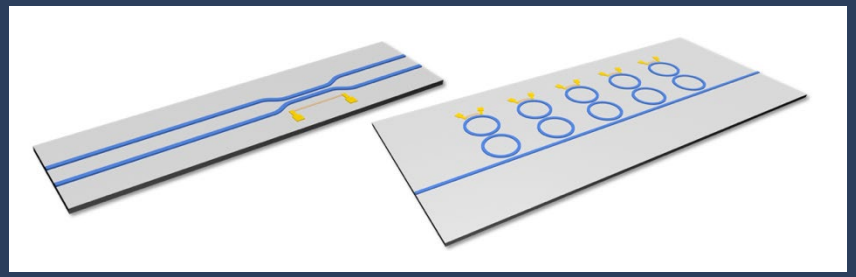
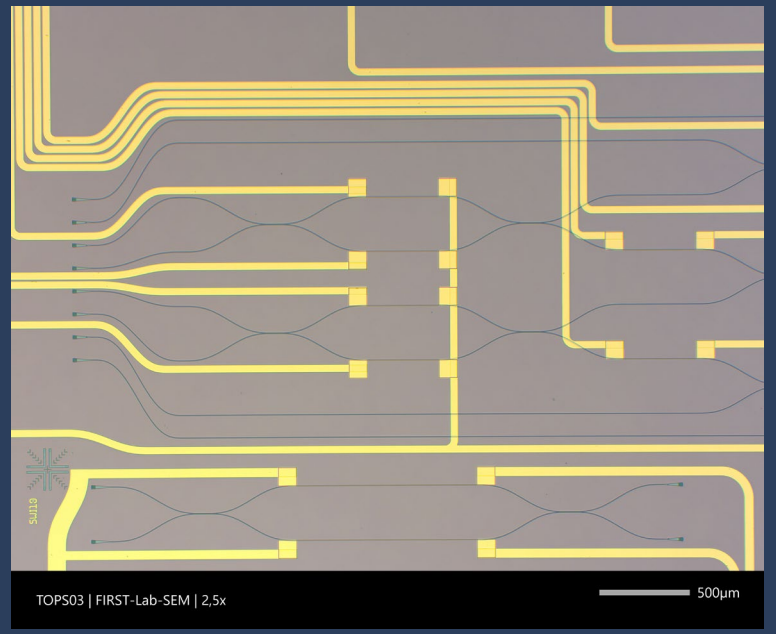
LION
Kick-off

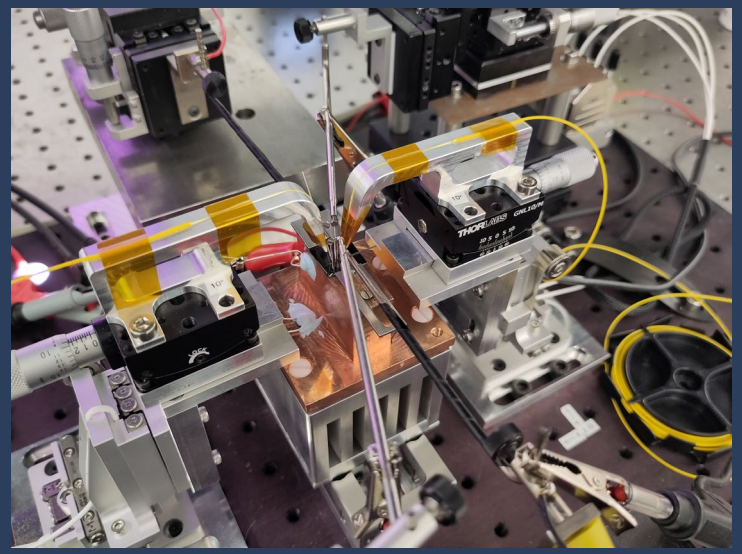


Rachel Grange

ETH Zurich
Department of Physics
Institute for Quantum Electronics
Optical Nanomaterial Group

www.ong.ethz.ch
grange@phys.ethz.ch
@rachel_grange





The Optical Nanomaterial Group ONG


Robert Chapman


Giovanni Finco


Sara Gasser


Franciele Henrique

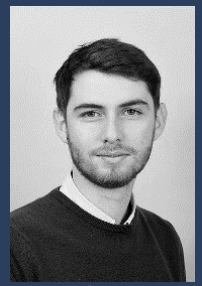

Artemis Karvounis


Fabian Kaufmann


Gaoyuan Li


Andreas Maeder

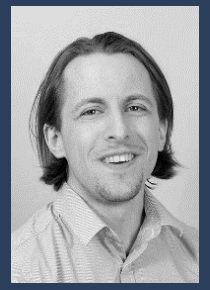

Alfonso Martinez


Andrea Morandi


Jost Kellner


Marc Reig Escalé

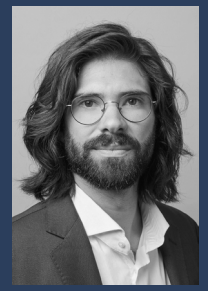

Alessandra Sabatti

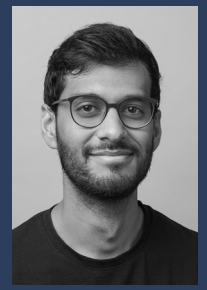

Grégoire Saerens


Ülle-Linda Talts


Sissi Wang


Helena Weigand


Alfonso Nardi


Prakhar Jain


Tristan Kuttner

Alumni: A. Sergeyev, N. Hendricks, C. Renaut, B. Jordaan, F. Richter, M. Timofeeva, F. Timpu, R. Savo, J. Mueller, W. Qiu, Hanh Duong, Viola Vogler-Neuling, David Pohl

Funding

FNSNF Fonds national suisse Schweizerischer Nationalfonds Fondo nazionale svizzero Swiss National Science Foundation

State Secretariat for Education, Research and Innovation SERI Swiss Space Office

SPACE INNOVATION

BRIDGE

esa

MARIE CURIE ACTIONS

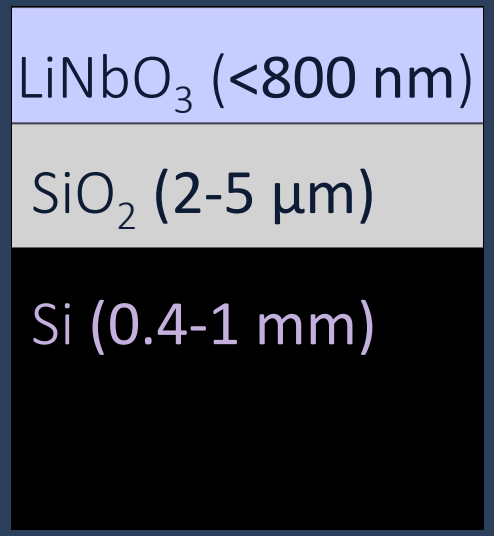
erc European Research Council Established by the European Commission

How small $\chi^{(2)}$ materials can be?

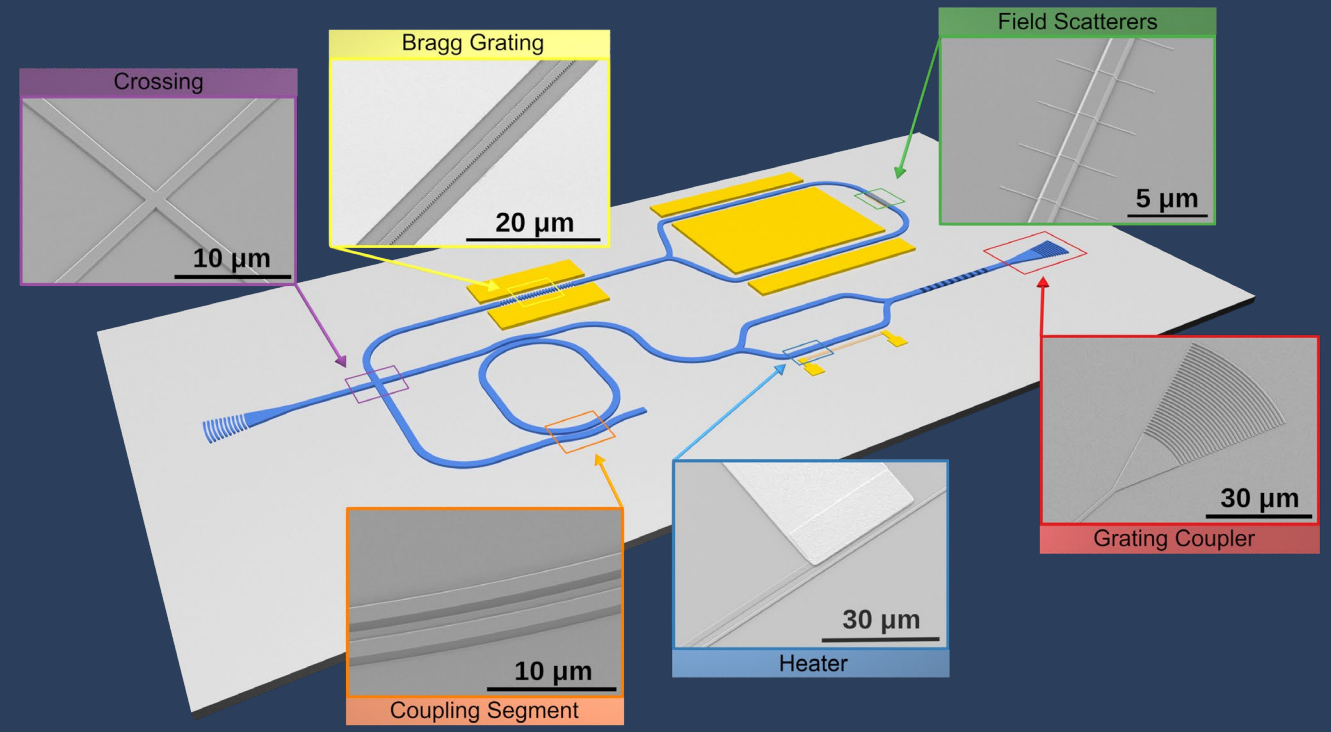
Top-down fabrication

Bulk crystals

Thin films



Rabiei, P.; Gunter, P. *Applied Physics Letters* **2004**, *85* (20).

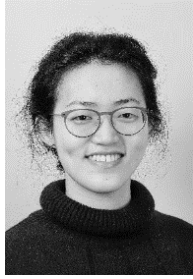


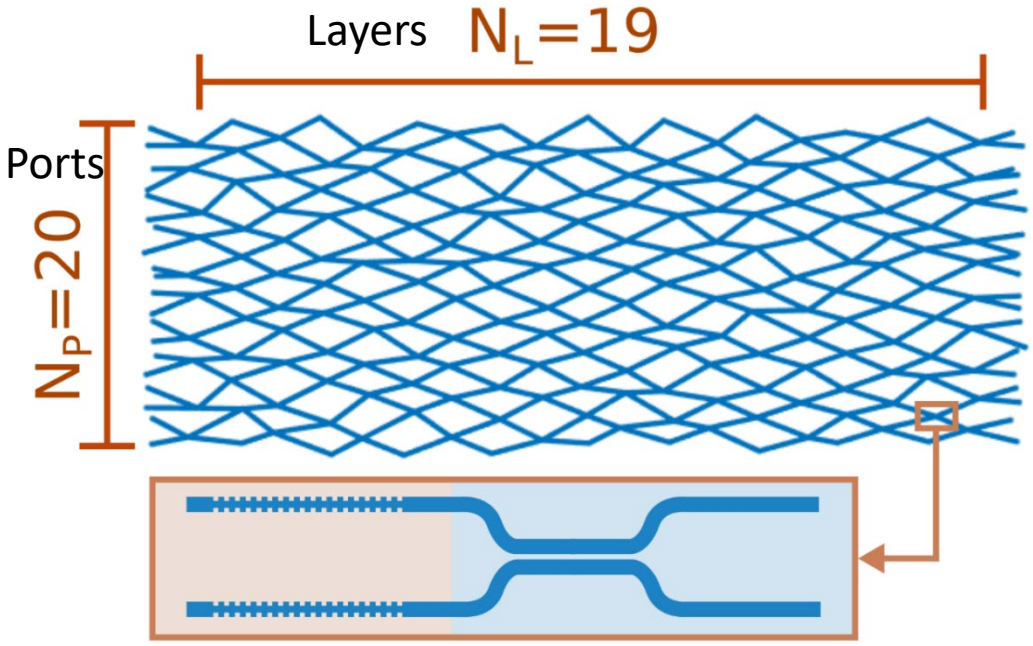
Pohl et al. Nat. Photonics, 2020
Weigand, et al. ACS Photonics, 8, 10, 2021
Maeder et al. Opt. Letters 2022

Lithium niobate ($LiNbO_3$)

Possible alternative for tunable linear interference layer

Sissi Wang

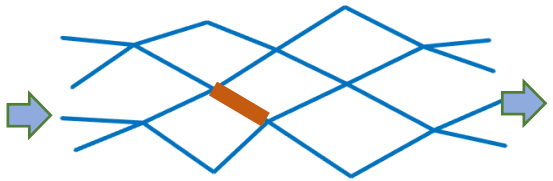


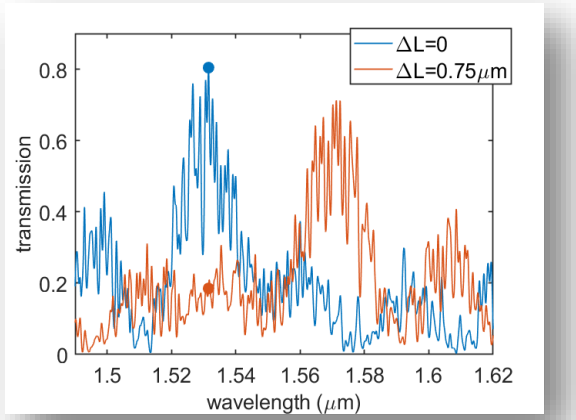


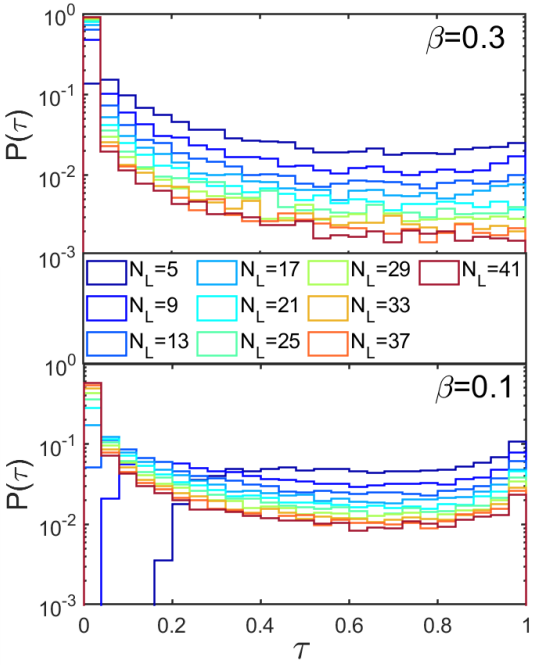
Wang , Savo et al. arXiv 2306.15483

Integrated network structures of LNOI waveguides connecting scattering nodes

- Backscattering is introduced at the nodes to go from unidirectional to multiple scattering
- Randomised geometry to mimic random media
- Reproduces common transmission features of random media (e.g. transmission eigenspectrum)



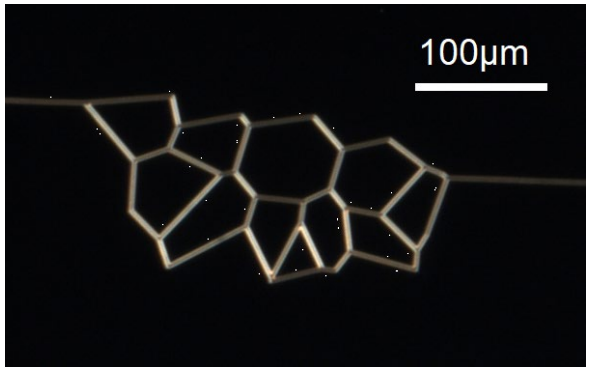


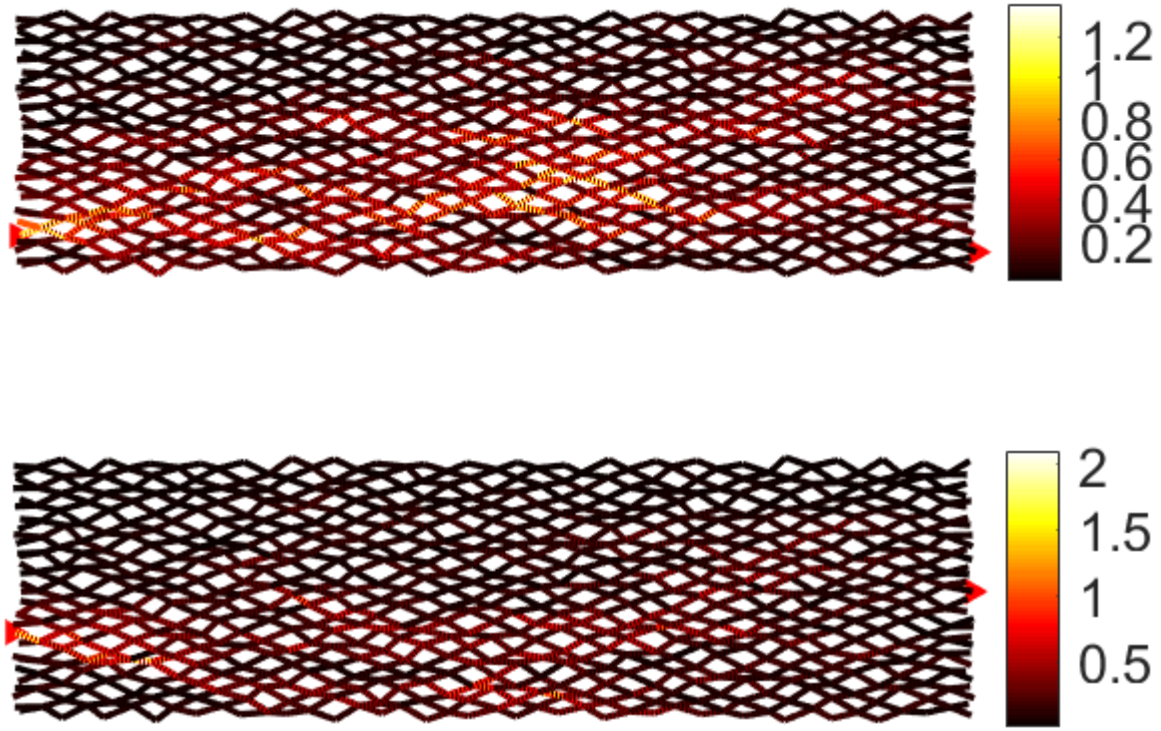


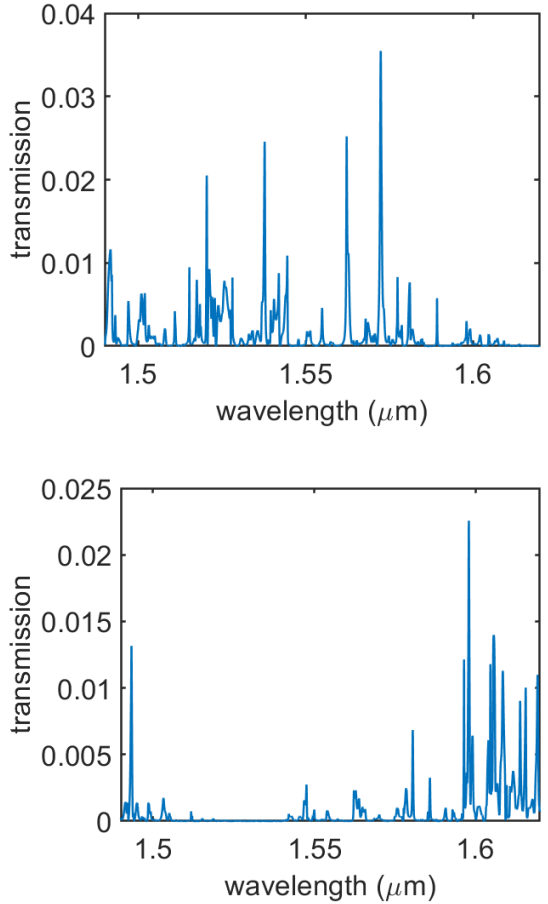
Tradeoffs

- Much lower dimension than 3D scattering media
- Full control over transmission matrix and electro-optic tuning capabilities
- Easy integration with other integrated systems

Possible alternative for tunable nonlinear network







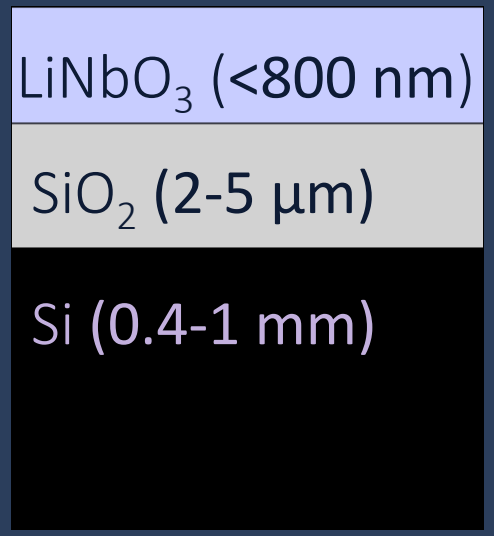
- Variable transmission spectra based on network geometry, waveguide parameters, and selected ports
- Possibility have a network of nonlinear waveguides, with a certain degree of control with EO or TO effect.

How small $\chi^{(2)}$ materials can be?

Top-down fabrication

Bulk crystals

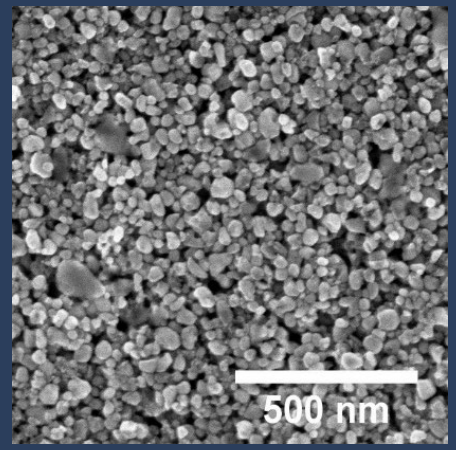
Thin films



Rabiei, P.; Gunter, P. *Applied Physics Letters* **2004**, *85* (20).

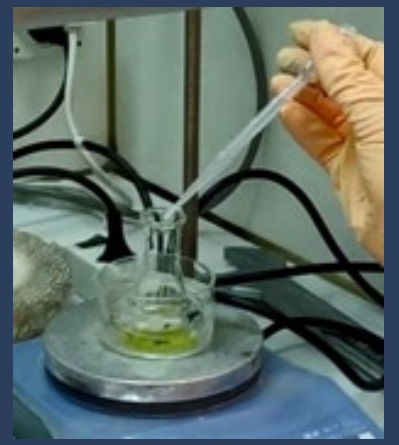
Bottom-up fabrication

Nanoparticles



Kim et al. ACS Nano **2013**, 7 (6).

Sol-gel

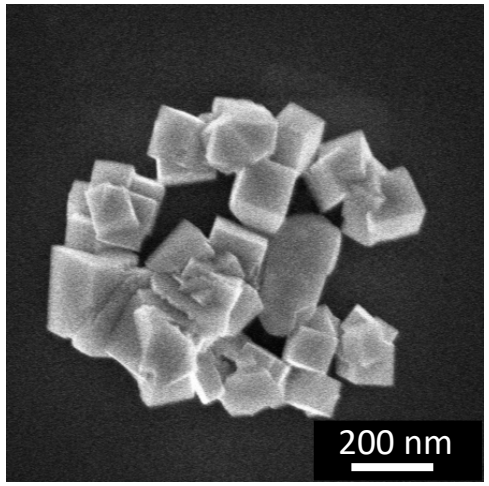


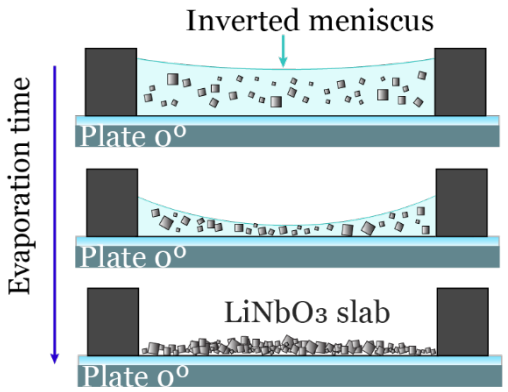
Polymers

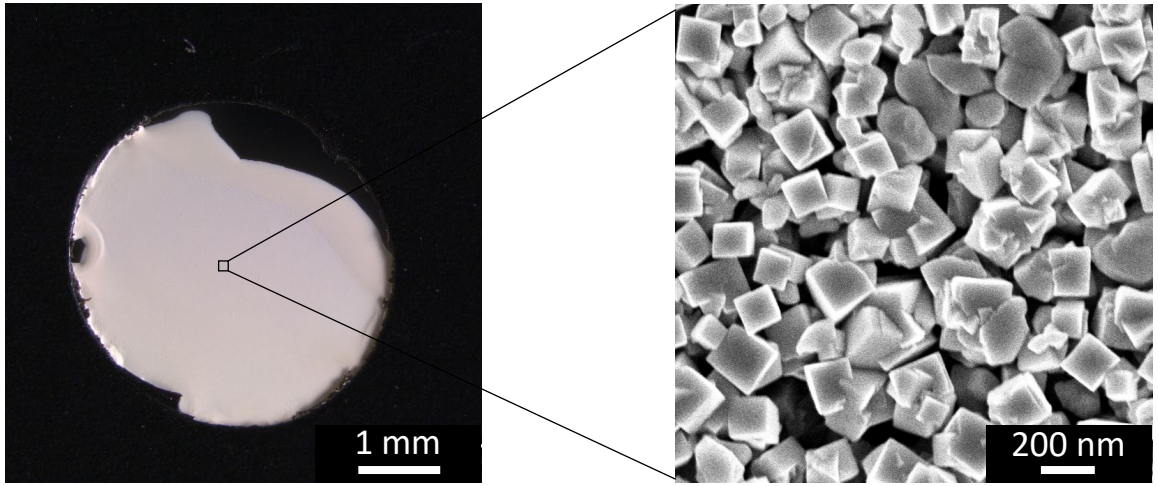
Benea-Chelmus et al. Nature Comm., 2022

- Barium titanate ($BaTiO_3$)
- Lithium niobate ($LiNbO_3$)
- GaAs nanowires

Lithium niobate nano-cubes for nonlinear and disordered slabs





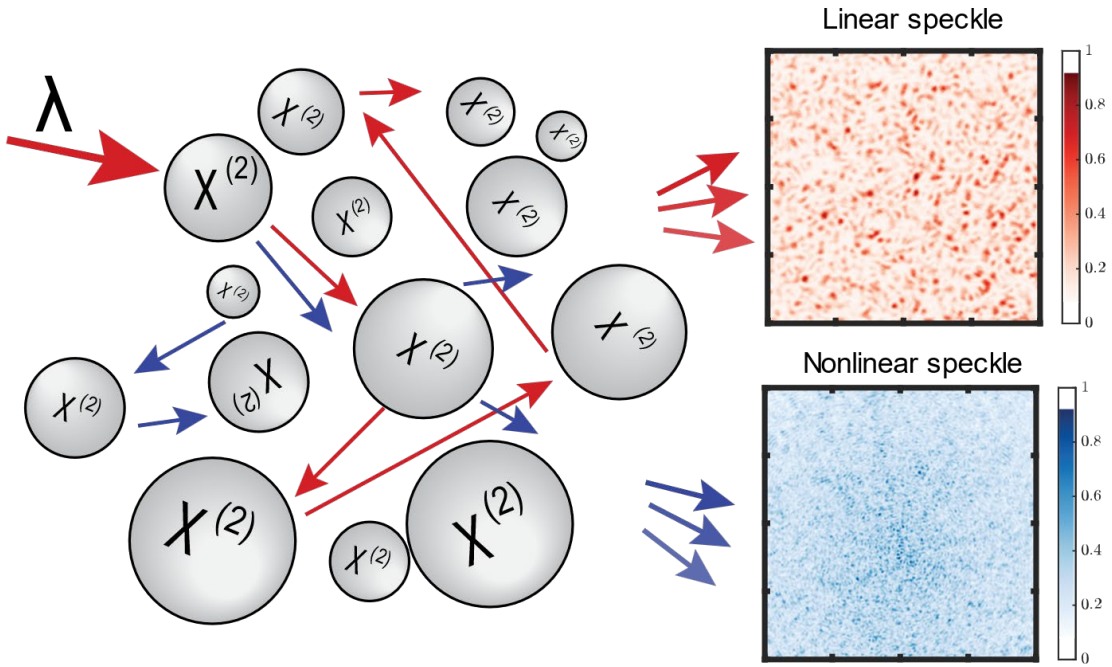


Bottom-up fabrication of complex and nonlinear material

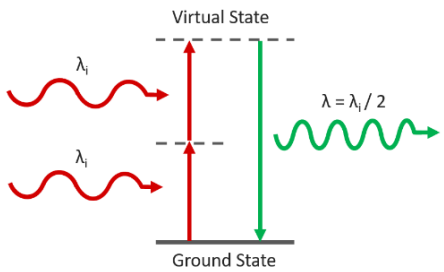
- Nanocubes (100-400 nm) of $LiNbO_3$ high scattering and second-harmonic generation
- Slabs with transport mean free path < 1 um
- Nonlinear generation with random quasi-phase matching

Alfonso Nardi

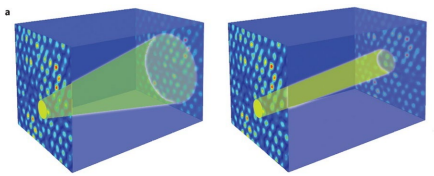
Andrea Morandi



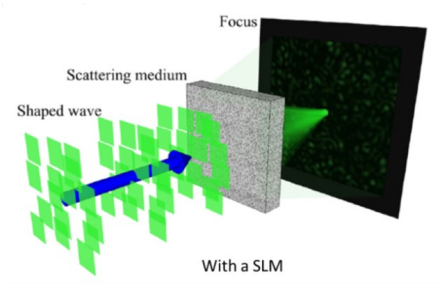
Input laser at wavelenght λ is scattered and converted to λ/2 by the nonlinear nanoparticle.
Asample measurement of the resulting speckle patterns is shown on the right.



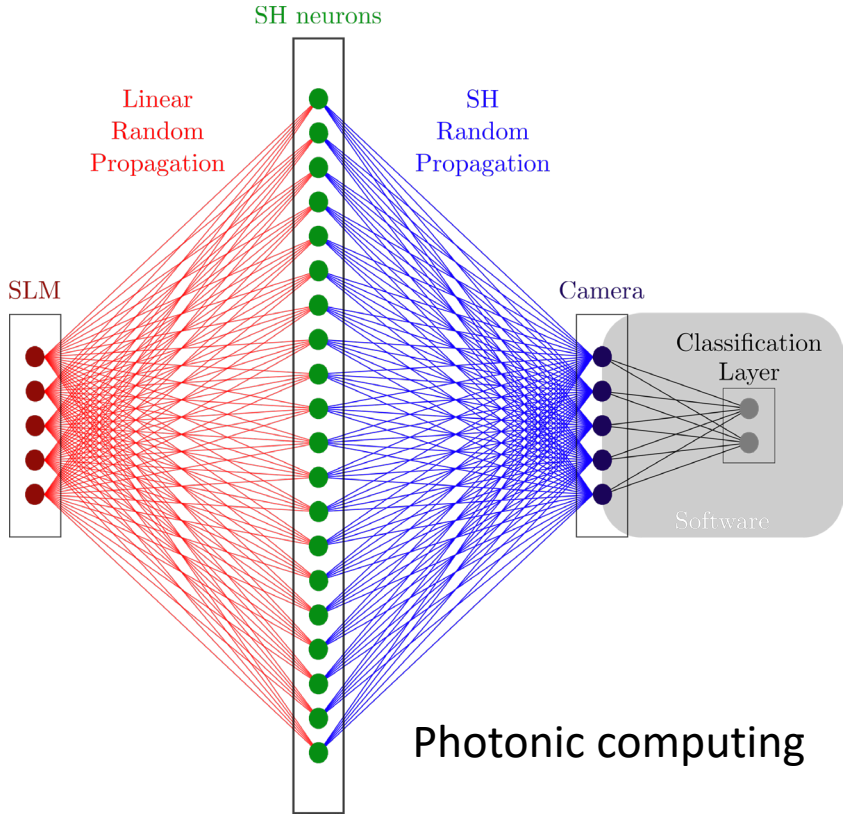
Broad-band second harmonic generation



Mesoscopic effects



Nonlinear scattering control

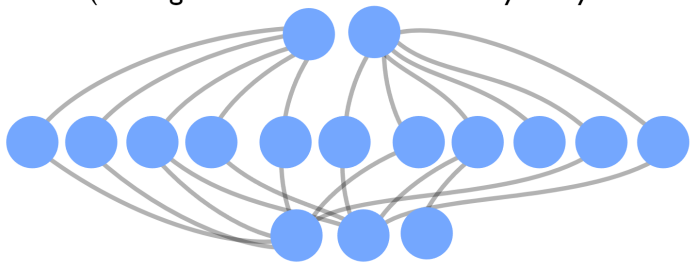


Photonic computing

One huge layer (10^5 neurons)

Any arbitrary (smooth) function (with vector input and vector output) can be approximated as well as desired by a neural network with a single (!) hidden layer.

(as long as we allow for sufficiently many neurons)



"Approximation by superpositions of a sigmoidal function", by George Cybenko (1989)