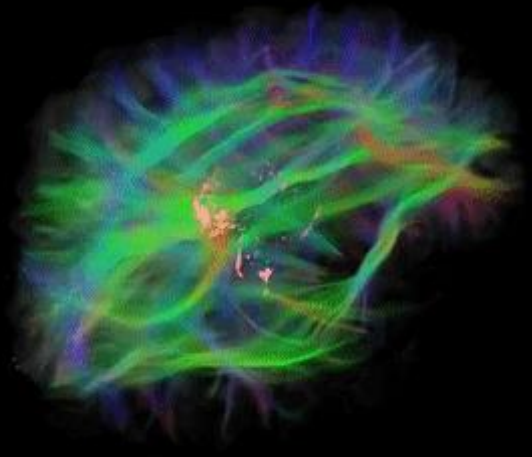
Intelligent Wave Systems Laboratory

Thinking with Light

Human Brain



http://www.digicortex.net/

Photonic Brain

Prof. Sunkyu Yu

Seoul National University

Personal Information – Sunkyu Yu

Prof. Sunkyu Yu

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EDUCATION

B.S. in ECE, Seoul National University (2007)
Ph.D. in ECE, Seoul National University (2015)
(Supervisor: Prof. Namkyoo Park)

EXPERIENCE

Postdoctoral Fellow
Dept. of ECE, Seoul National University
Sep. 2015 - Aug. 2020

Assistant Professor
Dept. of ECE, Seoul National University
Sep. 2020 -

HONORS & AWARDS

Rising Stars 30
OSK (2020)

Young Researcher Award
IASSF (2018)

Presidential Post-Doc. Fellowship,
Korean Government (2016)

Distinguished Dissertation Award,
Dept. of ECE, SNU (2015)

대통령Post-DOC 펠로우십

OSK OPTICAL SOCIETY OF KOREA 30 YEARS

- The mathematical/physical similarity in different fields inspires ***Multidisciplinary Perspectives*****:** quantum-classical analogy, biomimetics, & network-inspired materials.
- Based on this multidisciplinary perspective, we try to achieve
  (i) ***new analysis/design strategies*** for wave mechanics,
  (ii) ***new wave phenomena*** for engineering applications, and
  (iii) ***superior device performances*** for light-based signal processing, computing & AI technology.
- We are now focusing on achieving the neuromorphic realization of intelligent photonic systems

"Thinking with Light"

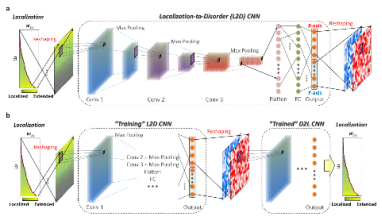
Long-Term Goal – *Photonic Brain*

AI Wave Mechanics

AI Design of Photonic AI Hardware

We explore the AI design of superior photonic-AI platforms.
The effect of ML architectures on material designs is studied.

Nature Communications *accepted* (2020).

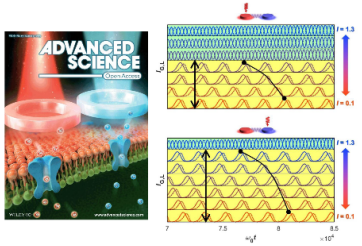


Neuromorphic Photonics

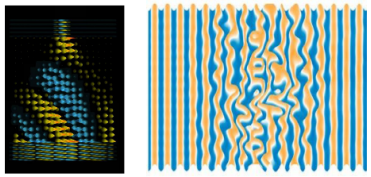
Wave Analogy of Neurons/Synapses

We develop neuromorphic elements with wave dynamics.
Nonlinear, dynamic, or magnetic materials are applied.

Advanced Science 6, 1900771 (2019).



"Thinking with Light"
Photonic Brain



Disordered Wave Systems

Scale-Free Wave Networks

We engineer disorder with a multidisciplinary view.
Scale-free materials for waves are developed.

Nature Reviews Mater. *accepted* (2020); PRL 120, 193902 (2018);
Nature Communications 6, 8269 (2015); Optica 3, 836 (2016);
Science Advances 2, e1501851 (2016); Advanced Mater. 24, 2375 (2012).

Open & Non-Euclidean Systems

Non-Hermitian & Enhanced Lattice DOFs

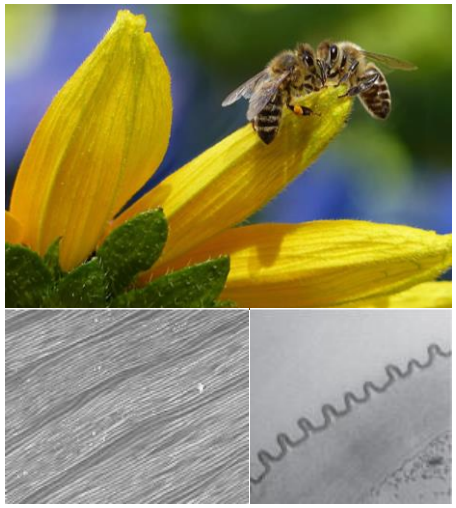
We explore non-Hermitian systems for waves.
We utilize non-Euclidean geometry for infinite lattice DOFs.

PRL 125, 053901 (2020); Optica 3, 1025 (2016);
PRA 97, 033805 (2018); Scientific Reports 6, 37754 (2016);
Optics Express 23, 24997 (2015).

Approaches to Long-Term Goal

Engineering Light Flows in…

Disordered systems



Photonic AI

Open systems

I. *Physical Principles*

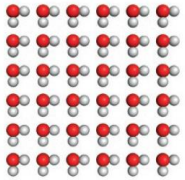
Quantum Mechanics (*Super-symmetry, Bohmian Mechanics, …*), Biomimetics

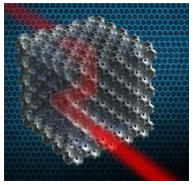
Network Theory (*Clustering, Scale-Free, …),* Mathematics (*Non-Euclidean*)

II. *Data-driven Methods*

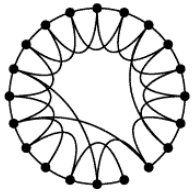
Deep Learning (*CNN, Autoencoder, Effects of Artificial Neural Networks, …*)

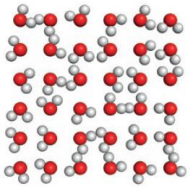
Disordered Photonics – *Brain-like photonic disorder*

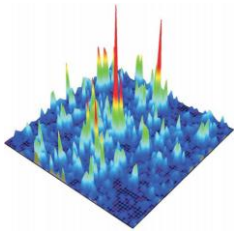




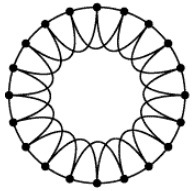
Scale-Free Net.





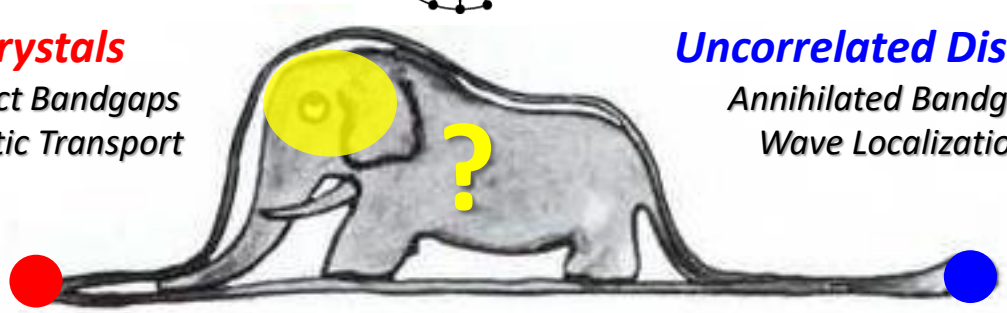


Regular Net.



Crystals

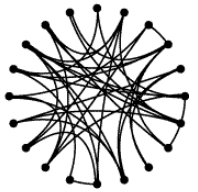
Perfect Bandgaps
Ballistic Transport



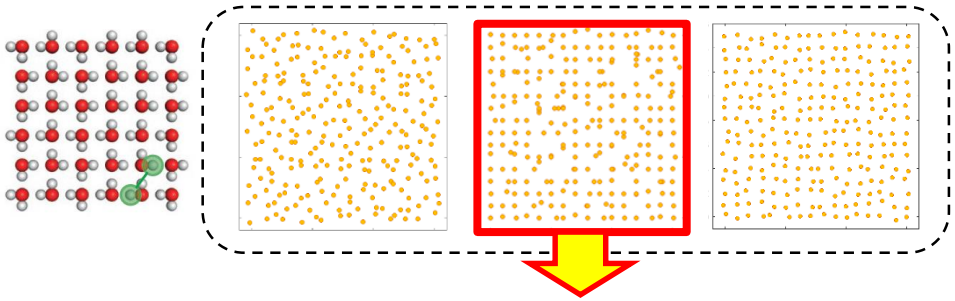
Uncorrelated Disorder

Annihilated Bandgaps
Wave Localization

Random Net.



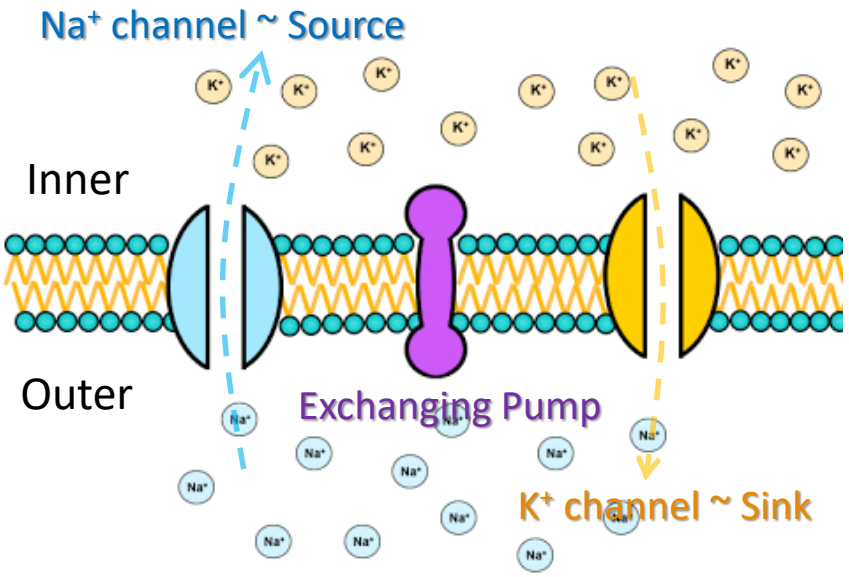
Engineered (Correlated) Disorder



Brain-like "scale-free" materials for light waves?

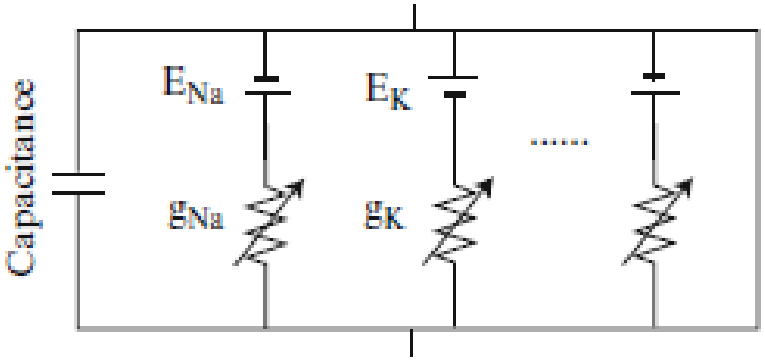
➔ ***Efficient & Robust & Tunable* "light" transport**

Open-System Photonics – *Neuromorphic dynamics*

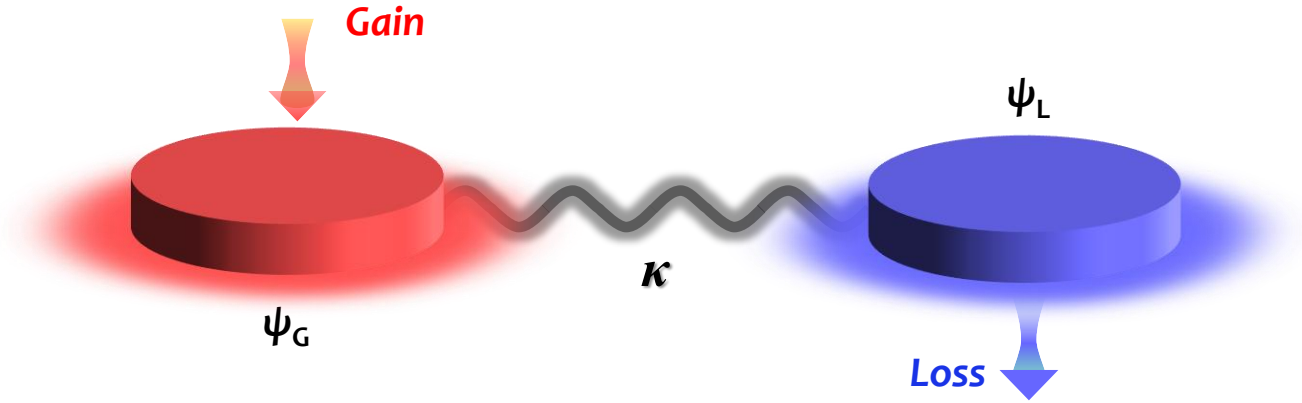


Source: J. Fontana *et al.* Functions of Cells and Human Body

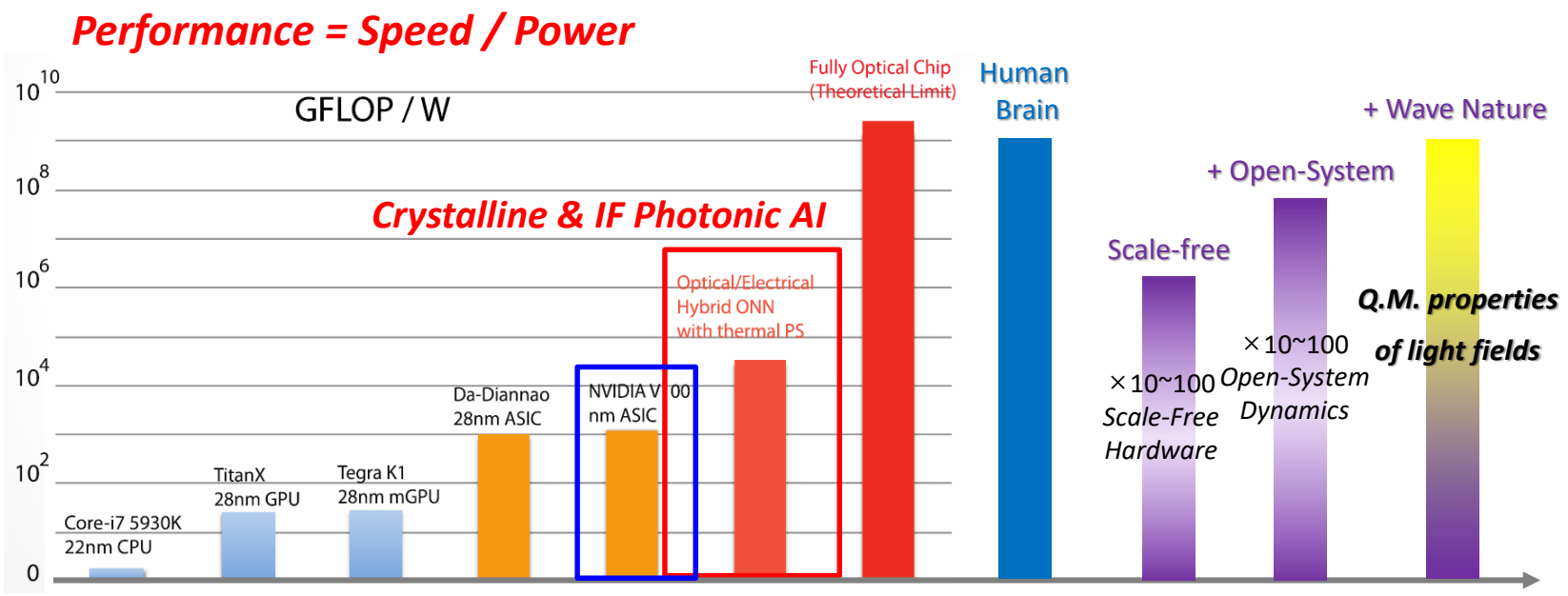
Hodgkin-Huxley (HH) model



= Electrical Open System
with *competing nonlinear channels*



Photonic AI versus *Electronic AI & Human Brain*

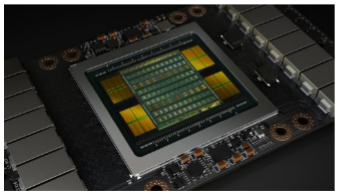


Y. Shen *et al.* Nat. Photon. (2017)

http://www.digicortex.net/

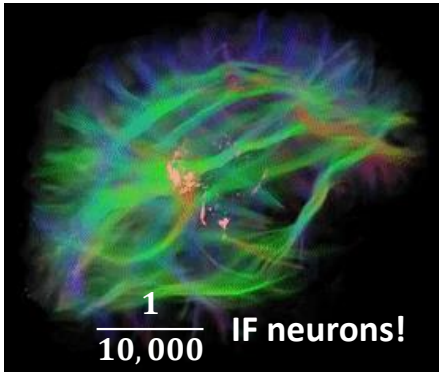
DigiCortex NVIDIA V100 ("Volta") Update: 12.7M Neurons Simulated in Real-time on 8x V100 GPU

Submitted by idimkovic on Thu, 10/26/2017 - 15:47

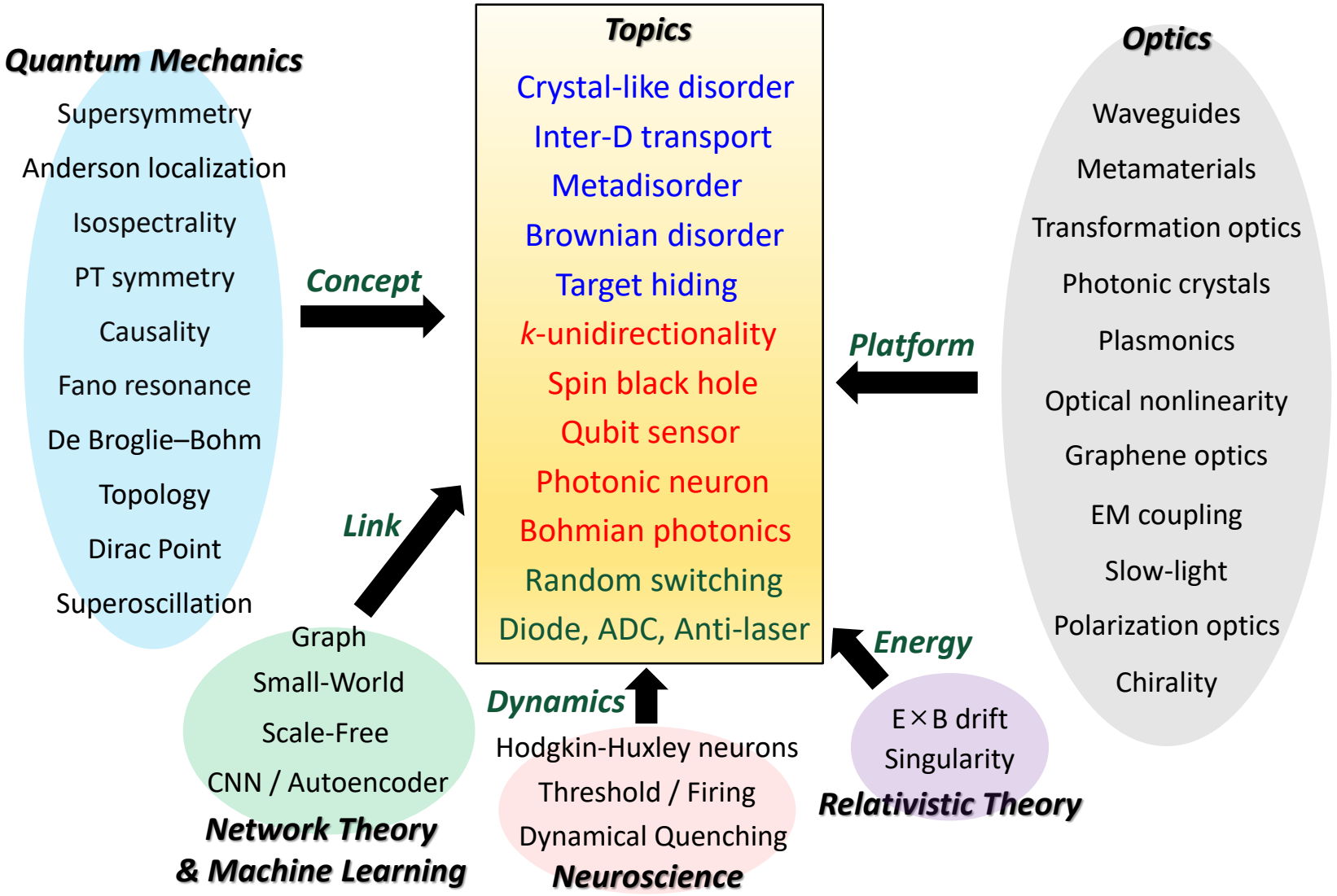


NVIDIA Volta has just been made available to wide public through AWS. We have tested DigiCortex v1.22 on a 8x NVIDIA V100 system and achieved real-time simulation performance of 12.6 million neurons and 431 million synapses, which is almost 3x speedup compared to K80!

Tags:
DigiCortex NVIDIA NVIDIA Volta V100 Tesla GPU CUDA Benchmark



Multidisciplinary Perspective on Photonics



Current / Future *Collaborations*

Prof. C.-W. Qiu

NUS
Disordered Photonics
Citation ~ 14,000

Prof. N. Park

SNU
B.E. / Ph. D. Supervisor
Citation ~ 9,000

Prof. B. Min

KAIST
Non-Hermitian Photonics
Citation ~ 4,300

Prof. J. Shin

KAIST
Non-Hermitian Photonics
Citation ~ 2,400

Prof. Y. Chong

NTU
Topological Photonics
Citation ~ 9,000

Prof. C. Lienau

Oldenburg
Nonlinear Photonics
Citation ~ 9,200

Prof. M. Jang

KAIST
Non-Hermitian Photonics
Citation ~ 1,700

Prof. S. Torquato (Late)

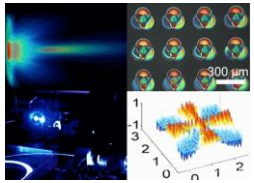
Princeton
Disordered Photonics
Citation ~ 41,000

Prof. J. H. Shin

KAIST
Disordered Photonics
Citation ~ 3,000

Collaborations

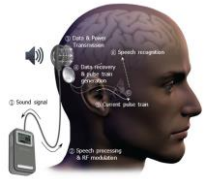
Photonics / Display



High-Power Laser for Photonic Neuron

Hyperuniform Display / Solar Cell

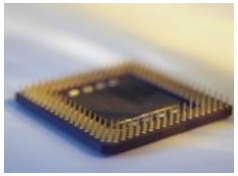
Semiconductor / AI



Hybrid Photonic NNs

Photonic Spiking NN

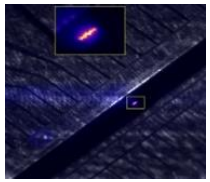
Wireless & RF



RF AI structure with 3D printing

PT symmetry for Wireless Power Transfer

Quantum Electronics



ML-design QM platforms

Open-System Qubit Devices

Future Collaborations: *SNU ECE*

Thank You for Your Attention!