Scalable & Low-Power Microwave Photonics for
Flexible Terabit Telecom Payloads
& High-speed Coherent Inter-satellite Links

FP7 PROJECT BEACON

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Motivation

Motivation


SMART HUB
Facebook
Netflix
Hulu Plus
YouTube
Angry Birds
Web Browser
USA TODAY
Twitter
Pandora
MOG Music
AllShare Play
ESPN ScoreCenter
AccuWeather
Skype
Samsung SPSN

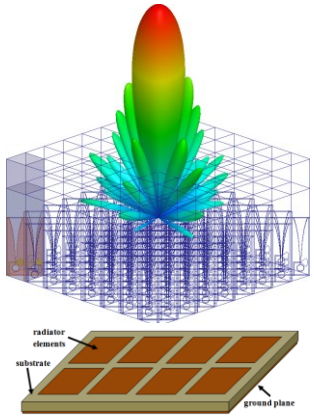

Wi-Fi
Inside


Wi-Fi
ONBOARD
Not Yet!

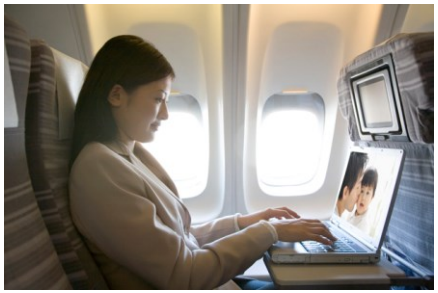
Motivation

- Ka band: plenty of bandwidth available within 27.5 - 31 GHz

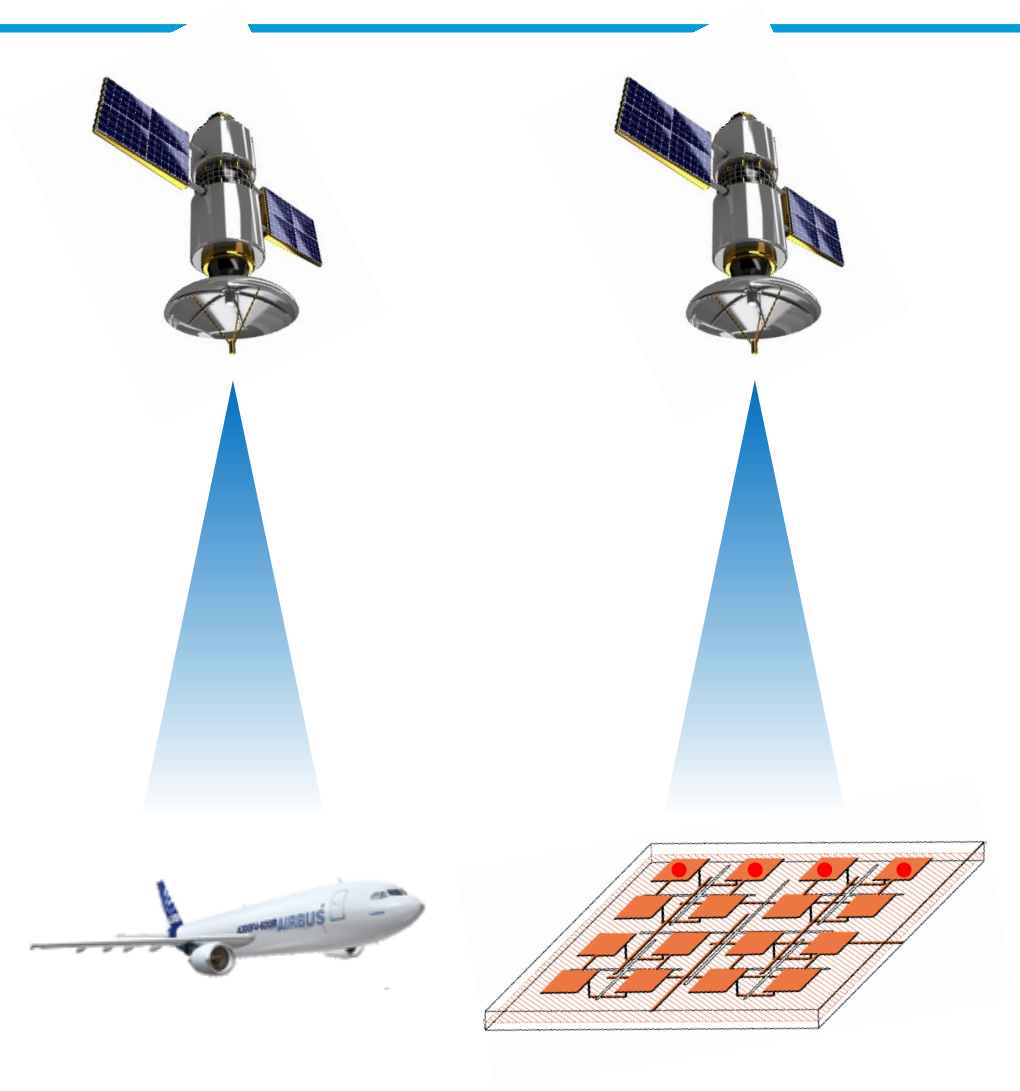
Bulky and with moving parts

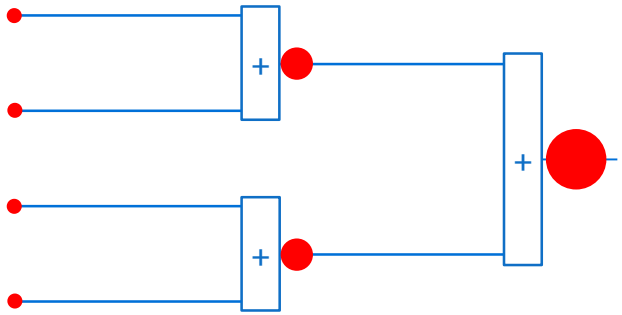


Beamforming
- no moving parts
- reduced dimension
- multiple beams



Beamforming: why is it needed?

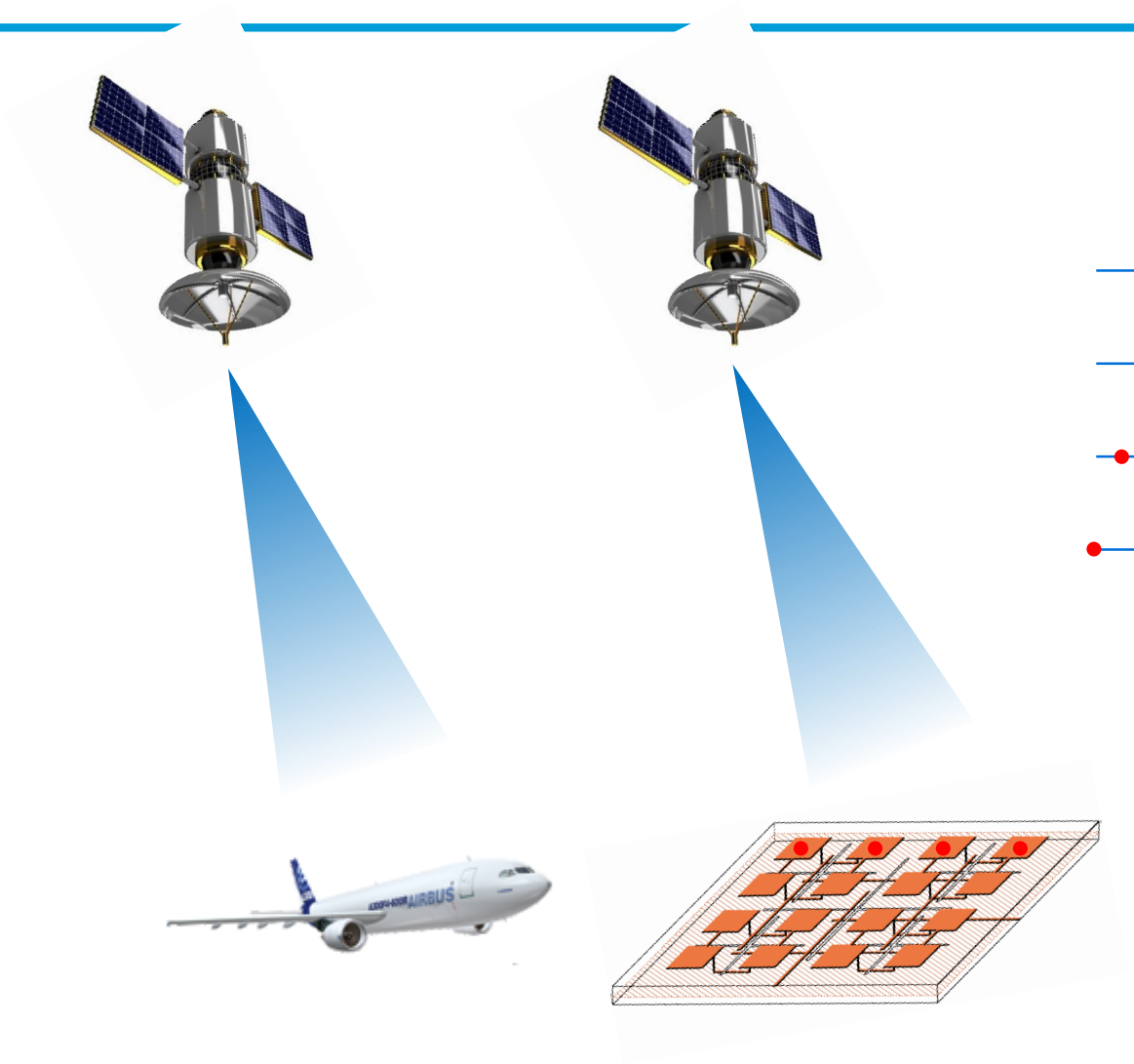


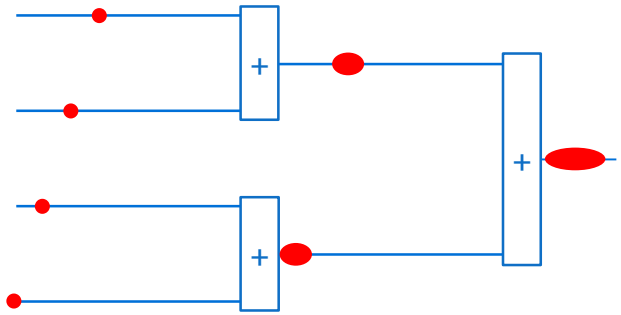


All antenna elements work **constructively** for

- More power
- Less noise

Beamforming: why is it needed?

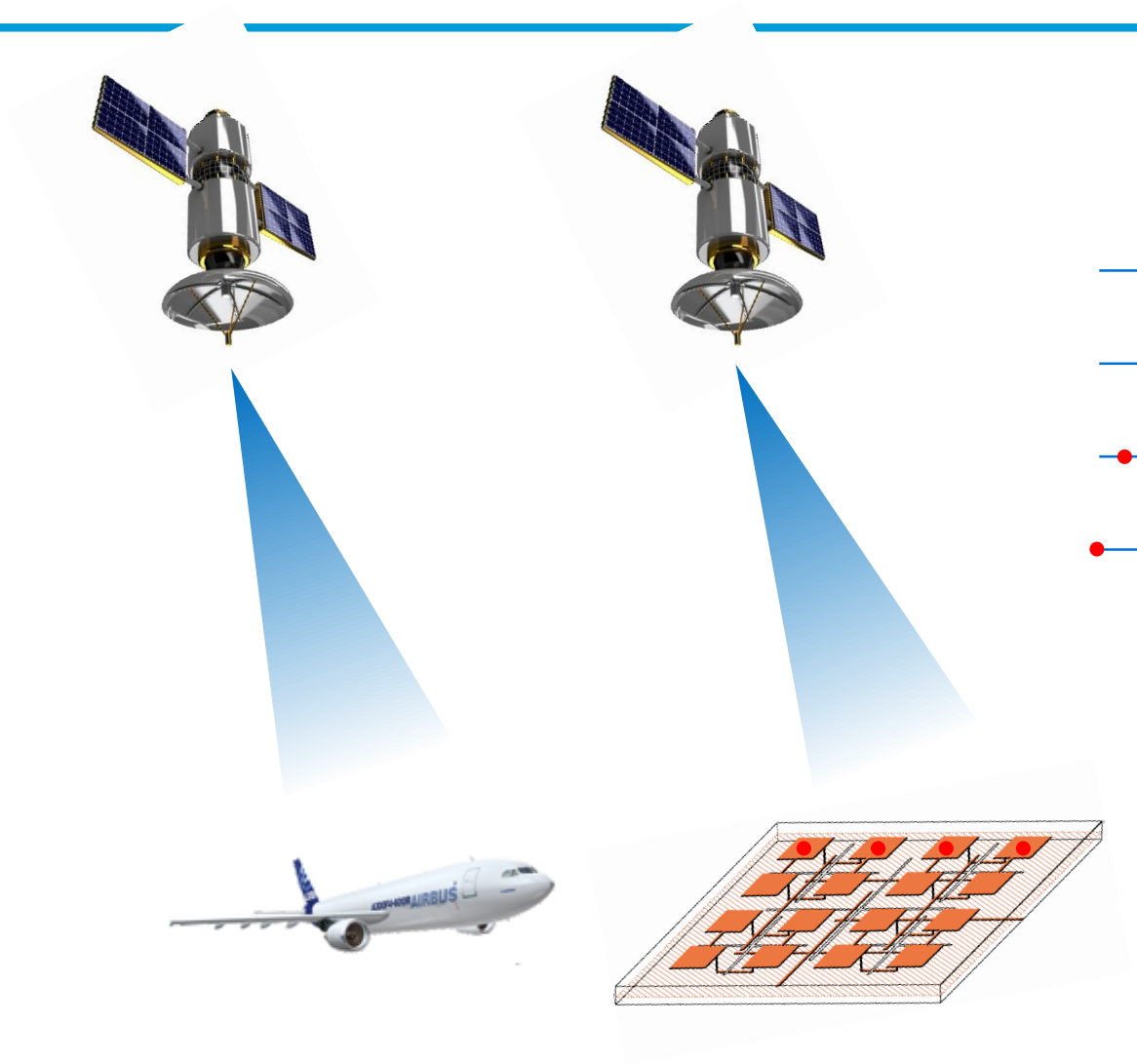


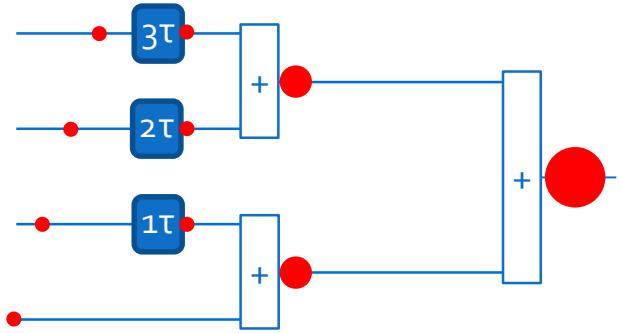


Antenna elements no longer work **constructively**

- Compensation needed!

Beamforming: why is it needed?





Beamforming requires

- Tunable delay lines
- Combiner networks

Why photonics?

- Processing RF signals using photonic technologies (aka Microwave photonics) has many advantages
  - Light waveguides have a huge operational bandwidth (at least 10 nm, i.e., 1.25 THz)
  - Bandwidth bottlenecks are found in electrical-to-optical and optical-to-electrical converters, which nonetheless can be easily of 30 GHz (compatible with Ka band)
  - Amplifiers are very linear
  - Mixing-related applications, such as frequency up or downconversion can be easily implemented
  - Immunity to electromagnetic noise
  - Many devices have proved to be radiation-hard, namely lasers and optical amplifiers
  - Dawn of Integrated Microwave Photonics

Microwave photonics – Nature Photonics 2007 rev.

REVIEW ARTICLE

Microwave photonics combines two worlds

Microwave photonics, which brings together the worlds of radiofrequency engineering and optoelectronics, has attracted great interest from both the research community and the commercial sector over the past 30 years and is set to have a bright future. The technology makes it possible to have functions in microwave systems that are complex or even not directly possible in the radiofrequency domain and also creates new opportunities for telecommunication networks. Here we introduce the technology to the photonics community and summarize recent research and important applications.

JOSÉ CAPMANY[1]* AND DALMA NOVAK[2]

to Alwyn Seeds at University College London, the development of the first semiconductor lasers and electro–optic modulators

Basic photonic beamformer

REVIEW ARTICLE

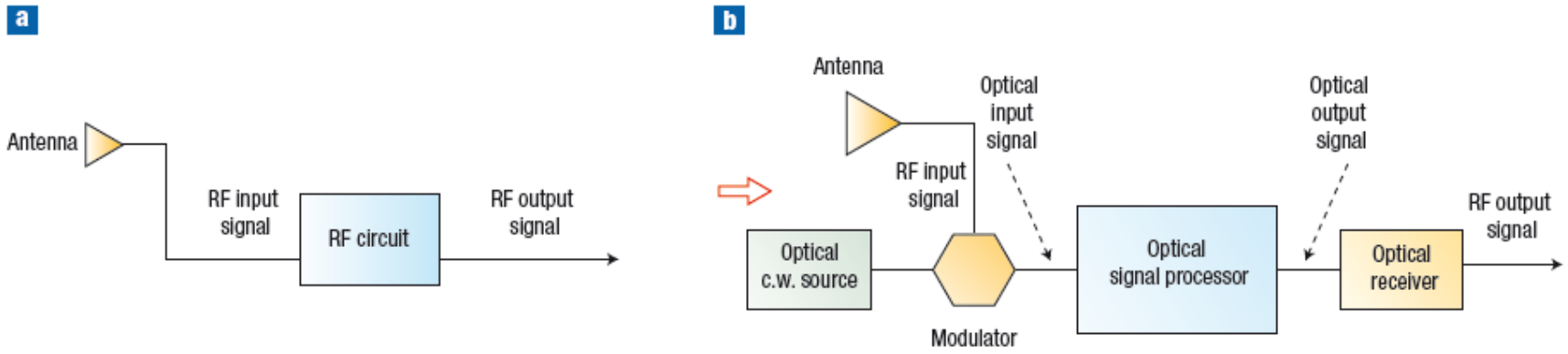


Figure 5 Schematics of RF signal processing. **a**, Traditional approach. **b**, Microwave photonic approach. (c.w. means continuous wave.) Reproduced with permission from ref. 85. Copyright (2005) IEEE and OSA.

Basic photonic beamformer

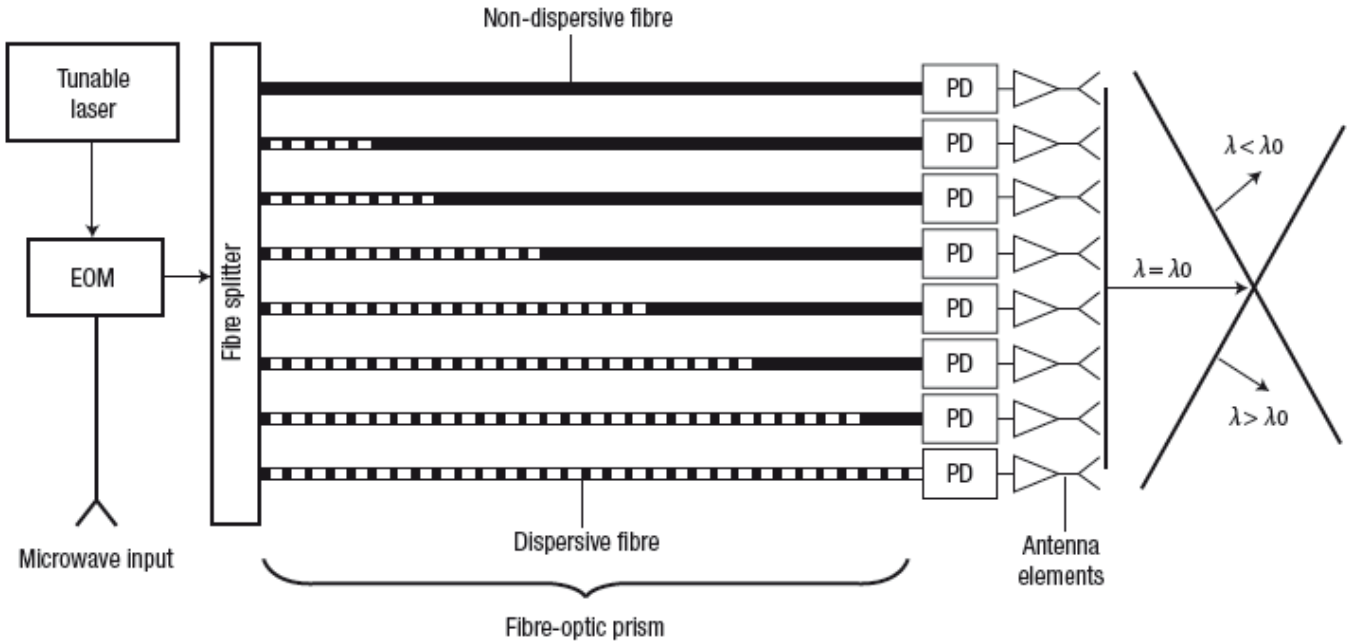
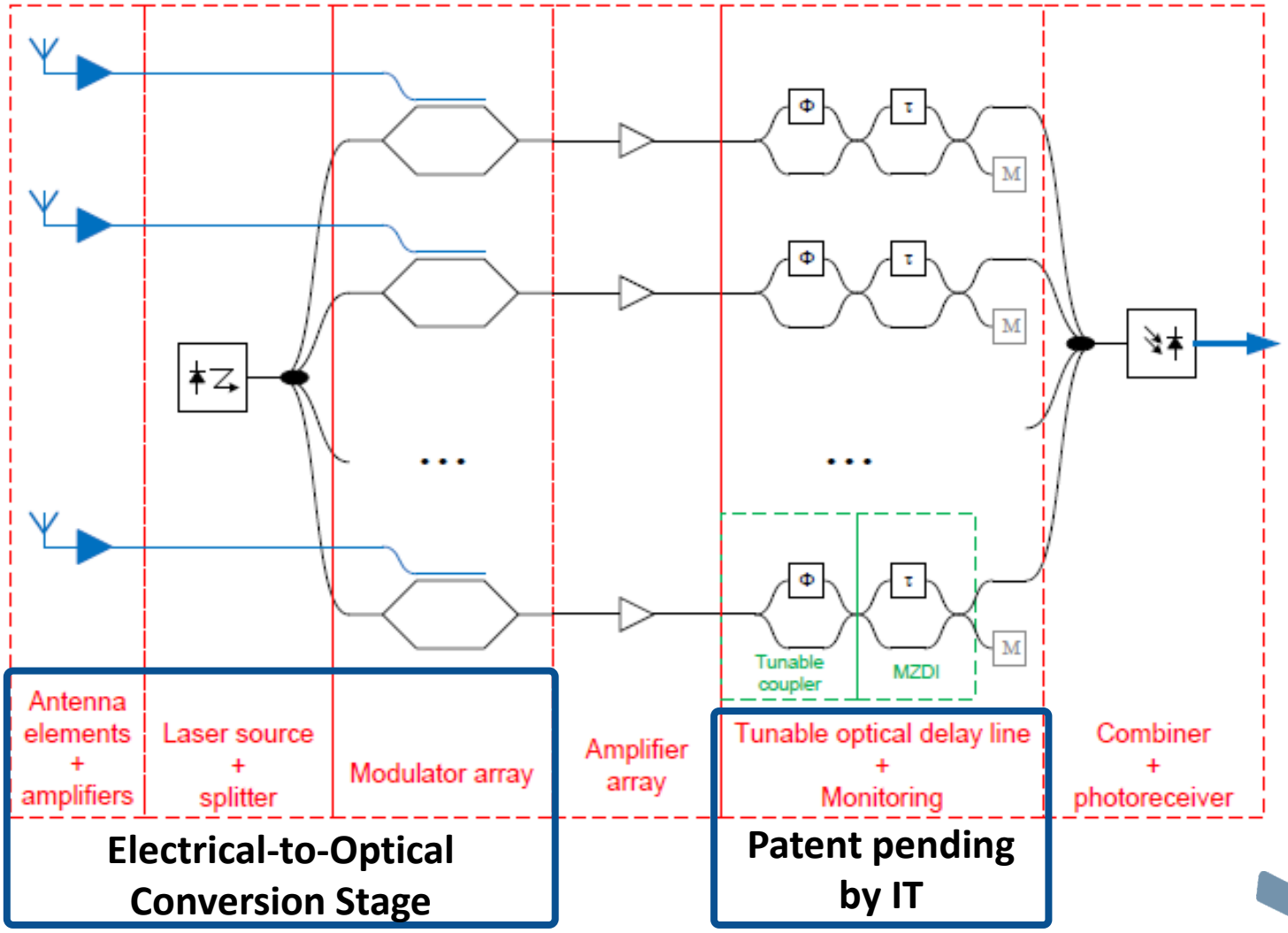
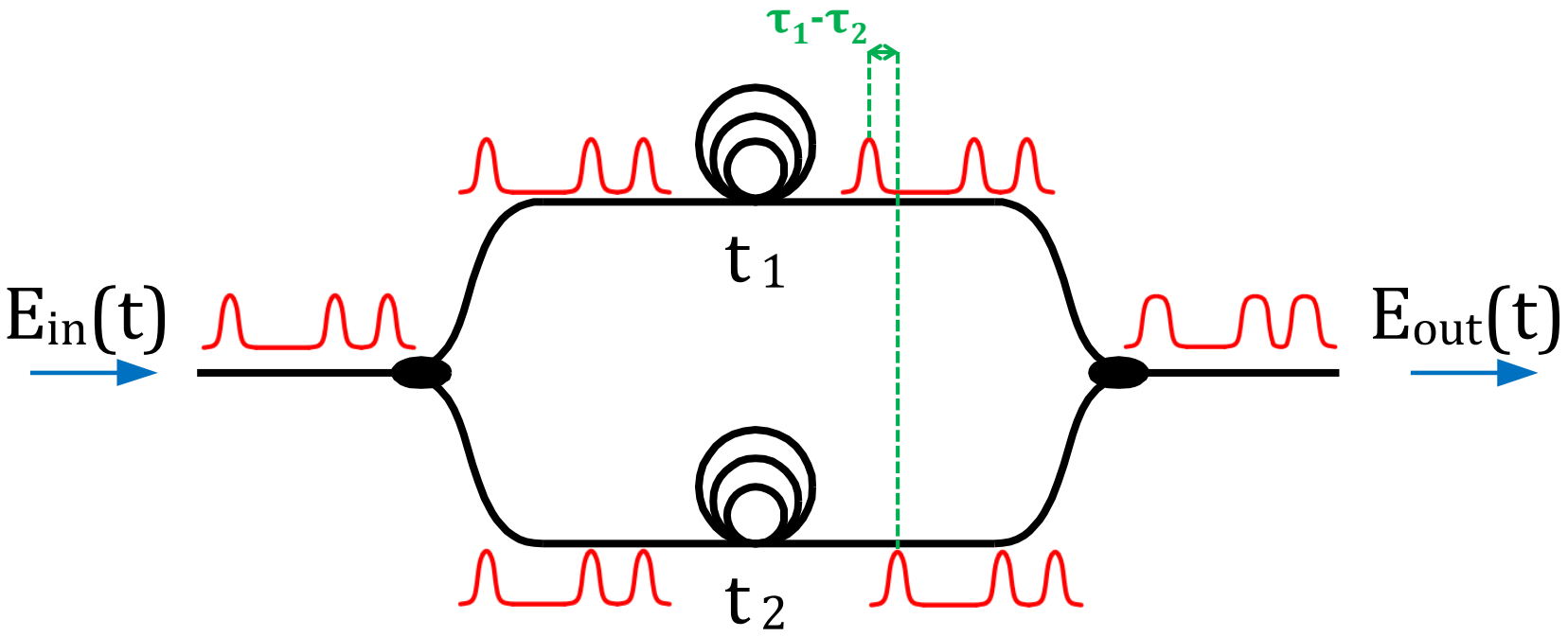


Figure 4 Schematic showing a fibre-optic prism with a single laser to feed numerous phased-array elements[68]. A true time-delay feed is formed by splitting the optical carrier into a fibre-optic prism, created by connecting varying amounts of highly dispersive and non-dispersive fibre. At a central wavelength, λ_0, the main antenna beam is directed broadside, whereas at wavelengths less (greater) than λ_0, each of the prism fibres adds (subtracts) a time delay proportional to its dispersion, resulting in element phasing such that the main antenna beam is steered towards (away from) the non-dispersive fibre side. (PD: photodetector; EOM: electro–optic modulator.) Reproduced with permission from ref. 68. Copyright (1993) IEEE.

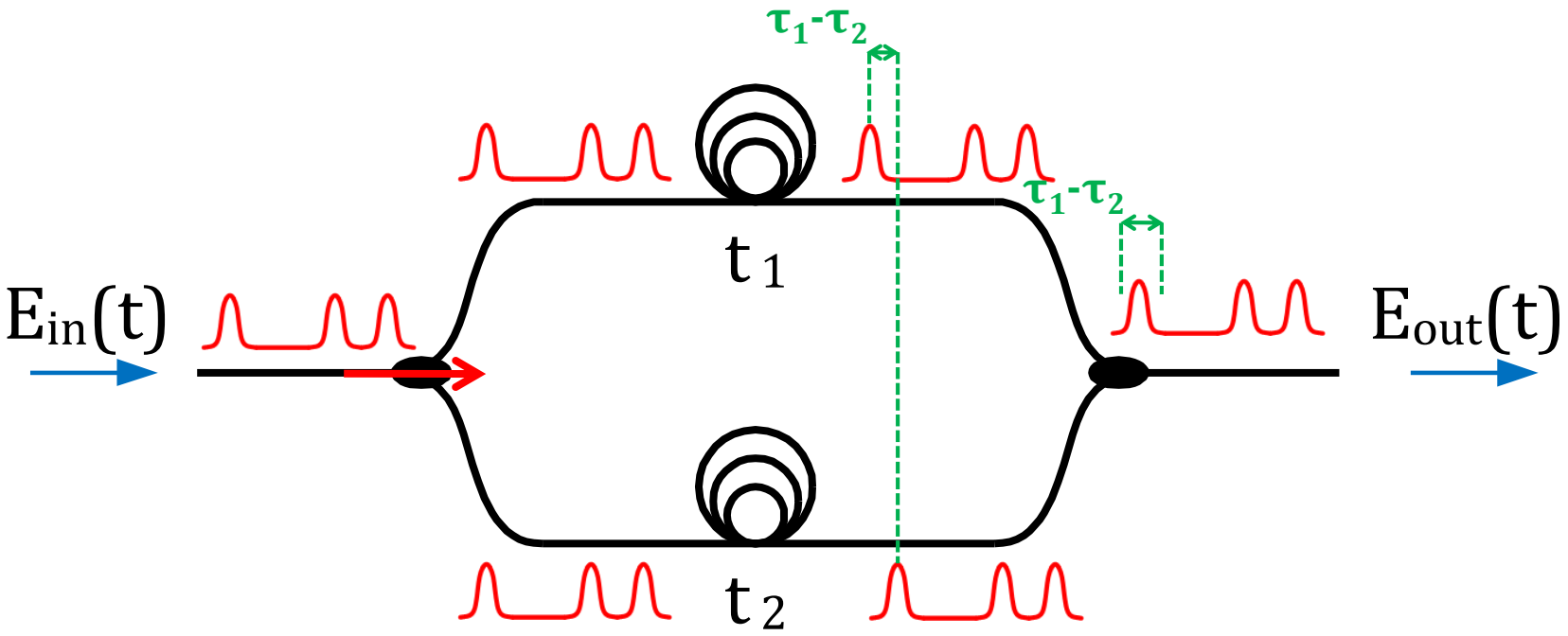
Proposed photonic beamformer



Basic concept – Mach-Zehnder Delay Interferometer



Tunable Optical Delay Line – Tunable Mach-Zehnder Delay Interferometer



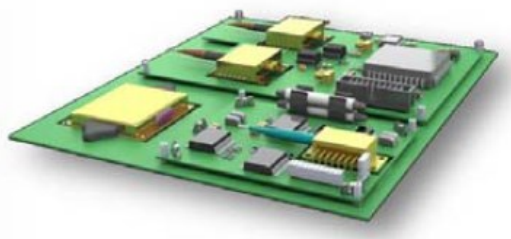
- Continuously adjustable optical delay line

concept

ASTRIUM KA-SAT MULTI-BEAM RF BEAMFORMING PAYLOAD

power cost mass size

BEACON PHOTONIC ANTENNA ARRAY BEAMFORMING BOARD



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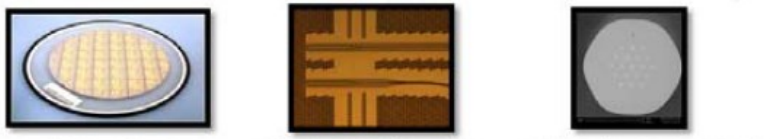

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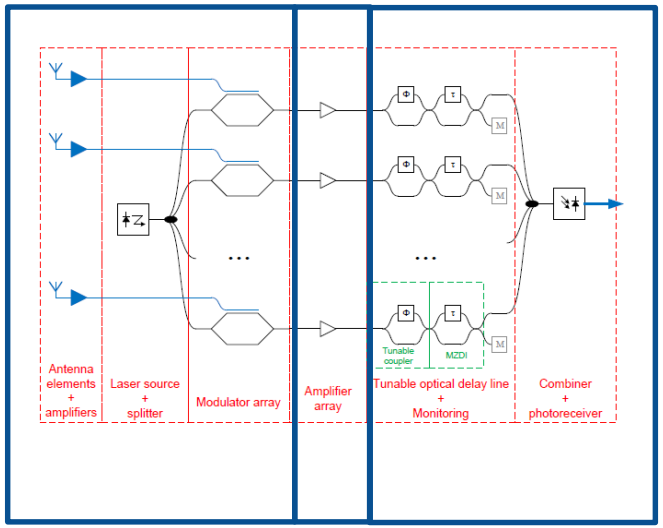
partners

AIRBUS

instituto de telecomunicações

ASTRIUM AN EADS COMPANY



Gooch & Housego

CONSTELEX technology enablers

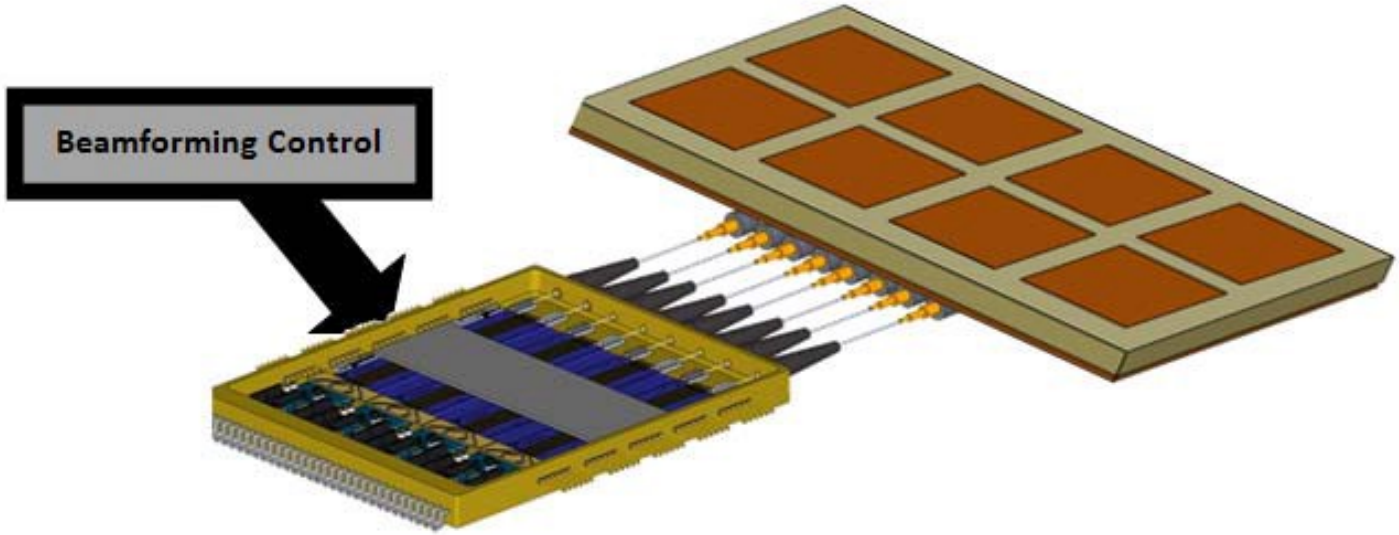
Finisar

u2t photonics

mPHOTECH Innovation photonics technology

ihp

prototype



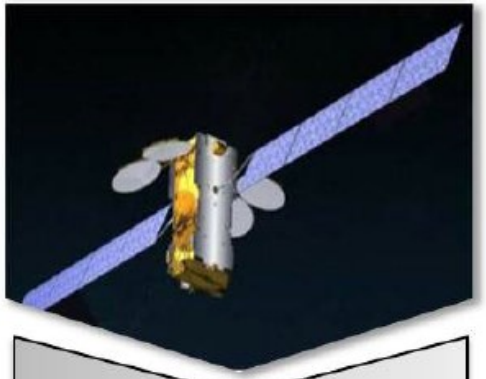
- It can be **scaled to Tb/s capacities**, with considerable **savings in size and power**
- This is a key advantage in face of current state-of-the-art kW power-consuming systems.

Outcomes (so far)

- System has been thoroughly optimized, leading to a final system architecture
- Main advantages of the new system
  1. True-time delay beamforming for *any* input RF frequency
  2. Photonic phase shifting for *any* input RF frequency
  3. Photonic up/downconversion to *any* desired output frequency
  4. Fully compatible with multibeam operation
- Only simple, highly linear modulators are required
- Optical amplifier array is fully specified
- Complete simulation platform for an arbitrary number of antennas is complete
- Future work will be implementing the system parts and assembling it

Project BEACON - Applications

Multi-beam Tb/s payloads



GaAs MZM arrays
Rad-hard EDFA arrays
Silicon photonic beamformers

Ground radar
Astronomy instruments

GaAs MZM arrays
Rad-hard EDFA arrays
Photonic beamformers
DP-QPSK for long haul links
EDFAs for short/long haul links

1.55um coherent inter-satellite communications

DP-QPSK modulator
Rad-hard optical amplifier

Future research directions

- We have plenty of ideas to explore basically aiming at
  - Improved (even more) photonic beamforming
  - Photonic ADCs
- We are open to (new) collaborations

BEACON
photonics for telecom satellites

Scalable & Low-Power Microwave Photonics for
Flexible Terabit Telecom Payloads
& High-speed Coherent Inter-satellite Links

Thank you!

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COOPERATION