

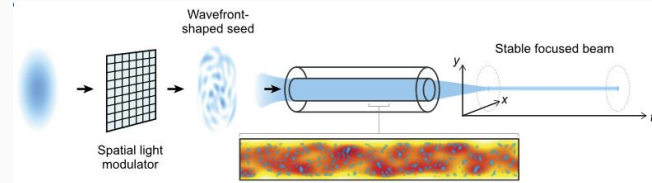
# Optics / Nanophotonics Physics research at Yale AP



A. Douglas Stone

## Complex and non-linear optical systems

- Laser theory and complex micro/nano lasers
- Quantum/wave chaos, random matrix theory
- Classical/Quantum optics in complex media
- Control of light propagation in random media
- Quantum measurement and control



Chen *et al.*, *PNAS* **120** (2023)

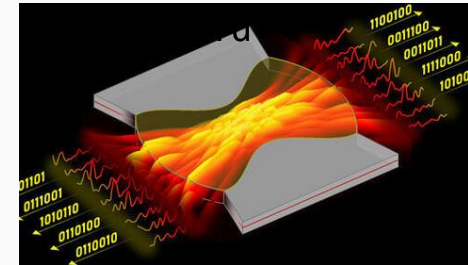


Hui Cao

## Complex light and lasers

Light transport, absorption, amplification, lasing in:

- Disordered or partially disordered nanostructures
- Wave-chaotic microcavities
- Multi-mode fiber with random mode mixing



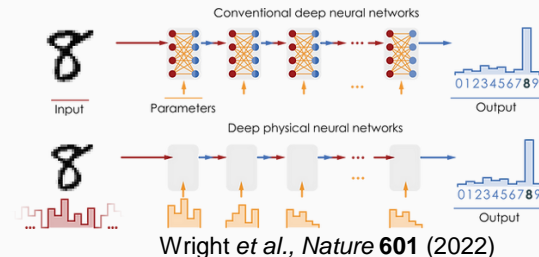
Kim *et al.*, *Science* **371** (2021)



Logan Wright

## Photonic computation, control, and complexity

- Physical and quantum neural networks
- Multimode quantum and nonlinear photonics
- Automated experimental discovery and control



Wright *et al.*, *Nature* **601** (2022)



Simon Mochrie

## Optical probes of biological interactions

- Optical tweezers (flow-forces, magnetic)
- STED microscopes
- DNA condensation
- Protein degradation

Simon Mochrie Among Scientists Named  
Allen Distinguished Investigators

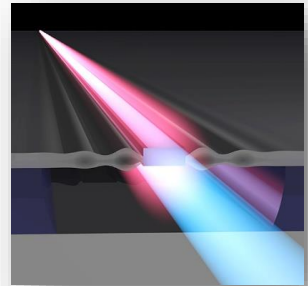


Peter Rakich

## Mixing Light and Sound for Classical and Quantum Applications

Light transport, absorption, amplification, lasing in:

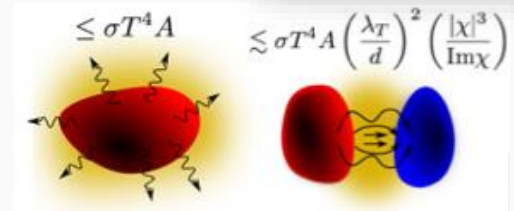
- Silicon Brillouin Photonics
- Bulk Crystalline optomechanics
- Hybrid superconducting qubits



Owen Miller

## Theory and design in nanophotonics

- Fundamental limits: what is possible?
- Large-scale inverse design
- Technology: energy-conversion devices, AR/VR, metalenses, analog computing, etc.

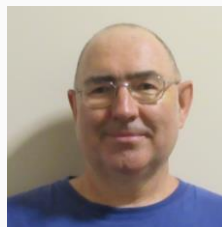


*Near-field “blackbody” (PRX 2019)*

## Applied Physics



A. Douglas Stone



Simon Mochrie (Phys / AP)



Peter Rakich



Hui Cao



Owen Miller



Logan Wright

## Physics



Jack Harris



David Moore



Nir Navon

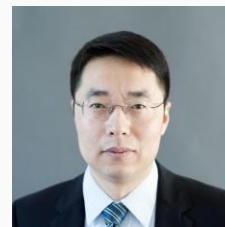


Charles Brown

## EE



Hong Tang



Fengnian Xia



Mengxia Liu



Cristina Rodriguez

## BME

## Math

John Schotland

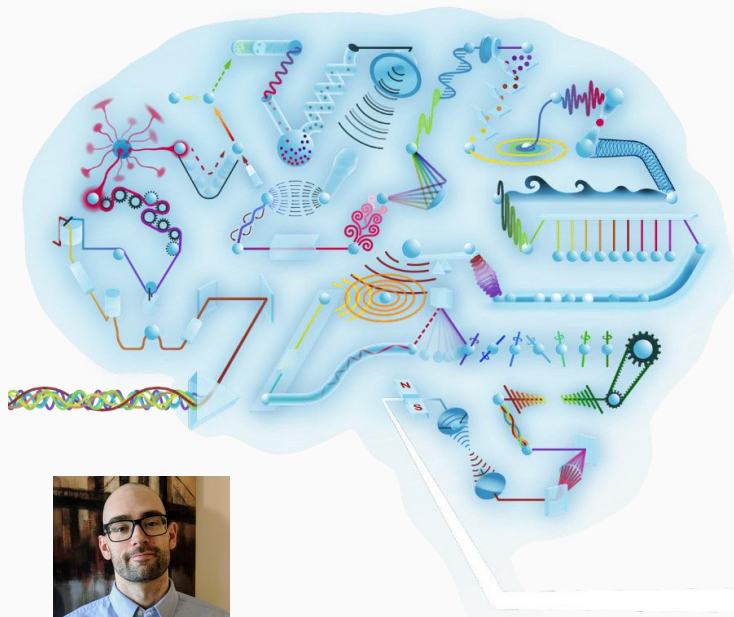


## MEMS

Diana Qiu

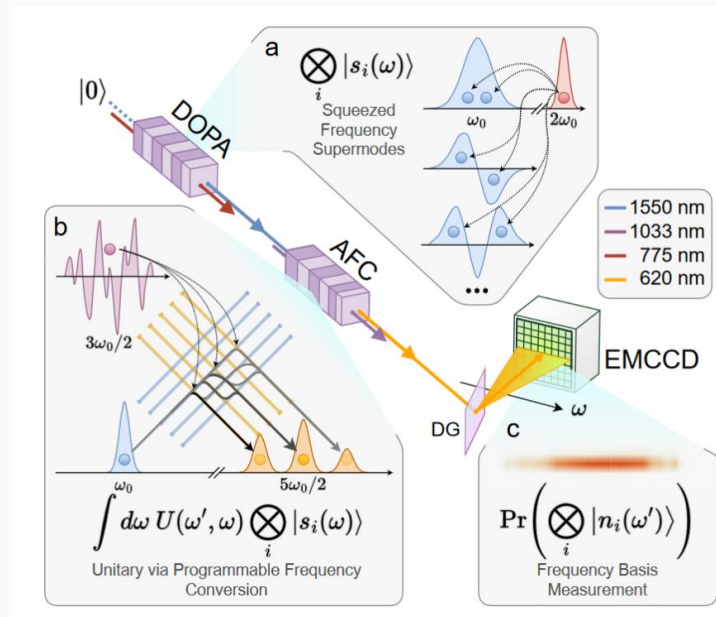
# Some recent highlights

Training networks of physical systems to perform computations like neural networks

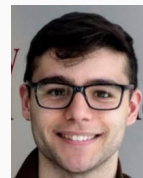


Wright\*, Onodera\* et al., Nature (2022)

HUUUUGE Hilbert spaces with nonlinear ultrafast quantum optics



With  
Federico Presutti,  
Shiyuan Ma  
&  
Peter McMahon,  
Cornell

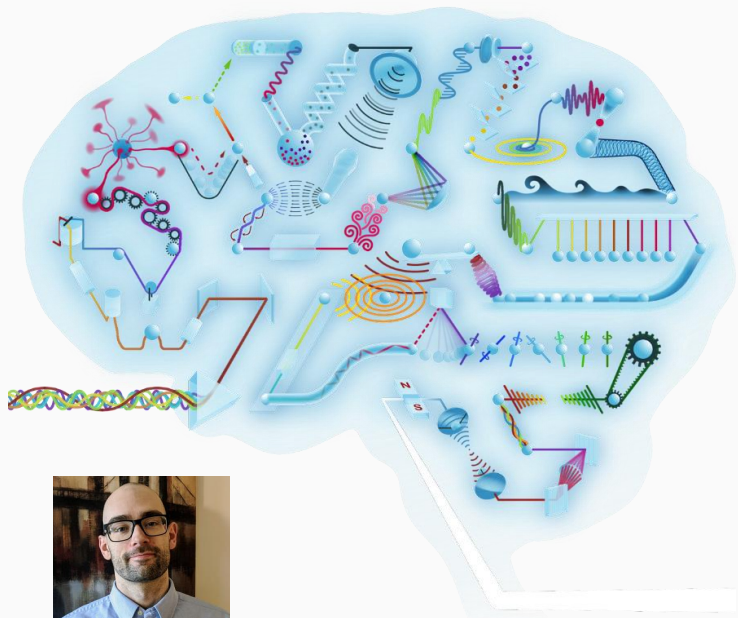


Presutti, Wright et al., in preparation



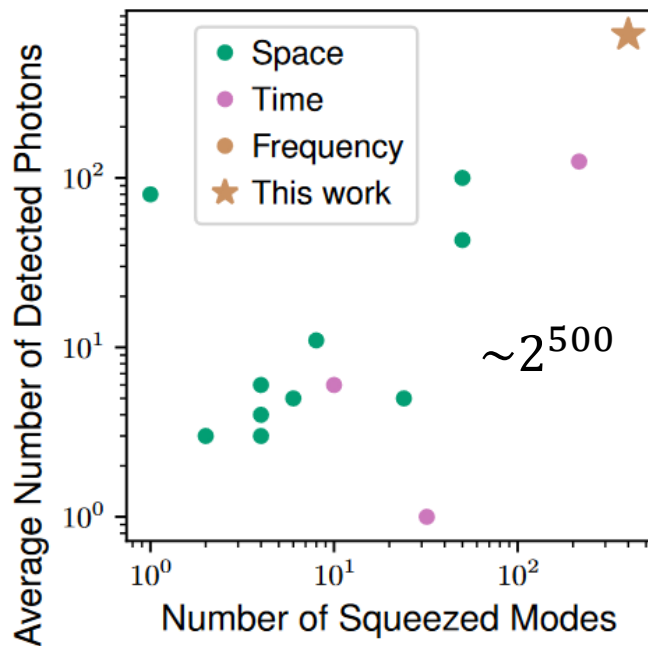
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Wright\*, Onodera\* et al., Nature (2022)

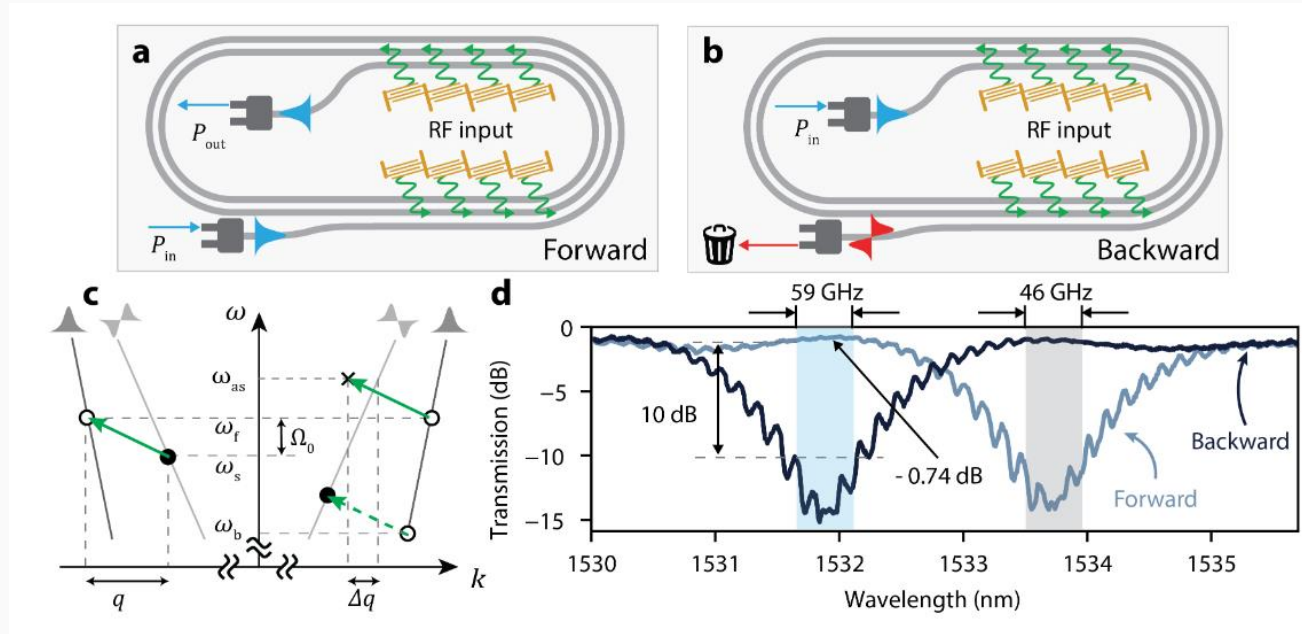
HUUUUGE Hilbert spaces with nonlinear ultrafast quantum optics



With  
Federico Presutti  
&  
Peter McMahon,  
Cornell

# Some recent highlights

## World-record silicon-chip optical isolator!



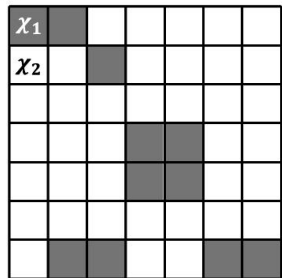
Hot from the lab: Zhou, Yishu, et al. "Intermodal strong coupling and wideband, low-loss isolation in silicon." CLEO: Science and Innovations. Optica Publishing Group, 2023.

# Some recent highlights

Applied math to completely upend photonic inverse design  
(Convert hard problems into ~convex ones by enforcing local conservation laws!)

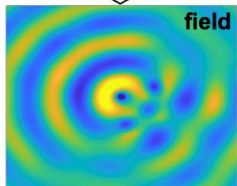
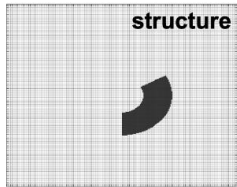


(a) **specific design**

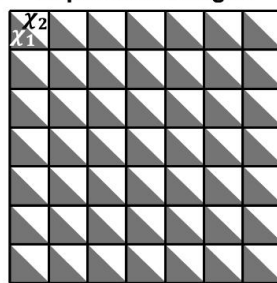


$$[\mathbb{L}(\chi_1)\psi - \xi]_i = 0 \text{ if } \chi_i = \chi_1$$

$$[\mathbb{L}(\chi_2)\psi - \xi]_i = 0 \text{ if } \chi_i = \chi_2$$

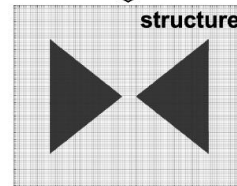
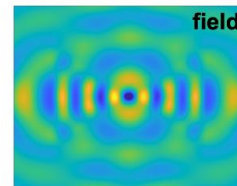


(b) **all possible designs**



at all points:

$$[\mathbb{L}(\chi_1)\psi - \xi]_i^* [\mathbb{L}(\chi_2)\psi - \xi]_i = 0$$



A few additional thoughts: A PhD should be an amazing ~6 years of your life

### Yale:

- Yale Sciences is “quality over quantity”. When normalized for  $N_{\text{grad students}}$ , Yale’s performance in any key research or post-grad metric is  $\geq$  virtually all peers



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→E.g.  $P(\text{Publishing in Science/Nature})$  [1] and  $P(\text{Becoming a professor})$  [2] among highest in world

[1] Based on 2022 and 2023 “Nature Index” normalized to PSE PhD student population\*

[2] Based on data from 2011-2020, normalized to PhD student population, from Wapman, K. H., Zhang, S., Clauset, A., & Larremore, D. B. (2022). Quantifying hierarchy and dynamics in US faculty hiring and retention. *Nature*, 610(7930), 120-127.\*

\*Obviously, these are crude and limited metrics; I include them solely because they are concrete and interpretable

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## Some of our great mentors (and scientists)!



Yiwen Chu  
→ ETH Zurich



Valla Fatemi  
→ Cornell



William Renninger  
→ Rochester  
(Adolph Lomb  
Medal 2023!!)

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- $|\text{Yale AP}\rangle \approx \frac{1}{\sqrt{2}} [|\text{Experiment}\rangle + |\text{Theory}\rangle]$  in a way I have not encountered anywhere else

$$\frac{1}{\sqrt{2}}[|\text{Experiment}\rangle + |\text{Theory}\rangle]$$



Collaborations include:

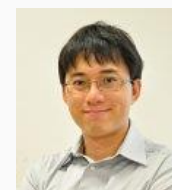
- The “Anti-laser”
- Random lasers
- Efficient focusing through biological tissue
- World-record fiber lasers? (In progress)



Hakan Tureci  
→ Princeton



Chia-Wei Hsu  
→ USC



Yidong Chang  
→ NTU



Stefan Rotter  
→ TU Wien



$$\frac{1}{\sqrt{2}}[|\text{Experiment}\rangle + |\text{Theory}\rangle]$$

## Puri awarded Landaur and Bennett award in Quantum Computing from American Physical Society



October 24, 2023

[Shruti Puri](#), assistant professor in applied physics and physics, received the [Rolf Landauer and Charles H. Bennett Award in Quantum Computing](#), which recognizes recent outstanding contributions in quantum information

science, especially using quantum effects to perform computational and information-management tasks that would be impossible or infeasible by purely classical means. She earned the award,

“For advancing the theoretical understanding of quantum fault-tolerance in the presence of biased noise.”



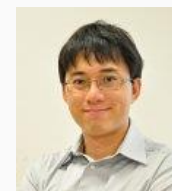
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Yidong Chang  
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→ TU Wien

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## Yale + New Haven Area:

- Fantastic diversity of people, and places to live and visit nearby; from forests and hiking, to beaches, to chill suburb to Downtown
- Walking & biking & dog friendly
- Yale's stipend and benefits are extremely high relative to costs
- "Elm city" – Green in town and all around

