Harnessing Optoelectronic Noises in a Photonic Generative Adversarial Network

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Abstract: With the assist of noise-aware training approaches, we harness the optoelectronic noises in photonic GANs based on a phase-change metasurface mode converter (PMMC) array to perform hand-written numbers generation task.

Introduction

Generative Adversarial Network (GAN) :

- GAN consists of the generator and the discriminator. The competition drives both networks to improve their capabilities until an equilibrium state is reached.

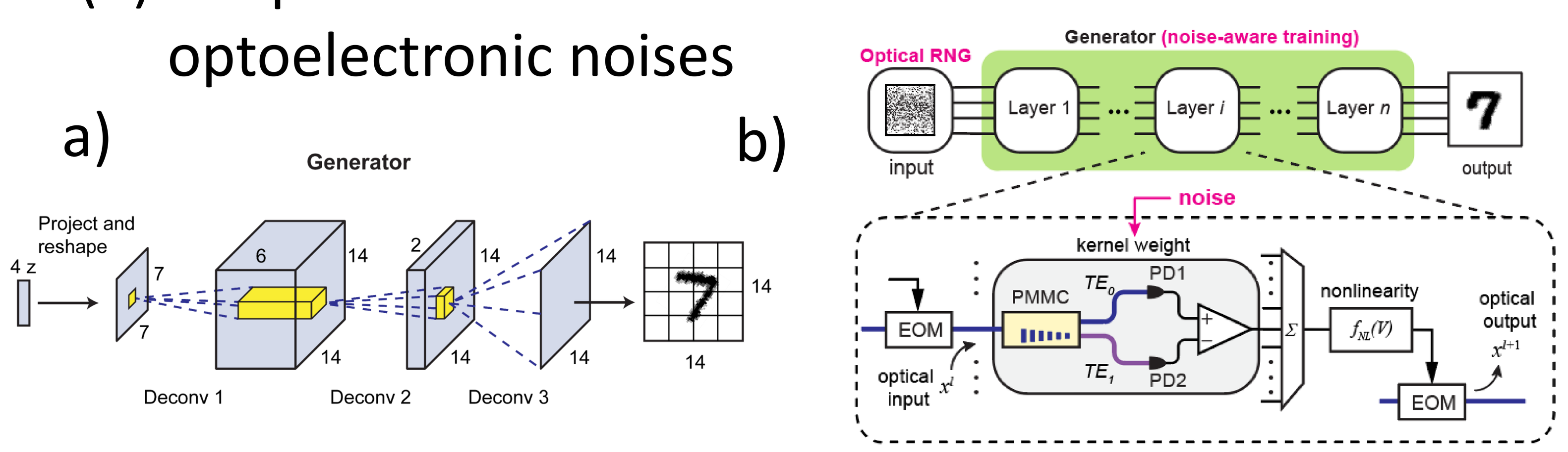
Phase-change Metasurface Mode Converter(PMMC):

- The PMMCs utilize the refractive index change of the GST225 during phase transition to control the waveguide spatial modes with a high precision of up to 64 levels in modal contrast.

We demonstrate:

(a) the photonic GAN based on PMMC array

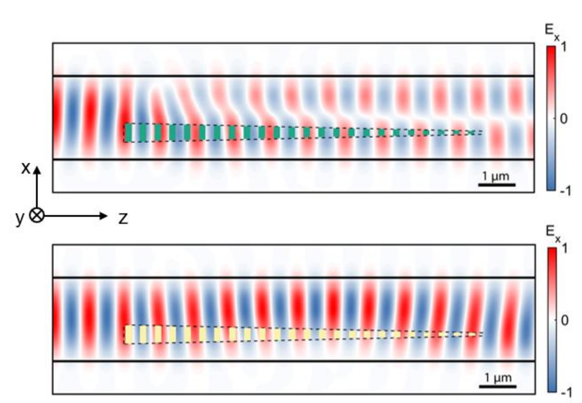
(b) the photonic GAN benefits from optoelectronic noises



PMMC design and characterization

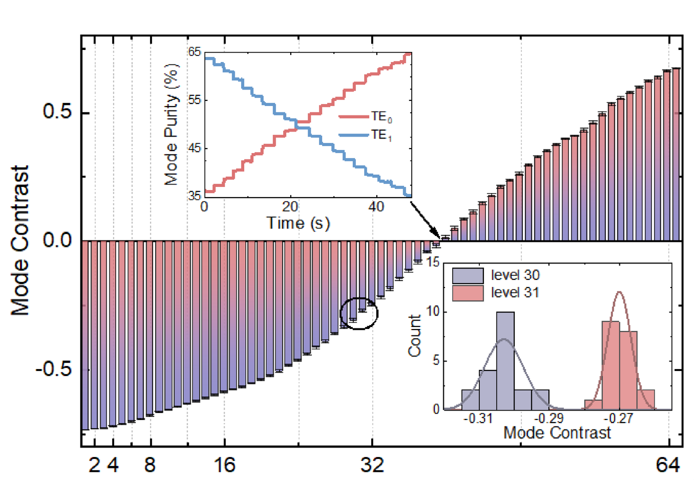
GST phase-gradient metasurface:

- TE_0 mode will convert to TE_1 mode when in cGST



- TE_0 mode will not convert when in aGST.

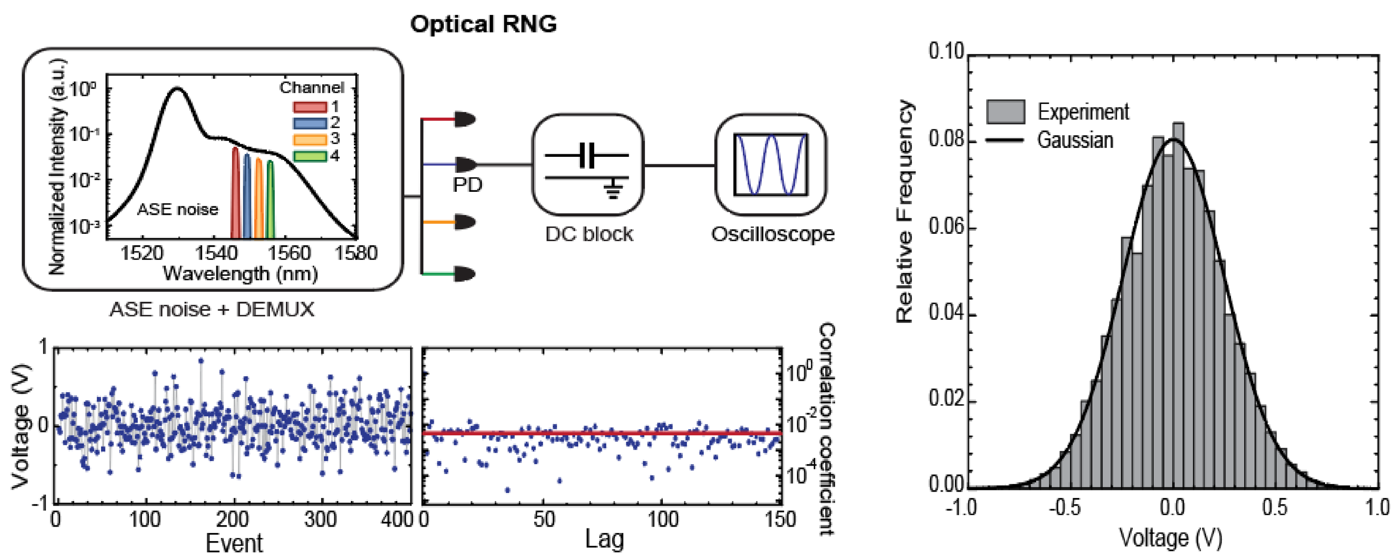
- Up to 64 levels of mode contrast when GST is in an intermediate state



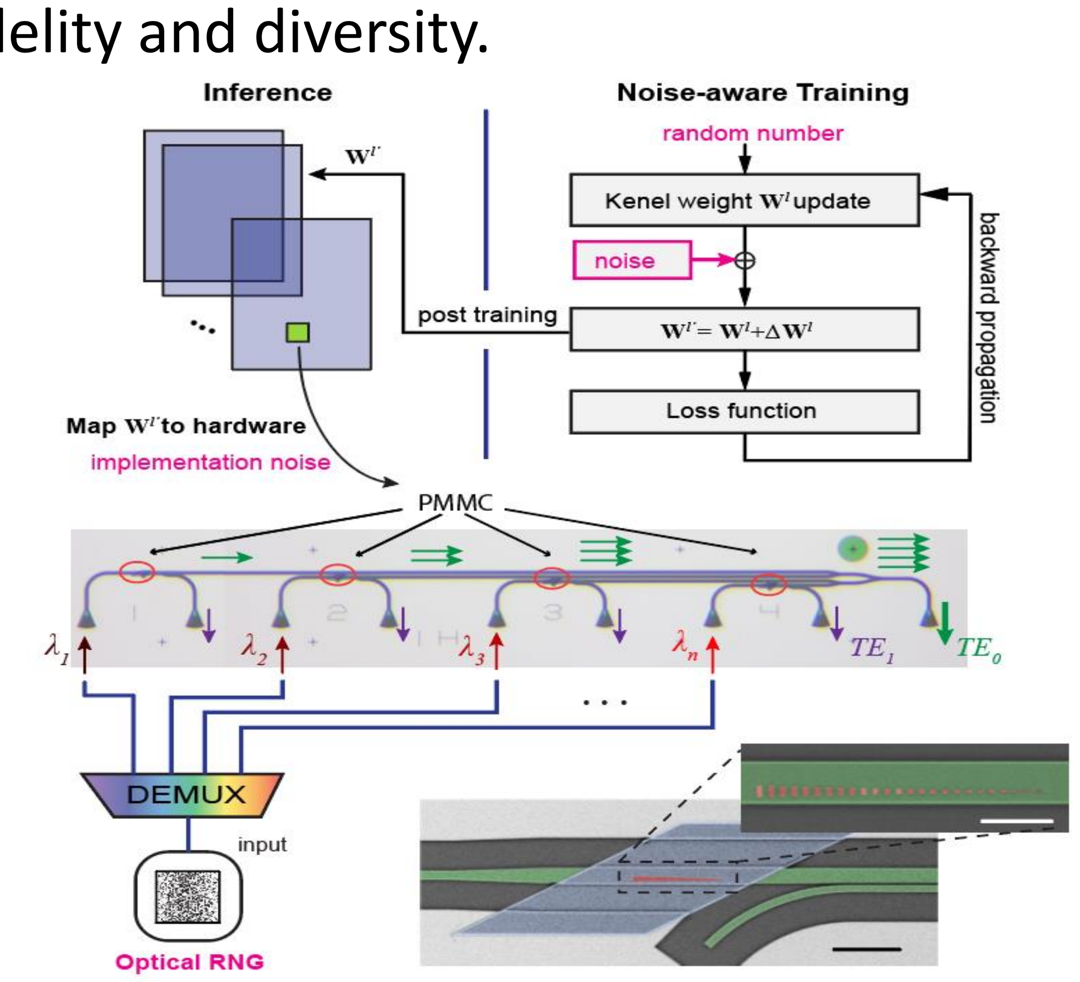
Harness the noises in GAN

The photonic GAN harness the noise in three ways:

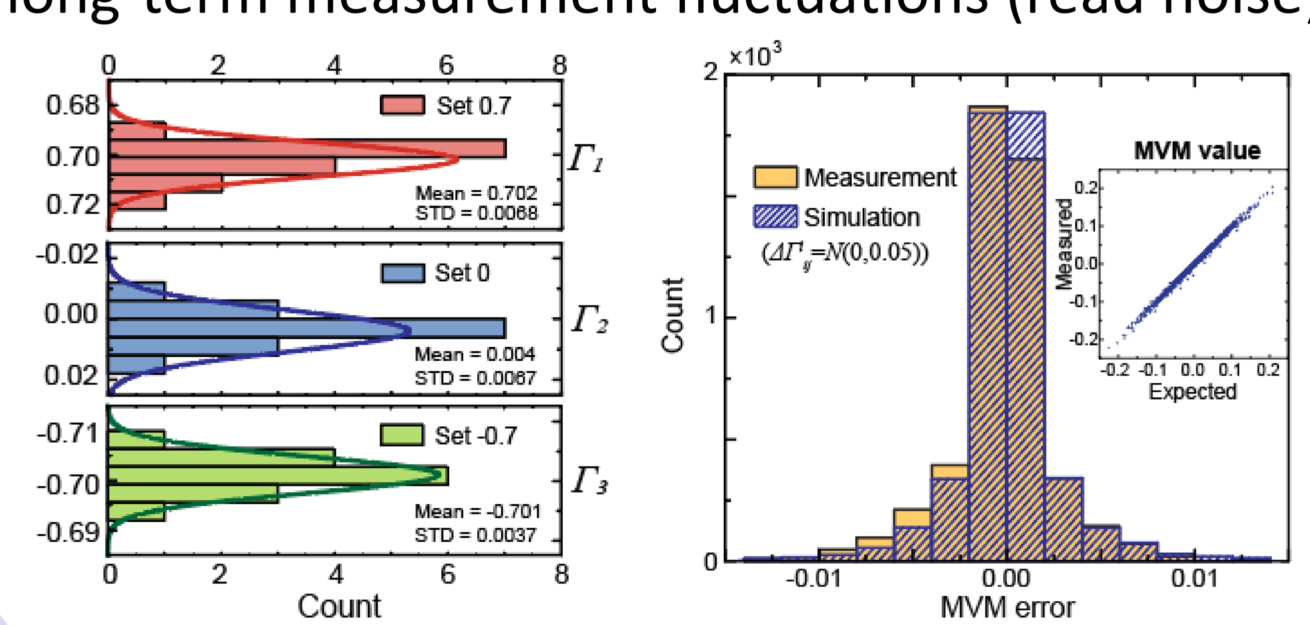
- Utilizing ASE noise to build the optical random number generator (RNG) as the input to GAN.



- The noise-aware training method is developed to improve the network's performance in both fidelity and diversity.

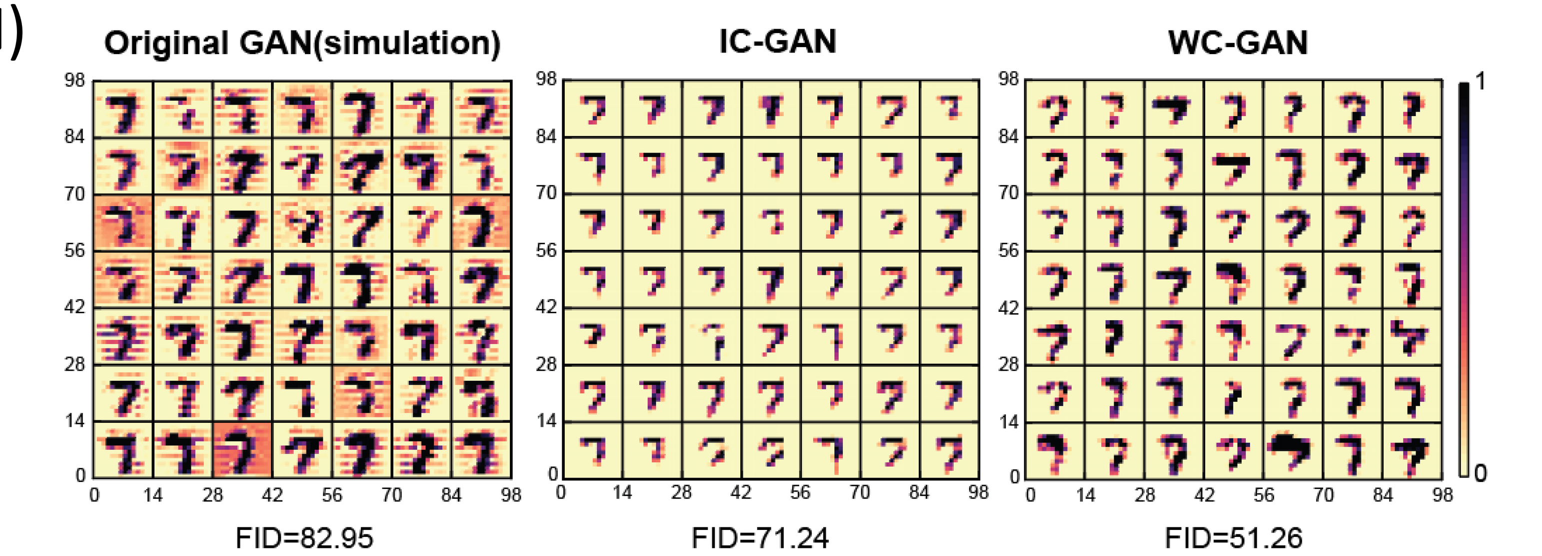


- The realistic hardware noises including short-term programming inaccuracy (write noise) long-term measurement fluctuations (read noise)

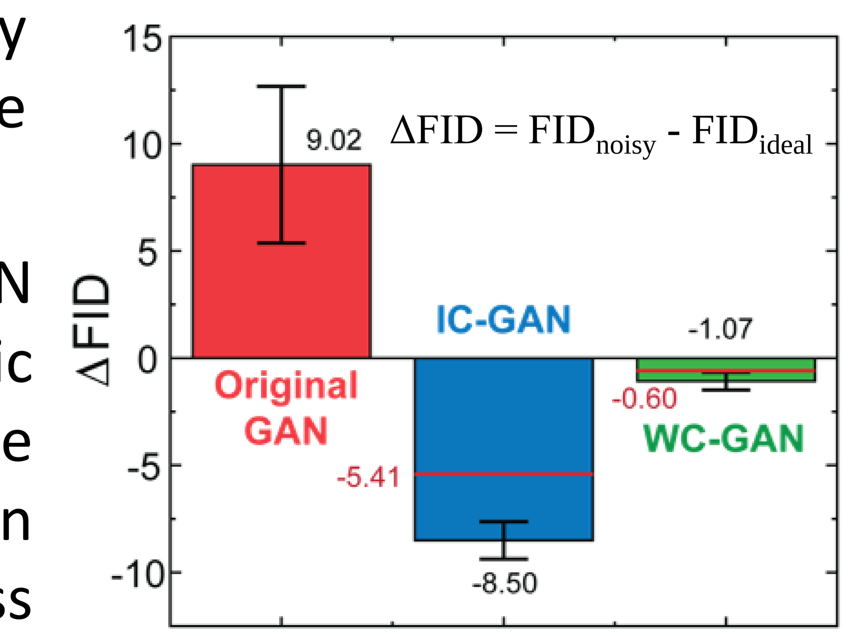


Generating hand-written numbers

- Noise-aware training input-compensatory (IC-GAN) and kernel weight-compensatory approaches (WC-GAN), performs better compared to the conventional training approach (original GAN)

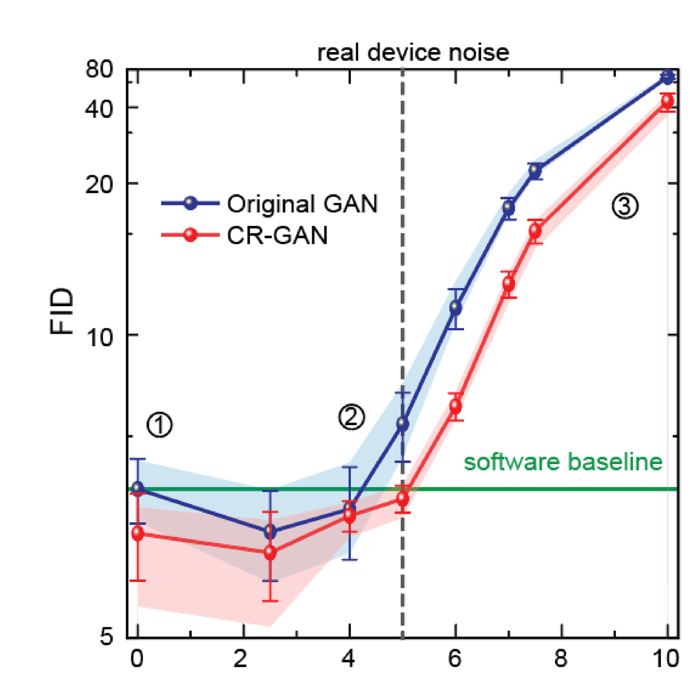


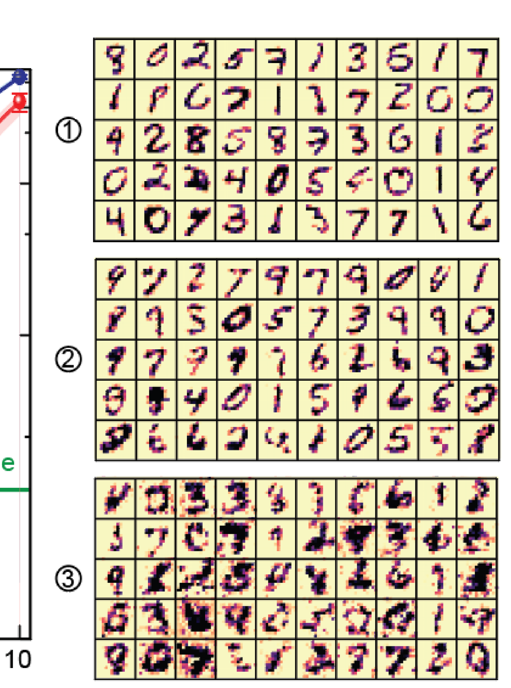
- Frechet inception distance (FID) is used to evaluate the quality of generated instances (the smaller the better)
- the WC-GAN and IC-GAN implemented on the photonic hardware with practical noise perform even better in inference than the noiseless hardware.



Scalability of the photonic GAN

- For a larger-scaled GAN to generate images of all 10 number digits, noise-aware trained GAN performs better than the original GAN
- Noise-aware trained GAN performs better than software baseline under practical noise level





Reference:

[1]. Wu, C. et al. Programmable phase-change metasurfaces on waveguides for multimode photonic convolutional neural network. Nature Communications 12, 96 (2021).
[2]. Goodfellow, I. J. et al. Generative Adversarial Nets. in Advances in Neural Information Processing Systems (2014).
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