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High speed Optical Communication systems Research in Brazil

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PHOTONICS RESEARCH CENTER

FOTONICOM

National Institute of Photonics and Optical Communications

Hugo E. Hernández Figueroa

Applied and Computational Electromagnetics Group
School of Electrical and Computer Engineering
University of Campinas – Brazil

Laboratório de Eletromagnetismo Aplicado e Computacional
LEMAC

BRICS Meeting – October 13, 2020

Brazilian Institutions (23) acting in **Optical Communications**

- Federal University of Ceara
- Federal U. of Pernambuco
- Federal University of Bahia
- Federal U. of Espirito Santo
- Pont. Cath. U. of R de Janeiro
- Federal University Fluminense
- Telecom Res. Center (CPqD)
- University of Campinas
- University of São Paulo
- Federal IT Center
- Tech. Institute of Aeronautics
- Mackenzie University
- State University of São Paulo
- Federal U. of ABC
- Pont. Catholic U. of Campinas
- Padetec
- BRPhotonics
- Idea!
- Federal Tech. U. of Parana
- Federal University of Para
- University of Brasilia
- Fed. U. of Minas Gerais
- CEITEC Foundry

Fed. Republic of Brazil

- **26 States**
- **1 Federal District: Brasilia (Capital)**
- **5 Regions**

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(Institutions: 12 Brazilian and 2 International)

- Federal U. of Para
- University of Brasilia

- Columbia University, USA
  Michal Lipson's Group

- Nokia Bell Labs, USA
  Andrew Chraplyvy's Group

- Federal University of Ceara
- Federal University of Bahia
- Federal U. of Pernambuco

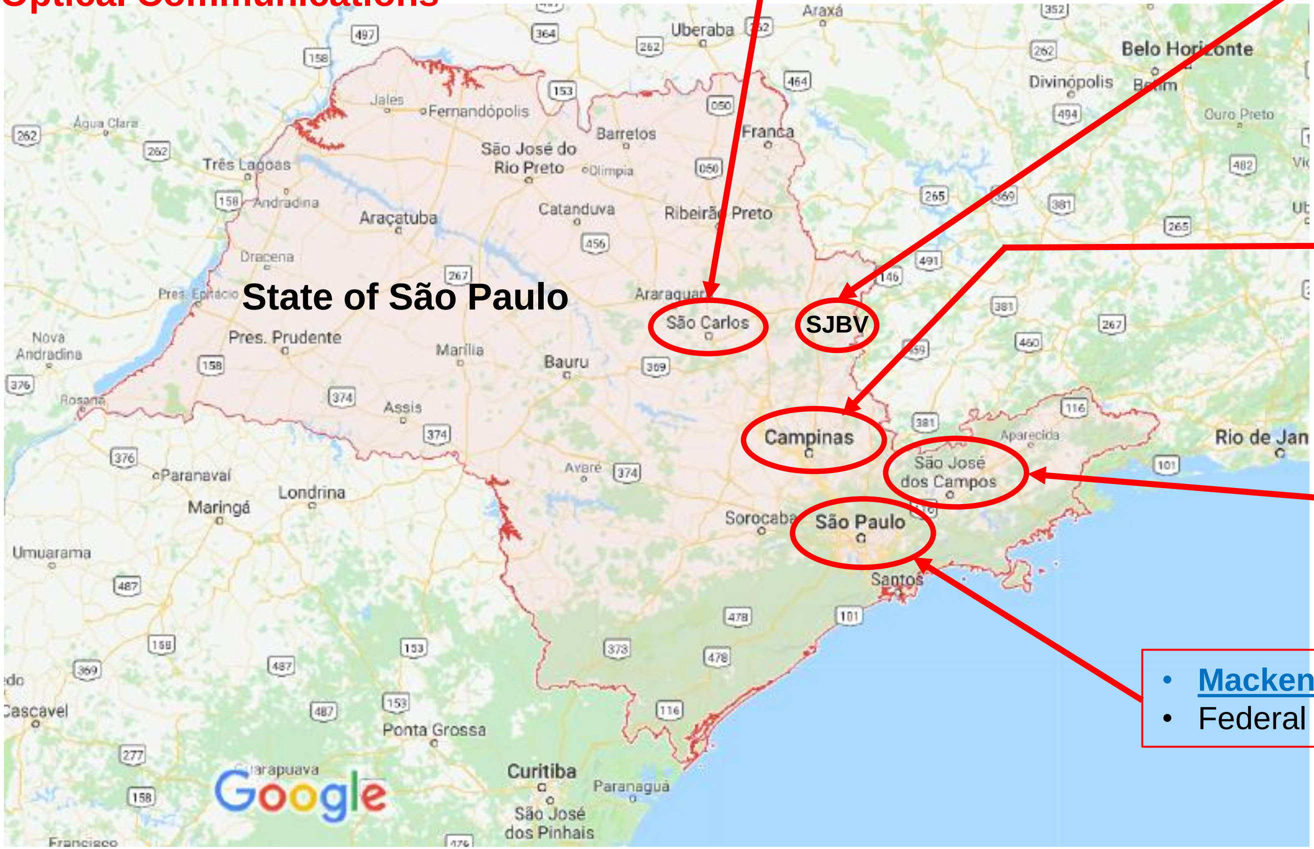
- Telecom Res. Center (CPqD)
- **University of Campinas**
- Tech. Institute of Aeronautics
- Pont. Catholic U. of Campinas
- State University of São Paulo
- BRPhotonics

- Federal Tech. U. of Parana

Institutions in the State of São Paulo (12) acting in **Optical Communications**

- University of São Paulo (São Carlos Campus)

- State University of São Paulo (São João da Boa Vista Campus)



- Telecom Res. Center (CPqD)
- University of Campinas
- Federal IT Center (CTI)
- Pont. Catholic U. of Campinas
- Padetec
- BRPhotonics
- Idea!

- Tech. Institute of Aeronautics

- Mackenzie University
- Federal U. of ABC

Distance between the cities of São Paulo and Campinas: about 100 Km

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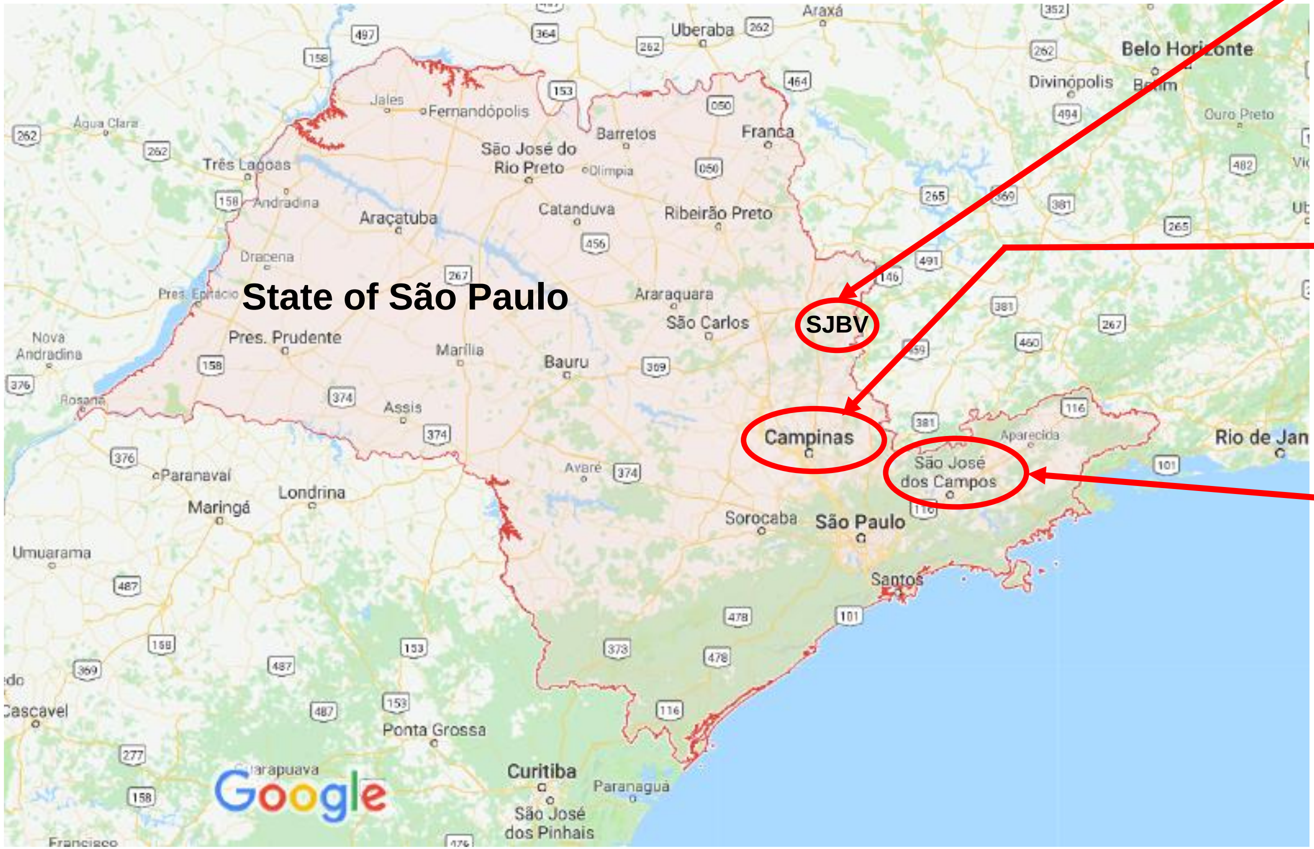
(Institutions in the State of São Paulo: 6)

- State University of São Paulo (São João da Boa Vista Campus)



- **Telecom Res. Center (CPqD)**
- **University of Campinas**
- Pont. Catholic U. of Campinas
- **BRPhotonics**

- **Tech. Institute of Aeronautics**

Distance between the cities of São Paulo and Campinas: about 100 Km

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PHOTONICS RESEARCH CENTER at
University of Campinas (UNICAMP)
Inaugurated in August 2018

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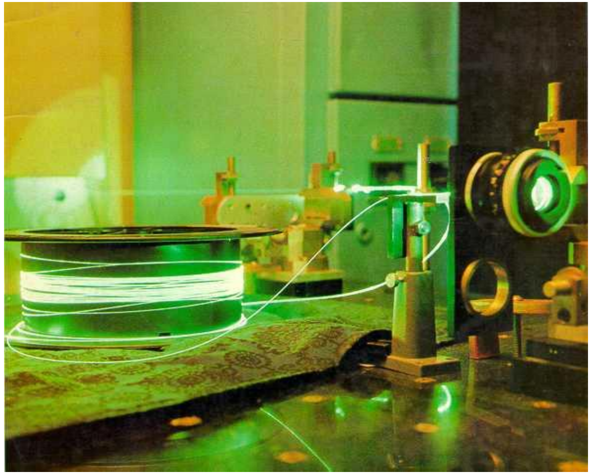
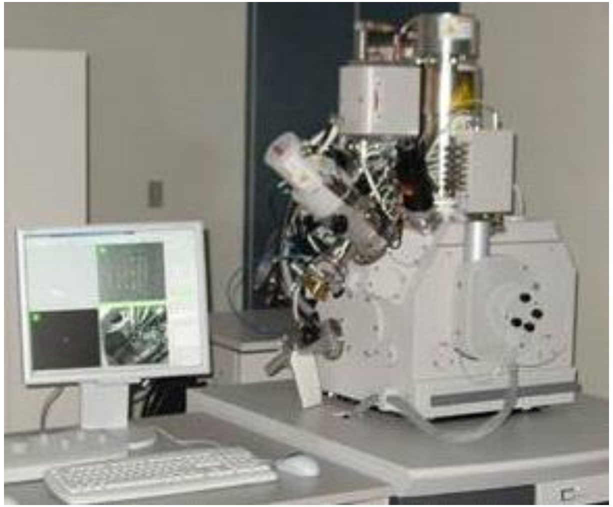
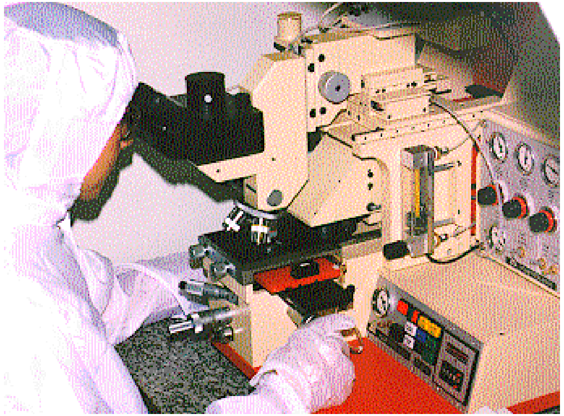
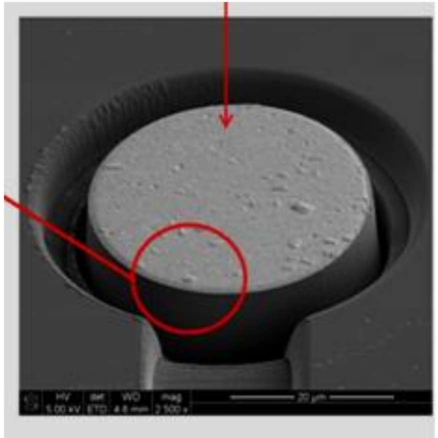
PHOTONICS RESEARCH CENTER at University of Campinas (UNICAMP)

* Optical Communications Labs
* Photonic Devices Characterization Labs



UNICAMP's Labs

Semiconductor Component Center for Nanotechnology (CCS-Nano):
Fabrication Labs for Photonic and Microwave Integrated Devices

Dual FIB (Focused Ion Beam), electron beam lithography,
SoI, SiN and III-V fabrication platforms

FOTONICOM's RESEARCH LINES

Our main goal is to develop the devices and techniques to allow data transmission at rates of 1 Tb/s and beyond with focus on industry-ready prototypes.

FOTONICOM project is divided into four research lines:

- Devices-Phenomena (DEP);
- Devices-Applications (DEA);
- Systems (SYS); and
- Networks (NET).

Each one has a leader responsible for the coordination of the groups and institutions in collaboration under that line; this structure is presented next.

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Research Line	Leader	Member	Institution
Devices-Phenomena (DEP)	Newton Cesário Frateschi UNICAMP-IFGW	Gustavo da Silva Wiederhecker	UNICAMP-IFGW
		Thiago Pedro Mayer Alegre	UNICAMP-IFGW
		Lázaro Aurélio Padilha Jr.	UNICAMP-IFGW
Devices-Applications (DEA)	Hugo Enrique Hernandez Figueroa UNICAMP-FEEC	Lucas Heitzmann Gabrielli	UNICAMP-FEEC
		Paulo Clóvis Dainese Jr.	UNICAMP-IFGW
		Vitaly Felix Rodriguez Esquerre	UFBA
		Júlio César Rodrigues F. de Oliveira	BrPhotonics
		Michal Lipson	Columbia University
Systems (SYS)	Evandro Conforti UNICAMP-FEEC	Aldário Chrestani Bordonalli	UNICAMP-FEEC
		Cristiano de Mello Gallep	UNICAMP-FT
		Darli Augusto de Arruda Mello	UNICAMP-FEEC
		Júlio César Rodrigues F. de Oliveira	BrPhotonics
		Juliano Rodrigues Fernandes de Oliveira	CPqD
		Andrew Chraplyvy	Bell Labs
Networks (NET)	Nelson Luis Saldanha da Fonseca UNICAMP-IC	Christian Esteve Rothenberg	UNICAMP-FEEC
		Gustavo Bittencourt Figueiredo	UFBA
		Joaquim Ferreira Martins Filho	UFPE
		Carmelo José Albanez Bastos Filho	UFPE
		Juliano Rodrigues Fernandes de Oliveira	CPqD

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Across all **4 Research Lines**, our team work in synergy aiming to excel in the following **8 Research objectives**:

1. Modulation **(MOD)** – MOD aims at the next generation **nanophotonic electrooptical modulators** and **advanced modulation formats** for beyond terabit per second integrated transceivers.

2. Optical Signal Processing **(OSP)** – OSP aims to alleviate the processing load required from the electronic systems in high-speed transceivers (especially in the case of coherent receptors) by executing part of the processing in the optical domain with bandwidth and power consumption advantages.

3. Nonlinear Optics **(NLO)** – NLO deals with the advances in nonlinear network devices, in particular with **optical signal amplification and regeneration (includng 2D materials)**, as well as the control of such devices in cascaded configurations on the system and network layers.

4. Photonics Crystals **(PHC)** – The field of photonic crystals promises incomparable functionalities for optical networks in terms of footprint reduction and advanced signal processing. The focus here is to reduce **the scattering losses**, that still prevent the widespread use of this technology, while pushing the limits in asymmetric transmission devices in direct collaboration with OSP.

***5. Spatial Division Multiplexing* (SDM)** – SDM focuses on enabling space division multiplexing in both fiber and free-space optical systems by **developing the necessary devices to couple, process, and discriminate modes in an integrated platform**.

***6. Free Space Optics* (FSO)** – High data rate transmissions must also include the requirements of mobile platforms, where only wireless links can be employed. FSO will focus on the enabling technologies for wireless optical links in NIR for indoor systems as well as chip-to-chip or board-to-board channels (including **photonics antennas in opt. comm. wavelenghts and THz**).

***7. Transport* (TRA)** – TRA deals with the **resource management and spectral allocation in next generation flexgrid networks** with efficient bandwidth utilization and power consumption without compromising the quality of transmission, both in the network and device layers.

***8. Control* (CTL)** – CTL focuses on algorithms and strategies for the reconfiguration of **software defined networks** at the control plane, employing **adaptive, predictive and cognitive actuation** on the operating points of network elements in close synergy with NLO and TRA.

Research objectives *are divided in* ***research topics***.

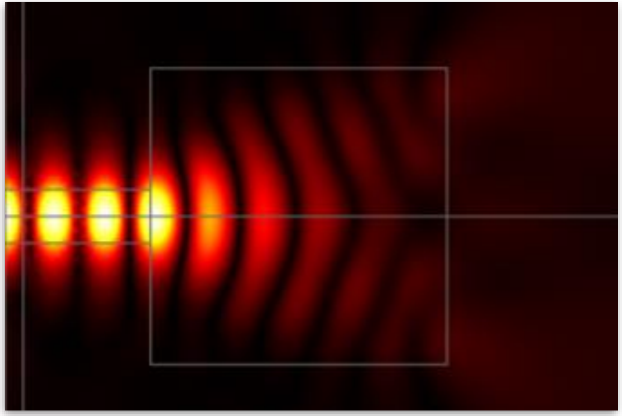
Matrix showing the ***research topics*** linked to each ***research line*** and ***researcher***.

	Institution	Researcher	Research Objectives							
			MOD	OSP	NLO	PHC	SDM	FSO	TRA	CTL
DEP	UNICAMP IFGW	**Newton C. Frateschi**	RSR		SRC1			OMEC2		
DEP	UNICAMP IFGW	Gustavo da S. Wiederhecker		OMEC1						
DEP	UNICAMP IFGW	Thiago P. M. Alegre			COMB					
DEP	UNICAMP IFGW	Lázaro A. Padilha Jr.			MAT					
DEA	UNICAMP FEEC	**Hugo E. H. Figueroa**	MOD1	OFDM2			OAM	ANT		
DEA	UNICAMP FEEC	Lucas H. Gabrielli					COUP	ANT		
DEA	UNICAMP IFGW	Paulo C. Dainese Jr.			PARA	SCA	MMWG			
DEA	UFBA	Vitaly F. R. Esquerre		GATE		ASYM		HYP		
DEA	BrPhotonics	Júlio César R. F. de Oliveira	MOD1							
DEA	Columbia University	Michal Lipson			PARA		COUP			
SYS	UNICAMP FEEC	**Evandro Conforti**	MOD2		SOA		MIMO		TB	
SYS	UNICAMP FEEC	Aldário C. Bordonalli	OFDM1							
SYS	UNICAMP FT	Cristiano de M. Gallep			SOA				TB	
SYS	UNICAMP FEEC	Darli A. de A. Mello					MIMO			
SYS	BrPhotonics	Júlio César R. F. de Oliveira	MOD2							
SYS	CPqD	Juliano R. F. de Oliveira	OFDM1						ROADM TB	
SYS	Bell Labs	Andrew Chraplyvy					OAM MIMO			
NET	UNICAMP IC	**Nelson L. S. da Fonseca**			COG				FLEX	SDN1 SDN2
NET	UNICAMP FEEC	Christian E. Rothenberg								SDN1 SDN2
NET	UFBA	Gustavo B. Figueiredo							FLEX	SDN1
NET	UFPE	Joaquim F. M. Filho			COG				FLEX	
NET	UFPE	Carmelo J. A. B. Filho			COG				FLEX	
NET	CPqD	Juliano R. F. de Oliveira							INT	SDN2

FOTONICOM's
Some Highlight Results

“Optimization of the electromagnetic scattering problem based on the topological derivative Method”, Vol. 27, No. 23 / 11 November 2019 / Optics Express

Novel Optimization Technique: Topological Derivative



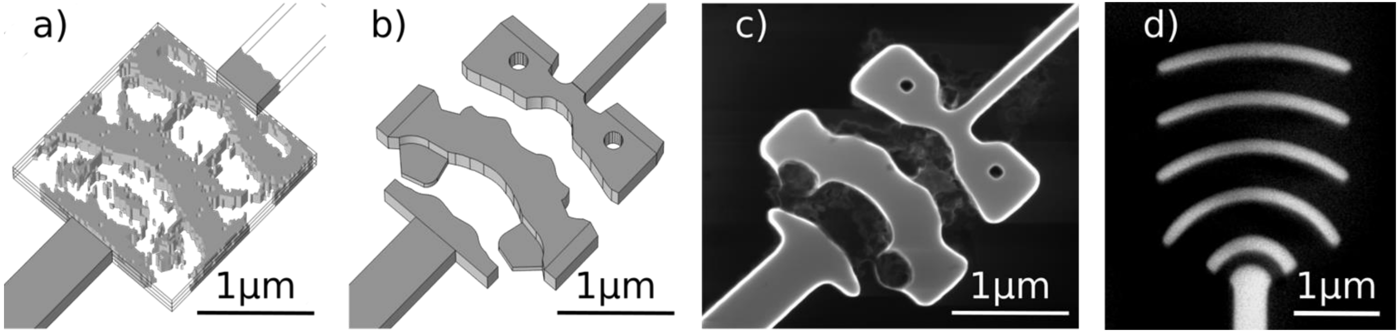
Reflectivity: -0.3 dB (2.5 × 2.5 μm²)

Ultra-compact fiber-to-chip SOI antenna

Very small footprint:
1.78 um x 1.78 um

1 Optimized antenna

2 Grating antenna



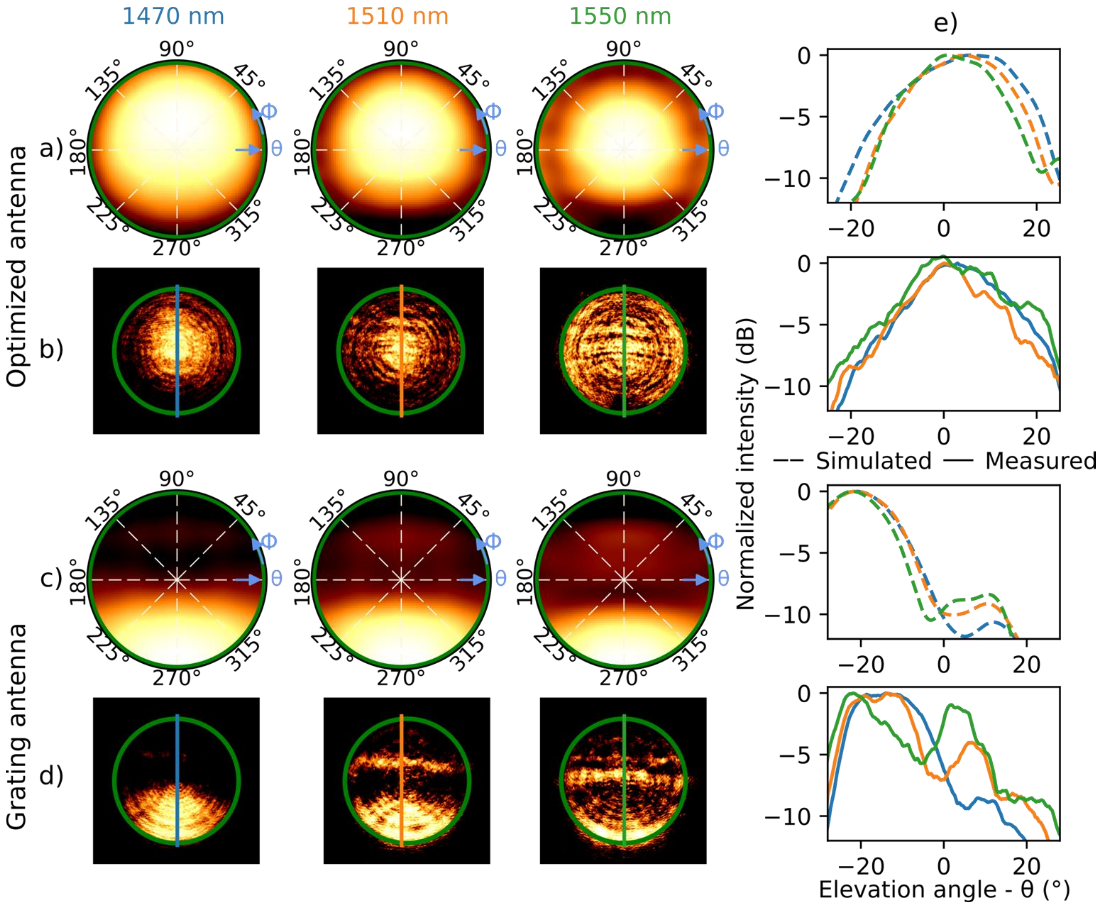
SEM images

a-c) PITA, J. L., et al., OSA Optics Express, Vol. 26, No. 3, pp. 2435-2442, 05 February 2018.

d) Grating antenna - J Sun et al.., Large-scale nanophotonic phased array. *Nature*, *493*(7431), 195-199 (2013).

Laboratory of Electronics, MIT.

Far-field pattern



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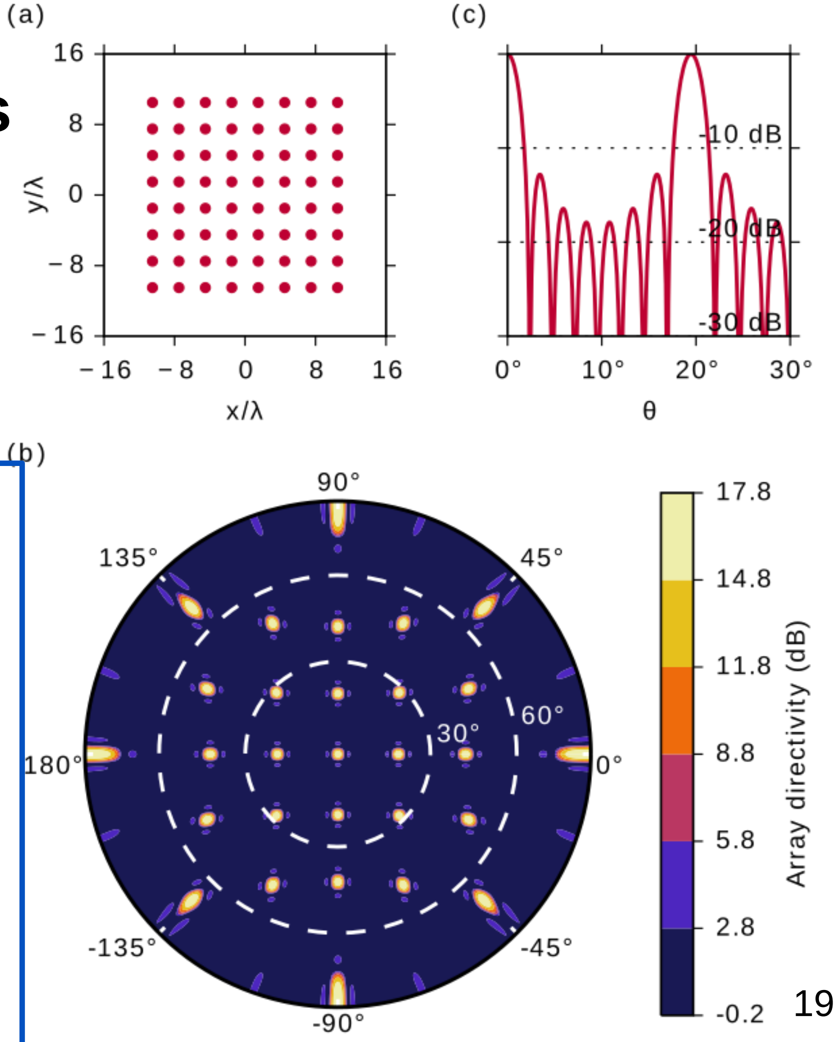
Limitations in Optics

- Large dielectric antennas > λ
- Large feeding dielectric network due to evanescent tails

Large separation distance between neighbor elements > λ

⬇

Uniform cartesian arrays with multiple grating lobes



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Sunflower Seed Array

Design based on **Fermat's spiral** (bio-inspired by sunflower seeds arrange)

Regularly-spaced elements, but aperiodic (no numerical optimization)

Ultra wideband, but more complex feeding network: why not use in optics?

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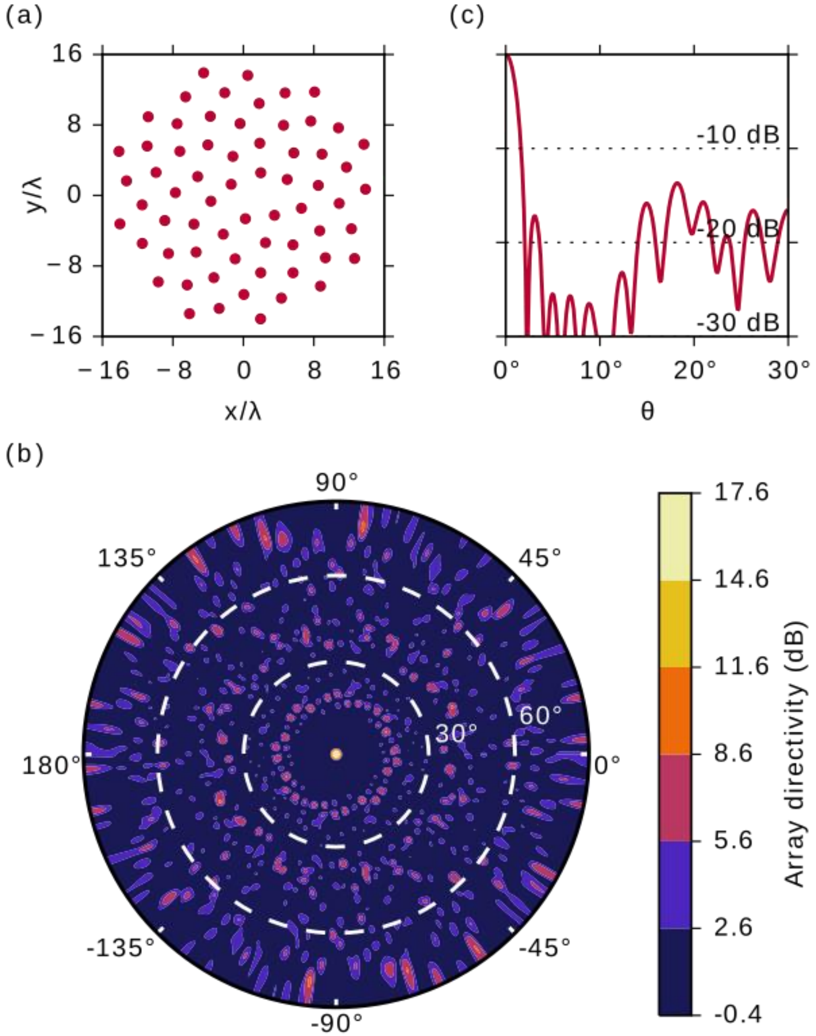
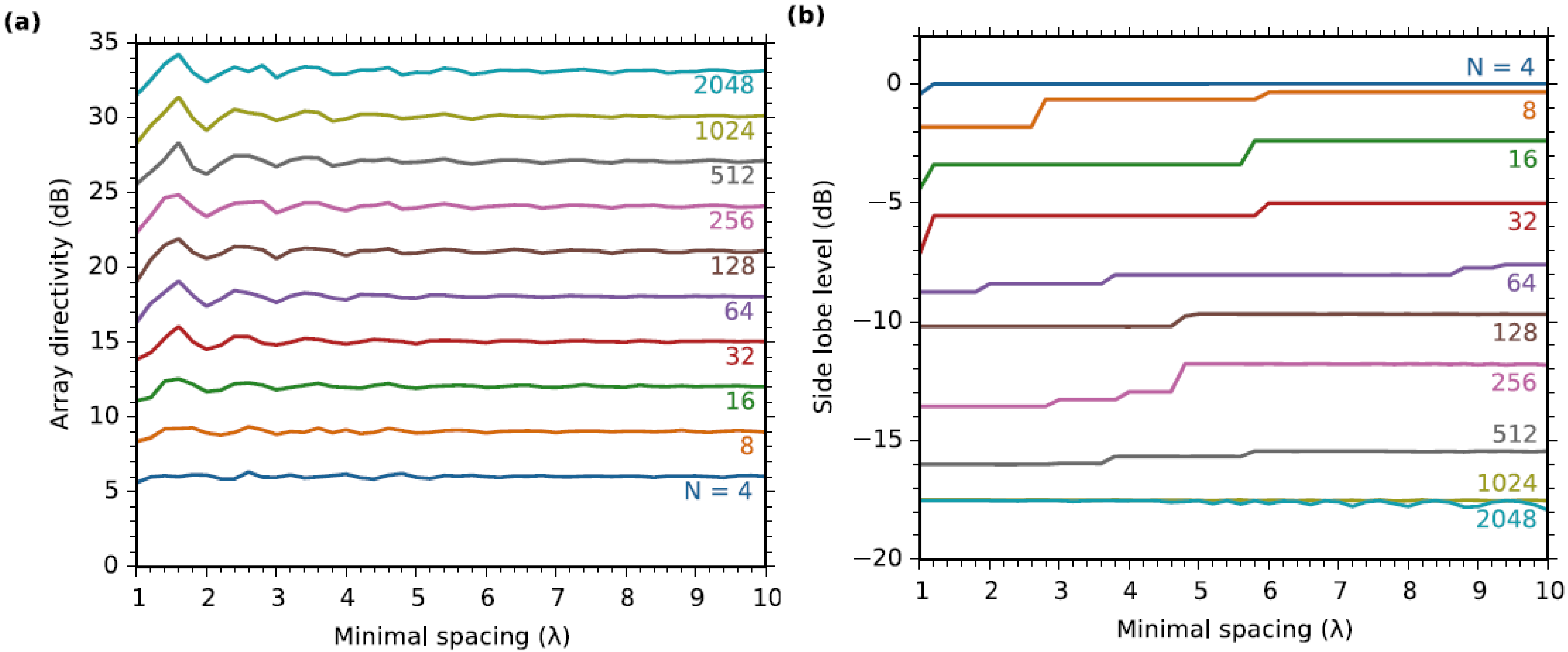
GABRIELLI, et al., IEEE Photonics Technology Letters.
Vol. 28, No. 2, pp. 209-212, January15, 2016.



Directivity, SLL Reduction and Bandwidth

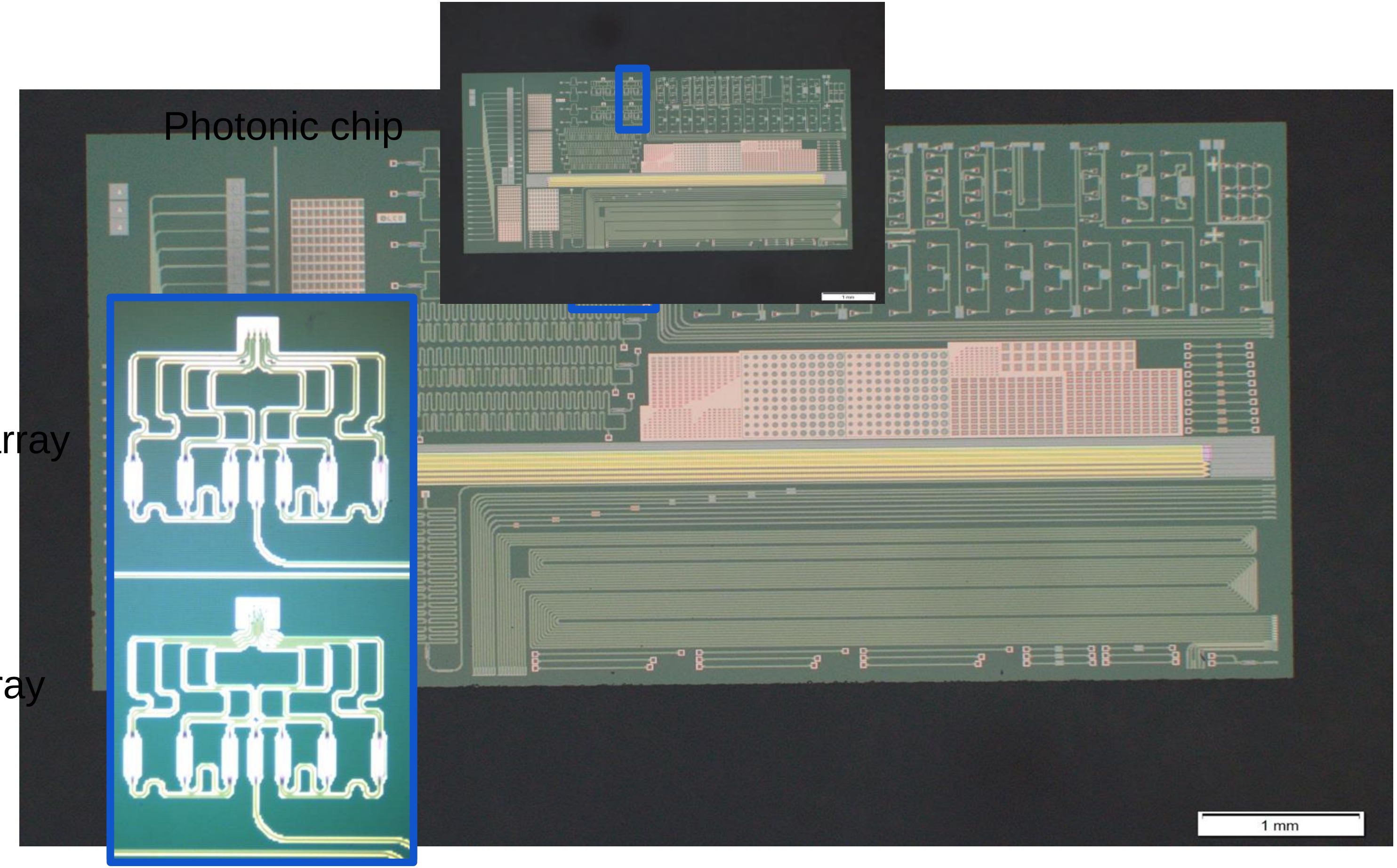


Nanoantenna-arrays and feeding network

Photonic chip

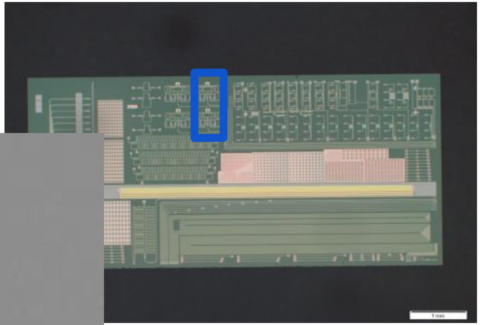
Rectangular array

Aperiodic array

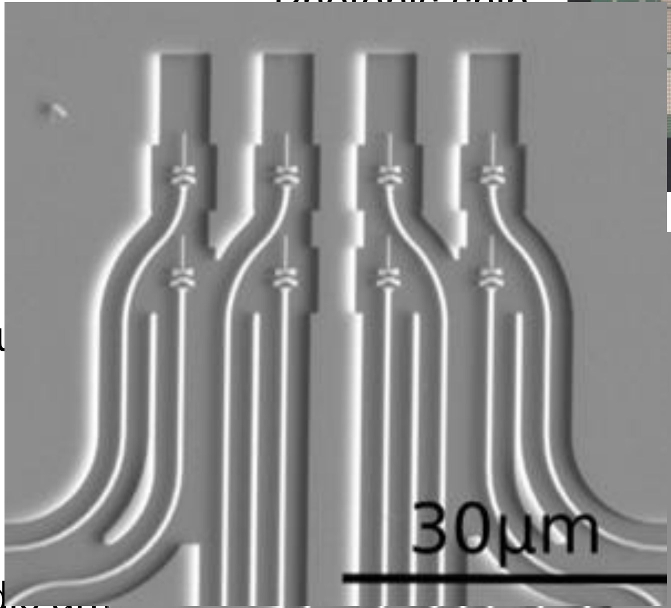


Nanoantenna-arrays and feeding network

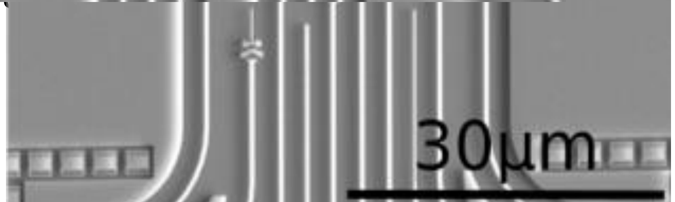
Photonic chip



Rectangu

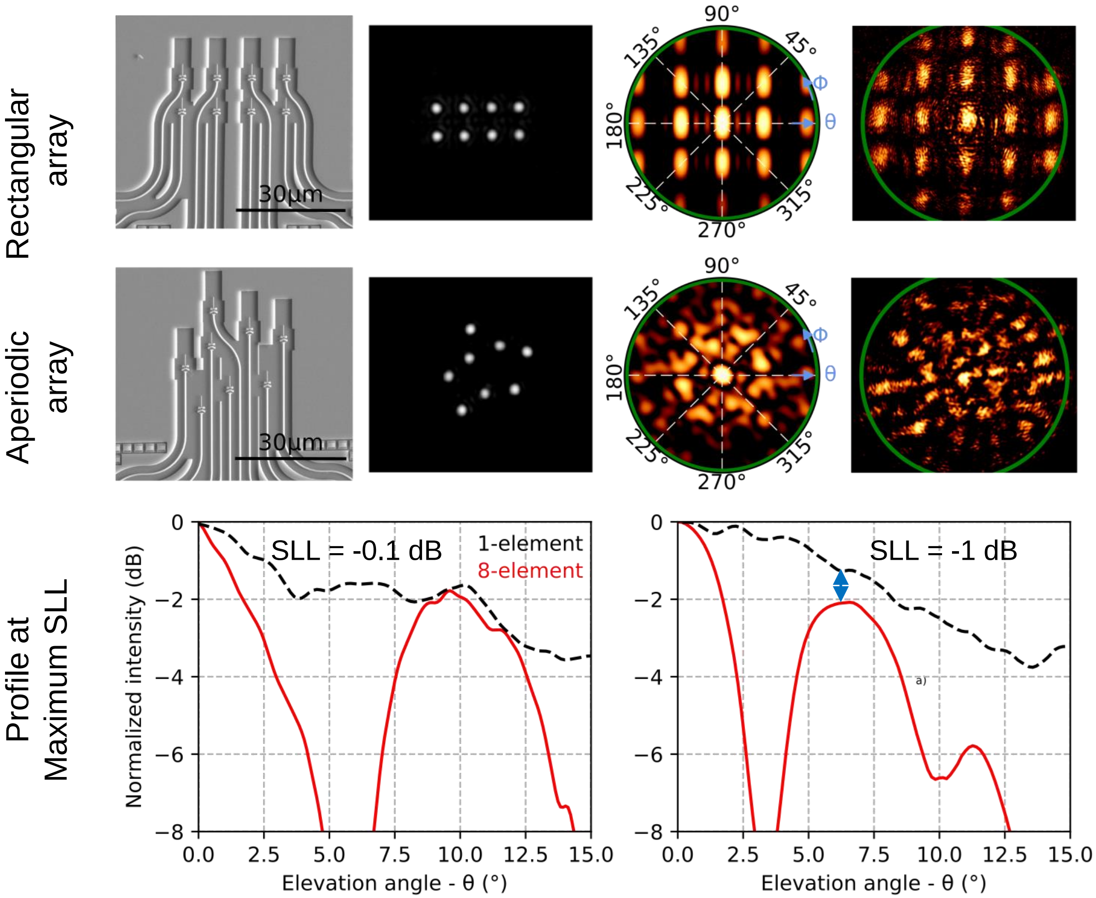


Aperiodic arr



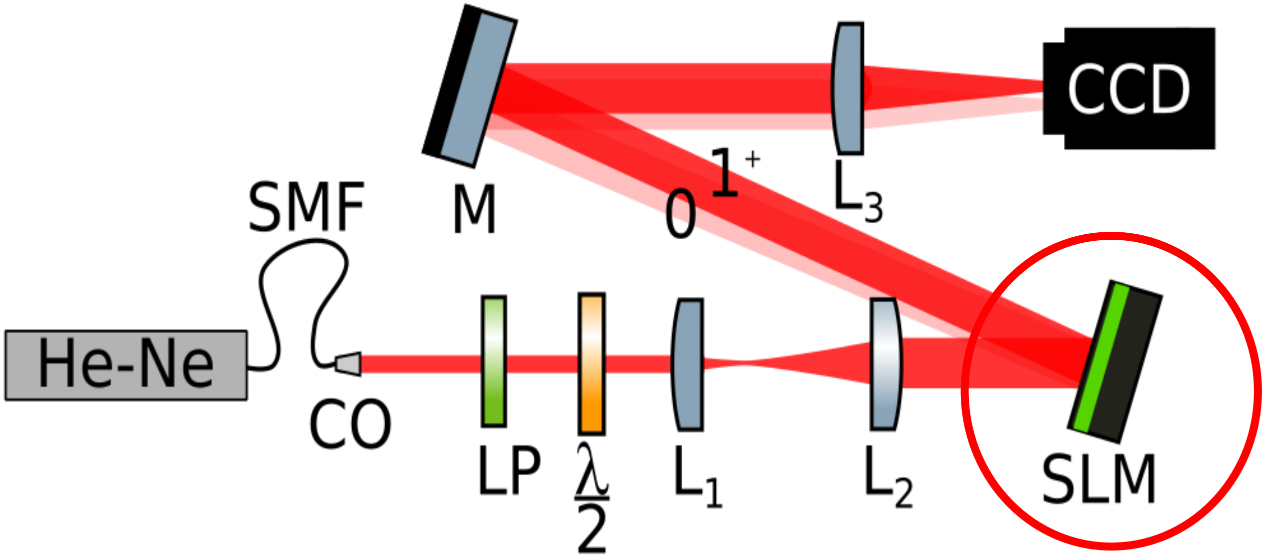
Separation of about 6λ

Nanoantenna arrays



PITA, J. L. et al., OSA Optics Express, Vol. 25, No. 24, 27 Nov 2017

Experimental Evaluation



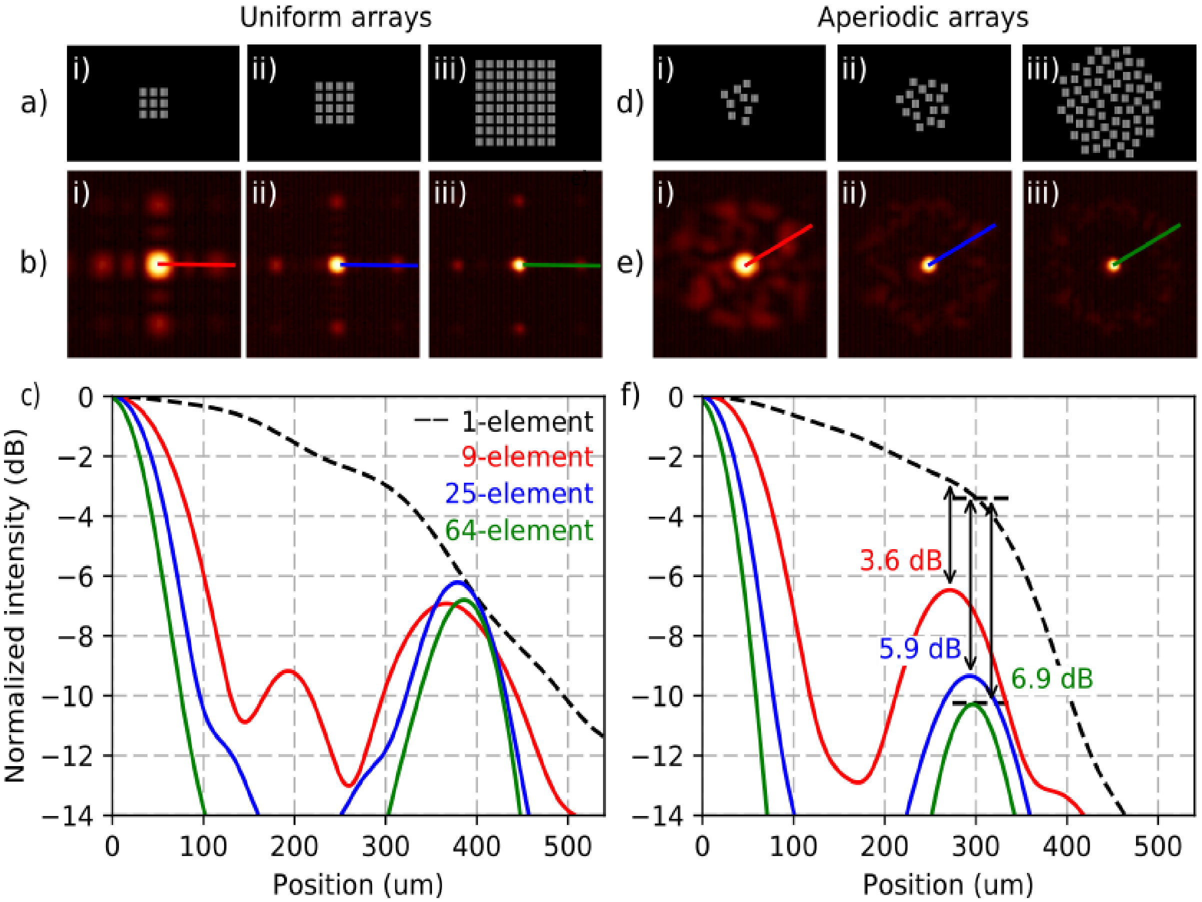
Ultra-sparse arrays:
Square × Sunflower

λ = 633 nm

d = 367.7 μm = 581λ

Antenna:
SLM (Spatial Light Modulator)
Grating aperture
(measurement in the 1st grating lobe to minimize noise)

Far-Field Measurements



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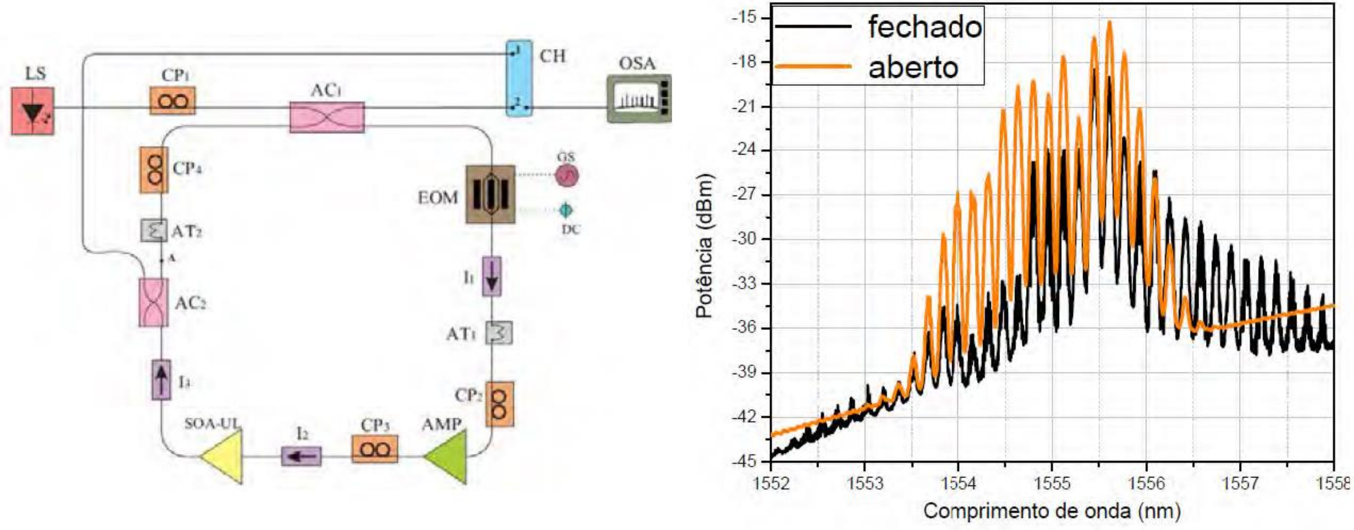
Development of a transmission system fully based on coherent technology using superchannels towards applications in *flexgrid* networks.



(a) (b)

OFCG (*Optical Frequency Comb Generator*) of Transmissor: (a) Experimental diagram and (b) frequency comb with separation of 19,9994 GHz.

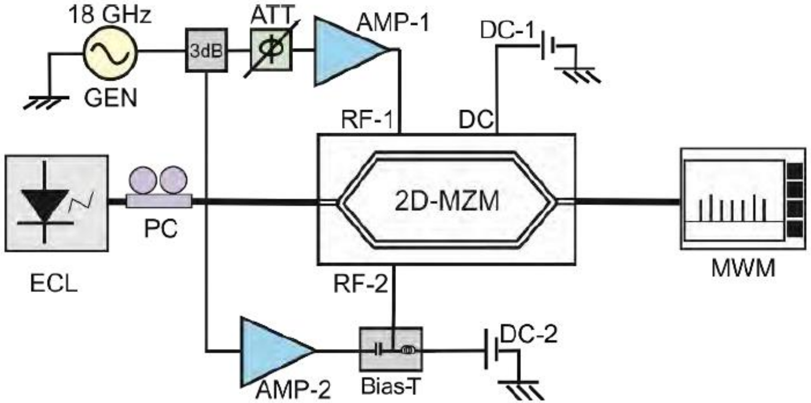
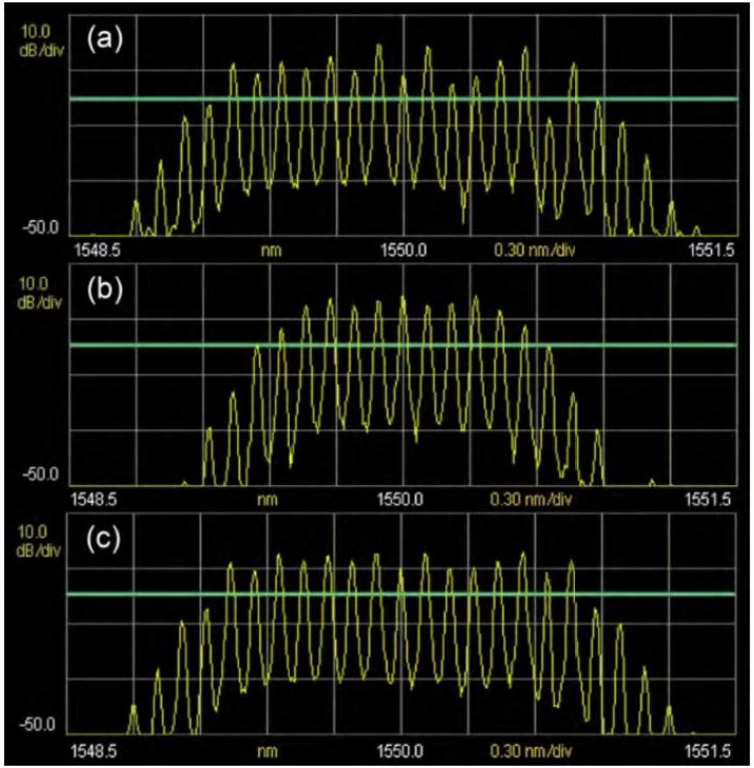


Figura 2: Diagrama do OFCG do receptor.



Spectra produced by OFCG of receptor, when (a) there is not equalization adjustment, (b) with equalization adjustment for 9 central lines and (c) with equalization adjustment for 15 central lines.

FOTONICOM’s BRICS Contacts

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