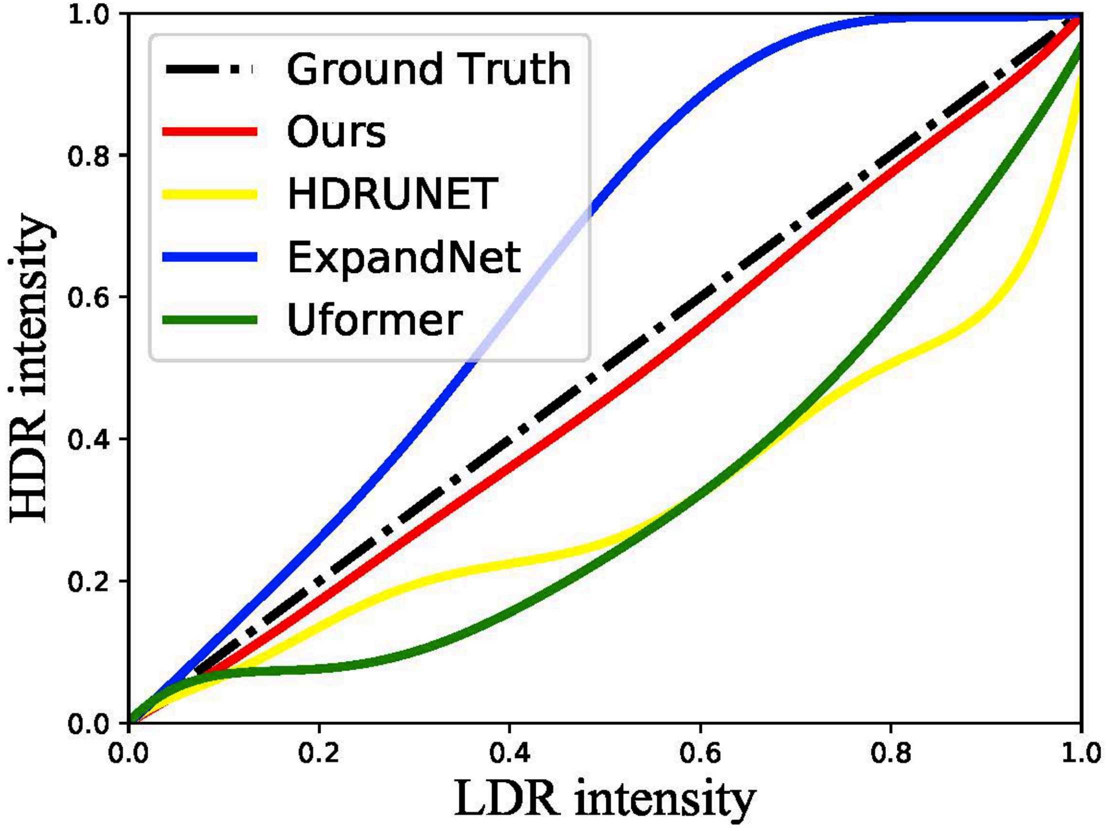
γ = 0.7

Curve Estimation Evaluation



γ = 0.8

Curve Estimation Evaluation



γ = 1.0

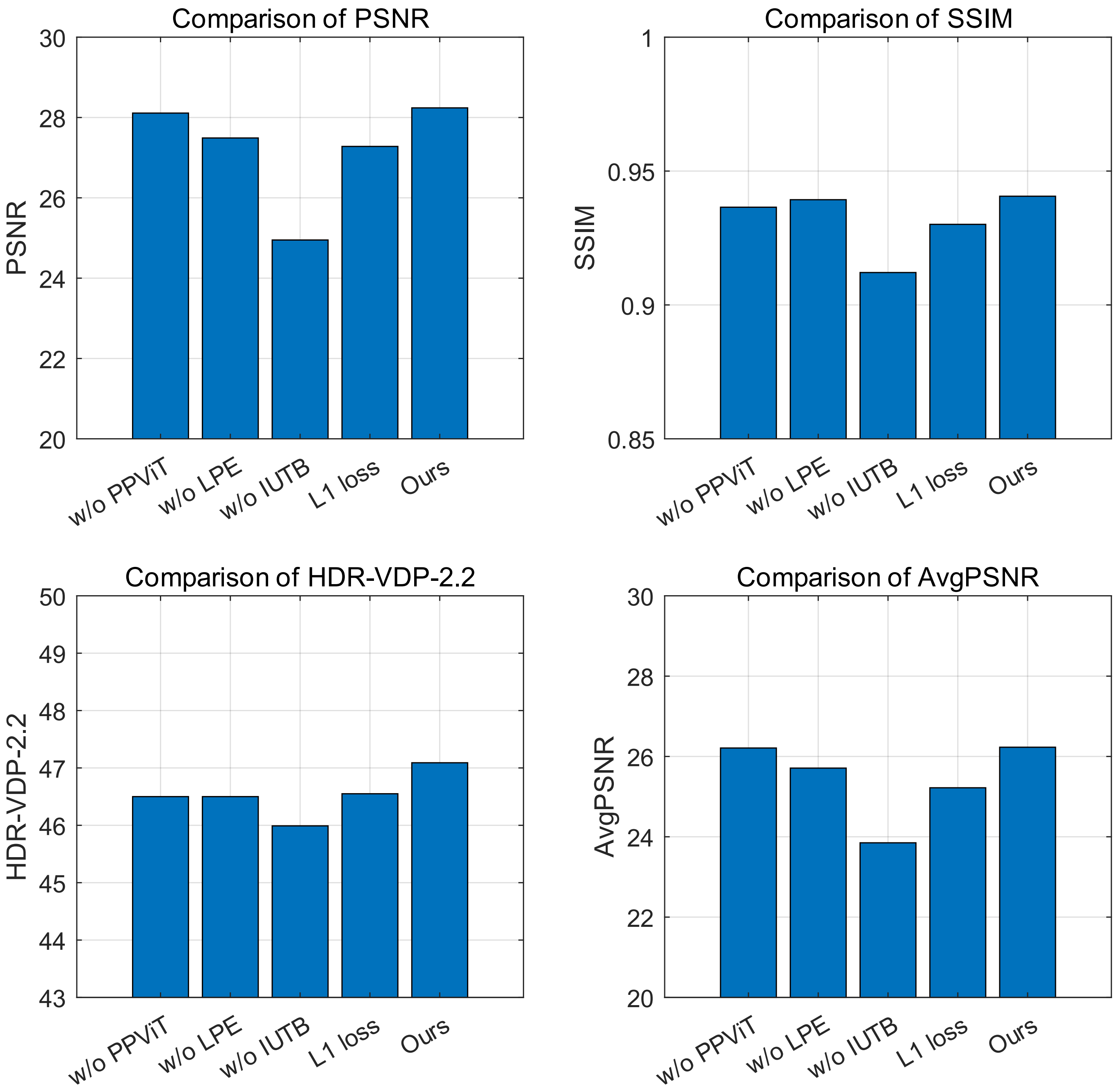
HDR Reconstruction in the Wild

LDR

HDR

Ablation Study

In **Test-Real** dataset


Comparison of PSNR
PSNR
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w/o PPViT
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L1 loss
Ours
Comparison of SSIM
SSIM
1
0.95
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w/o PPViT
w/o LPE
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L1 loss
Ours
Comparison of HDR-VDP-2.2
HDR-VDP-2.2
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w/o PPViT
w/o LPE
w/o IUTB
L1 loss
Ours
Comparison of AvgPSNR
AvgPSNR
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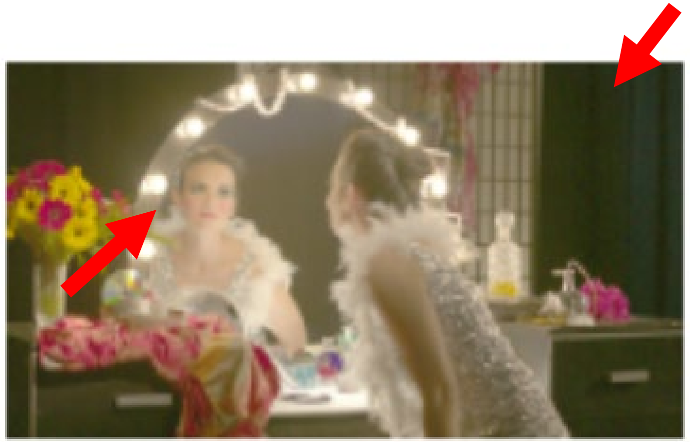
22
20
w/o PPViT
w/o LPE
w/o IUTB
L1 loss
Ours

Limitations and Future Work

- **Extreme tone mapping curves** (e.g., gamma=0.2)

LDR



Reconstructed HDR

Ground Truth

➢*Adopting a **more flexible tone curve estimation** strategy*

➢*Providing a larger tone space in data or network*

Conclusion

- Explicit framework for HDR reconstruction
- SOTA performance
- Useful for real-world HDR reconstruction in **various practical scenarios**.

Thanks

3/10/2023

Project Page

My LinkedIn