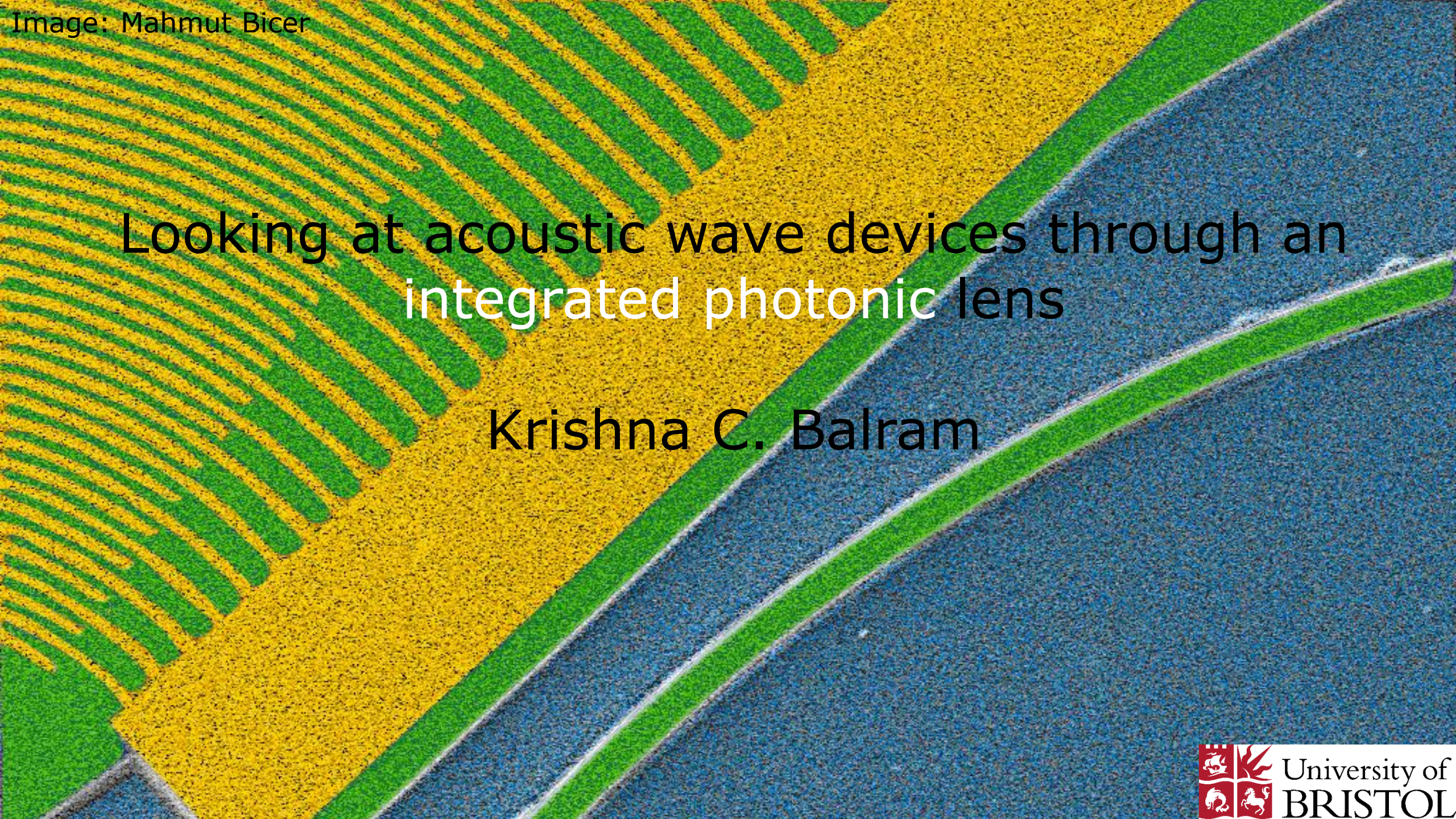
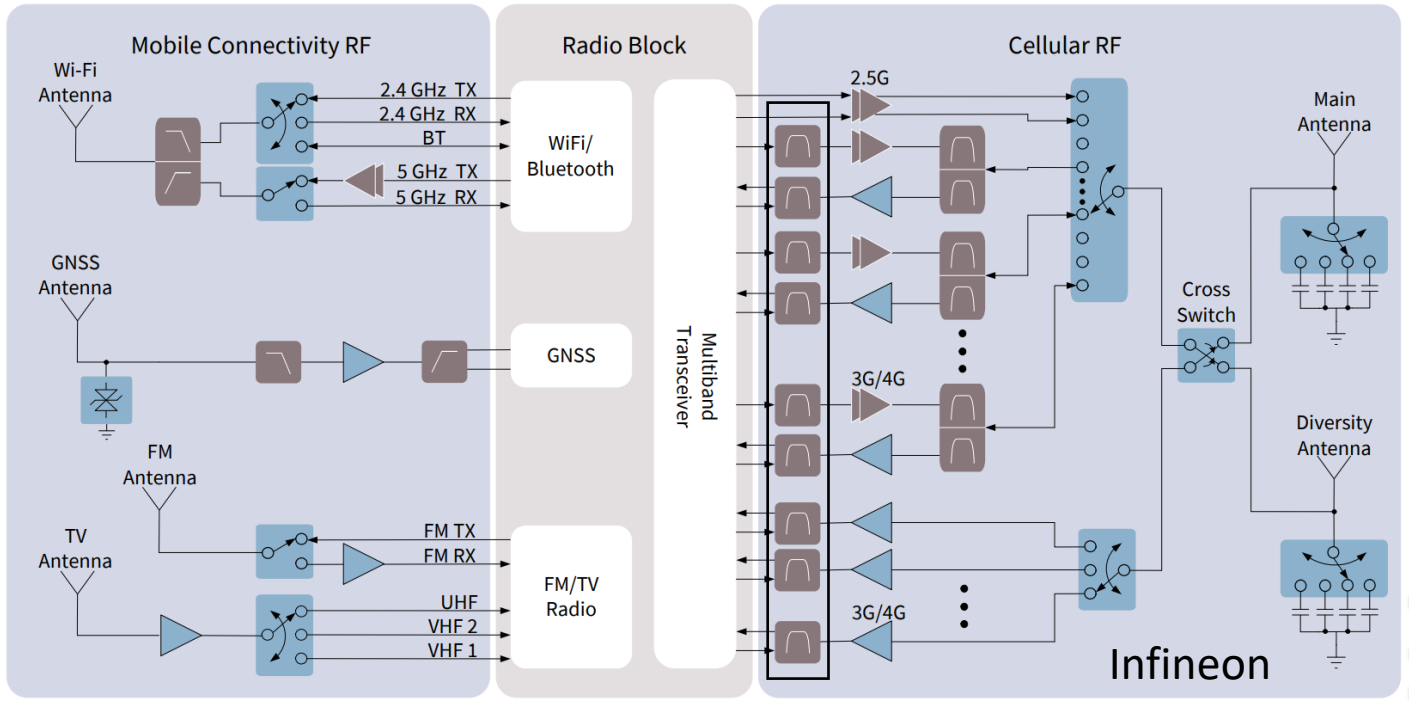


Looking at acoustic wave devices through an integrated photonic lens

Krishna C. Balram

University of BRISTOL

Motivation:



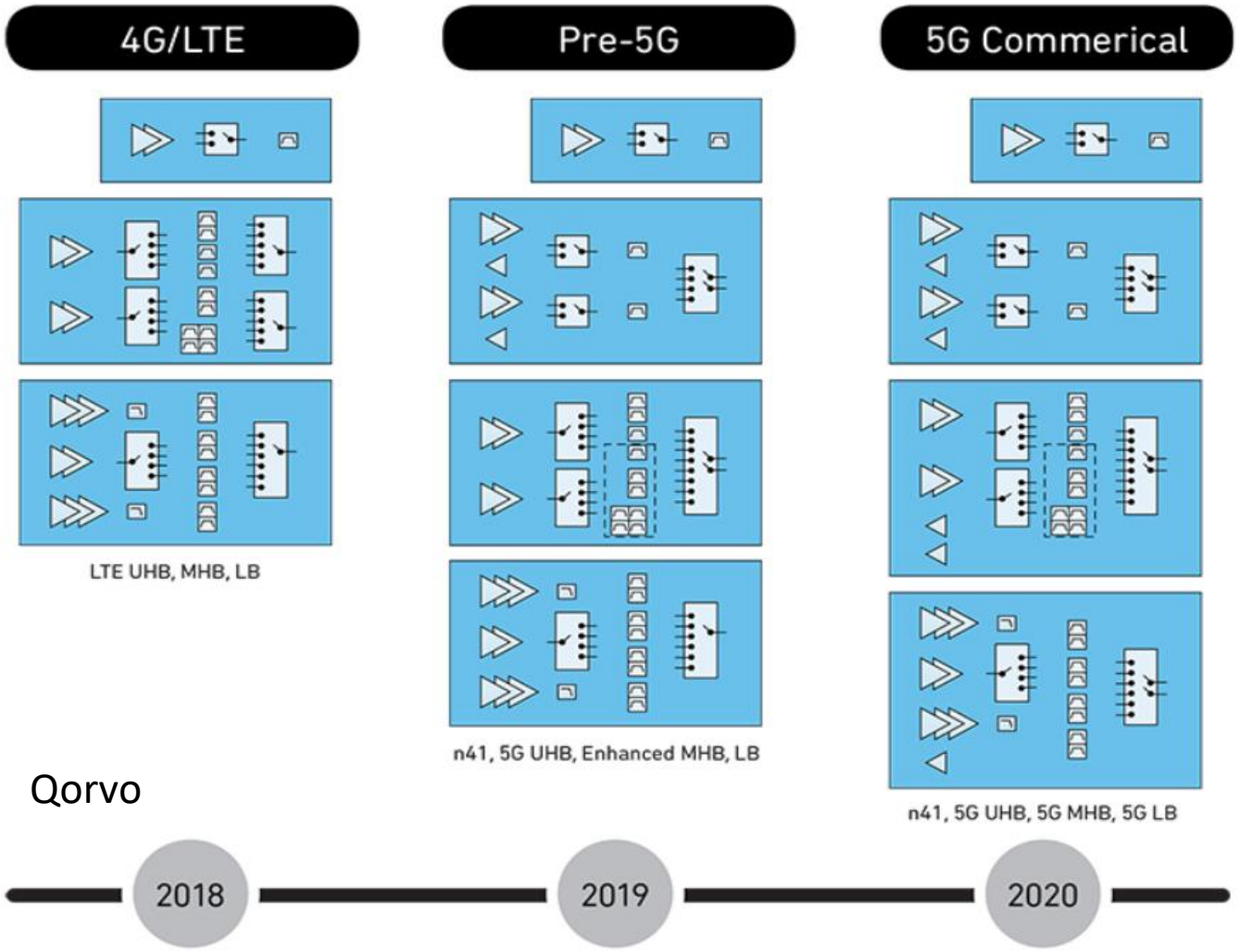
"Today, the iPhone 7 accesses 23 to 24 GSM, CDMA and LTE frequency bands, while the Galaxy flag ship phones from Samsung have 16 bands (not counting the GPS, Wi-Fi, Bluetooth and NFC radios)"

Rich Ruby (Director of FBAR Technology)
Broadcom

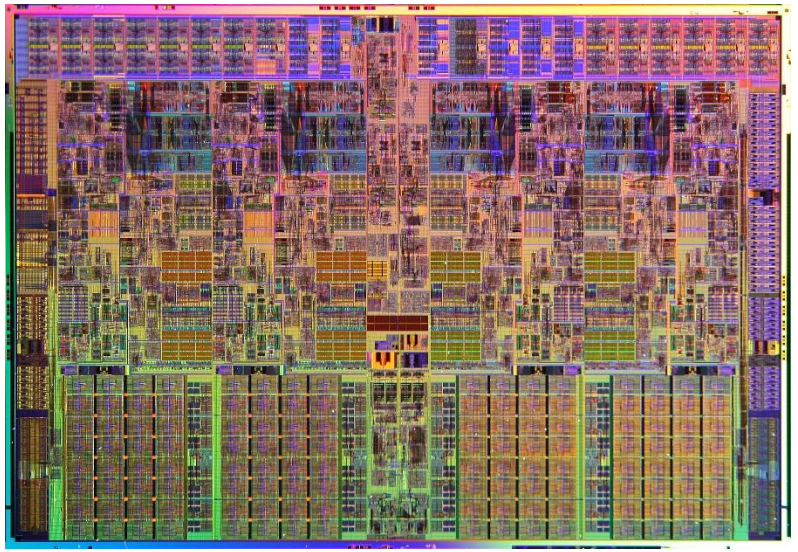
- As we move towards 5G, the filtering requirements will only get more challenging (more bands, higher frequencies)

Review: CS Lam (IEEE UFFC 2016)

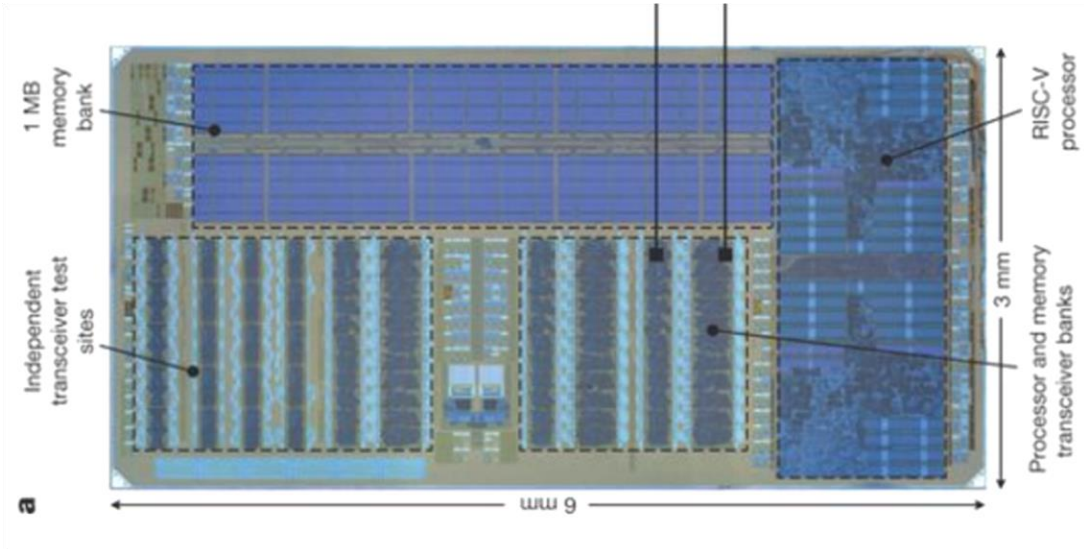
Why monolithic integration?



Qorvo

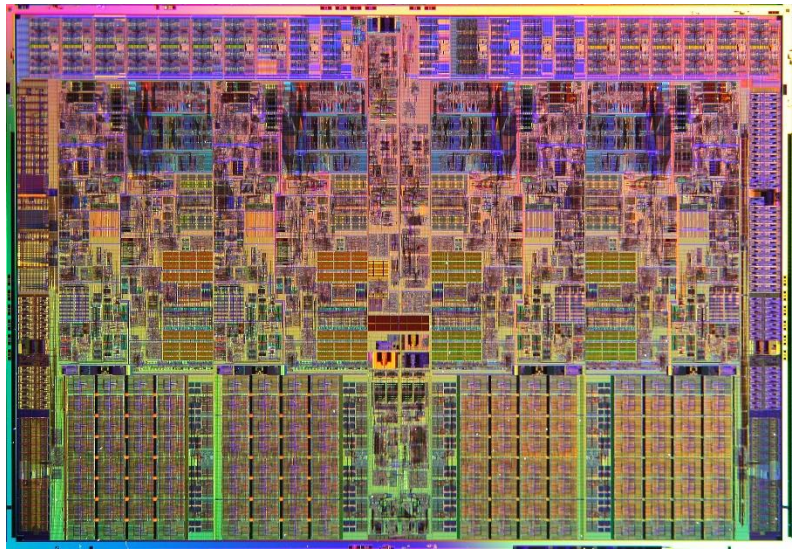


Intel i7

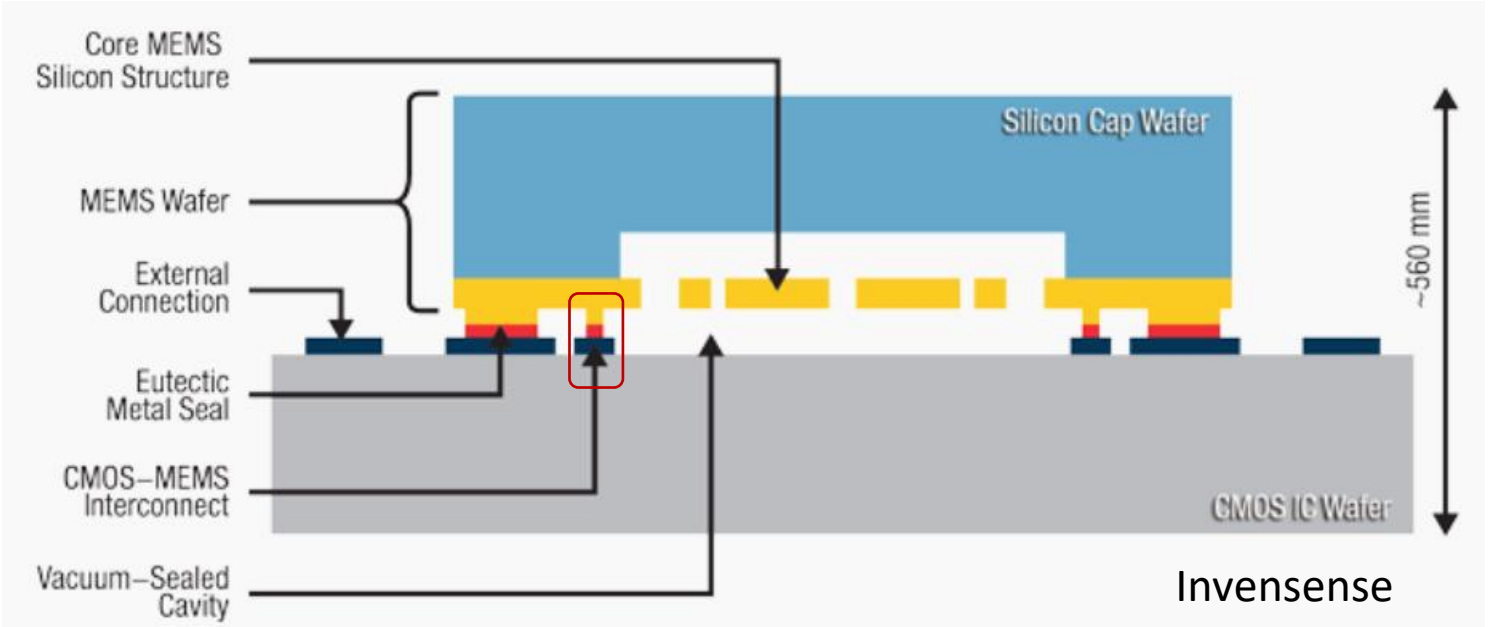


Silicon integrated photonics (Nature, 2015)

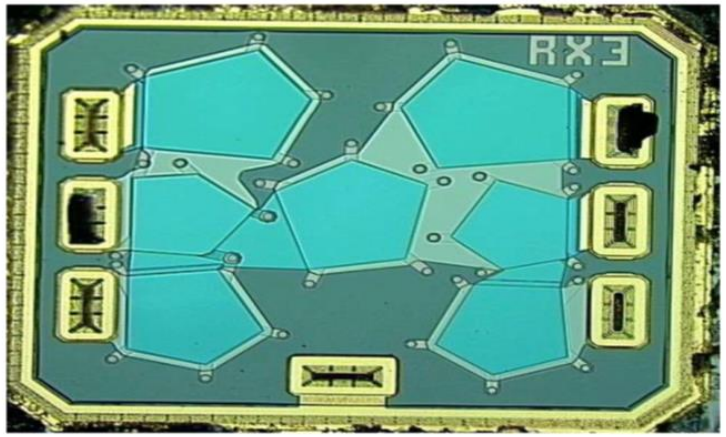
Material compatibility vs process compatibility:



Intel



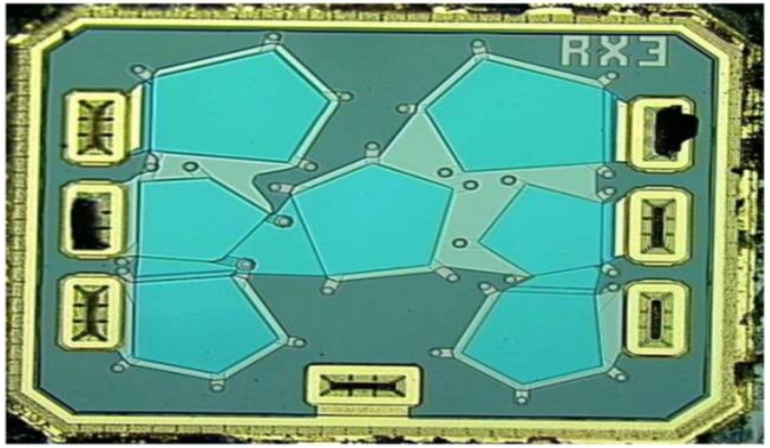
Invensense



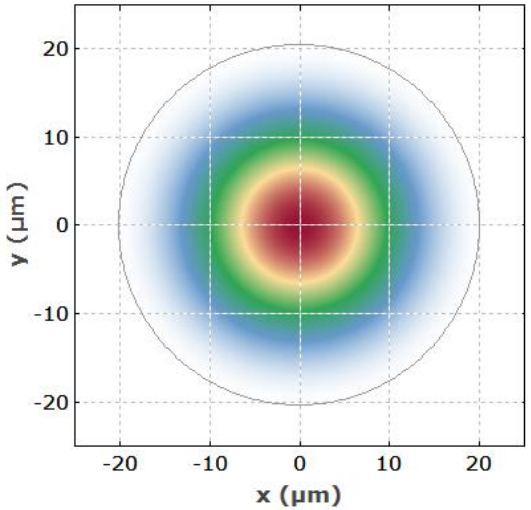
Avago

- Material compatibility ≠ Process compatibility
- AlN Film bulk acoustic resonators (FBAR) require substrate release which makes process integration with CMOS electronics challenging

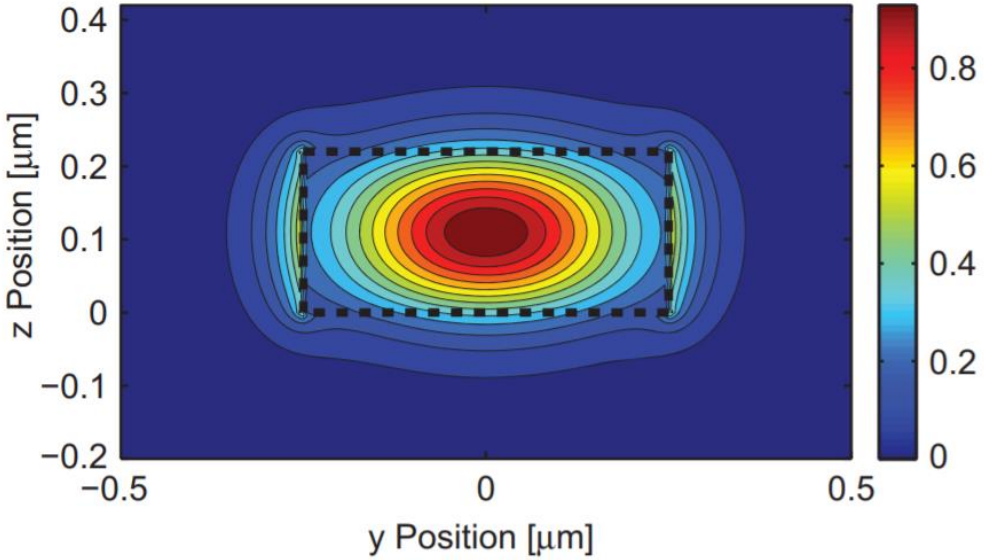
A history lesson from integrated photonics

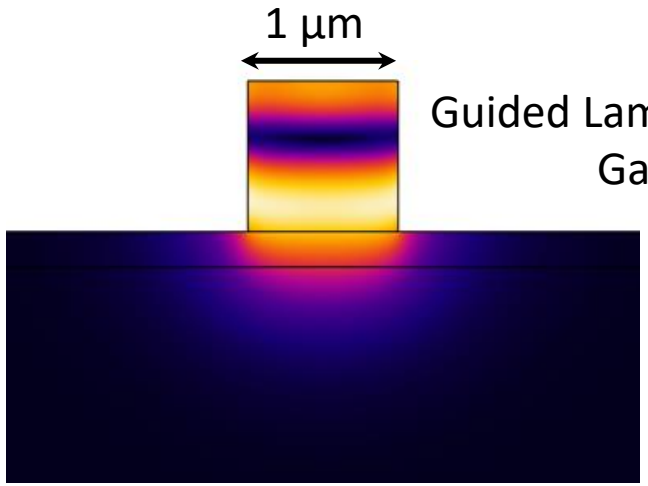


Avago



Optical fiber fundamental mode (RP Photonics)

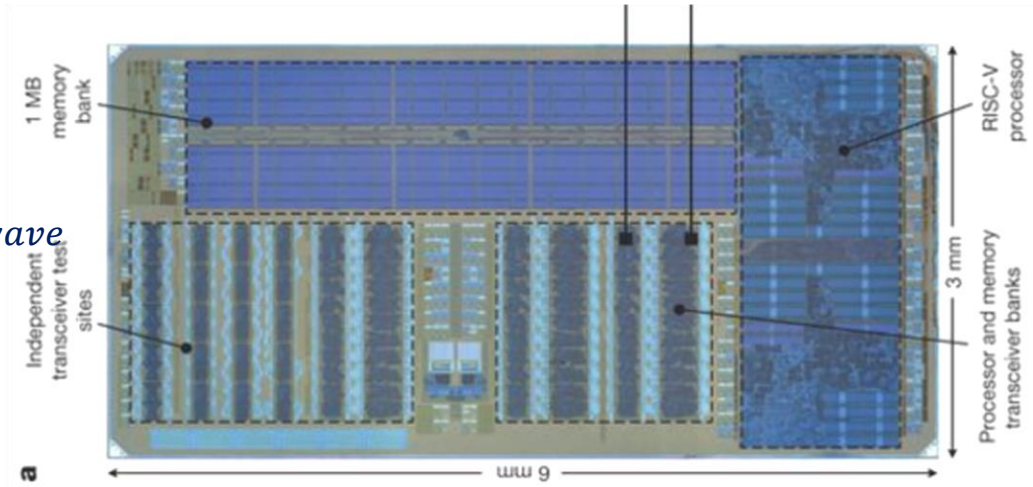




Guided Lamb wave in GaN

$\lambda_{GHz,acoustic\ wave} \sim \lambda_{1.55\ \mu m\ optical\ wave}$

How far can we push this analogy?

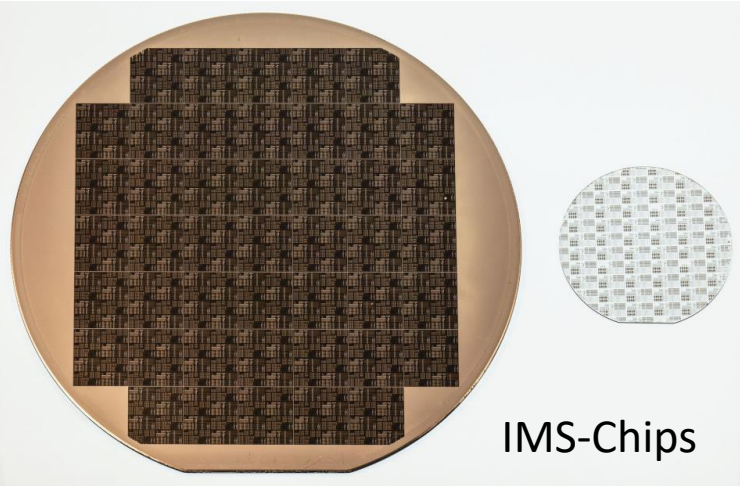


Silicon integrated photonics (Nature, 2015)

Related ideas: Yale, Stanford and Sandia

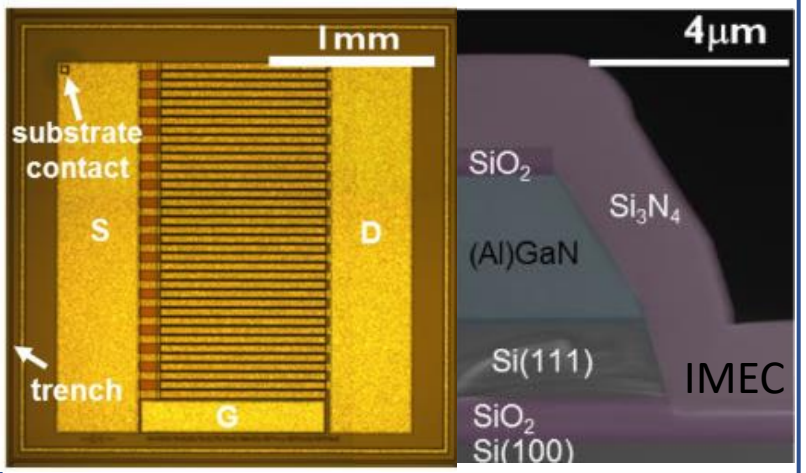
Why GaN, why now?

Advances in epitaxy



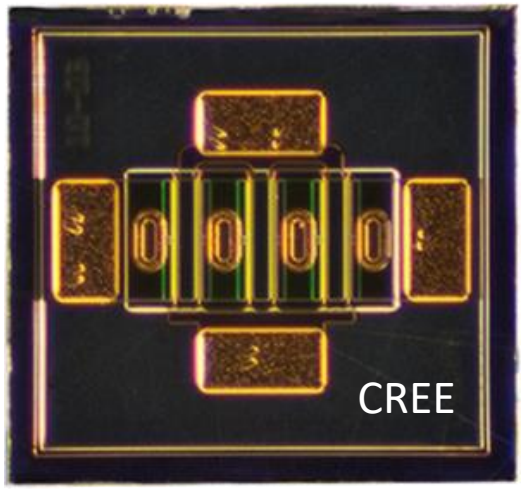
Thin buffer + film substrates with very low defect density are widely available

Foundry MPWs



Ready access to high-performance GaN HEMTs allows us to focus on filter design and integration

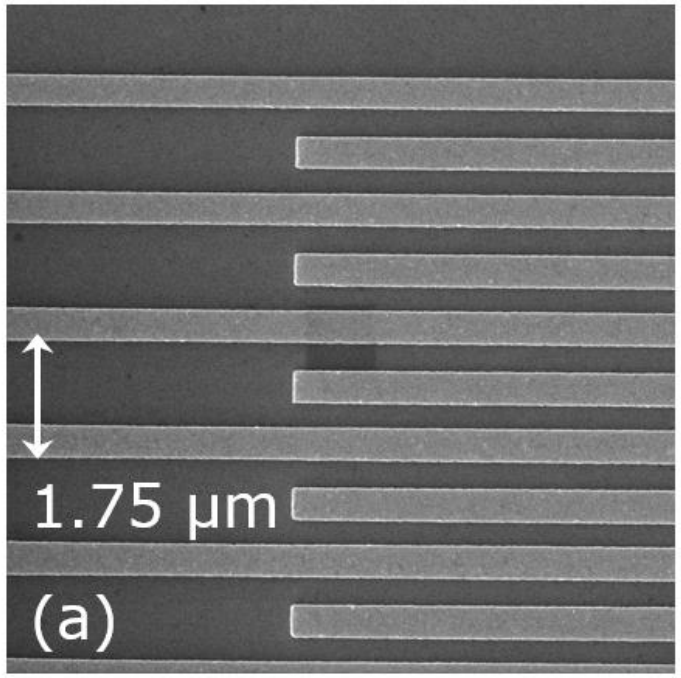
5*G: GaAs -> GaN PAs

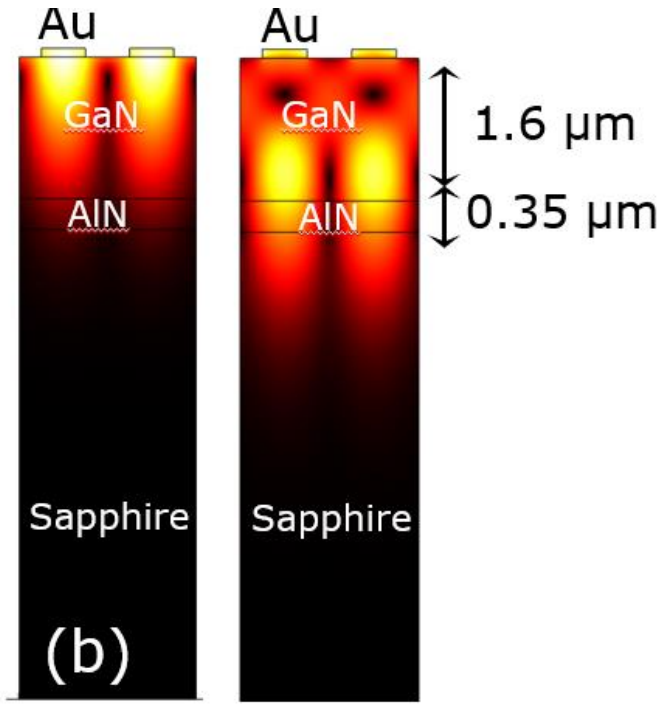


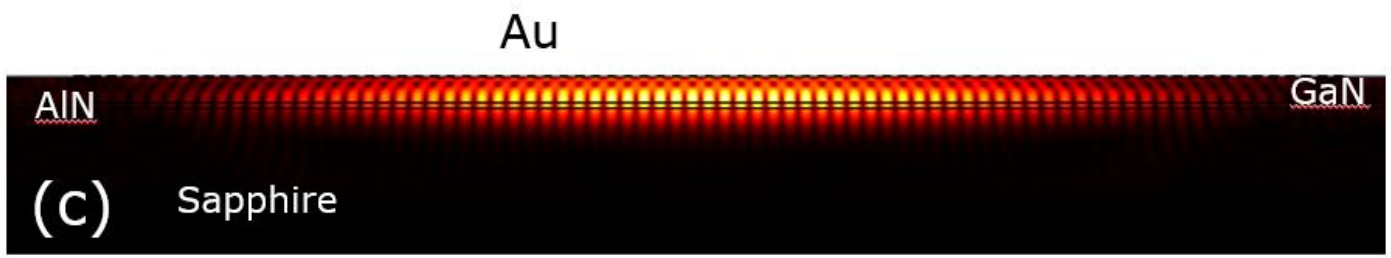
Replacing GaAs power amplifiers with GaN PAs provides a once-in-a-lifetime opportunity for monolithic integration

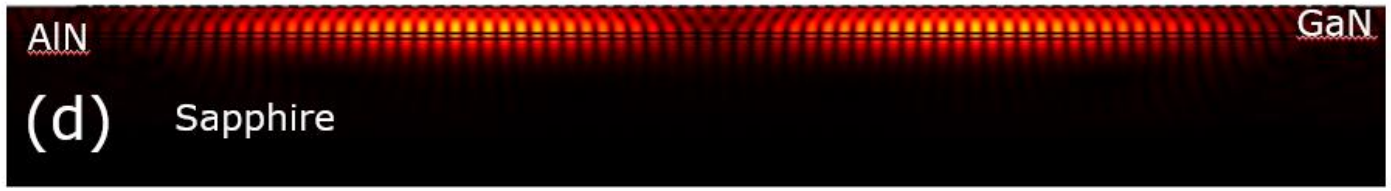
M Rais-Zadeh et al., 'GaN as an electro-mechanical material' 2014

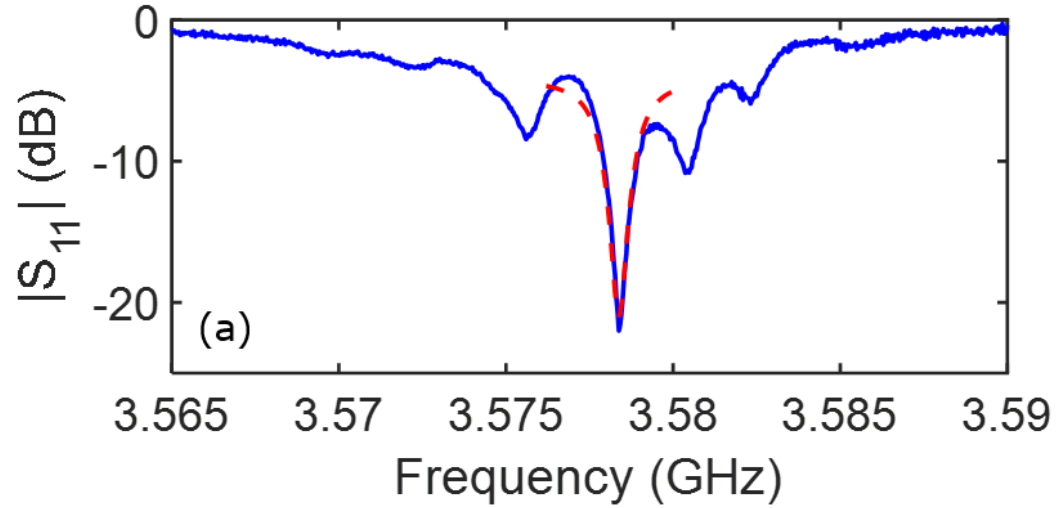
Waveguiding and confinement in GaN

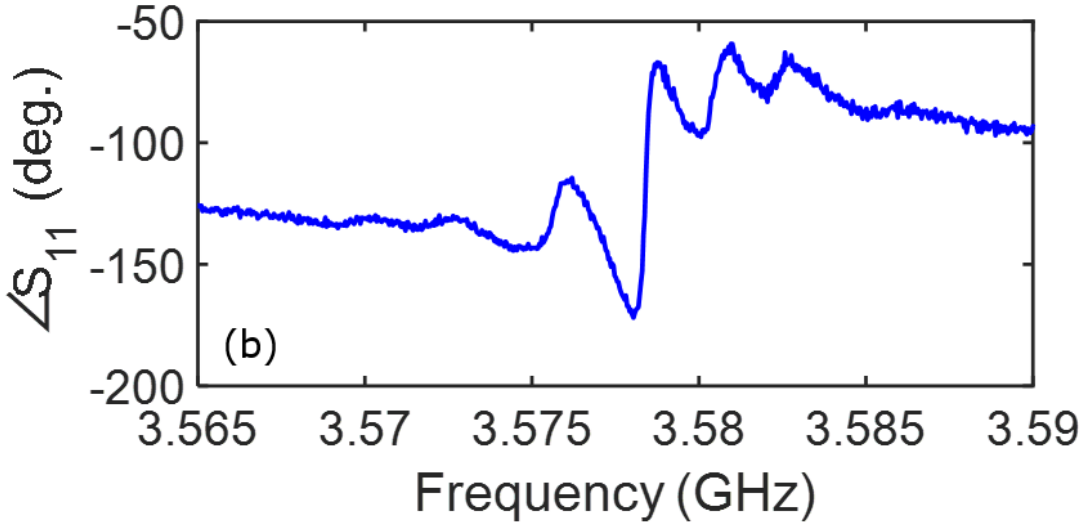












Valle, Singh, Cryan, Kuball and Balram APL (2019)

A brief diversion: quantum transduction

Electromechanical transduction (k_{eff}^2, Q_{RF})

Weak microwave signal from quantum circuit

($\gamma_{m,RF}$)

Weak acoustic mode

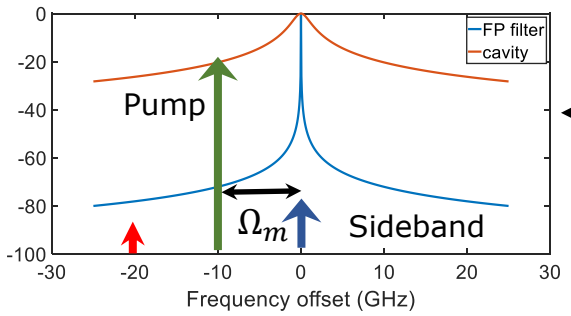
Phonon injection efficiency (η_{PIE})

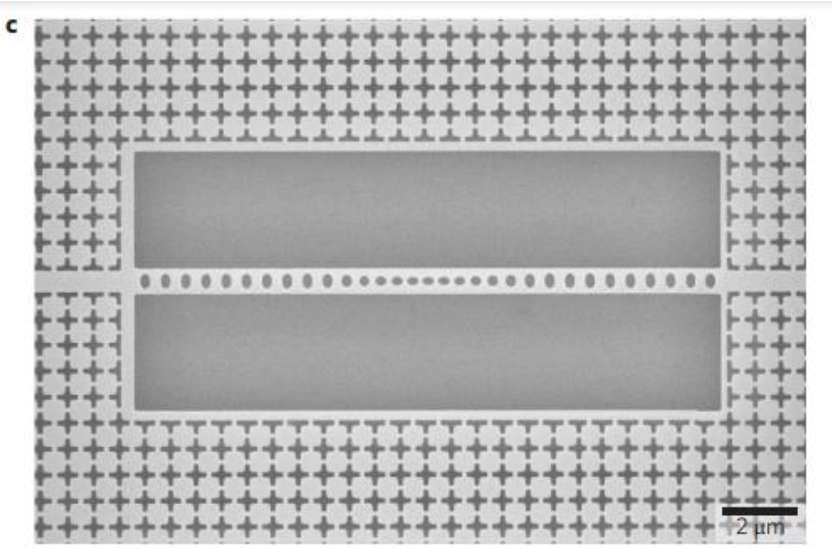
Optomechanical interaction

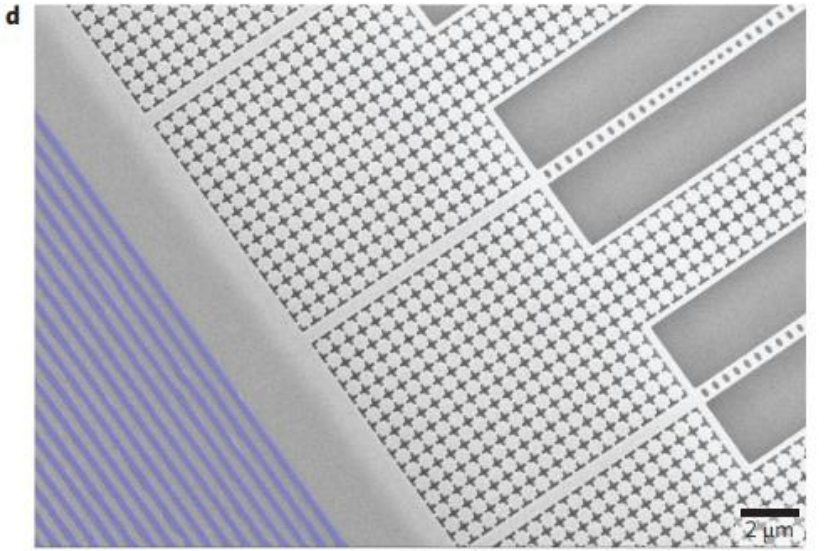
($g_0\sqrt{N_{cav}}, \kappa_{om}, \gamma_{om}$)

Optical pump field

Off-chip filtering







Balram and Srinivasan, in preparation

Balram et al., Nat. Phot. 2016

European Research Council
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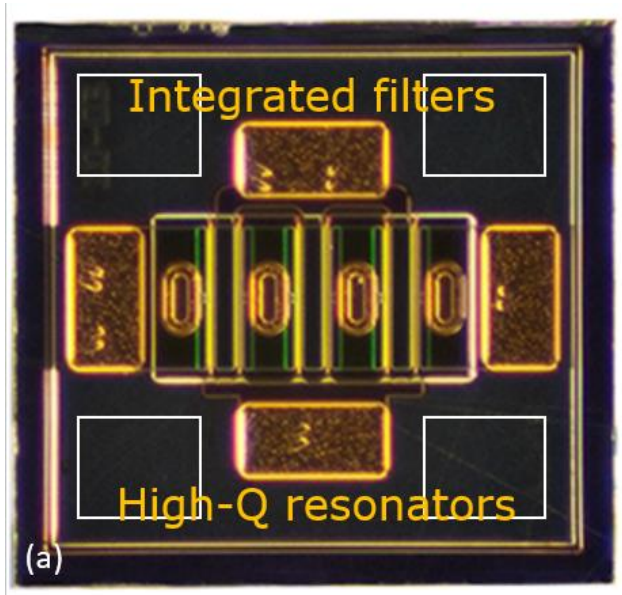
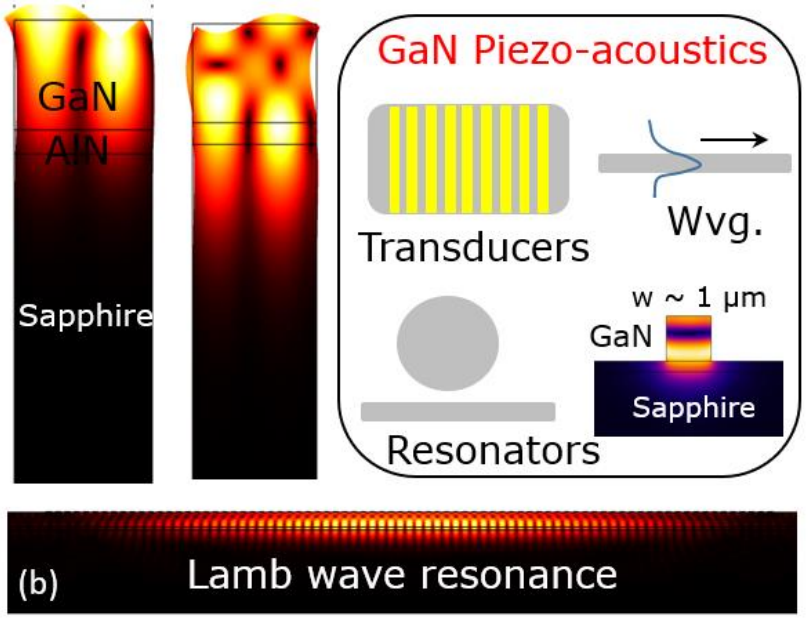
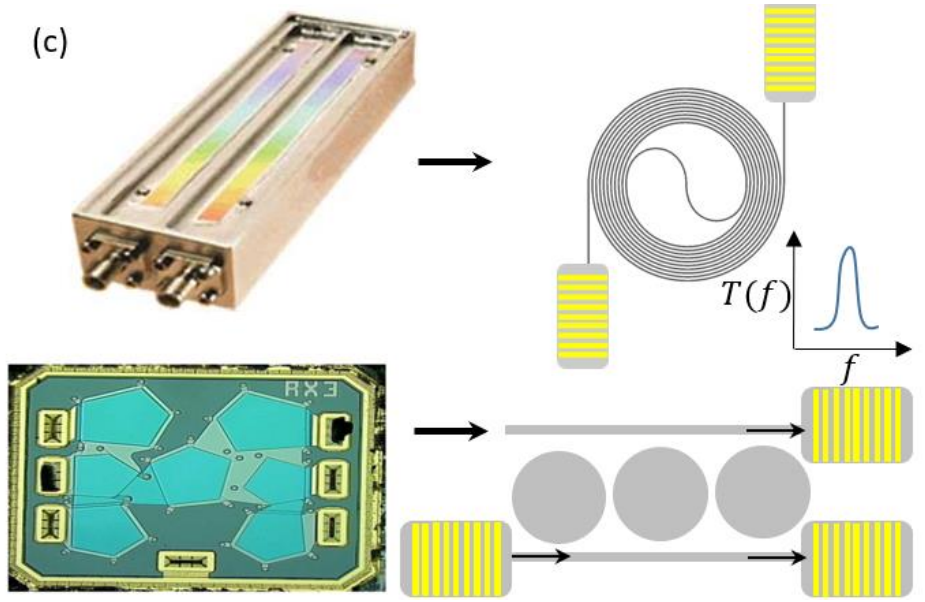
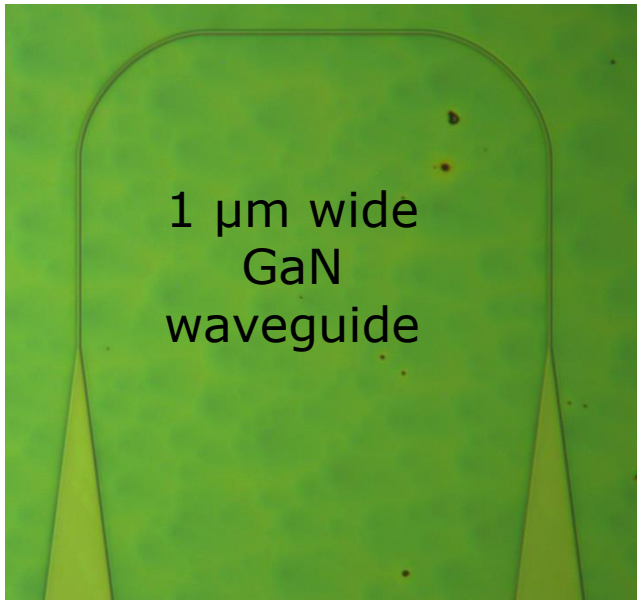
GLIMMER (Guiding Localizing and IMaging Elastic waves in waveguides and Resonators):









- Interfacing piezoelectric devices with GaN HEMT amplifiers
- Building a phononic integrated circuits platform in GaN on SiC
- Imaging confined high-frequency vibrations (gated Raman imaging)

Acknowledgements:

Martin Cryan

Bruce Drinkwater

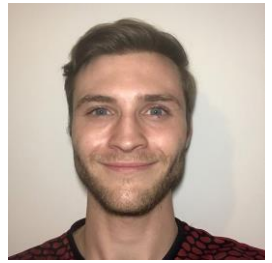
Martin Kuball

John Haine

INTEGRATED
PIEZO-OPTOMECHANIC
UNIVERSITY OF BRISTOL

Stefano Valle

Mahmut Bicer



Jacob Brown

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