Advancing integrated photonics with electro-optic polymer modulators

Michael Lebby, CEO

14th September 2021, Market Focus

Safe harbor

LIGHTWAVELOGIC™

The information in this presentation may contain forward-looking statements within the meaning of the Private Securities Litigation Reform Act of 1995. You can identify these statements by use of the words "may," "will," "should," "plans," "explores," "expects," "anticipates," "continue," "estimate," "project," "intend," and similar expressions. Forward-looking statements involve risks and uncertainties that could cause actual results to differ materially from those projected or anticipated. These risks and uncertainties include, but are not limited to, general economic and business conditions, effects of continued geopolitical unrest and regional conflicts, competition, changes in technology and methods of marketing, delays in completing various engineering and manufacturing programs, changes in customer order patterns, changes in product mix, continued success in technological advances and delivering technological innovations, shortages in components, production delays due to performance quality issues with outsourced components, and various other factors beyond the Company's control.

Lightwave Logic overview

- **Successfully up-listed to NASDAQ in 1st Sept 2021**
  - Organic up-list (no reverse split)
  - Invited to speak at investment conferences
  - Invited to speak at international technical conferences
- **Strong Balance Sheet**
  - Looking to strengthen for product acceleration to market
- **Very strong IP and patent position**
  - Over 70+ patents & patent applications
  - Freedom of manufacturing

Lightwave Logic NASDAQ: LWLG	
Share Price[1]	$9.80
Market Cap[1]	$1.06B
Cash[2]	$13.9M
Total Liabilities[1]	$1.0M
Shares Outstanding	107.8M
Headquarters	Englewood, CO

1) As of 2nd September, 2021
2) As of 16th August, 2021

Company Headquarters

Ringing the bell at NASDAQ (last week)

NASDAQ energy…..

Closing the market 10th September at 4pm East coast time precisely…


LIGHTWAVELOGIC™
Faster by Design
Applications & Markets

Proprietary EO polymer technology

LIGHTWAVELOGIC™

Starting With Fiber Communications, Our Technology Can be Extended To More Applications

Lightwave's proprietary, internally-engineered organic polymer materials use **less power** & **increase data throughput in existing network infrastructure**

How? By developing **ultrafast optical modulators** using its polymers that convert ultra-high-speed electrical data to light that travels over existing fiber-optic networks

Current Applications

- Initial prototypes cover today's state-of-the-art 50/100 Gbaud and the next-generation 400 Gbaud fiber optic applications
- Target speeds up to 100 & 200 Gigabaud per device, 800 & 1600 Gbit/s in aggregate with low voltage
- Modulators can be integrated to make more complex chips such as multi-channel modulators for higher aggregate speed

Future Applications

- Potential development of new polymer materials for specific **non-communication applications** such as: LIDAR automotive, sensing, displays, high speed computational processing, crypto, medical, and areas **where light needs to be switched quickly at low power**

Our polymers enable faster devices, low power solutions today

Photonics markets broaden significantly

LIGHTWAVELOGIC™

Photonics applications	Photonics → 2030 (rough forecasts*)	Opportunity for PICs (polymer & silicon photonics/InP)
5G systems/back haul/RF	~$4-10B	Yes
Display/project	~$5-20B	Yes
Automotive (LIDAR)	~$20-50B	Yes
Optical sensing/3D	~$2-5B	Yes
Bio-photonic sensing	~$2-5B	Yes
Medical	~$5-10B	Yes
Instrumentation	~$1-3B	Yes
Fiber comms	~$40-60B	Existing
HPC/computational/AI	~$10-20B	Existing
DCI/datacenter	~$20-30B	Existing

Photonics becomes ubiquitous during the next decade

*Source: *Many market forecasts predict huge photonics opportunities; Oculi*


LIGHTWAVELOGIC™
Faster by Design
Technologies

Key PIC technology platforms

LIGHTWAVELOGIC™

- Historic incumbent:
  - InP (Indium Phosphide)
  - GaAs (Gallium Arsenide)
- New incumbent:
  - SiP (Silicon photonics)
- ***New platforms and hybrid accelerators for PICs***
  - *Polymer, dielectrics, glass, lithium niobate thin film, plasmonic, barium titanate, silica, glass, germanium etc.*

Hybrid PICs are the future!

Source: LWLG

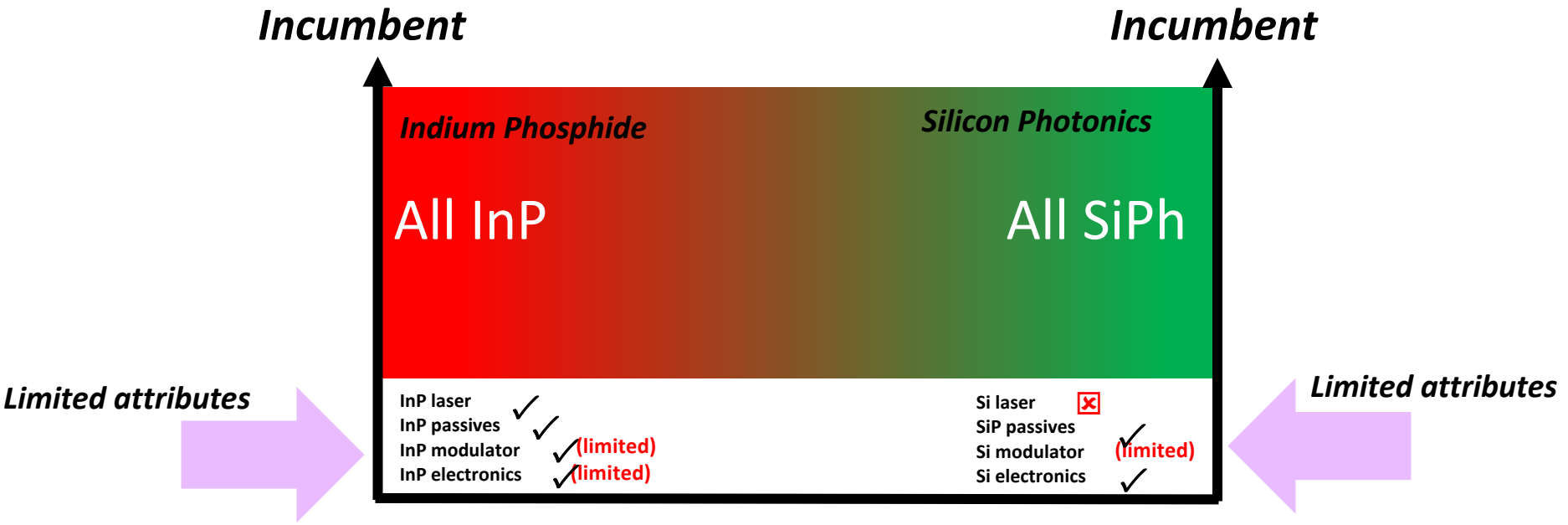
Sample global players and their PIC platforms

- Growth of Silicon photonics
- Trend towards hybrid platforms for PICs
- What combinations of technology make sense for ***hybrid*** PICs?

Challenge is to further PIC performance with other materials → hybrid PICs

Source: Yole

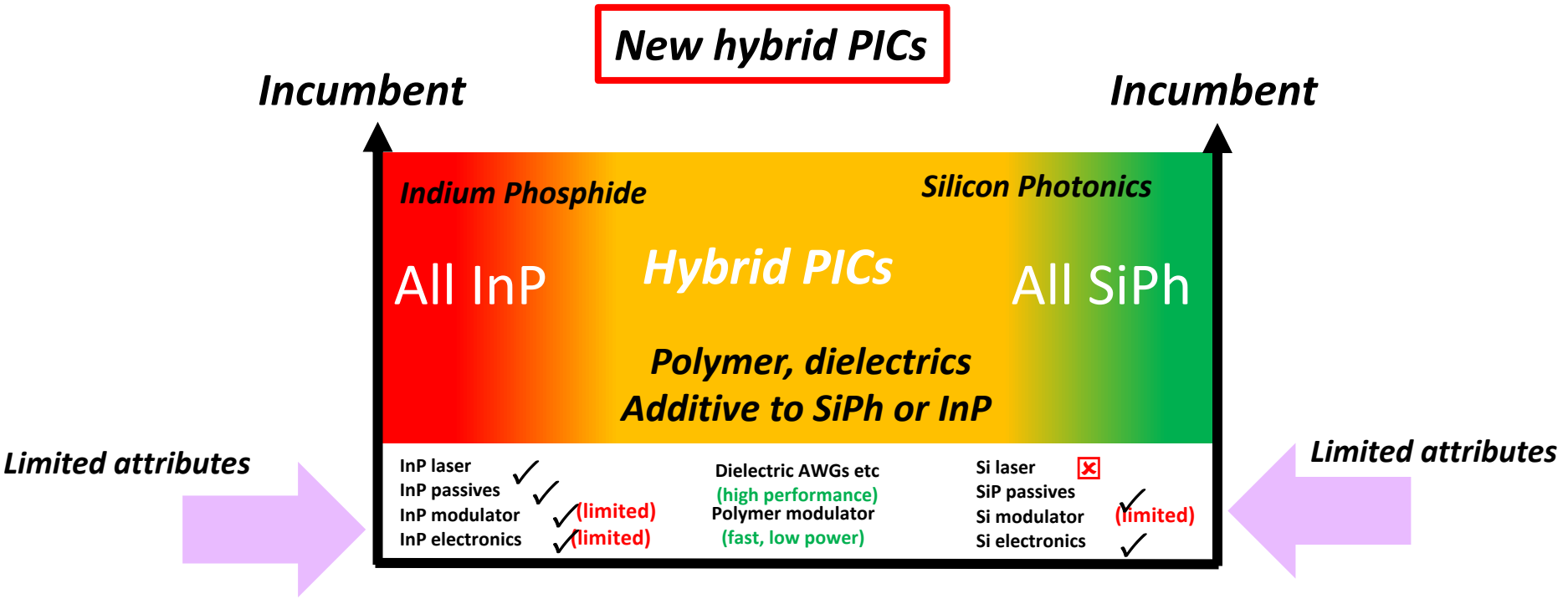
Industry has 2 incumbent PICs, however…



Incumbent technologies can't do everything…

Source: LWLG

Hybrid PICs increase performance…



Hybrid PICs can boost performance of PICs

Source: LWLG

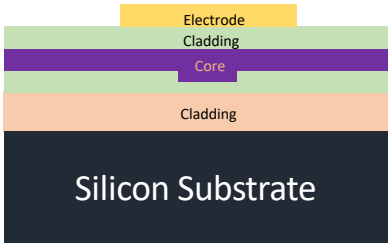

LIGHTWAVELOGIC™
Faster by Design
E-O polymers

Natural integration with big foundries

LIGHTWAVELOGIC™

Additive to semiconductor platforms (silicon photonics, InP, GaAs…) to enhance performance

Polymer Stack™

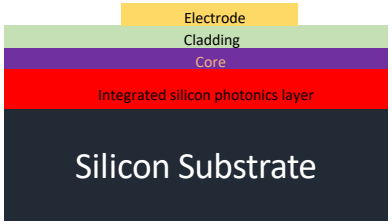


Classic!

Polymer stack modulator

- 3-layer polymer stack waveguides
- Linear Pockel's effect phase modulator (or Amplitude modulator if in Mach-Zehnder)
- Excellent high-speed performance (>100 GHz), low voltage (~1 V Vπ), and high stability.
- Standard fab equipment & methods

Polymer Plus™

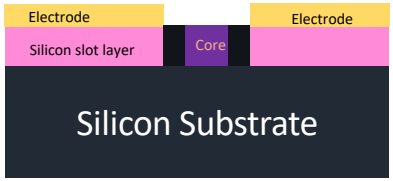


Additive!

Simpler and easier to integrate

- Minimizing polymer layers for integration of modulator with other devices in Si (or other) PIC platform
- Spin-on wafer-level hybrid integration
- Natural integration with PDK of silicon foundries

Polymer Slot™



Tiny!

Polymers in Si slot modulators

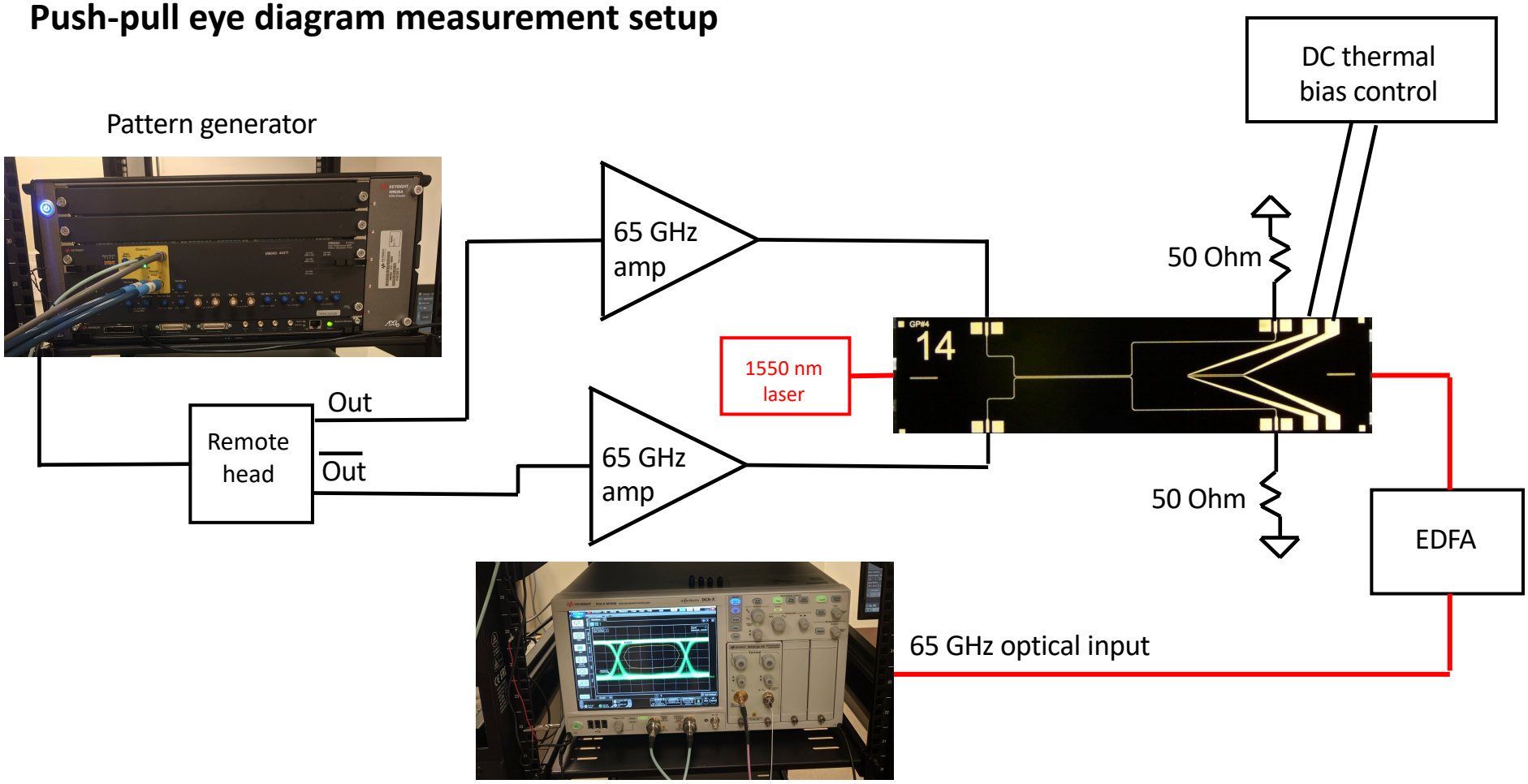
- Small size for highest integration levels
- Modulator device itself is hybrid silicon-EO Polymer (Silicon provides the waveguiding and electric field, EO polymer provides the high-speed EO functionality)
- Natural integration with PDK of silicon foundries

Turbo-charge your silicon photonics & integrated photonics with polymers…

Test set up

LIGHTWAVELOGIC™

Push-pull eye diagram measurement setup



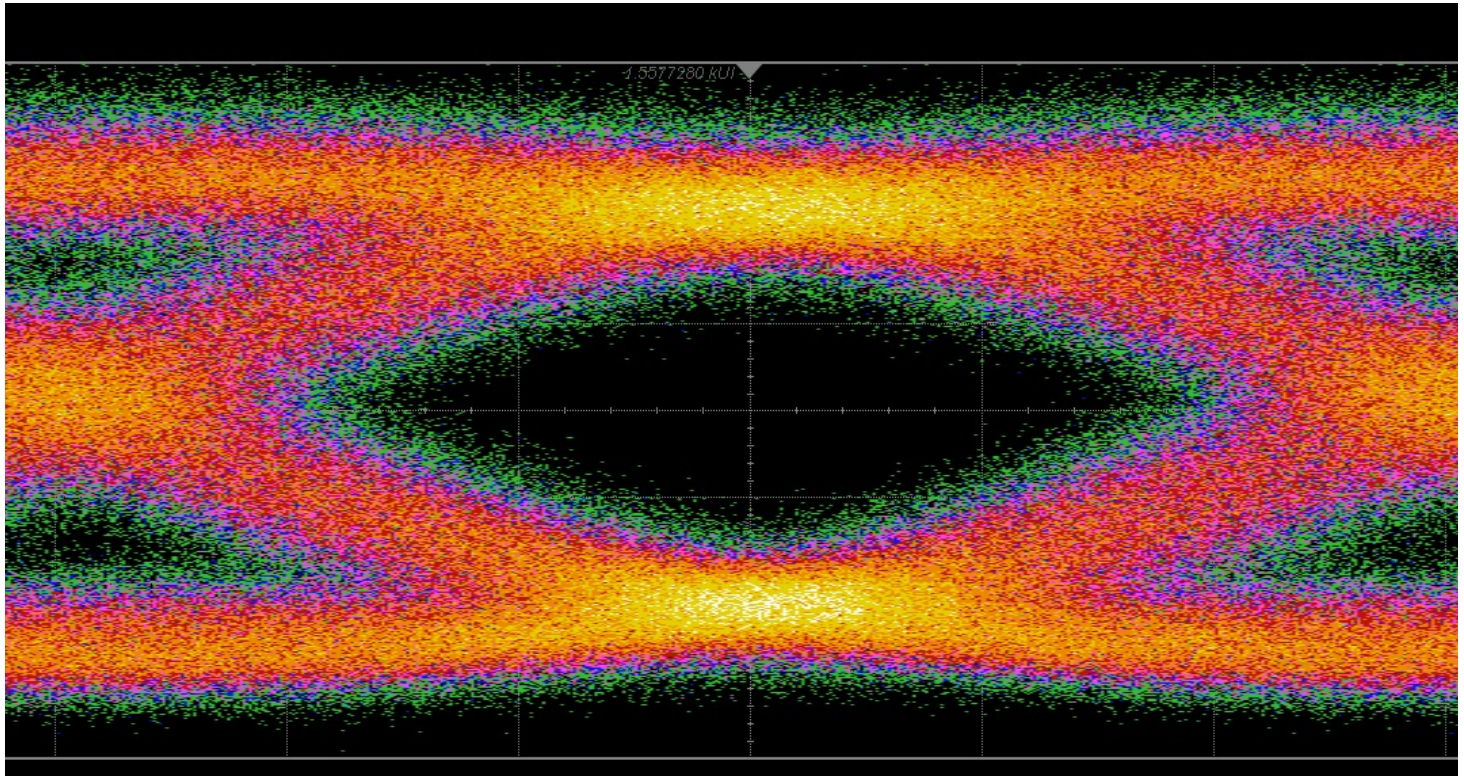
High speed test set-up at 65GHz push-pull

Source: LWLG

65GHz open eye

LIGHTWAVELOGIC™

Push-pull drive voltage typically < 4V
ER typically > 5 dB
65 GHz (maximum BERT frequency)



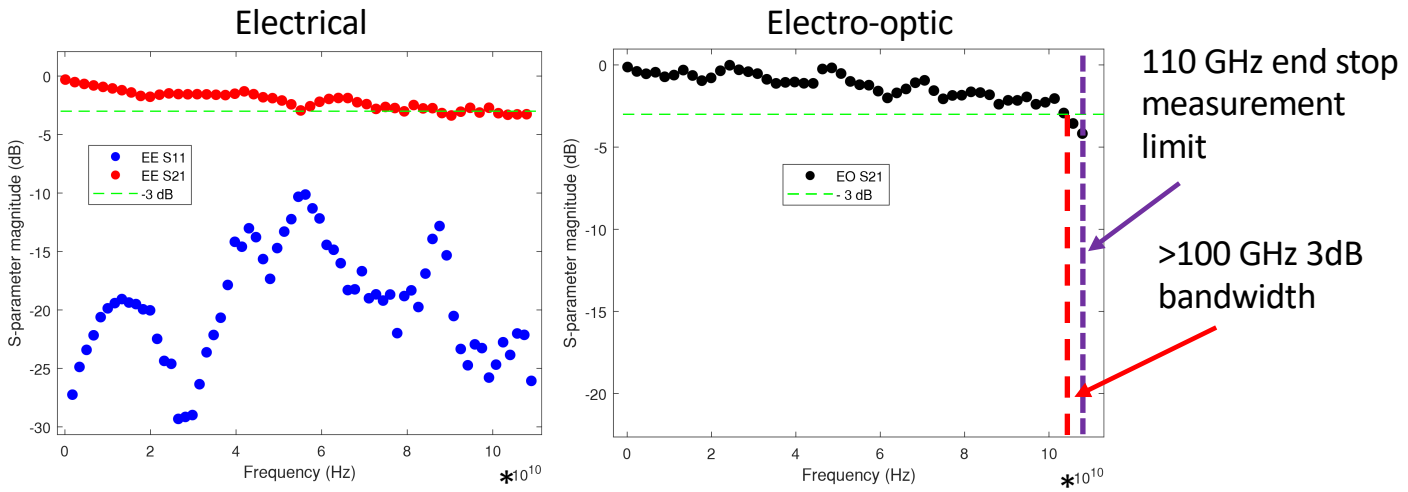
65GHz at the limit of the pulse generator

Source: LWLG

Super high optical bandwidth modulators

LIGHTWAVELOGIC™

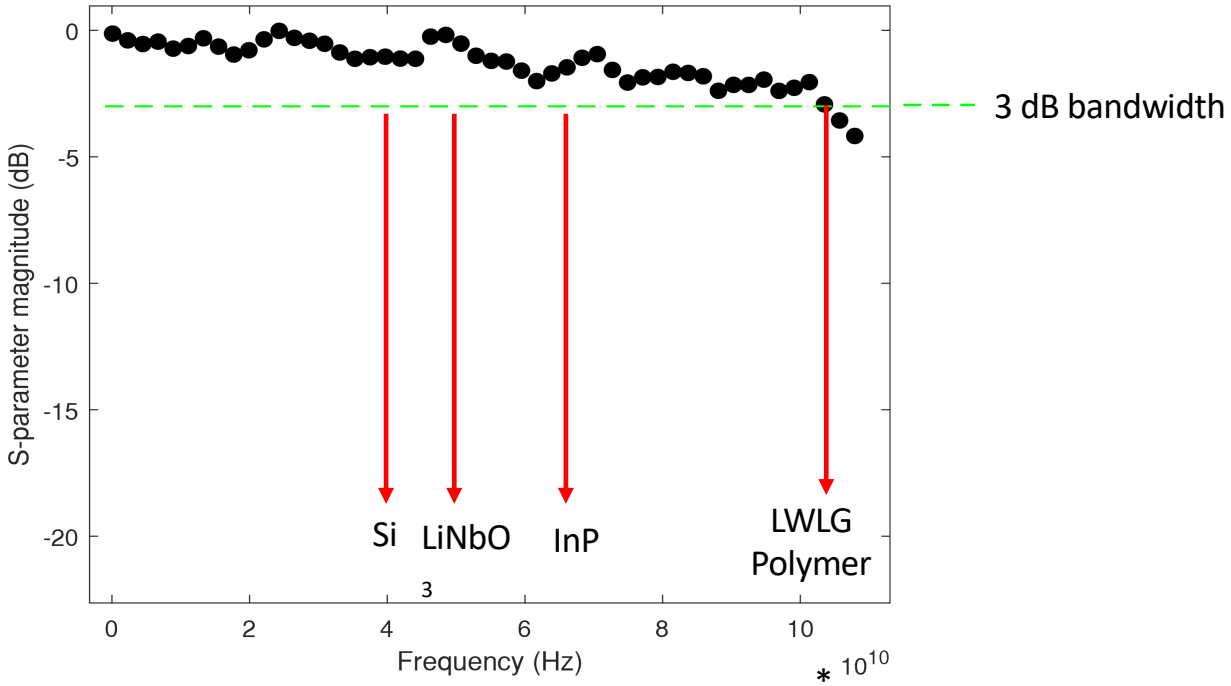
Recent high-frequency S-parameter data from polymer modulators



Super high performance > 100GHz S21 EO 3dB bandwidth

Source: LWLG

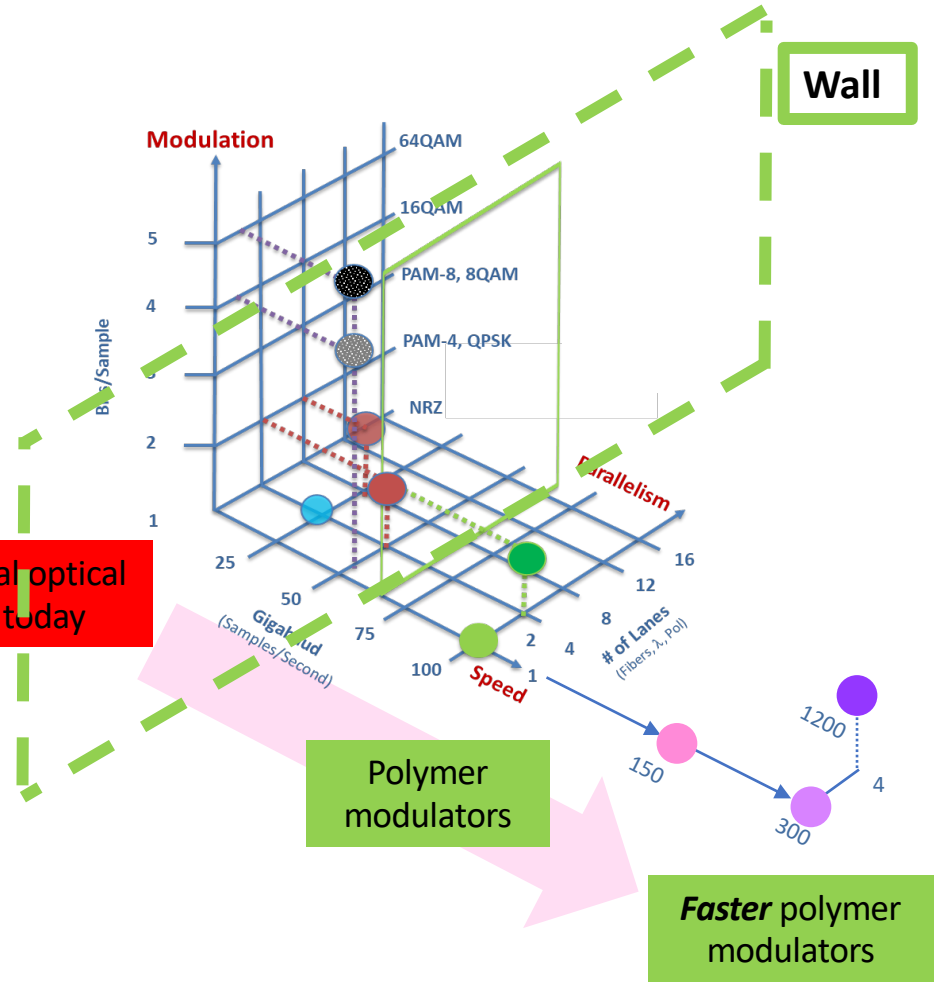
Relative comparison of modulators



Polymer modulators outperform competitive semiconductor technologies

Source: LWLG

Our technology breaks through the wall…



Data rates after breaking through the wall…

- 100Gbps = 100Gbaud, NRZ, 1 lane
- 800Gbps = 100Gbaud, PAM4, 4 lanes
- 150Gbps = 150Gbaud, NRZ, 1 lane
- 300Gbps = 150Gbaud, PAM4, 1 lane
- 1200Gbps = 150Gbaud, PAM4, 4 lanes

Polymers are 3X faster…

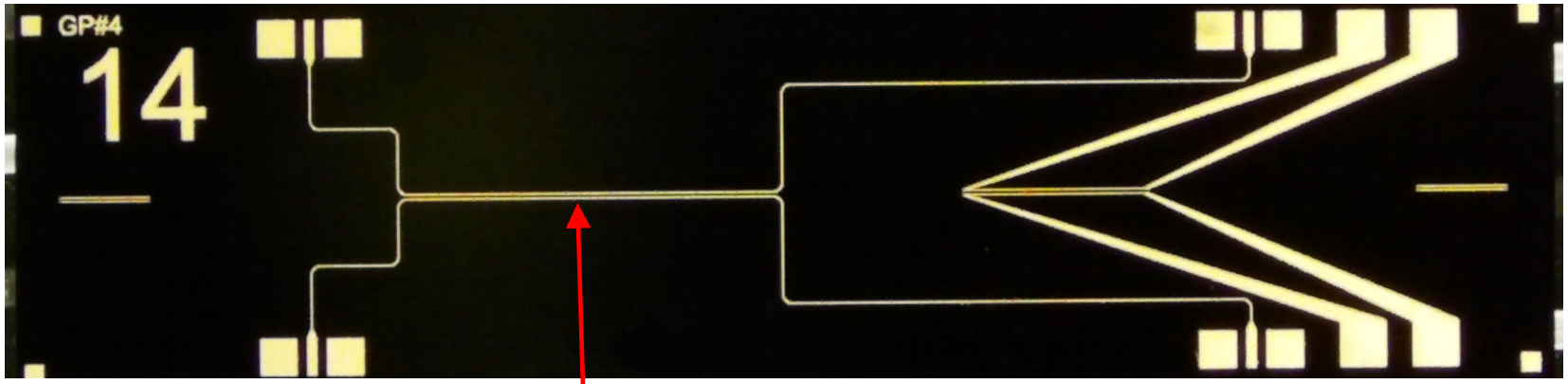
Polymer has head-room to go ***much much*** faster than competition

Polymer modulator chip

Optical input

Die 17 mm long x 4 mm wide

Optical output



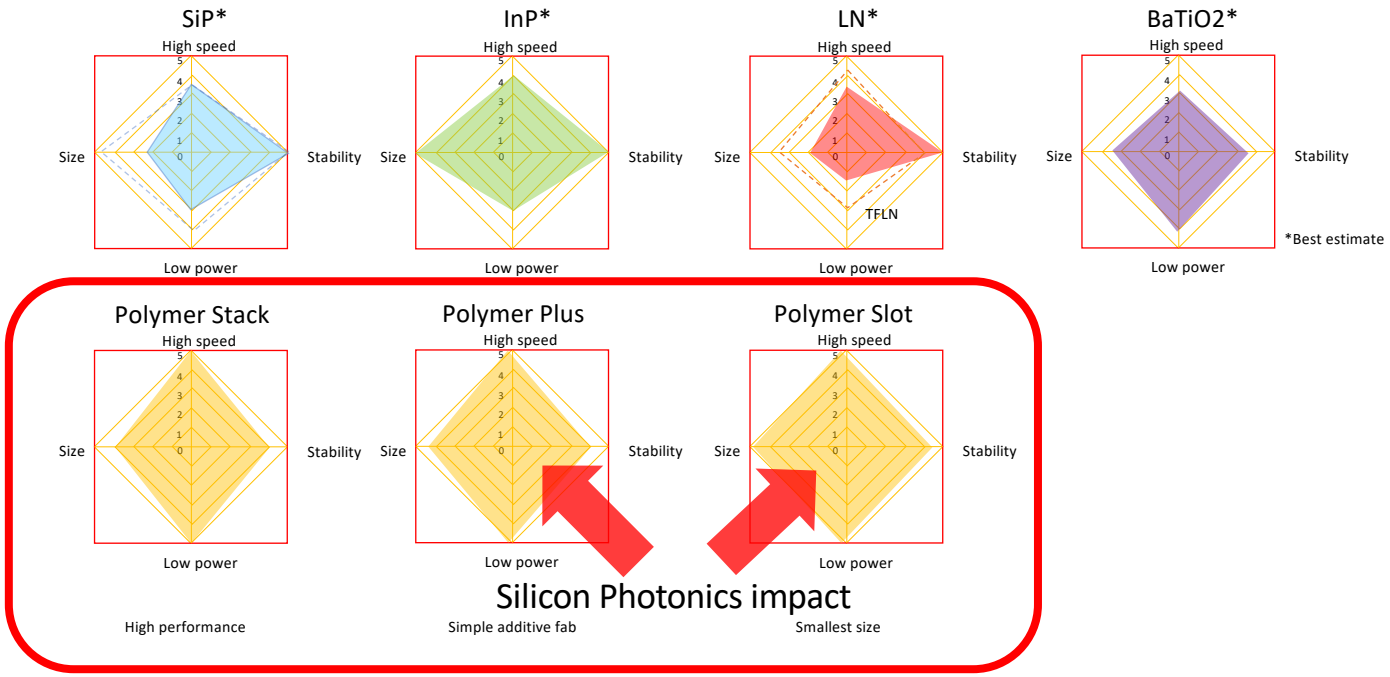
RF contacts

Active region (4mm) where the waveguides are

Thermal bias control

Polymer optical modulator chip fabricated on silicon wafers

Polymer attributes are impressive…



- **Polymer Stack** - traditional design. Very high performance
- **Polymer Plus** - additive to SiPh PICs. Simple fabrication
- **Polymer Slot** - smallest form factor. Ideal for SiPh

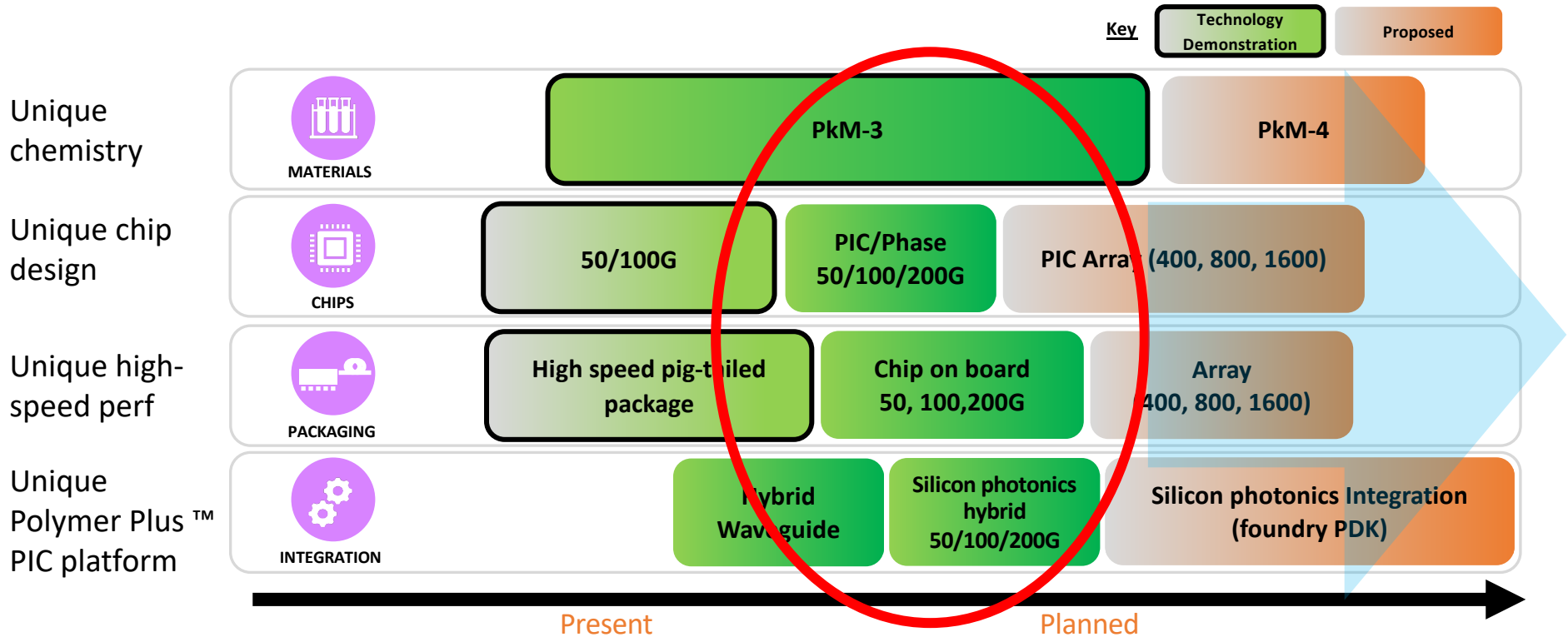
Technology strengths and weaknesses → polymer platforms are attractive

** Best estimates*


LIGHTWAVELOGIC™
Faster by Design
Foundry scaling

Technology roadmap

LIGHTWAVELOGIC™

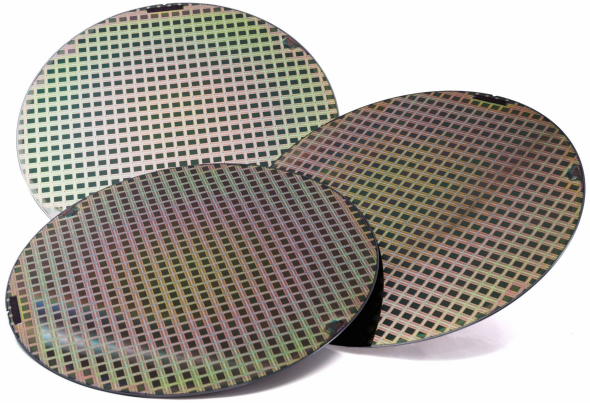


Our technology roadmap emphasizes our unique value to the industry

Partnering with silicon foundries

LIGHTWAVELOGIC™

- Process Development Kit (PDK) *to include polymers*
  - PDK is a library or set of building blocks used to lay out your idea into a photonic integrated circuit
  - PDK is provided by the foundry in SiPh
  - PDK allows you to create innovative designs and ramp volume quickly…*perfect vehicle for polymers*



© imec

PDKs are the route to partner with foundries

*PDK = Process Development Kit

Silicon foundries are hungry for ‘opto’ business

- CMOS fabrication plants want silicon photonics…new upside
- PDKs will drive the hybrid integration of PIC platforms

Drive to 200/300mm allows competitive PIC cost/volume and scale

*PDK = Process Development Kit


LIGHTWAVELOGIC™
Faster by Design
Intellectual Property

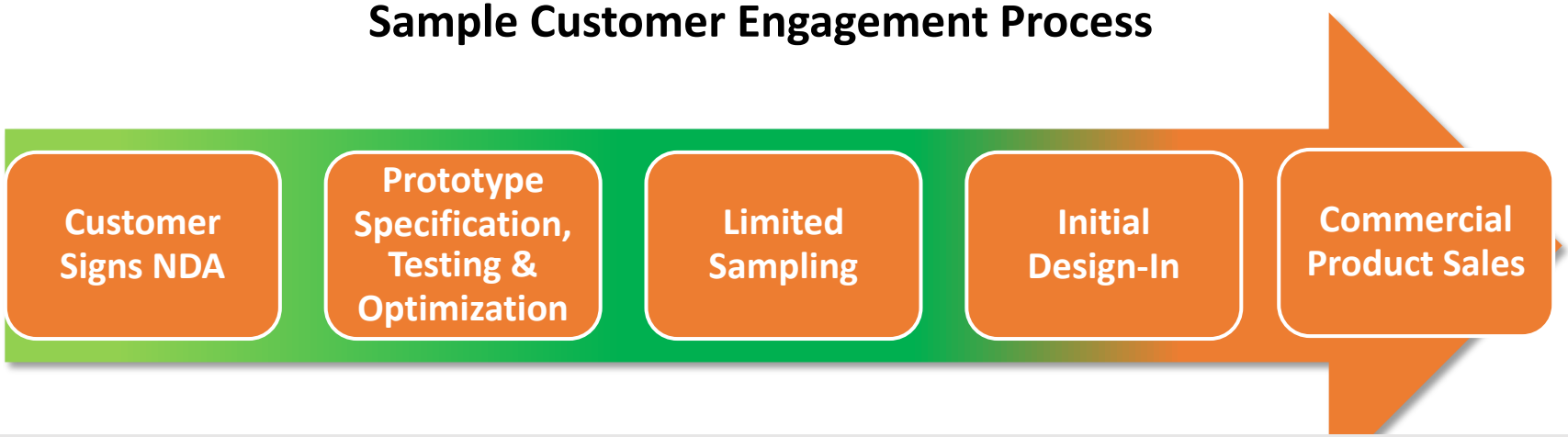
Business model & commercialization roadmap

LIGHTWAVELOGIC™

Multi-Pronged Business Model:

1. **Selling Components**
2. **Licensing of Technology**
3. **Technology Transfer**

Sample Customer Engagement Process



3-pronged business model with customer engagement process…

Robust intellectual property portfolio

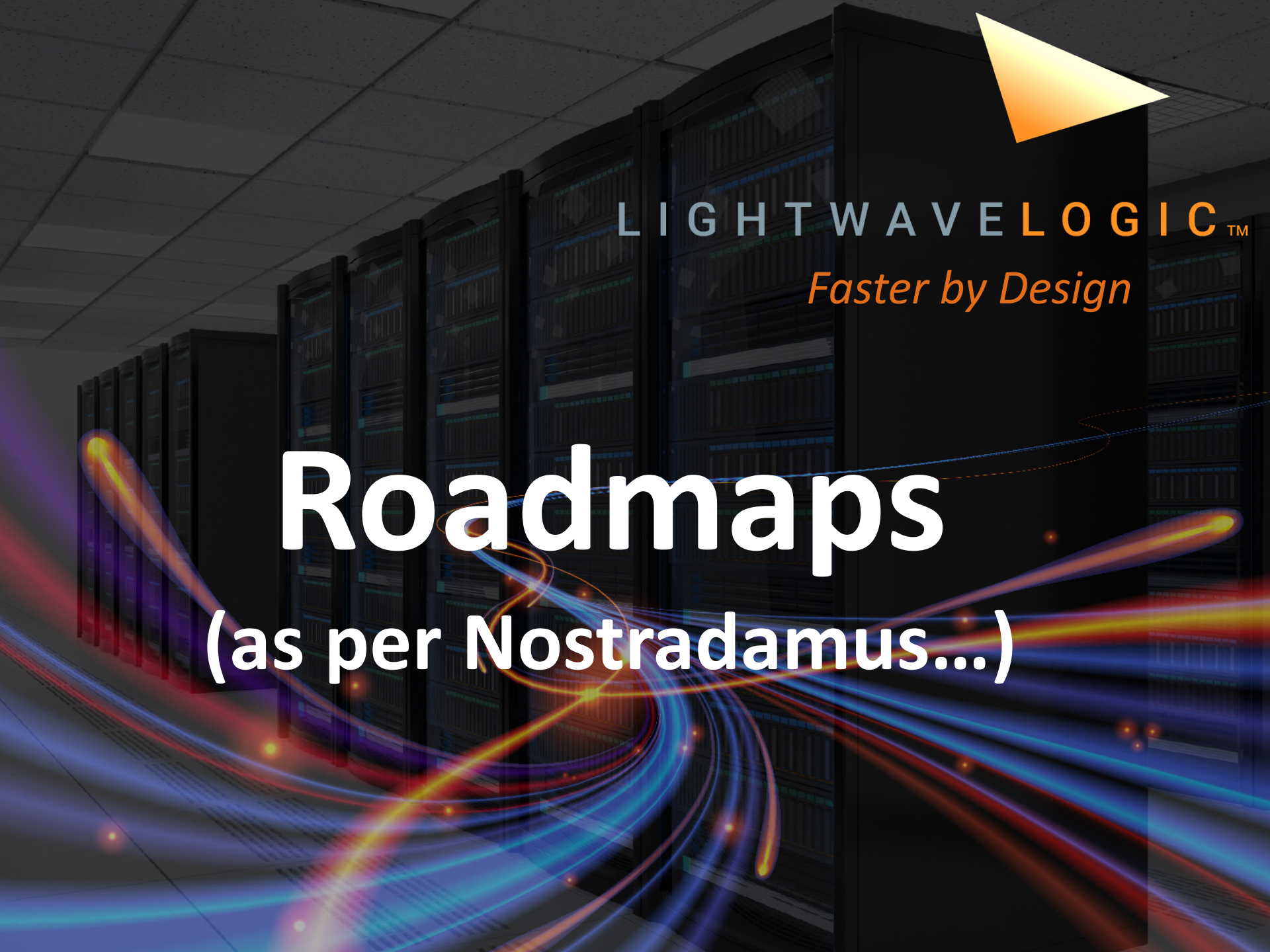
LIGHTWAVELOGIC™

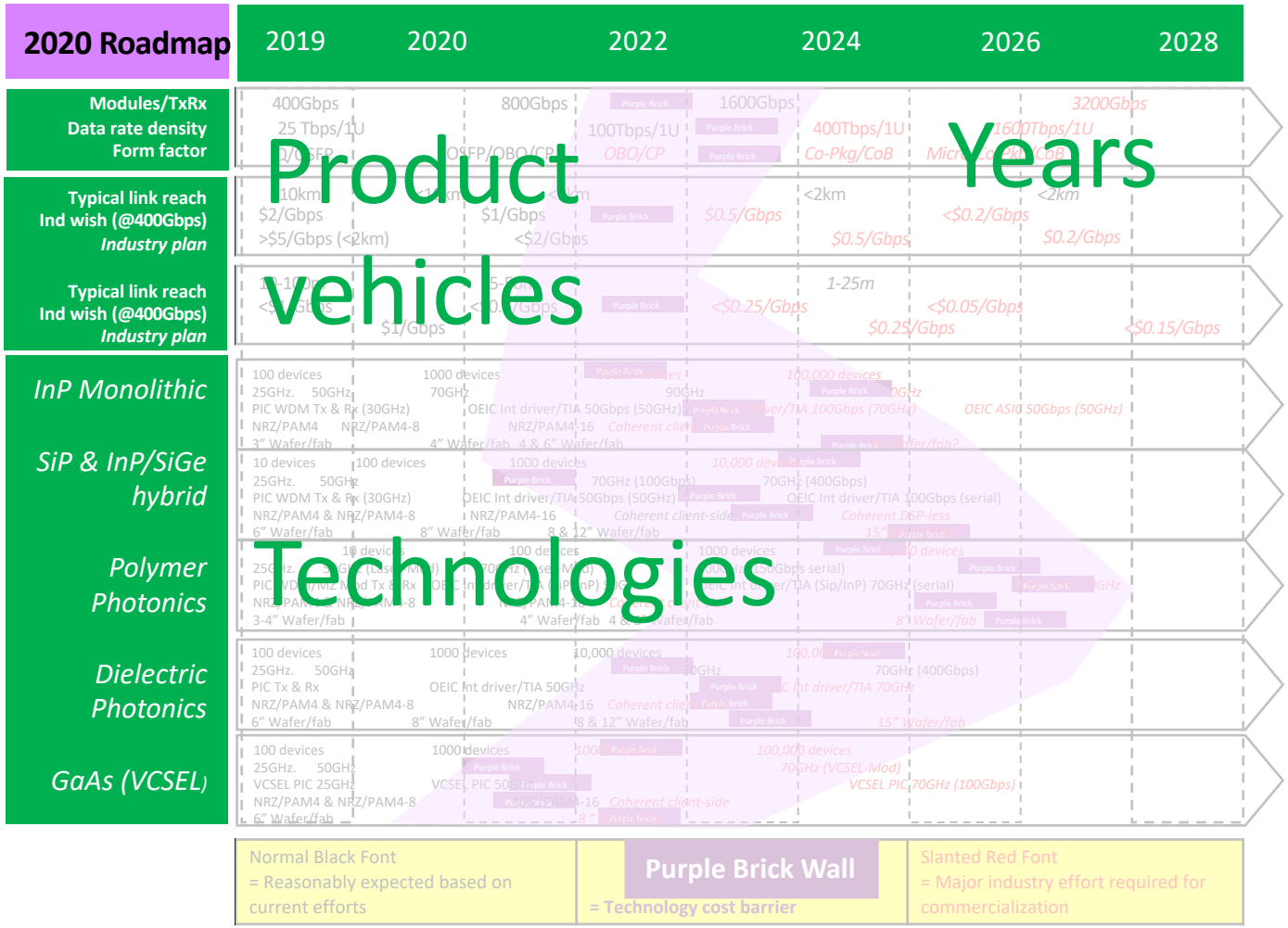
70+ Patents & Patent Applications

Freedom of manufacturing
Technology transfer (large foundries)
Licensing royalties (OEM, CM, Comms customers)

ISSUED	ISSUED	INTERNATIONAL
Heterocyclical chromophore architectures	Polymer modulator devices Fab, high speed, PIC, pkg	USA, EU, Canada, Japan and China
PUBLISHED	**ACQUIRED**	**FILING**
Advanced polymer/ silicon photonics materials, devices inventions	Lumera/Gigoptix Patent portfolio (15 Patents)	Innovative polymers Silicon photonics

Powerful patent portfolio with freedom of manufacturing


LIGHTWAVELOGIC™
Faster by Design
Roadmaps
(as per Nostradamus…)



Tough to design >1600Gbps+ TxRx modules…

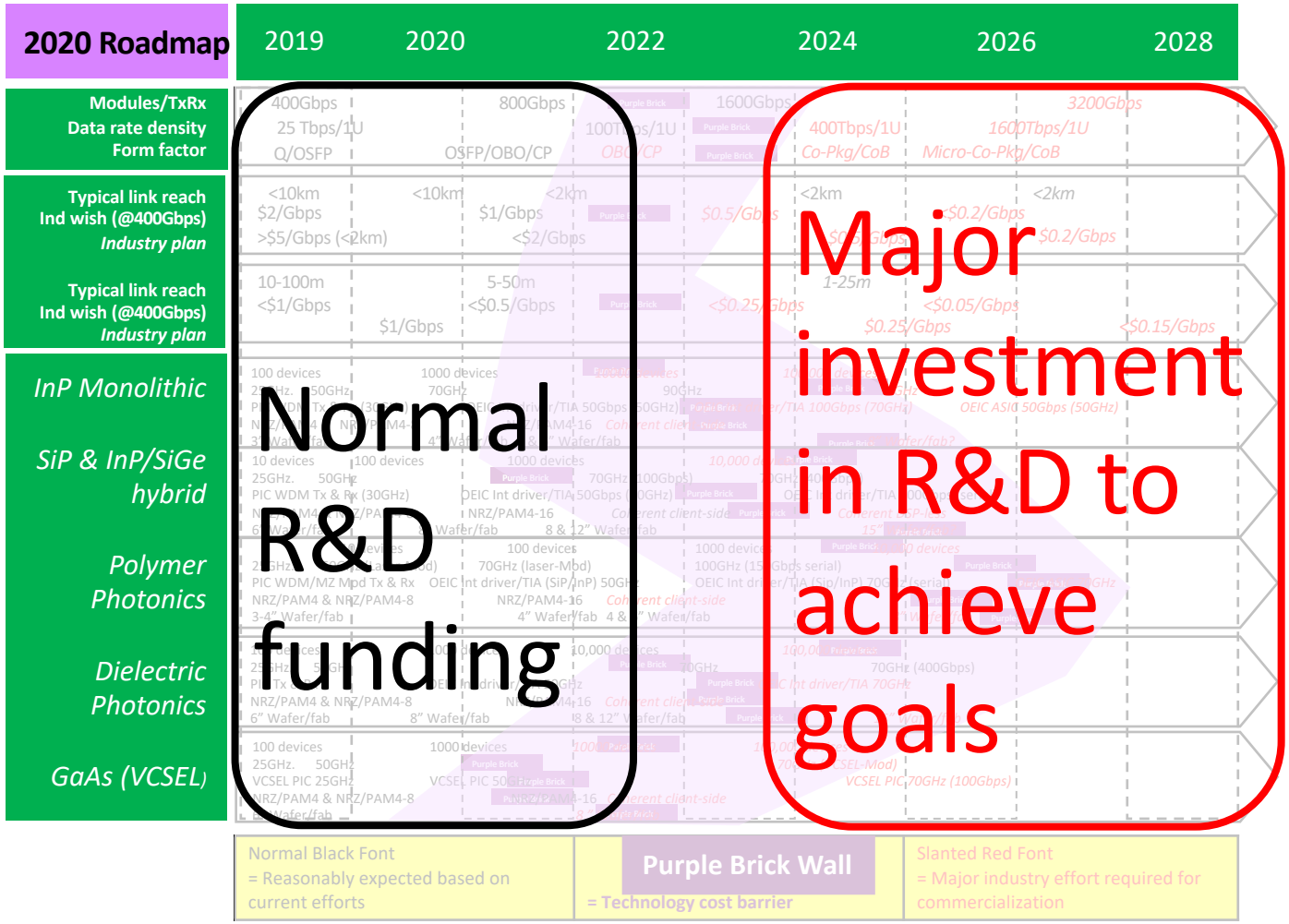
Tough to design >70GHz bandwidth devices…

Some technologies have higher performance….

How to scale PIC integration?

Simple metrics

Sources: LWLG, iNEMI, AIM Photonics, Photon Delta



Tough to design >1600Gbps+ TxRx modules…

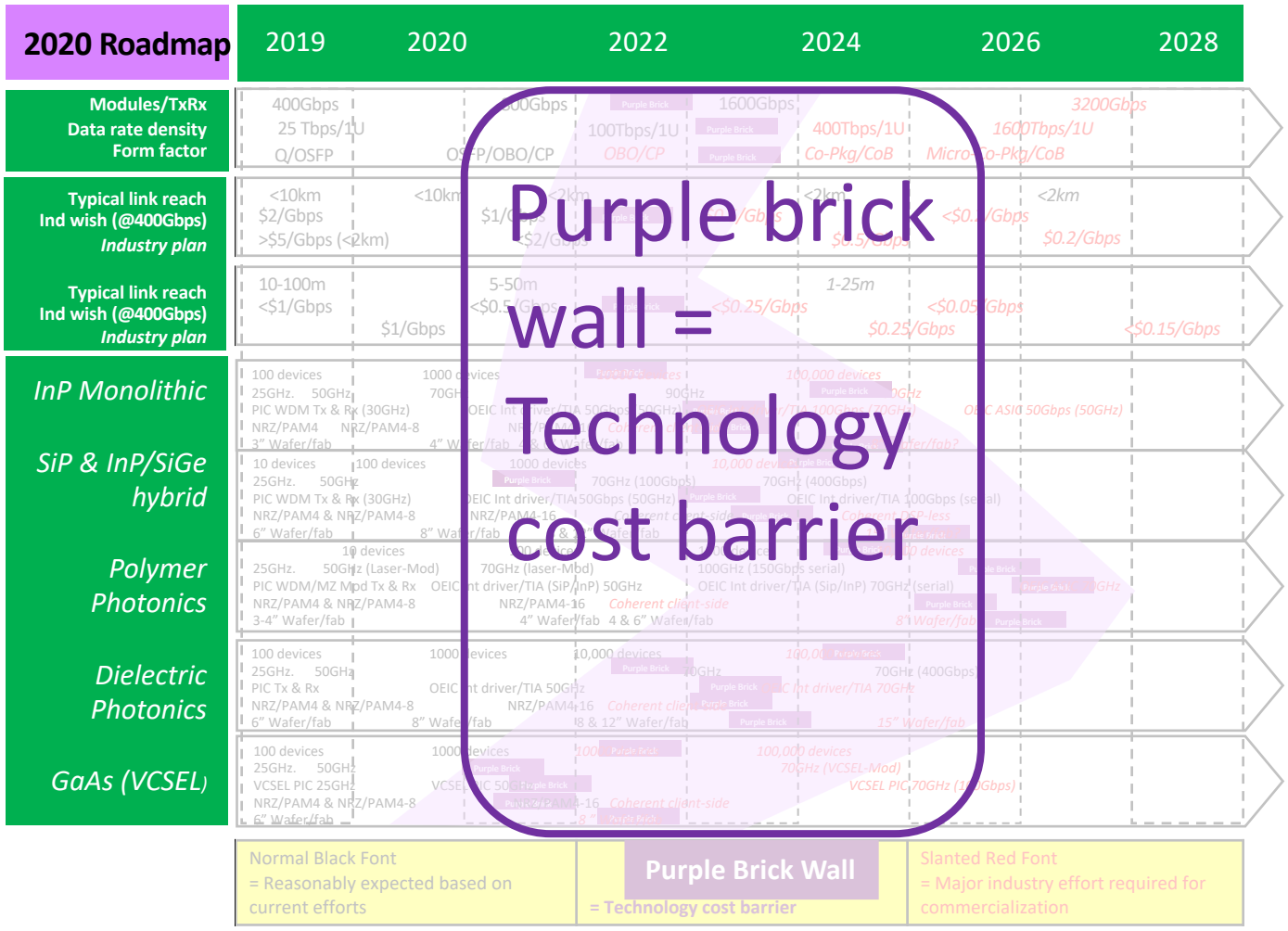
Tough to design >70GHz bandwidth devices…

Some technologies have higher performance….

How to scale PIC integration?

Red means major industry efforts needed for commercialization

Sources: LWLG, iNEMI, AIM Photonics, Photon Delta



Tough to design >1600Gbps+ TxRx modules…

Tough to design >70GHz bandwidth devices…

Some technologies have higher performance….

How to scale PIC integration?

We may have photonics technology → but not at a cost for commercialization

Sources: LWLG, iNEMI, AIM Photonics, Photon Delta

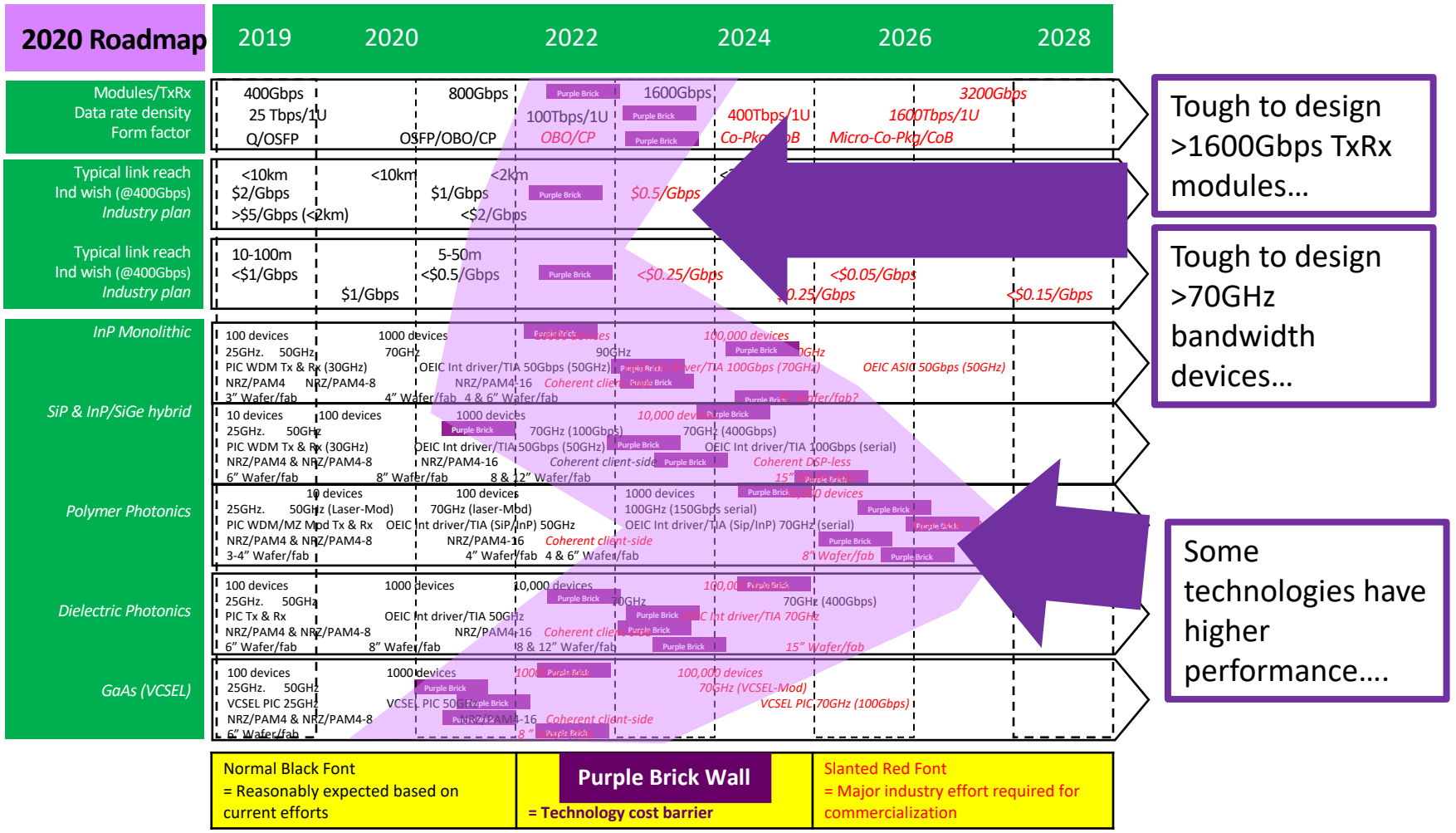
Advice on a 1-page roadmap…

LIGHTWAVELOGIC™

- Huge amount of data and small font…1-page…
- Details can be better viewed better *online*

Roadmaps provide a vehicle for all stakeholders: Gvt, industry, academia, bankers and investors…

Sources: LWLG, iNEMI, AIM Photonics, Photon Delta



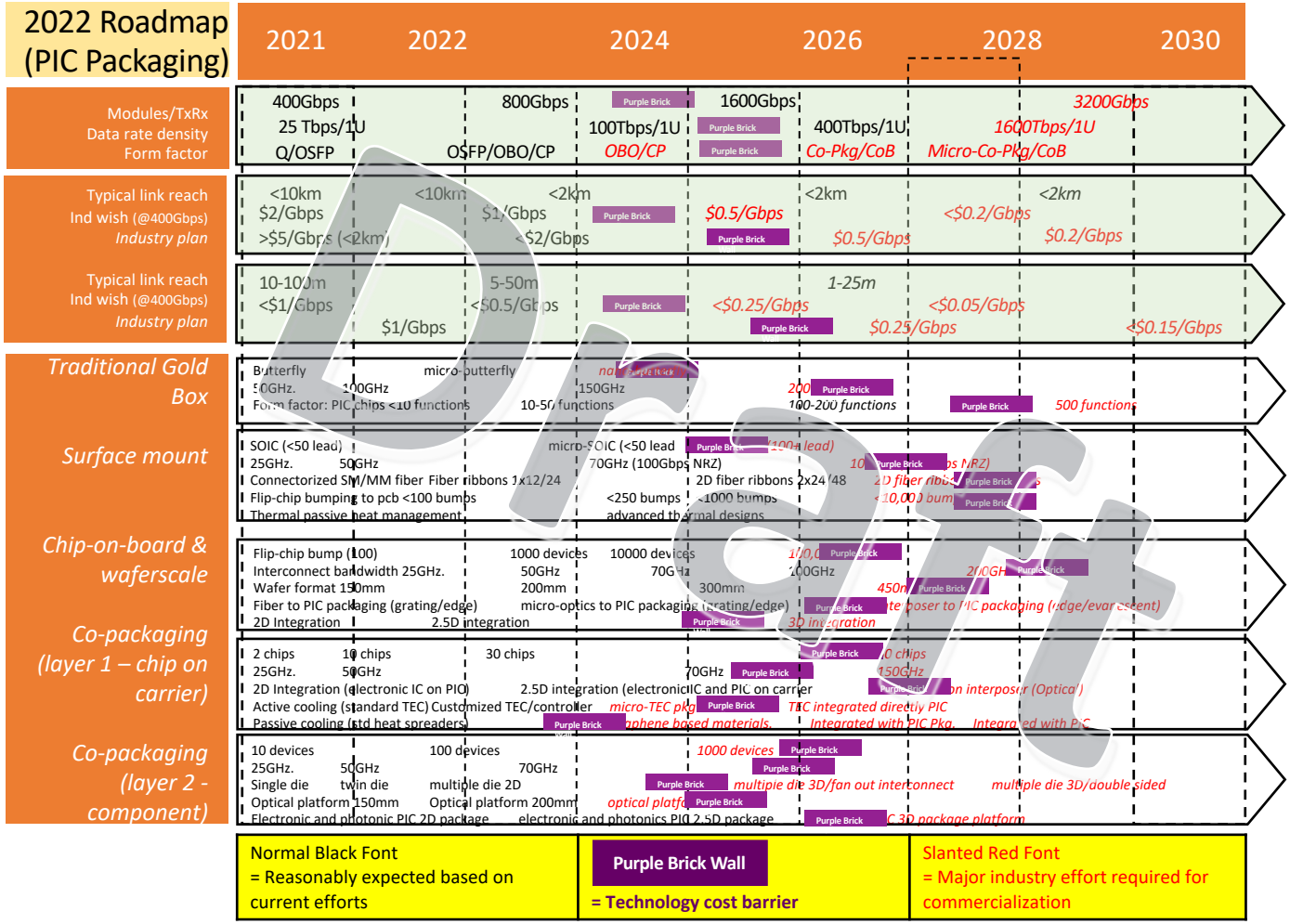
Where we penetrate the 'Purple Brick Wall'?

Sources: LWLG, iNEMI, AIM Photonics, Photon Delta

- A *1-page PIC packaging roadmap*…
- Details can be better viewed better *online*

Simple 1-slide roadmaps – have impact

Sources: LWLG, iNEMI, AIM Photonics, Photon Delta



1 page roadmap…

Still in draft form…

Evolving document…

A PIC packaging roadmap…

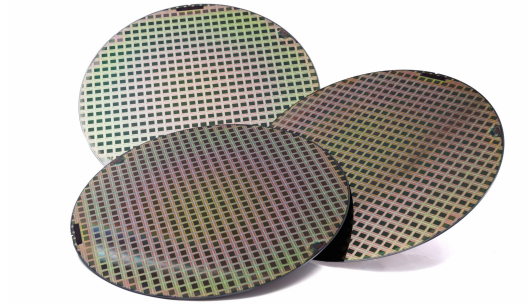
Source: Lightwave Logic, EPIC


LIGHTWAVELOGIC™
Faster by Design
Summary

Partnering for success

LIGHTWAVELOGIC™

- Our technology platform that is working to help scale existing internet structure (enabling technology)
- Technology designed to transmit data at higher speeds with less power (with 3dB optical bandwidths in excess of 100GHz)
- Leveraging internally-engineered electro-optic (EO) polymers to create photonic devices that convert data from electrical signals into optical signals
- Working with multiple foundries, module/packaging partners to position Lightwave for future high-volume production
- Technology roadmaps guide us all…packaging is next



© imec

Leveraging our partners to commercialize our technology in polymers

Contact

Investor Relations Contact

Greg Falesnik or Luke Zimmerman
MZ Group - MZ North America
949-259-4987
LWLG@mzgroup.us
www.mzgroup.us

LIGHTWAVELOGIC™

369 Inverness Parkway, Suite 350
Englewood, CO 80112

lightwavelogic.com