Radiofrequency Architectures Applying Photonic Timing and Routing (RAAPTR)

Justin Cohen, Ph.D.
Program Manager, Multi X Office

Proposers Day

June 16, 2026

Distribution Statement (A): Approved for public release. Distribution unlimited.

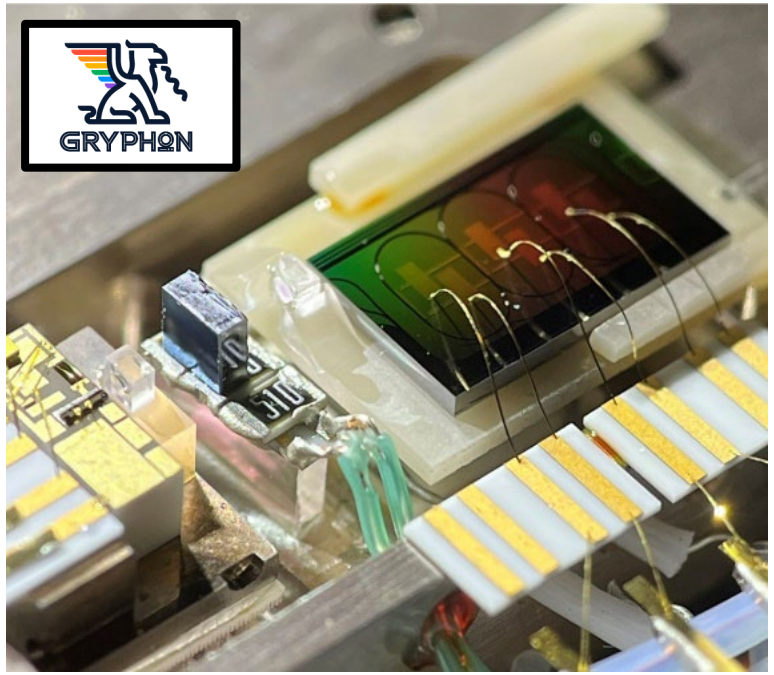
A new generation of precision microwave sources is here

State-of-the-Art Quartz Oscillator
Acoustic 100 MHz multiplied up to 10 GHz

Wenzel Associates

vs.

Prototype Photonic Oscillator
Optical 200 THz divided down to 10 GHz



Caltech, UCSB, NIST

Operating at fundamental noise limits after 90 years of optimization, and unable to maintain performance on mobile platforms

10 – 100 times lower noise
Manufacturable at semiconductor economies of scale
Inherently rugged

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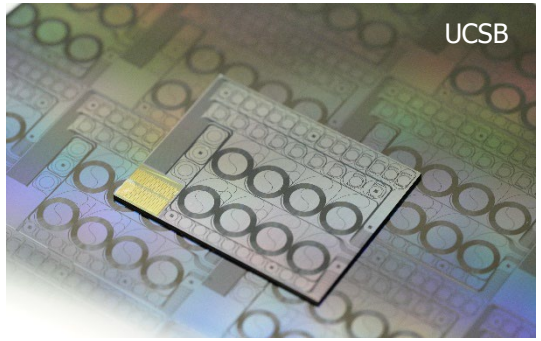
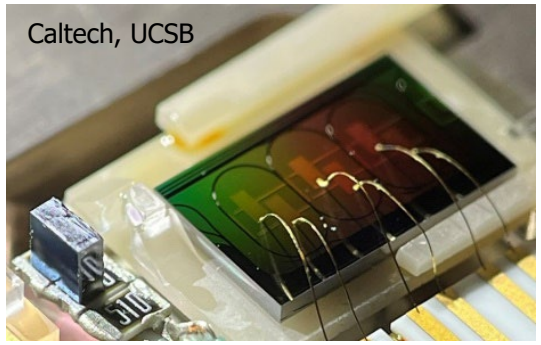
2022 – 2025: Generating RF with Photonics for Low Noise (GRYPHON)

Chip-scale photonics

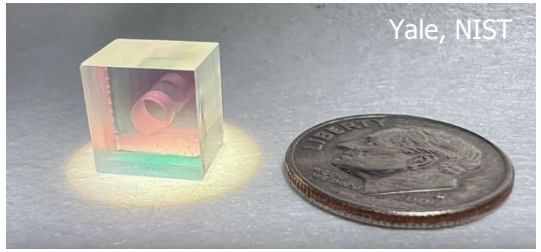
Chip-scale low-noise lasers



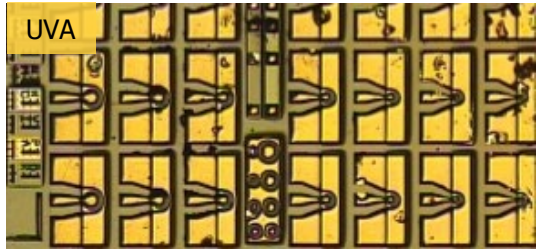
Chip-scale frequency combs



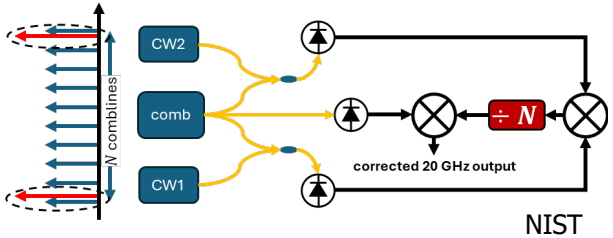
Stable miniature optical references



High-frequency photodetectors

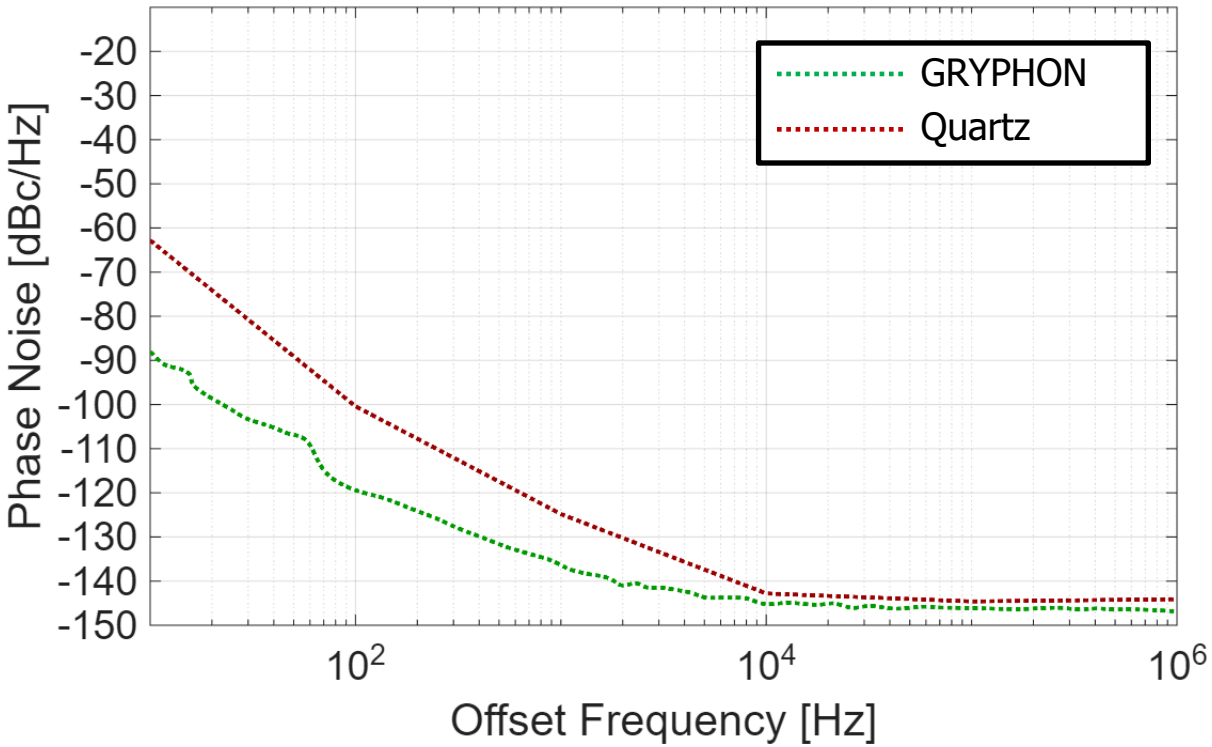


Low-noise microwave generation techniques



NIST

Low-noise microwave



Data adapted from Wenzel GMXO-FR data sheet and Nakamura et al., *Nat. Photon.* (2026)
Phase noise converted to equivalent noise for 10 GHz carrier

Science questions have been answered

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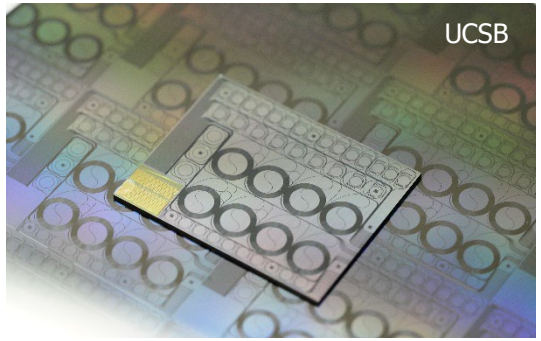
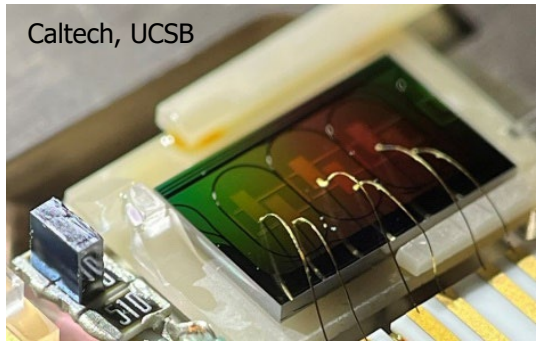


Chip-scale frequency combs



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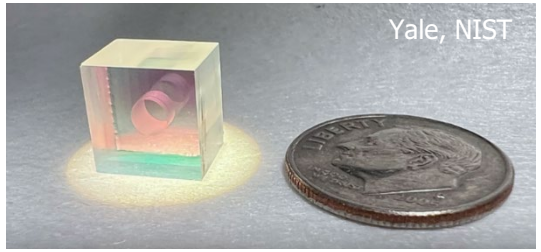

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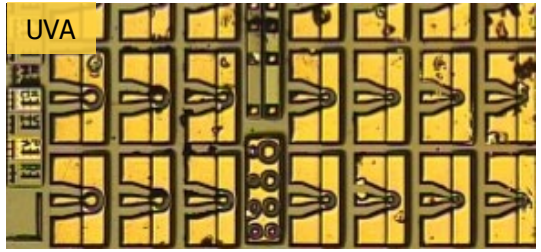
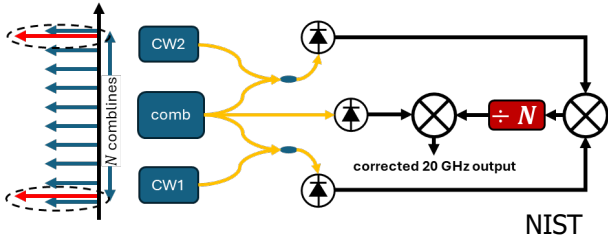
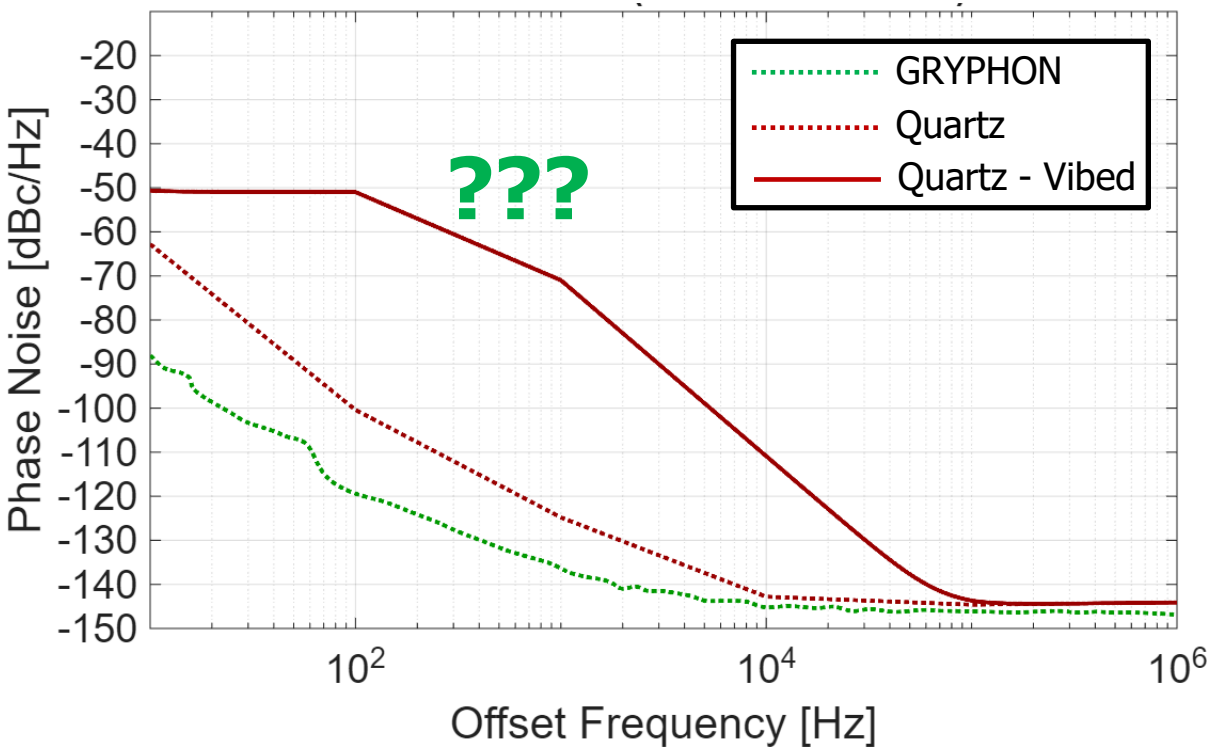


Low-noise microwave generation techniques



NIST

Low-noise microwave



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Phase noise converted to equivalent noise for 10 GHz carrier

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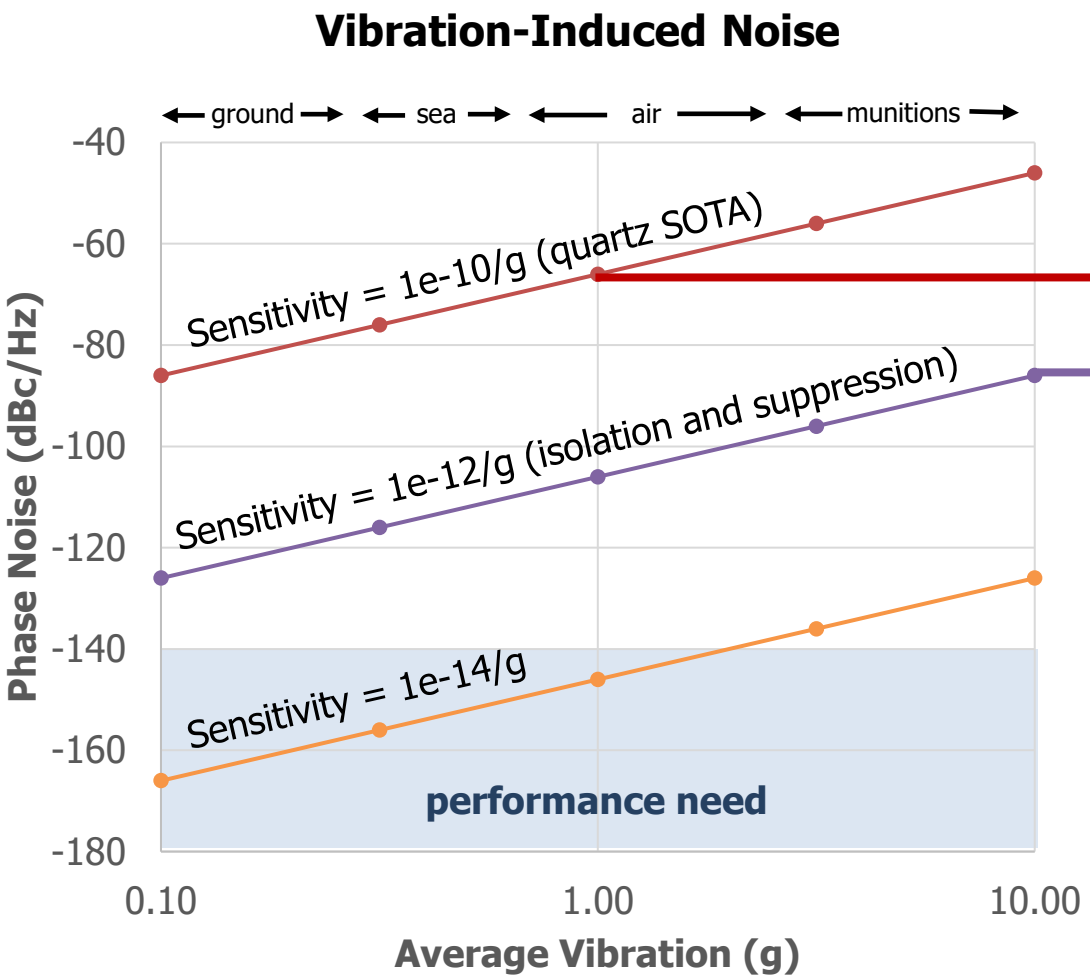
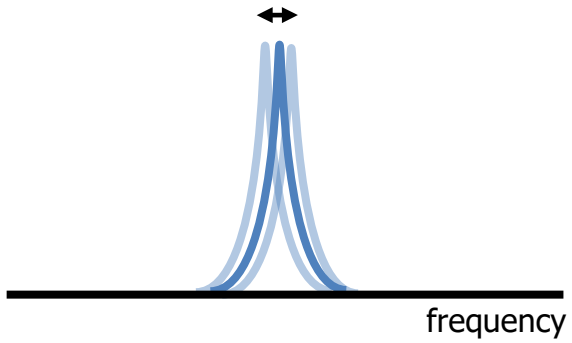
Outstanding challenge: maintaining low noise under environmental stress



Δf = 1 Hz around 10 GHz carrier!



Mitigation methods only go so far, and add SWaP

Isolation Mount

Aeroflex

Compensation Circuit

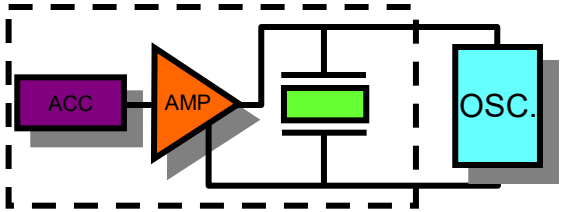


Illustration Courtesy of John Vig

Environmental effects, especially vibration, severely degrade performance

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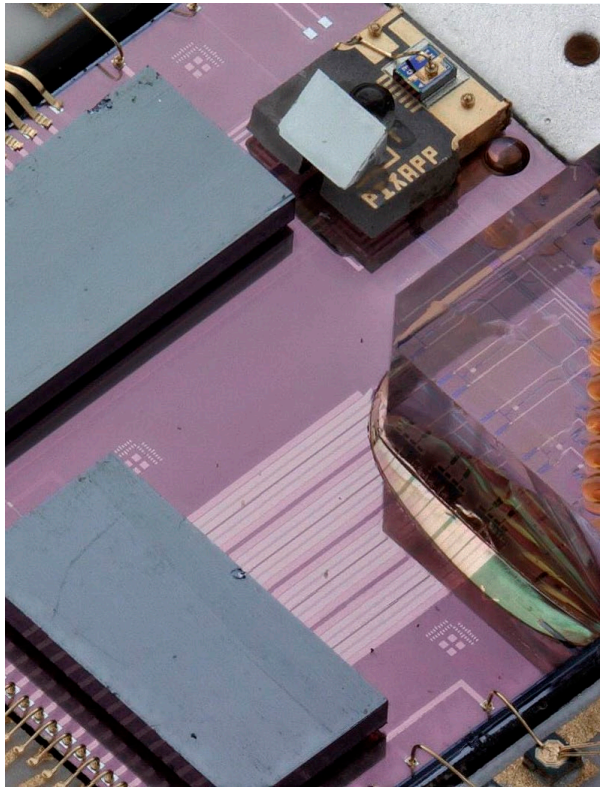
Outstanding challenge: microsystem integration

Hybrid Integration

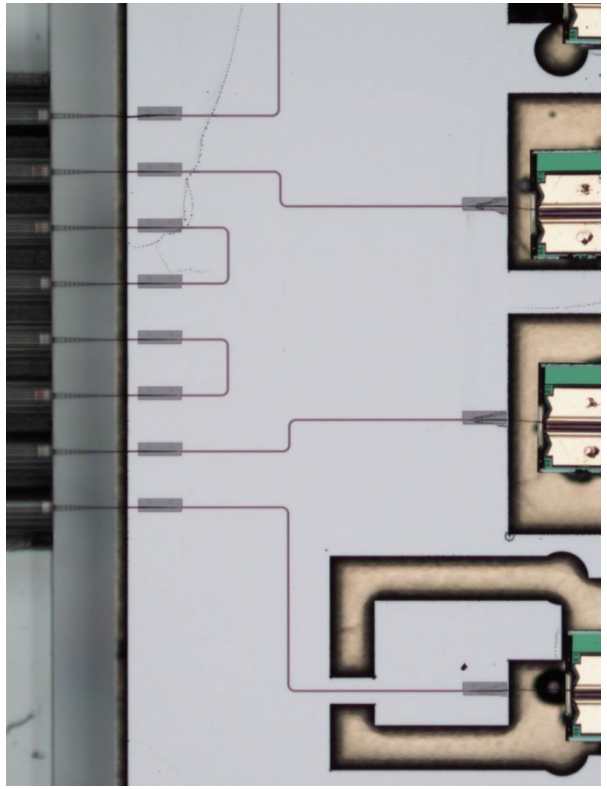


Pixapp

Multi-Chip Modules

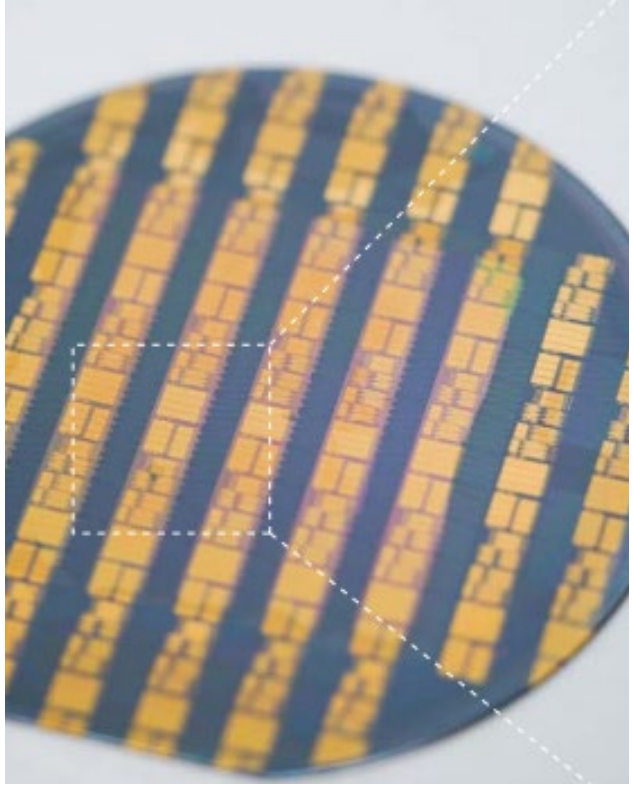
ficonTEC

Photonic Wire Bonding



Dream Photonics

Heterogeneous Integration



UCSB: Xiang et al., *Science* (2021)

Many compelling capabilities, each with unique manufacturing advantages and challenges

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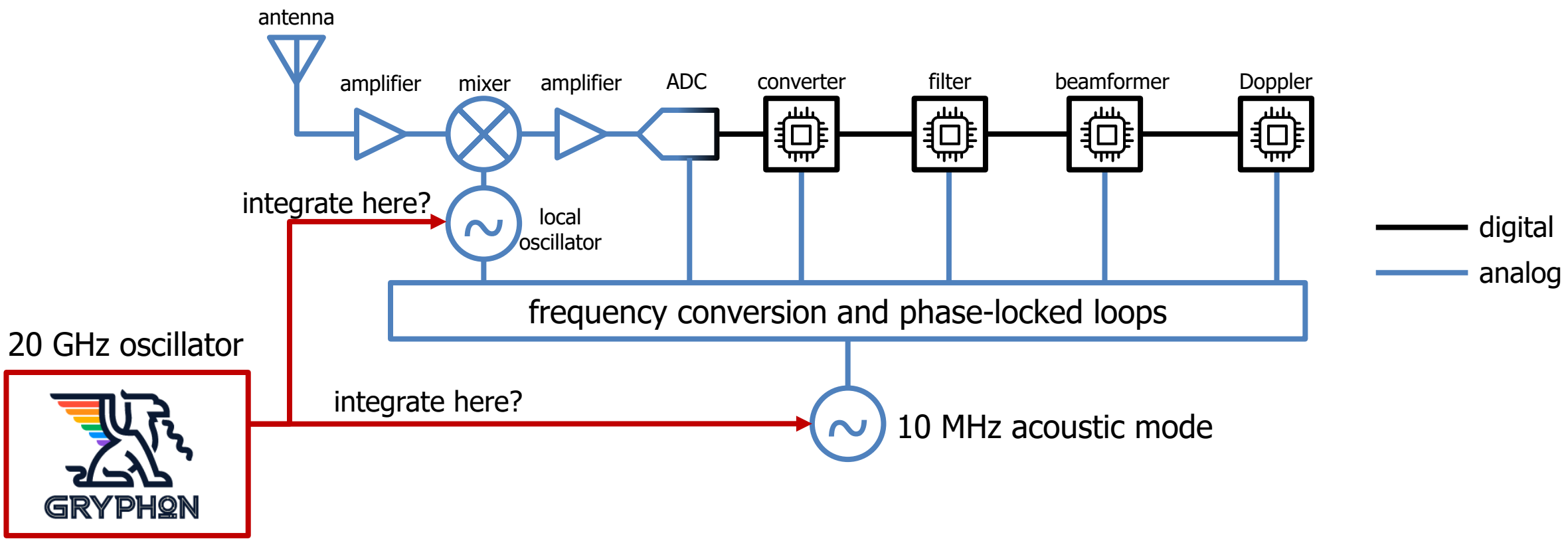
Outstanding challenge: maintaining low noise at system level



Photonics can provide a low-noise source, but downstream components degrade the advantage

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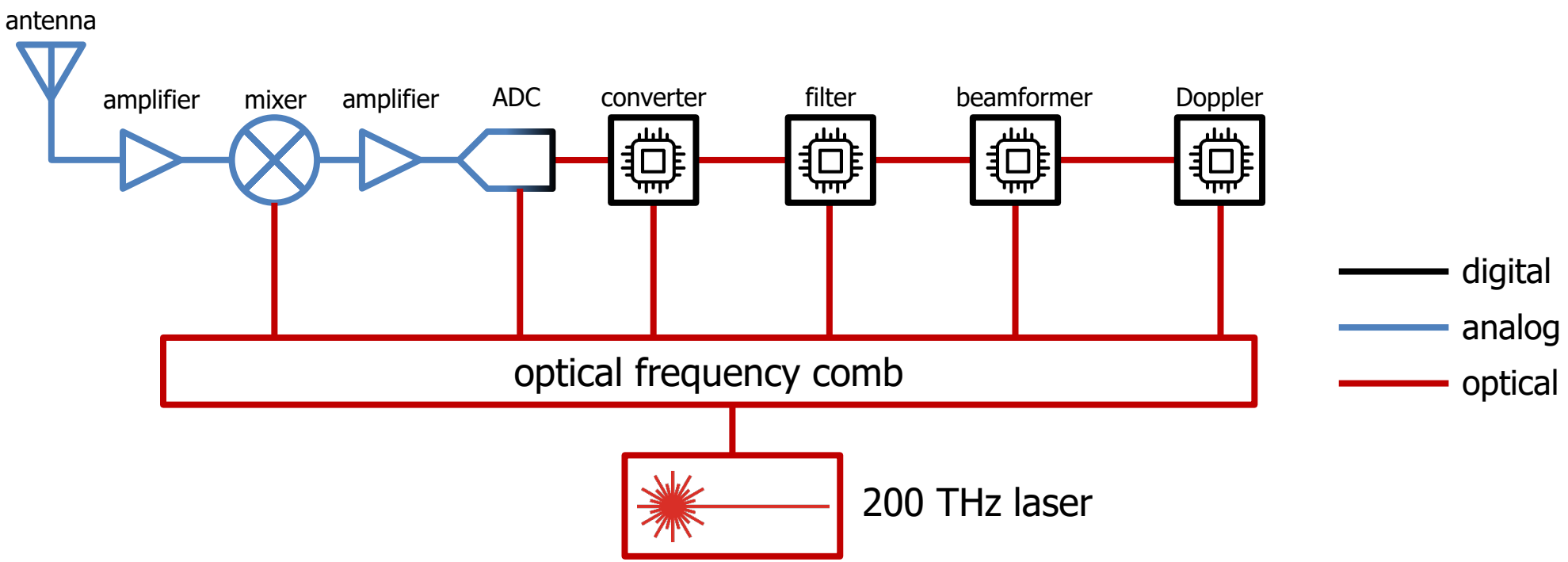
RF Architectures Applying Photonic Timing and Routing (RAAPTR)



Re-imagining RF system architectures, with performance rooted in optics

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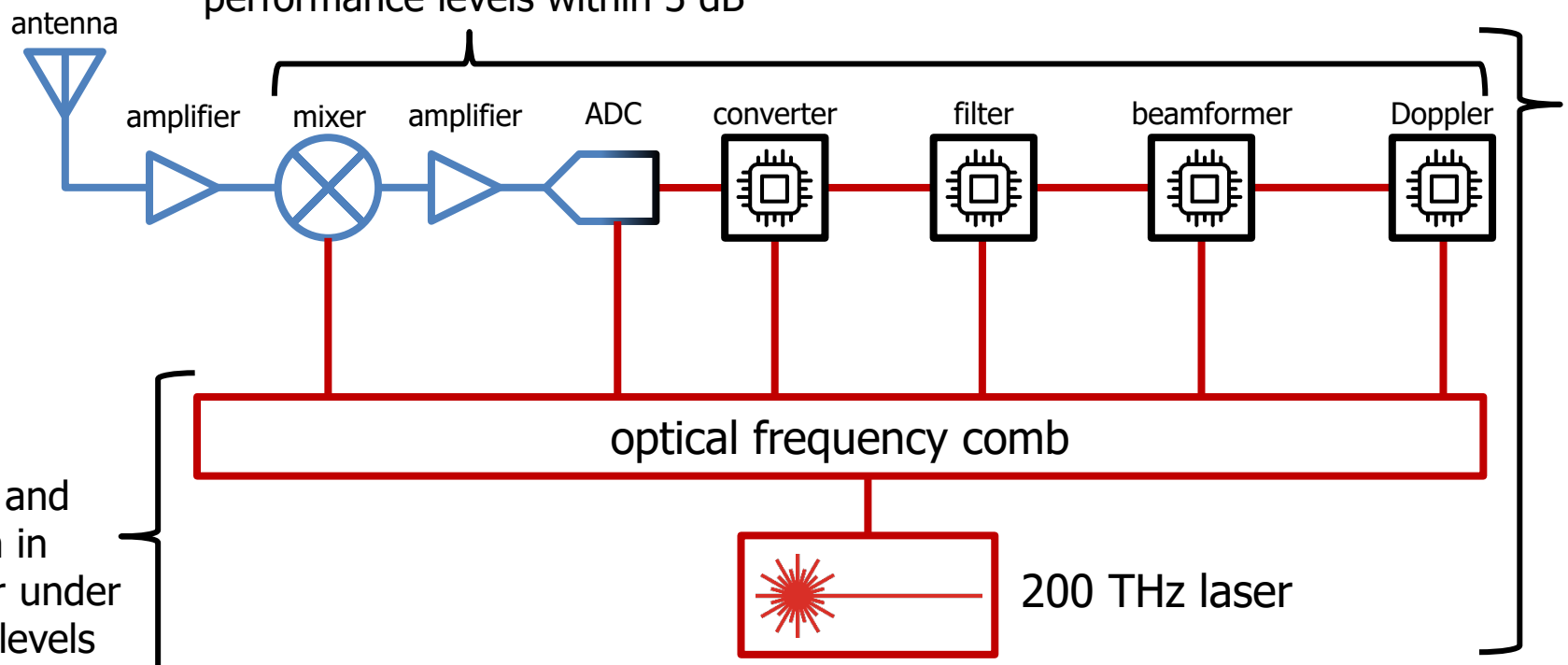
Key RAAPTR goals

Architecture
Retains noise and timing performance levels within 3 dB

System
Differentiated radar, EW, and comms capabilities for compact mobile platforms (proposer defined)



digital
analog
optical

Oscillator
Low phase noise and timing deviation in compact form factor under airborne vibration levels

Linking breakthrough component performance with clear defense use case and platform capabilities

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Program metrics

Category	Metric	Value
Oscillator	Phase Noise at 100 Hz*	-120 dBc/Hz
	Phase Noise at 10 kHz*	-150 dBc/Hz
	Output Frequency	Selectable within 1–40 GHz
	Timing Deviation from 1 to 100 seconds	1 ps
	Output Power	Proposer Defined
	Volume**	300 cc
	Power Consumption	Proposer Defined
Architecture	Phase Noise and Timing Budget***	3 dB
	Performance Attributes	Proposer Defined
Environment	Vibration****	0.04 g^2/Hz
	Temperature	-40 to 85 °C

** Phase noise metrics are defined at the specified offset frequency from a 10 GHz carrier frequency. Proposals to operate at other output frequencies f within the 1–40 GHz band must scale the phase noise metric by 20log(f/10).*

*** The oscillator volume metric includes all optoelectronic components necessary to operate the oscillator, such as pump lasers and photodetectors. Control electronics may be implemented in printed circuit boards that do not contribute to the volume metric in Phase 1, but must be integrated into the volume metric in Phase 2.*

**** The noise and timing budget metric requires that at any point of the analog RF system, phase noise and timing deviation do not exceed 3 dB of the oscillator output performance. Architecture metrics must be met under the environmental conditions specified in the table in an integrated breadboard in Phase 1.*

***** Vibration profile as specified in MIL-STD-883-2, Method 2026, Test Condition I/B.*

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Program structure

FY27	FY28	FY29	FY30
Phase 1 (24 months) Components in the Lab		**Phase 2 (18 months)** Integrate and Demo on Platform	

M6: Oscillator design meets metrics in simulation

M12: Internal oscillator devices characterized for vibration sensitivity

M12: Analog components characterized for noise performance

M12: Initial architecture design completed with use case flow-down requirements

M15: Un-packaged oscillator functional test

M18: Un-packaged oscillator and analog signal chain functional on integrated breadboard

M21: Packaged oscillator functional test

M24: Packaged oscillator characterized under relevant environmental conditions in lab

M24: Integrated analog sub-system characterized under relevant environmental conditions in lab

M24: Final architecture design and test plan completed

M24: Functional demonstration concept and budget completed → Potential award modification: Phase 2 functional system development and demonstration, pending availability of funds and transition partner interest

M27: Integrated oscillator and analog sub-system breadboard test under relevant environmental conditions in lab

M30: Integrated brass-board with oscillator, analog, and digital subsystem complete

M36: Flight test of brass-board on Government-furnished test platform

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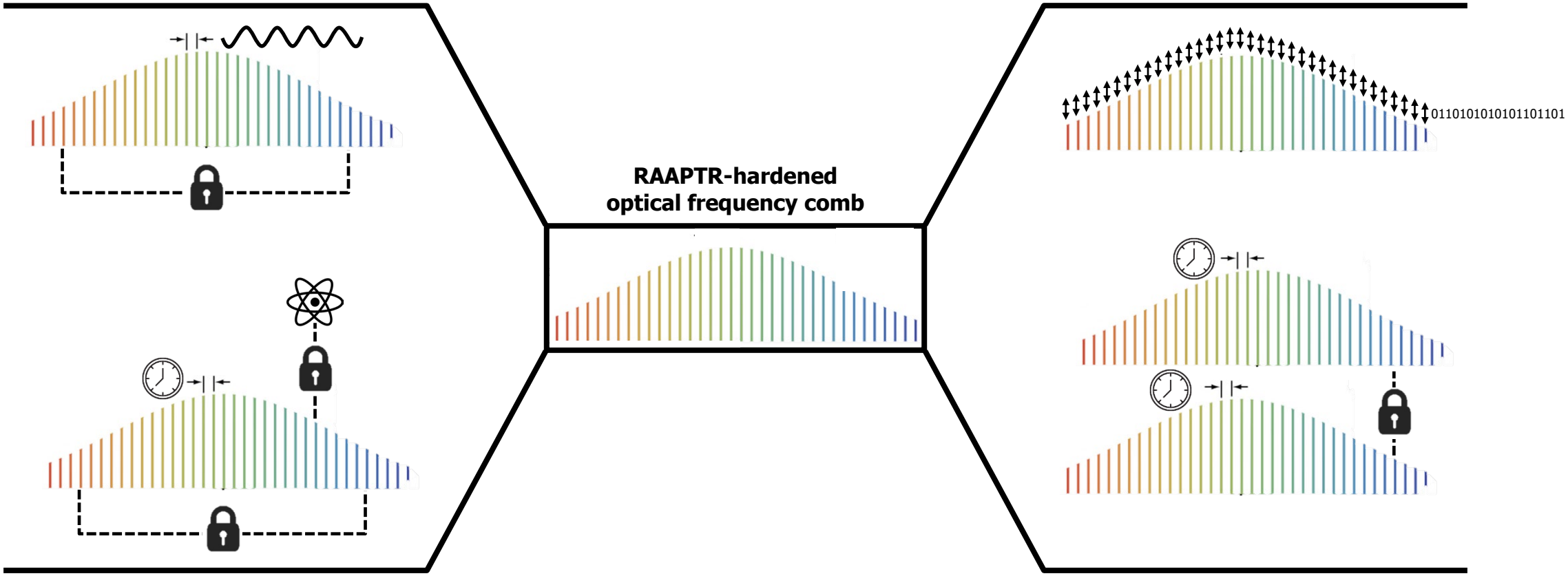
Rugged combs enable more than just low-noise oscillators

Low-noise microwave oscillators
GRYPHON, DODOS, PULSE

High-bandwidth data movement
PIPES, SOAP, POEM



RAAPTR-hardened optical frequency comb

High-stability clocks
ROCkN, A-PhI, ACES, ONR NGAC

High-precision time transfer
ROCkN, PULSE

Solving the RAAPTR challenge also enables fielding decades of record-setting optical device R&D

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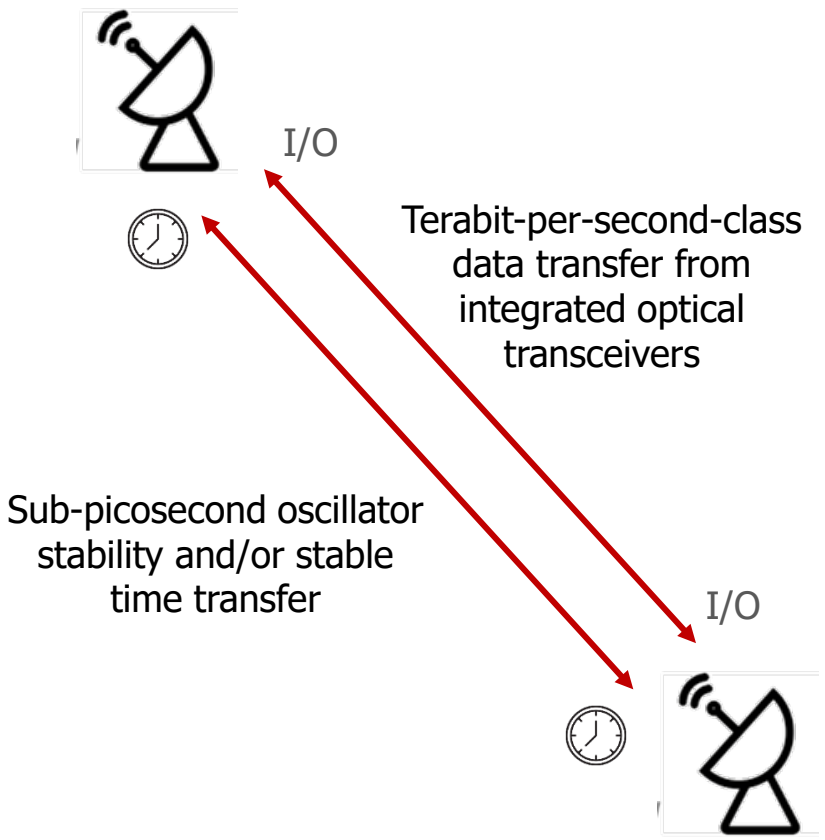
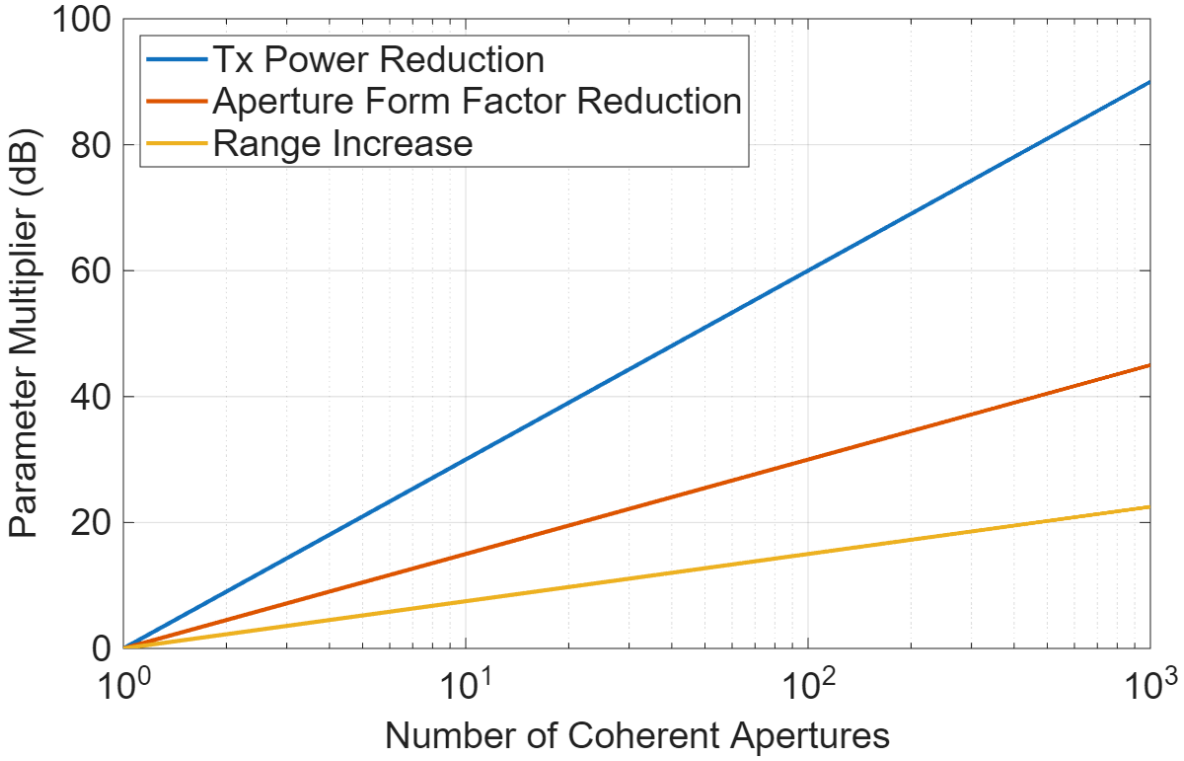
Optical timing + data movement = coherence over arbitrary distances



RAAPTR optical backbone can be extended across multiple platforms to fuse large numbers of apertures



Extending multi-statics to the microwave band and to mobile platforms

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Capturing the impact

WE WANT YOU

To identify the use case and host platform that makes best use of photonic oscillators and optical devices!

Application to guide RF architecture design and proposer-defined performance metrics

Initial categories of interest to DARPA included in forthcoming CUI addendum

Compelling concepts could lead to Phase 2 expanded effort

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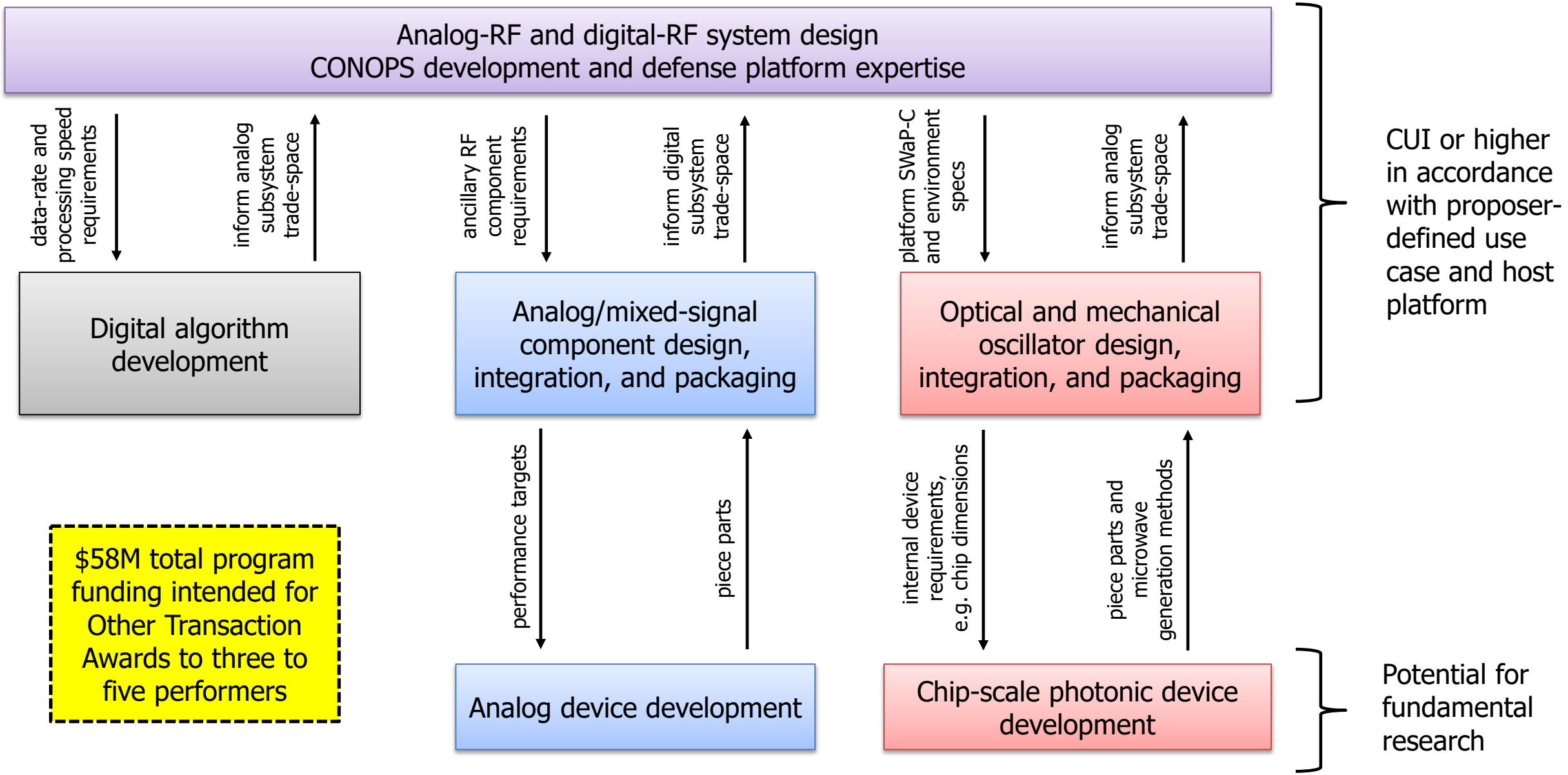
Elements of a successful performer team



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Goals for today

- Proposers Day Special Notice and presentation materials include sufficient background to form teams and initial concepts in advance of program solicitation
- Today is about showcasing relevant capabilities across organizations to jump-start proposal development
- Questions about the program?
  - Send to RAAPTR@darpa.mil and we will seek to clarify in the upcoming Program Solicitation

Start (ET)	Topic/Speaker
8:15 AM	**CHECK-IN**
9:00 AM	**Welcome, Logistics** *MXO Technical SETA*
9:05 AM	**Security** **MXO Security PSR**
9:10 AM	**Introduction to DARPAConnect** *Joseph "Rob" Newton*
9:15 AM	**Program Overview** *Justin Cohen, DARPA/MXO Program Manager*
9:45 AM	**Attendee Presentations Session 1** *Approved Participant Requests Only*
10:20 AM	**Break**
10:30 AM	**Attendee Presentations Session 2** *Approved Participant Requests Only*
11:05 AM	**Introduction to MXO** *Whitney Mason, DARPA/MXO Office Director*
11:15 AM	**Attendee Presentations Session 3** *Approved Participant Requests Only*
11:45 AM	**Attendee Presentations Session 4** *Approved Participant Requests Only*
12:30 PM	**LUNCH (not provided)**
1:30 PM	**Teaming Expo** *DARPA Conference Center 01-200*
1:00 PM	**Sidebar Discussions (by appointment)** *Justin Cohen, DARPA/MXO Program Manager*
5:00 PM	**ADJOURN**

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