NANOPHOTONICS TECHNOLOGY CENTER

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Photonic Integrated Circuits for Radio Beamforming: Part 2: True Time Delay and Optical Heterodyning

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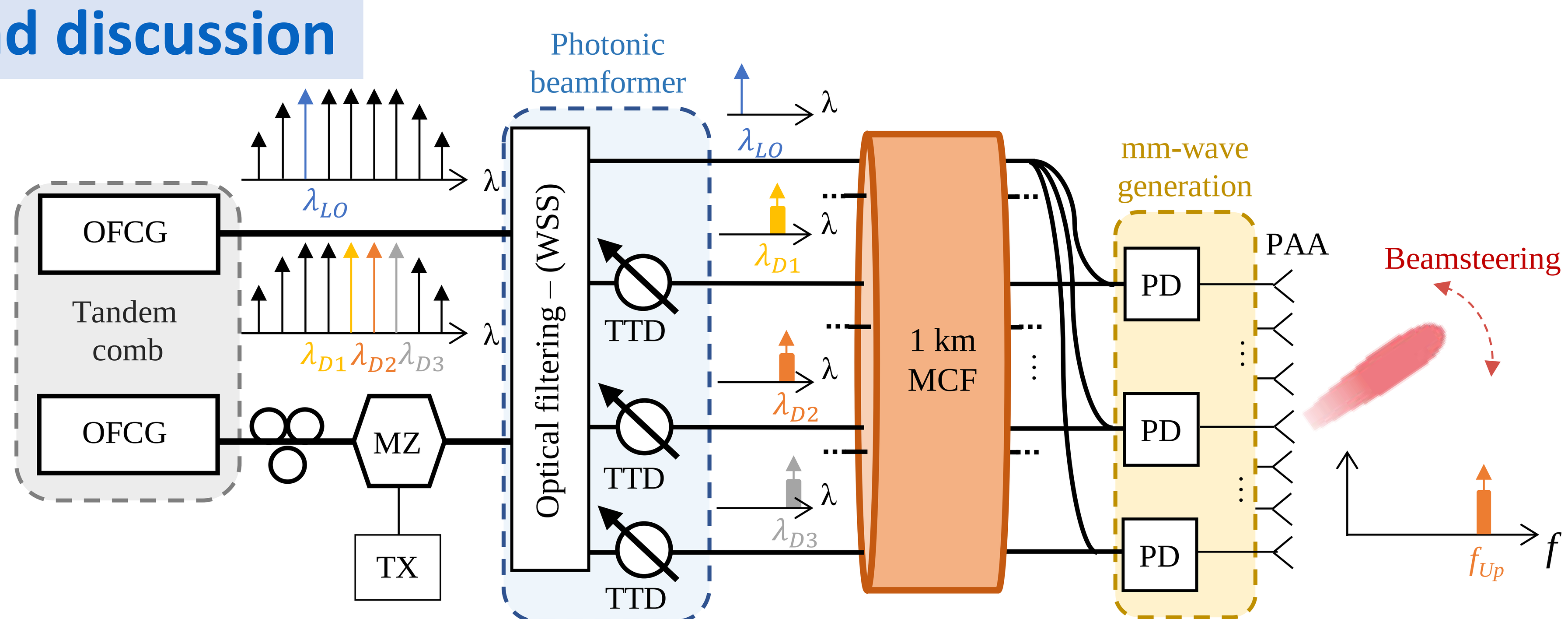
Research progress

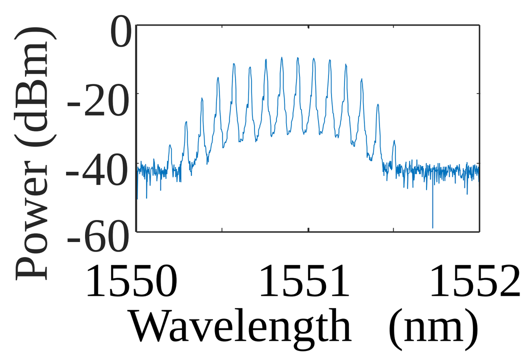
- State-of-the-art review of 5G transmitters, true time delay (TTD) systems, multi-core fibers (MCF) and optical filtering techniques.
- Experimental setup developed to evaluate a 1 km optical link with 5G and WiMAX signal transmission including beamsteering and mm-wave upconversion.
- Simulation evaluation of radio beamsteering for different delays and number of antennas and frequency upconversion performance with optical heterodyning.

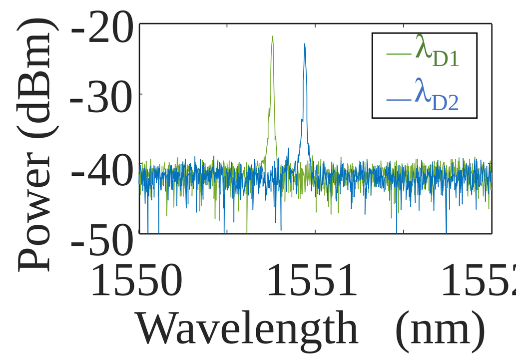
Results and discussion

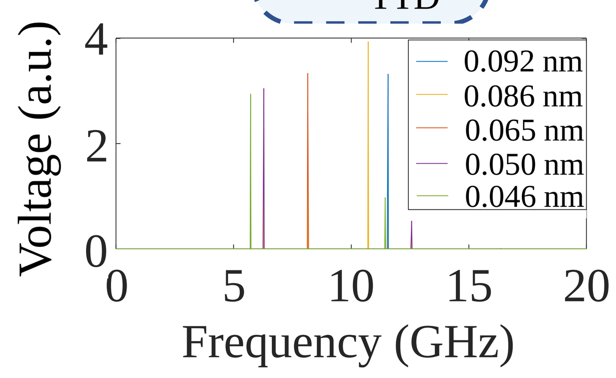
- OFCG providing multiple phase correlated optical carriers λ=1551 nm with FSR from 5 to 12 GHz
- 5G and WiMAX data modulation (center frequencies from 780 MHz to 9 GHz and bandwidths from 15 MHz to 2GHz)
- Channel isolation implemented using a wavelength selective switch (WSS)
- TTD implementation using tunable ODLs, delays from 0 ps to 600 ps
- Propagation through 1-km of 7-core MCF to each antenna element
- Frequency upconversion to mm-wave region via optical heterodyning



Comb generation and optical filtering





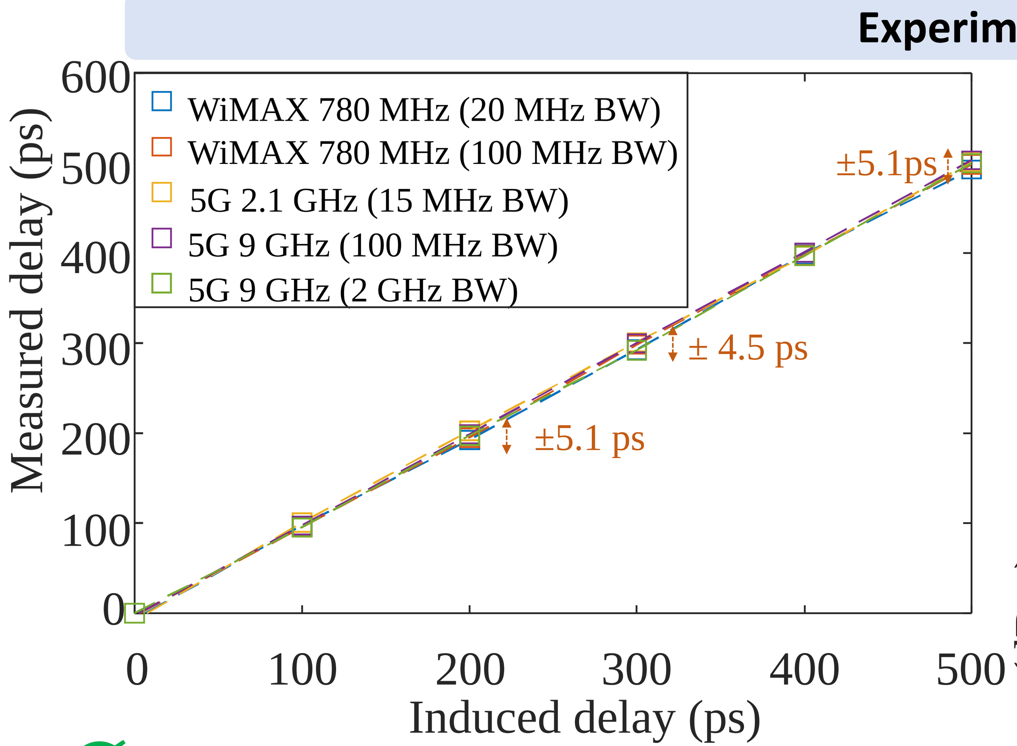


Line separation appears as RF interference with non-perfect filtering

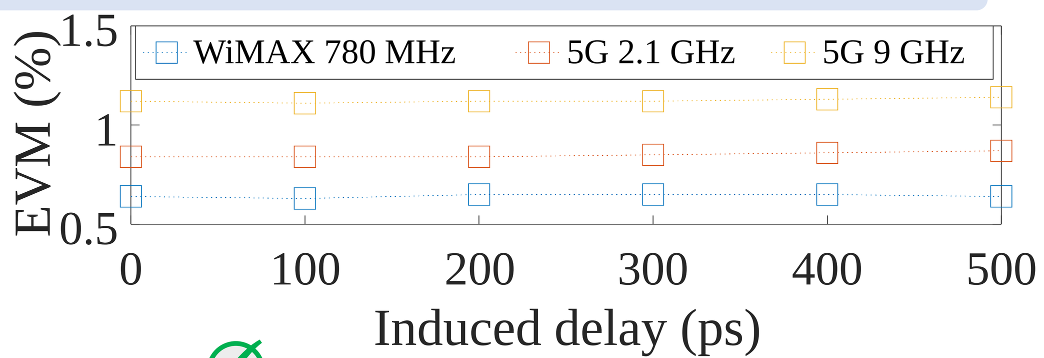
True time delay for radio beamforming – state of the art

Technique	Frequency (GHz)	Bandwidth (GHz)	Variation	Max delay	Measured error	Ch	Power drawn
Digital	1	0.1	Step	7.5 ns	<1º	16	453 mW
Phase-shift based	Base band	0.1	Step	15 ns	5 ps	4	47 mW
	28	3	Step	n/a	2.6º	64	220 mW
	60	2	Step	n/a	15º	512	9.4 W
	28	0.8	Step	n/a	0.3º	48	299 mW
ORRs	18.7, 19.5	2.2, 3.5	Cont	1.8 or 1 ns	100 or 50 ps	4	n/a
	26, 17.6	4.2	Cont	180 ps	n/a	4	n/a
	40	0.3	Cont	1.9 ns	1 ps	4	17.5 W
	41, 90	6.3	Cont	209 ps	n/a	4	n/a
AWG	10	16	Step	300 ps	2ps	4	n/a
Fiber Bragg grating	6	NA	Step	200 ps	n/a	16	n/a
	10	16	Step	200 ps	5 ps	16	n/a
Switched ODL	3	n/a	Step	670 ps	0.8 ps, <0.5º	64	4.32 W
	5	5	Step	1.3 ns	n/a	4	n/a
	41, 90, 94	1000	Step	22.5 ps	4.5 ps	4	n/a
	13	10	Step	434 ps	2.5 ps	8	1.45 W

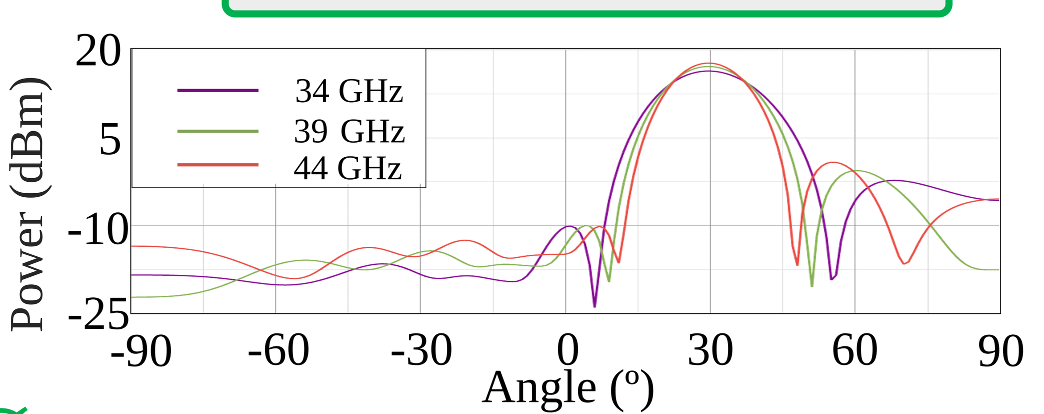
Experimental results



Suitability of OTTD to different radio signals, center frequencies and bandwidths



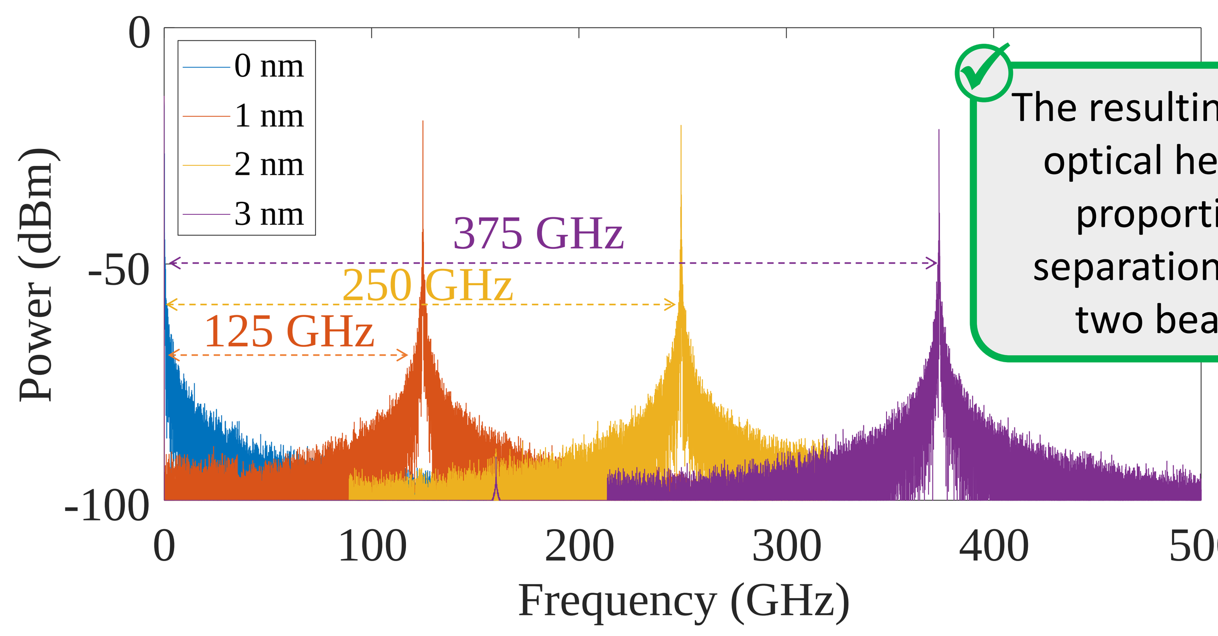
EVM independent of applied delay



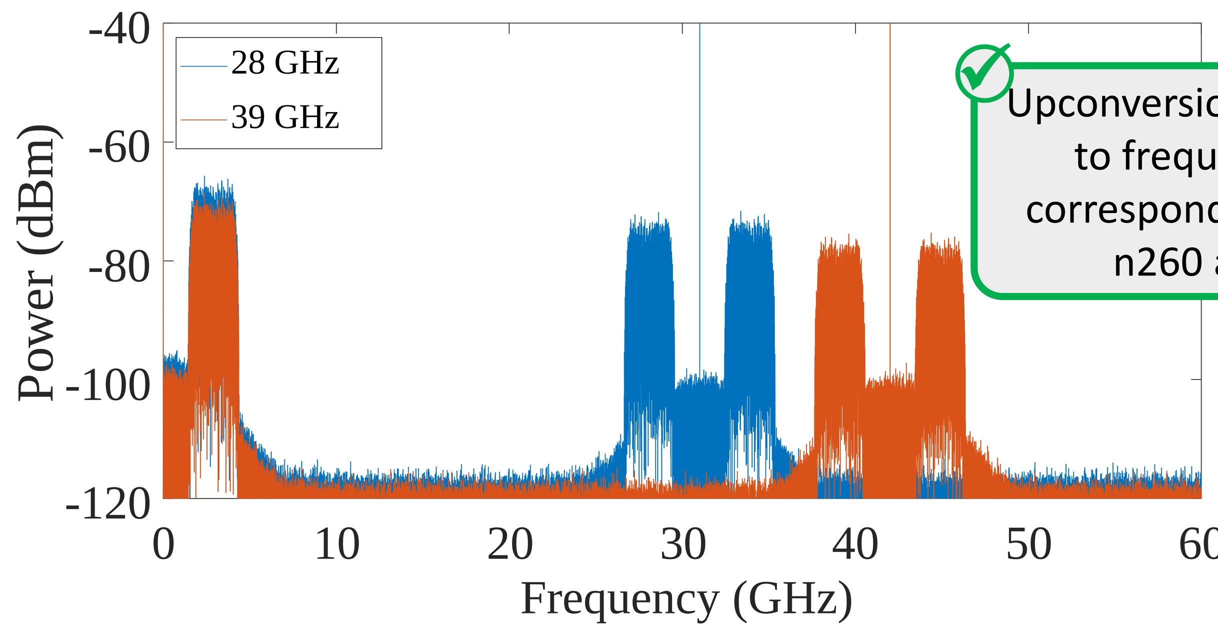
Radio beamforming with optical true time delay over high bandwidth

Optical upconversion – simulated results

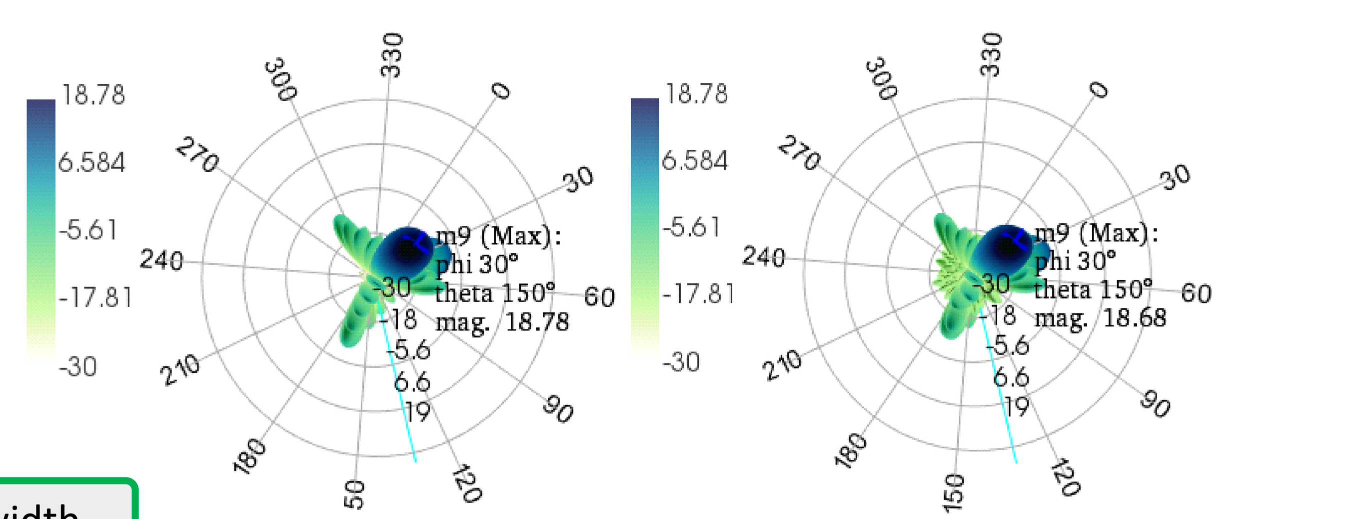
Optical heterodyning: combination of two optical frequencies in f_1 and f_2 generates two new signals at $f_1 + f_2$ and $f_1 - f_2$



The resulting frequency of optical heterodyning is proportional to the separation between the two beating signals



Upconversion of 5G signals to frequency bands corresponding to 5G FR2 n260 and n261



Dissemination results

[1] R. Llorente, V. Fito and M. Morant, "Optical combs and multicore fiber as technology enablers for next-generation datacenter infrastructure", SPIE Proceedings Volume 12027, Metro and Data Center Optical Networks and Short-Reach Links V, 120270E (2022) https://doi.org/10.1117/12.2615351

[2] V. Fito, M. Morant and R. Llorente, "Design requirements for mm-wave integrated optical beamforming networks", SPIE Proceedings Volume 124290, Next Generation Optical Communication: Components, Sub-systems and Systems XII, 124290V (2023) https://doi.org/10.1117/12.2660412

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