

# Phy-CoSF: Physics-Guided Continuous Spectral Fields Reconstruction and Spectral Super-Resolution for Snapshot Compressive Imaging

Wudi Chen Zhiyuan Zha\* Xin Yuan Shigang Wang Bihan Wen Jiantao Zhou Gang Yan Zipei Fan Ce Zhu

Jilin University Westlake University Nanyang Technological University University of Macau  
University of Electronic Science and Technology of China

\*Corresponding author

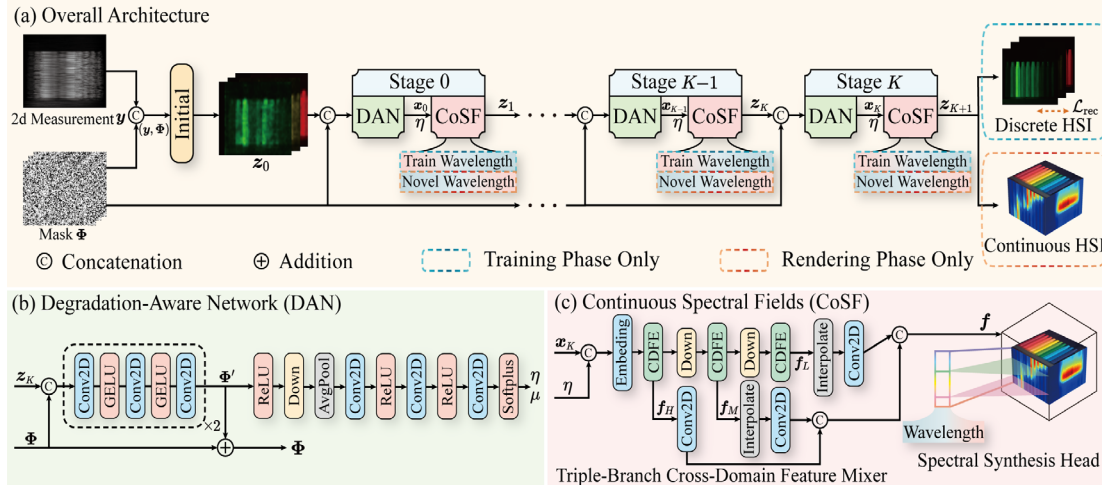
## Motivation

Recent advances have demonstrated that coded aperture snapshot spectral imaging (CASSI) systems show great potential for capturing 3D hyperspectral images (HSIs) from a single 2D measurement. Despite the inherent spectral continuity of scenes captured by CASSI, most existing reconstruction methods are restricted to fixed, discrete spectral outputs, thereby precluding continuous spectral reconstruction or spectral super-resolution. To address this challenge, we propose Phy-CoSF, which synergizes deep unfolding networks with implicit neural representations, establishing a new paradigm for continuous spectral reconstruction and super-resolution in CASSI. Specifically, we propose a two-phase architecture that bridges discrete-wavelength training with continuous spectral rendering, enabling the synthesis of high-fidelity HSIs at arbitrary target wavelengths. At the core of our framework lies the continuous spectral fields (CoSF) module, embedded within each unfolding stage as a dynamic prior, which comprises a triple-branch cross-domain feature mixer for comprehensive spatial-frequency-channel feature fusion, alongside a spectral synthesis head that generates spectral intensities by querying continuous wavelength coordinates. Extensive experimental results demonstrate that Phy-CoSF not only achieves continuous modeling at arbitrary spectral resolutions but also outperforms many state-of-the-art methods in both reconstruction fidelity and spectral detail preservation.

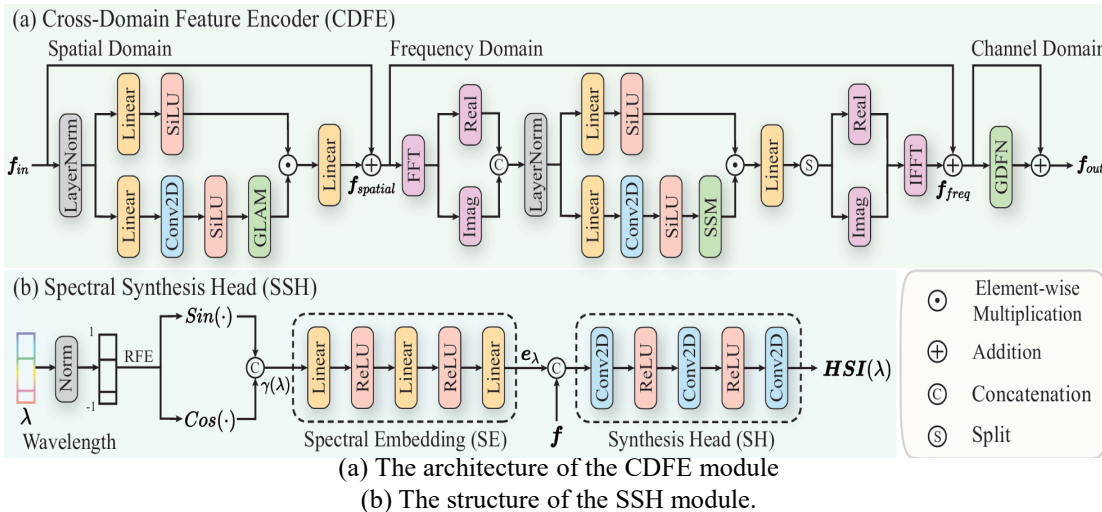
## Contributions

- We propose the Phy-CoSF framework for continuous spectral reconstruction and super-resolution, which incorporates implicit continuous modeling while preserving physical interpretability.
- We establish a train-render two-phase paradigm, which empowers models trained on discrete spectral bands to natively render arbitrary spectral resolutions.
- We design a CoSF module, achieving dynamic, continuous spectral modeling via a Fourier Mamba-based triple-branch cross-domain feature mixer and a SSH.

## Method



The overall architecture of the proposed Phy-CoSF. The framework operates in two distinct phases: a training phase that utilizes discrete training wavelengths and a rendering phase capable of generating outputs at arbitrary continuous wavelengths.



## Experiments

Quantitative comparison with baseline methods on ICVL scenes.

Algorithms	Params(M)	FLOPs(G)	Scene1	Scene2	Scene3	Scene4	Scene5	Scene6	Scene7	Scene8	Scene9	Scene10	Avg
MST++ (Cai et al., 2022b)	0.07	1.18	30.91	3.70	2.17	2.08	1.68	1.75	2.36	2.26	2.29	3.46	2.43
CST-L+ (Cai et al., 2022a)	0.15	3.94	30.77	29.99	35.96	39.60	39.39	40.09	37.53	32.60	27.44	31.24	34.48
GAP-Net (Meng et al., 2020a)	4.21	65.73	0.813	0.798	0.939	0.950	0.947	0.944	0.922	0.879	0.765	0.878	0.884
DAUHST-9stg (Cai et al., 2022c)	2.42	6.68	2.46	3.54	2.14	2.14	1.82	1.90	2.31	2.26	2.18	3.41	2.41
PADU1-12stg (Li et al., 2023)	0.29	4.64	32.42	31.29	38.79	41.57	40.84	40.99	39.63	33.70	28.32	32.51	36.01
RDLUF-MixS2-9stg (Dong et al., 2023)	0.11	31.49	0.871	0.852	0.964	0.969	0.960	0.954	0.949	0.906	0.832	0.905	0.915
DERNN-LNL7-9stg (Dong et al., 2024)	0.93	122.14	2.51	3.43	1.96	1.83	1.61	1.69	2.20	2.13	2.40	3.47	2.32
Lade-DUN-10stg (Wu et al., 2024)	1.23	8.34	2.76	3.96	2.24	2.08	1.70	1.77	2.46	2.31	2.48	3.56	2.53
Mijun-9stg (Qin et al., 2025)	0.04	6.01	0.849	0.825	0.957	0.960	0.956	0.951	0.943	0.896	0.786	0.890	0.901
Phy-CoSF-9stg	0.27	801.38	1.39	1.70	0.82	1.12	0.97	1.08	1.00	0.90	1.15	1.26	1.14
			0.865	0.857	0.967	0.967	0.961	0.955	0.949	0.905	0.805	0.916	0.915

