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S-LAB FOR ADVANCED INTELLIGENCE

AnyBokeh: Physics-Guided Any-to-Any Bokeh Editing with Optical Fingerprint Transfer

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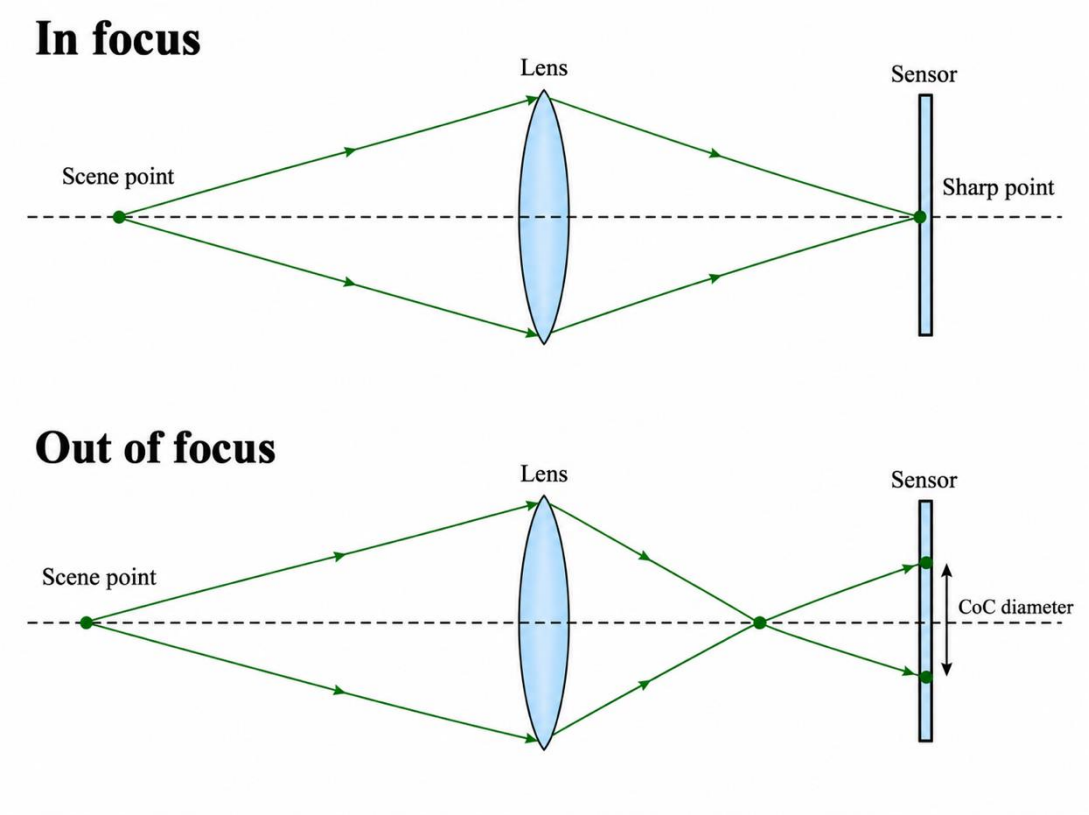
S-Lab, Nanyang Technological University



NEURAL INFORMATION PROCESSING SYSTEMS

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How Focus And Aperture Shape Bokeh



- Focus distance selects the depth that appears to be sharp
- Circle-of-Confusion (CoC) measures the blur-disk diameter
- Larger aperture (smaller f-number) increases defocus

$$|CoC| \propto \frac{|D_{focus} - D|}{N}$$

Fixed focal length and image scale, $S_1 \gg f$

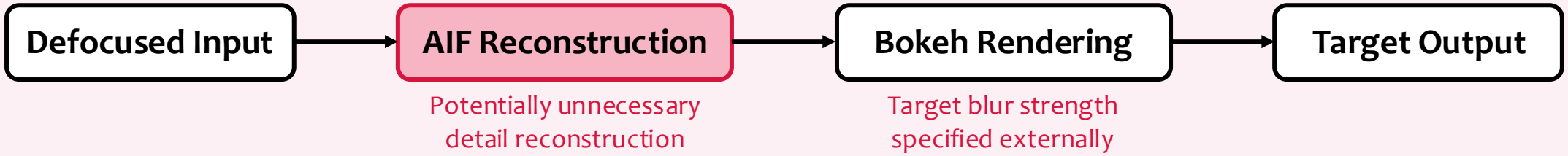
D: disparity (inverse depth) · D_{focsu}: focus disparity
N: f-number · f: focal length · S_1: focus distance.

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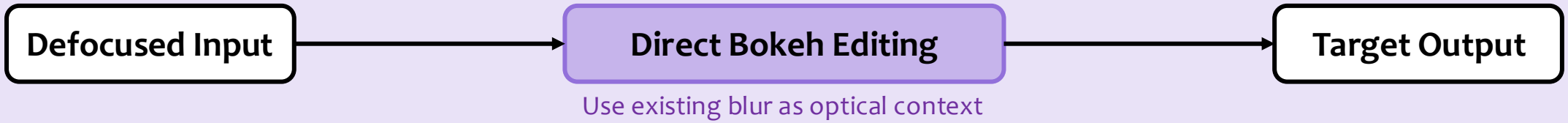
Beyond the All-in-Focus Bottleneck

Real photographs may already contain spatially varying defocus.

Deblur-then-render



Our goal: AnyBokeh



Direct edit without an all-in-focus intermediate.

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From Camera Optics to Pixel-Space Blur

Pixel-space CoC depends on optics, scene geometry, and image scale.

$$CoC_{px} = \underbrace{\left[\frac{f^2}{N(S_1 - f)}\right] \times \left[\frac{S_2 - S_1}{S_2}\right]}_{\text{Optics and scene geometry}} \times \underbrace{\left[\frac{W_{res}}{W_{sensor}}\right]}_{\text{Conversion to pixel unit}}$$

f: focal length · N: f-number · S_1: focus distance · S_2: scene depth · W_{res}: image width in pixels · W_{sensor}: sensor width in mm

Image preprocessing

Resize by s → CoC in pixels scaled by s.
Crop alone → local CoC diameter in unchanged.

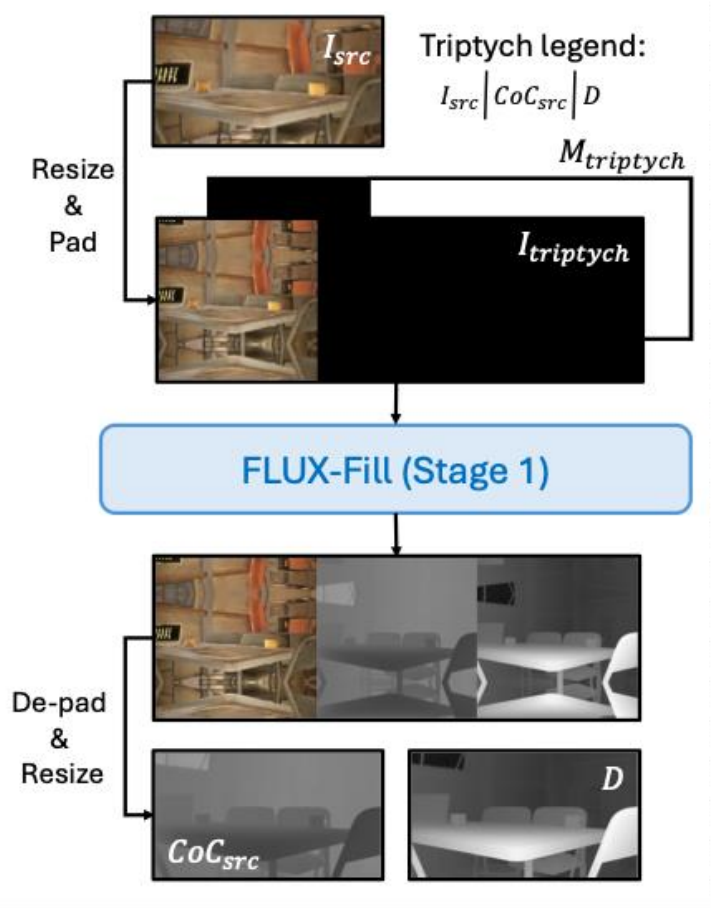
$$CoC_{px} \approx \kappa \cdot |D_{focus} - D|$$

$$\kappa \approx \frac{f^2 W_{res}}{N W_{sensor}} \text{ assuming } S_1 \gg f$$

Estimating the source optical scale from CoC-disparity relation.

The fitted κ captures camera optics and absorbs scale changes from image resizing and disparity estimation.

Estimate Source Blur and Geometry



Stage 1 of AnyBokeh framework.

Joint Prediction

Signed source CoC + disparity

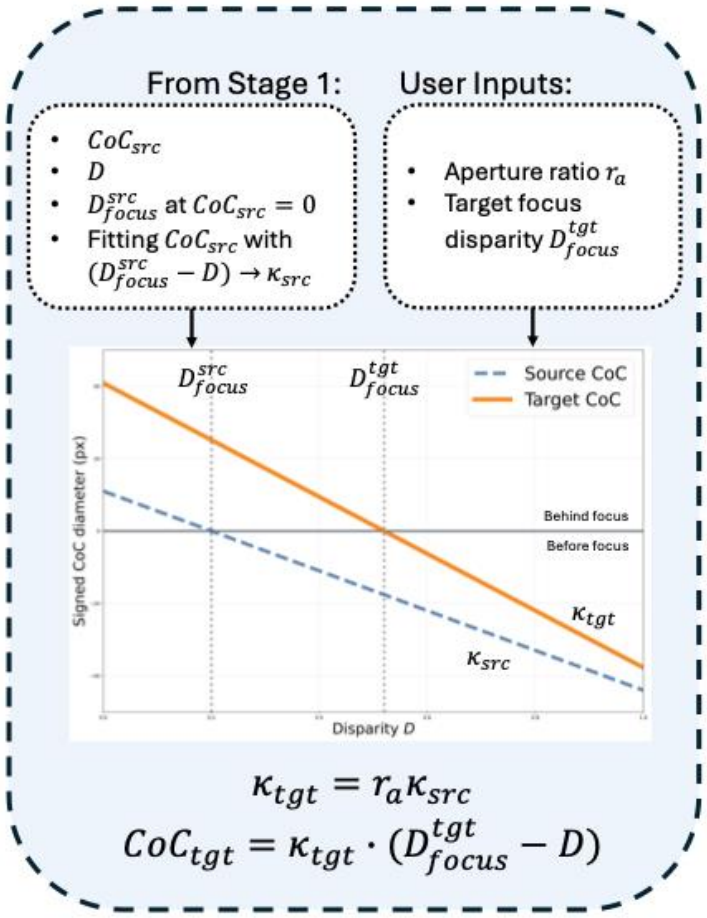
Source CoC captures existing blur
Disparity provides scene geometry

Full-Image Estimation

Keep disparity scale consistent across the entire image

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Transfer the Source Optical Fingerprint



Target CoC Calculation.

❶ Fit the source optical fingerprint

$$CoC_{src} \approx \kappa_{src} \cdot (D_{focus}^{src} - D)$$

❷ Apply the requested aperture change

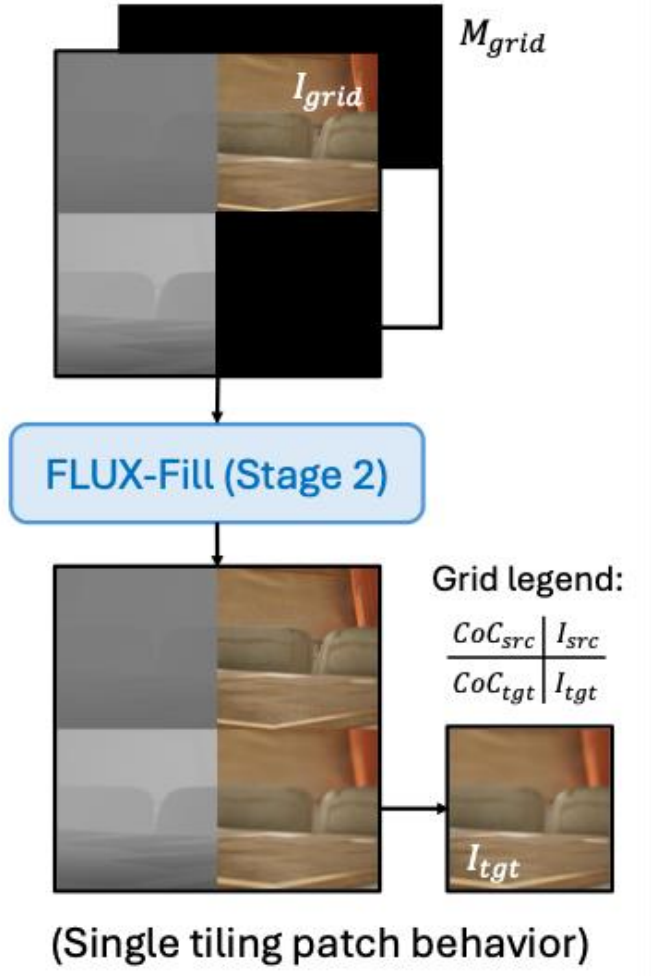
$$\kappa_{tgt} = r_a \cdot \kappa_{src} \quad r_a = \frac{N_{src}}{N_{tgt}}$$

❸ Set the target focus

$$CoC_{tgt} = \kappa_{tgt} \cdot (D_{focus}^{tgt} - D)$$

Source-anchored control without the need of complete EXIF or test-time calibration.

Condition on Both Blur State



Stage 2 of AnyBokeh framework.

$$(I_{src}, CoC_{src}, CoC_{tgt}) \rightarrow I_{tgt}$$

Source CoC: What is already there

Explicit guidance for current blur state

Target CoC: What we want

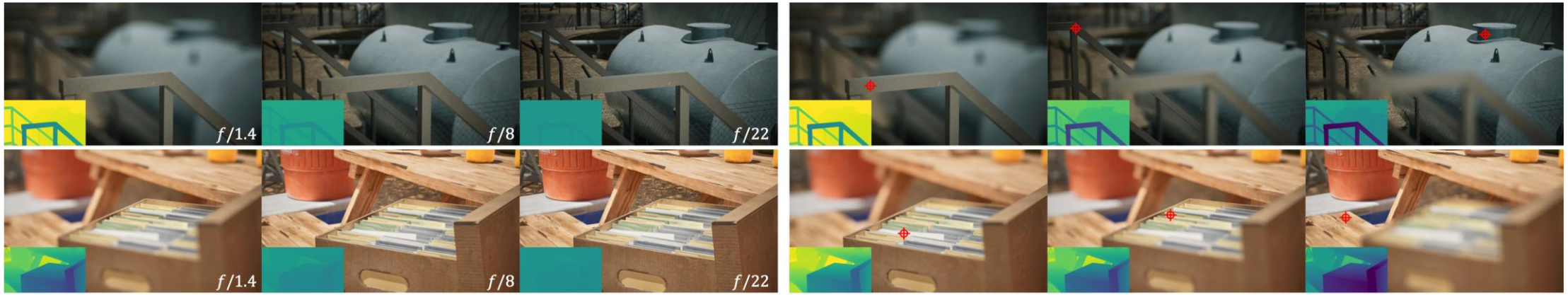
Explicit guidance for the desired blur state

Deblur · Preserve · Add Blur

Different regions may require different edits

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UnrealBokeh: Physics-Grounded Supervision



(1) Change of aperture. Aperture values are marked in right bottom corner.

(2) Change of focus distance. Focus points are marked by crosshair markers.

Examples from UnrealBokeh.

Controlled optics

Vary aperture and focus
at fixed viewpoints

Dense Supervision

Ground truth depth +
signed CoC + complete EXIF

Paired Editing Data

11,477 images
382,888 pairs

All Evaluation on real photography datasets: EBB! And RealBokeh

Zero-shot cross-domain generalization

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Separate Defocus from Scene Geometry

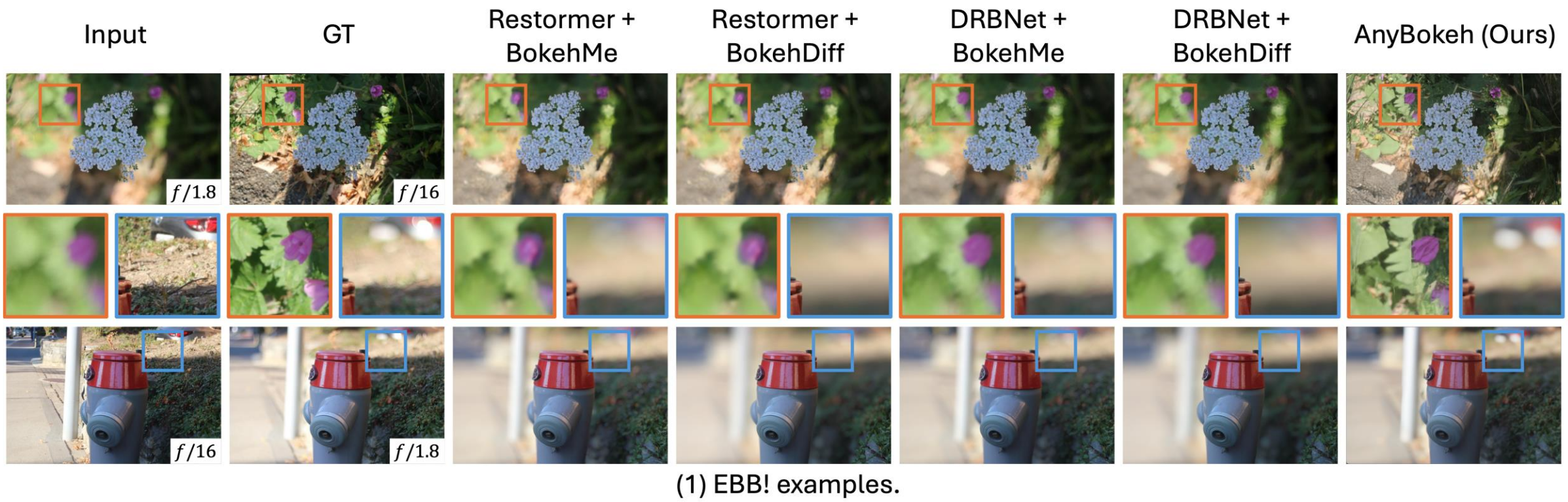


Qualitative Stage 1 predictions on EBB! And RealBokeh.

- CoC magnitude changes with the observed defocus
- Disparity remains largely consistent across aperture changes

Qualitative evidence of how Stage 1 separate blur state from scene geometry.

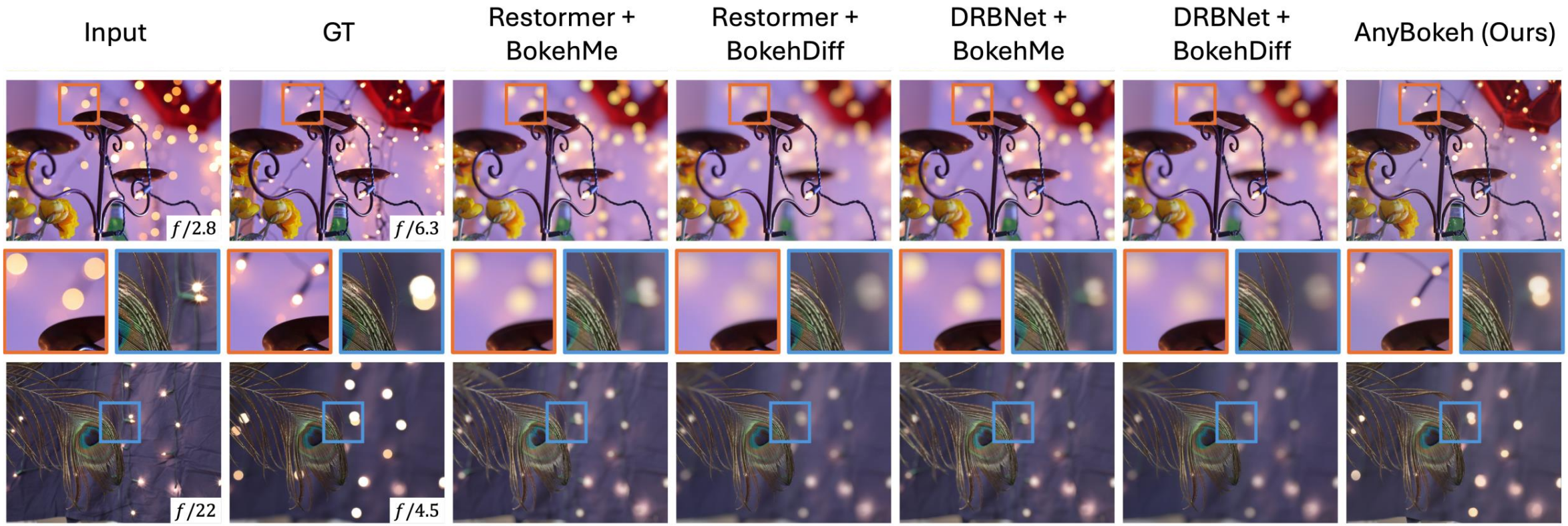
Any-to-Any Bokeh Editing



Qualitative comparison on any-to-any bokeh editing.

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Any-to-Any Bokeh Editing



(2) RealBokeh examples.

Qualitative comparison on any-to-any bokeh editing.

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Real Photography Benchmark

Quantitative comparison on any-to-any bokeh editing.

AIF Estimator	Bokeh Module	Editing Protocol		EBB!			RealBokeh		
		Direct Edit	No Calib.	LPIPS↓	DISTS↓	FID↓	LPIPS↓	DISTS↓	FID↓
Restormer	BokehMe	✗	✗	0.4451	0.2634	38.2801	0.3190	0.1399	48.2732
Restormer	BokehDiff	✗	✗	0.4449	0.2663	42.5686	0.3360	0.1505	61.6716
DRBNet	BokehMe	✗	✗	0.4424	0.2588	36.8142	0.3211	0.1415	48.6855
DRBNet	BokehDiff	✗	✗	0.4444	0.2634	42.1294	0.3424	0.1557	63.3783
–	**AnyBokeh**	✓	✓	**0.4010**	**0.1426**	**24.6042**	**0.3033**	**0.0944**	**33.6655**

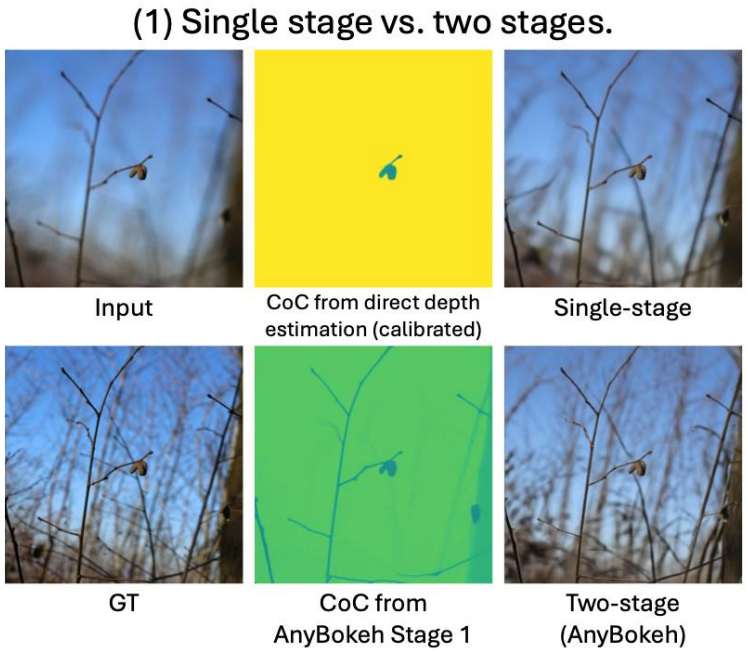
Baselines: deblur → render pipeline, which global bokeh-level calibration.
Ours: direct edit, without bokeh-level calibration.

Lower LPIPS, DISTS, and FID on both datasets.

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Validation of Two Key Designs

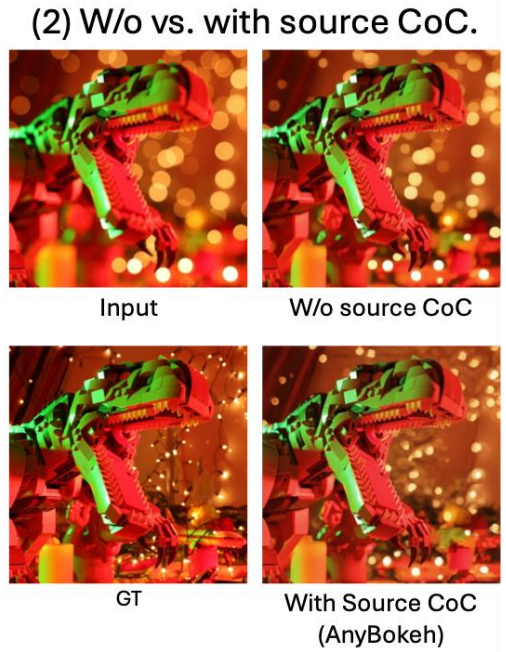
Two-Stage Design



Visual comparisons for ablation studies.

Joint CoC–disparity estimation captures blur-aware geometry.

Dual-CoC Conditioning



Dual-CoC conditioning explicitly specifies the blur-state transition.

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Making Bokeh Editing Physically Controllable

Contribution

Edit focus and aperture directly from images with pre-existing bokeh, without an all-in-focus intermediate.

Limitation

- Extreme defocus can cause missing details or artifacts
- Tiling strategy increases inference time

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Project Page

Code

Pretrained Weights