# LIGHTWAVELOGIC Faster by Design

Using polymer modulators to upgrade your PIC Michael Lebby, CEO, Lightwave Logic Inc<sup>.</sup> 4<sup>th</sup> November 2020

## Safe Harbor

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.

## Slides will be posted at our website

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## www.lightwavelogic.com

#### **Corporate Video**



#### News & Events

2020-10-21 Lightwave Logic Announces Optimization of Advanced Ultra-High-Speed Polymer with Unparalleled Photostability

#### 2020-10-15 Lightwave Logic Announces its Proprietary Polymer Technology Compatible with Standard Integrated Photonics Platforms

Screen shot of Lightwave Logic web page

#### Sit back...relax (no need to take notes!)

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## Marketing positioning in a dynamic environment

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## **Our Technology Suite Addresses Major Pain Points Facing Network Operators**

#### ENGINEERING ADVANTAGE



#### **Technology Platform Flexibility**

Full control from materials science to device & package design allows greater flexibility to adapt performance and cost to each individual application.



#### We enable faster networks.

Our robust, stable chromophore family of materials allows network architects to squeeze more performance from existing network infrastructure at 70GHz and beyound.



#### We reduce network energy costs.

Our low-cost, easy to fabricate modulators operate at a low voltage, saving network operators on energy costs as compared to competing solutions.

#### Flexible and custom chemistry, very fast modulators, very low power, and easy to integrate

## **Hybrid** Photonic Integrated Circuits (PICs)



### Upgrading your integrated photonics platform with polymer modulators

## Adding polymer modulators to your platforms...

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### Our polymer modulators addresses different semiconductor platforms



performance, low voltage, and high stability. Polymer layers are added onto silicon substrates in a traditional semiconductor fab. Innovative polymer plus modulator Minimizing polymer layers for a moresimpler, easy to integrate, high performance, low voltage device. Fabrication is using spin on polymers in standard fabs.

Our super miniaturized slot modulator is the smallest form factor for integrated silicon photonics solutions using our proprietary chromophore and polymer materials.

#### Polymer modulators...easy to fab, low power, fast, and flexible in performance

## Polymers *can* deliver radical innovation...

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### Enabling lower power, faster, unique and differentiated solutions

Source: Lightwave Logic (LWLG)

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LIGHTWAVELOGIC™ Faster by Design

# Industry Photonics roadmap

## Roadmaps: What did we predict in 2016 for 2020?

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2016 Roadmap		2017 20	018	2020	2	022	2024		2026
	Modules/TxRx Data rate density Form factor	100Gbps 10 Tbps/1⊍ QSFP	400Gbps miłcoQSFP	25Tbps/1U DSFP	Purple Brick Wall 1 Purple Brick Wall SF	Purple Brick Wall .00Tbps/1U .7+ (new)	400Tbp Micro-SFP	1000Gbps s/1U	
	Typical link reach Ind wish (@400Gbps) <i>Industry plan</i>	<10km <1 \$5/Gbps >\$10/Gbps (<2km)	.0km <2kr \$2/Gbps <\$5/Gbp	n Purple Brick Wall S	\$1/Gbps	km <i>\$1/Gbps</i>	< SO.5/Gbps چ	2km \$0.5/Gbps	
	Typical link reach Ind wish (@400Gbps) <i>Industry plan</i>	10-100m <\$1/Gbps \$1/Gb	5-50m <\$0.5/Gbps ps	Purple Brick Wall	<\$0.25/Gbp\$	1-25m \$0.25/Gl	<\$0.05/Gbps bps	<\$0	.15/Gbps
	InP Monolithic	100 devices 25Gbps 50Gbps PIC WDM Tx & Rx NRZ/PAM4 & NRZ/PAM4-8	1000 devid OEIC Int driver/TIA 500	E Purple Brick Wall 100Gb Sbps Purple Brick W NRZ/P	10000 ps all OPIC AM4-16	D devices Purple Brick Wall 40 Int driver/TIA 100G Irple Brick Wall CC	00Gbps ibps (serial) bherent client-side	100,000 devices OEIC ASIC 506b	DS
	SiP & InP/SiGe hybrid	100 devices 100 devi 25Gbps 50Gbps PIC WDM Tx & Rx NRZ/PAM4 & NRZ/PAM4-8	OEIG Int driver/TIA 50G	100Gt bps OEICI NRZ/PAM4-16	nt driver/TIA 100Gbps	devices Vall 40 S (serial) Purple Purple Brick Wall Co	Purple Brick Wall DOGbps Brick Wall Dherent Client-side	0EIC ASIC 50Gbp	95
	Polymer Photonics	10 devi 25Gbps 50Gbps PIC WDM/MZ Mdd Tx & Rx NRZ/PAM4 & NRZ/PAM4-8 3-4" Wafer/fab	es ; (Laser-Mod) OEIC Int d 4" Wafer/	100 de 100 de 100Gt 1000	vices ps (laser-Mod) 50Gbps OEIC Wafer/fab	Purple Brick Wall 10 Int driver/TIA (Sip/ Purple Brick Wall CC Purple Brick Wall	nek wali 2000 devices 8rick wali INP) 100Gbps (seria 2010 devices de	13 Wajer/Jap? 10,0 400Gbps 1) Purple Brick Wall 8" Wafer/fab	000 devices OEIC ASIC
	Dielectric Photonics	100 devices 25Gbps 50Gbps PIC Tx & Rx NRZ/PAM4 & NRZ/PAM4-8 6" Wafer/fab	1000 devic OEIC Int d 8" Wafer/	tes 100Gb river/TIA 50Gbps NRZ/P fab 8 & 12	10,000 devices ps 4000 Purple Brick Wall AM4-16 "Wafer/fab	Purple Brick Wall  DDS  Purple Brick Wall  Purple Brick Wall  Purple B	100,000 ( Purple Brick Wall EIC Int driver/TIA 10 pherent client-side rick Wall	devices OGbps (serial 15″ Wafer/fab	
	GaAs (VCSEL)	10 devices 25Gbps 50Gbps I VCSEL PIC 25Gbps VCSEL I NRZ/PAM4 & NRIZ/PAM4-8 3-4." Waf	100 devices Purple B Purple Brick Wall PIC 50 Gbps Pr er/fabl	rick Wall 1000 ( 100Gbps (VCSEL urple Brick Wall NRZ/F	AM4-16	10 40 VCSEL PIC 1 Cafer/fab	0,000 devices 00Gbps (VCSEL-Moo 00Gbps (serial) oherent client-side	<i>I)</i>	

**Purple Brick Wall** 

= Technology cost barrier

Slanted Red Font: Major industry efforts are required for commercialization Source: Lightwave Logic

#### Result: Assessment in 2020 $\rightarrow$ Accurate !!! L I G H T W A V E L O G I C 🖬 = Technology cost barrier **Purple Brick Wall** 2026 2018 2022 2017 2024 2016 Roadmap 1000Gbps 100Gbps Purple Brick Wall Modules/TxRx 400Gbps TxRx 400bps 400Tbps/1U Data rate density 10 Tbps/1U 25Tbps/1U Purple Brick Wal 100Tbps/1U Form factor mitcoQSFP SFP+ (new) ue Brick Wall Micro-SFP **QSFP** <10km **Typical link reach** <10km <2km <2km <2km <\$5/Gbps \$2/Gbps <S0.5/Gbps \$5/Gbps \$1/Gbps Ind wish (@400Gbps) Purple Brick Wall >\$10/Gbps (42km) \$0.5/Gbps Industry plan <\$5/Gbps \$1/Gbps **Typical link reach** 10-100m 5-50m 1-25m <\$1/Gbps <\$0.5/Gbps Ind wish (@400Gbps) Purple Brick Wall <\$0.25/Gbps <\$0.05/Gbps Industry plan <\$0.15/Gbps \$1/Gbps \$0.25/Gbps InP Monolithic ou devices 1000 device ick Wall 10000 devices 100,000 devices 50Gbps+ devices 25Gbps Purple Brick Wall 50Gbps 400Gbps Gbps PIC WDM Tx & Rx 100Gbps (serial) OEIC Int driver/TIA 50Gbps Purple 7 ck Wall **OEIC Int driver/TIA OEIC ASIC 50Gbps** NRZ/PAM4 & NRZ/PAM4-8 NRZ/PAM4-16 Purple Brick Wall Coherent client-side 3″ Wa W \ . . . 4 & 6"!Wafer/fab 8" Wafer/fab Purple Brick Wall SiP & InP/SiGe hybrid 1000 devices 10 devices 100 devices **Purple Brick Wall** 10.000 devices 25Gbps 50Gbps 100Gbps Purple Brick Wall 400Gbps OEIC Int driver/TIA 100Gpps (serial) PIC WDM Tx & Rx OEIG Int driver/TIA 50Gbps Purple Brick Wall **OEIC ASIC 50Gbps** NRZ/PAM4 & NRZ/PAM4-8 NRZ/PAM4-16 Purple Brick Wall Coherent client-side 6" Wafer/fab 8" Wafer/fab 8 & 12" Wafer/fab 15" Wafer/fab? Purple Brick Wall **Polymer Photonics** 10 devices 100 devices Purple Brick Wall ! 1000 devices 10,000 devices 25Gbps Purple Brick Wall 400Gbps 50Gbps (Laser-Mod) 100Gbps (laser-Mod) PIC WDM/MZ Mod Tx & Rx OEIC Int driver/TIA (SiP/InP) 50Gbps OEIC Int driver/TIA (Sip/InP) 100Gbps (serial) Purple Brick Wall OEIC ASIC 50GL I NRZ/PAM4 & NRZ/PAM4-8 NRZ/PAM4-16 Purple Brick Wall Coherent client-side 3-4" Wafer/fab 4" Wafer/fab 4 & 6" Wafer/fab Purple Brick Wall 8" Wafer/fab 100 devices 1000 devices 10,000 devices 100,000 devices **Purple Brick Wall Dielectric Photonics** Purple Brick Wall 25Gbps 50Gbps 100Gbps 400Gbps Purple Brick Wall OEIC Int driver/TIA 50Gbps OEIC Int driver/TIA 100Gbps (serial PIC Tx & Rx NRZ/PAM4 & NRZ/PAM4-8 Purple Brick Wall Coherent client-side NRZ/PAM4-16 Purple Brick Wall 6" Wafer/fab 8" Wafer/fab 8 & 12<sup>''</sup> Wafer/fab 15" Wafer/fal 100 devices Purple Brick Wall 1000 devices 10 devices 10,000 devices GaAs (VCSEL) 100Gbps (VCSEL-Mod) 400Gbps (VCSEL-Mod) 25Gbps 50Gbps Purple Brick Wall VCSEL PIC 25Gbps VCSEL PIC 100Gbps (serial) VCSEL PIC 50Gbps Purple Brick Wall Purple Brick Wall NRZ/PAM4-16 NRZ/PAM4 & NRZ/PAM4-8 Coherent client-side Purple Brick Wall \_3\_4" Wafer/fab 6" Wafer/fab 8 " Wafer/fab

Slanted Red Font: Major industry efforts are required forgeommercialization (OTCQB: LWLG) Source: Lightwave Logic

# New for 2020 $\rightarrow$ Where are we going?

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2020 Roadmap	201	2019 2020		2022		2024	2026		2028
	Modules/TxRx 4000 Data rate density 25 T Form factor Q/O	bps bps/1U SFP OS	800Gbps FP/OBO/CP	Purple Brick Wall 100Tbps/1U <u>OBO/CP</u>	1600Gbps Purple Brick Wall Purple Brick Wall	400Tbps/1U <u>Co-Pkg/CoB</u>	1600 Micro-Co-Pkg	3200Gbr 9Tbps/1U /CoB	<i>s</i>
In	Typical link reach d wish (@400Gbps) Industry plan	n <10km os ops (<2km)	<2kr \$1/Gbps <\$2/Gbp	N Purple Brick Wall S	\$0.5/Gbps	<2km <i>\$0.5/Gbps</i>	<\$0.2/Gbp	<2km \$ \$0.2/Gbps	
In	Typical link reach d wish (@400Gbps) Industry plan	m ops \$1/Gbps	5-50m <\$0.5/Gbps	Purple Brick Wall	<\$0.25/Gbps	1-25m \$0.25	<\$0.05/Gbps /Gbps	<	\$0.15/Gbps
	InP Monolithic	es 1 50GHz 70GHz Tx & Rx (30GHz) 6 4 NRZ/PAM4-8	000 devices DEIC Int driver/TIA	Purple Brick Wall 50Gbps (50GHz) NRZ/PAM4-16	10000 device 90GHz Purple Brick Wall OP Purple Brick Wall Cor Nofor (fab	S Purple Brick Wall IC Int driver/TIA 10 nerent client-side	100GHz 0Gbps (70GHz)	100,000 devic OEIC ASIC 500	es Ibps (50GHz)
SiP	& InP/SiGe hybrid	s 100 devices 50GHz Tx & RX (30GHz) 0 I4 & NRZ/PAM4-8	Purple Brick Wall Purple Brick Wall EIC Int driver/TIA 5 NRZ/PAM4-16	1000 devices 70GHz (100Gbps) 0Gbps (50GHz) Coherent client	urple Brick Wall t-side Purple Brick Wall	Purple Brick Wall 70GHz (400 Coherent DS	10,000 devices DGbps) OEIC Int driver/TI P-less	A 100Gbps (serial)	
	Polymer Photonics	10 devices 50GHz (Laser-Mod) /MZ Mdd Tx & Rx 14 & NRZ/PAM4-8 er/fab	70GHz (laser-Mo OEIC Int d 4" Wafer/	100 devices i) iver/TIA (SiP/InP) & NRZ/PAM4-16 fab 4 & 6 <sup>rd</sup>	100GHz (15 60GHz OP <i>Co</i> f Wafer/fab	Purple Brick Wall OGbps serial) IC Int driver/TIA (S herent client-side 8″ V	1000 devices Purple Brick W ip/InP) 70GHz (Se Purple Brick Wall Vafer/fab Purple	rall Purple Brick Wall	10,000 de ASIC 70GHz
D	ielectric Photonics	es 50GHz ix 4 & NRZ/PAM4-8 fab 8″	1000 devic OEIC Int dr Wafer/fab	es Purple Brick Wall iver/TIA 50GHz NRZ/PAM4-16 8 & 12" Wafe	10,000 devices 70GHz Purple Brick Wall Purple Brick Wall r/fab Purple Brick Wall	Purple Brick Wall	70GHz (400Gbps) OEIC In 15	100,000 devic t driver/TIA 70GHz ' Wafer/fab	es
	GaAs (VCSEL) 1 100 devia 25GHz. 1 VCSEL PIO NRZ/PAN 6" Wafer	es 50GHz 25GHz VCSEL PIC 500 14 & NRIZ/PAM4-8 (fab	1000 devit Purple Brick Wall SHZ Purple Brick Wall Purple Brick Wall	RRZ/PAM4-16	10000 devices Col <u>8 ″ Wof</u> er/fab	70GHz ( VCSEL PIC 7 herent client-side	100,000 VCSEL-Mod) 0GHz (100Gbps)	devices	

**Purple Brick Wall** 

= Technology cost barrier

Source: Lightwave Logic

## Roadmap for 2023 $\rightarrow$ Low power, hybrid PIC, faster devices

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LIGHTWAVELOGIC™ Faster by Design Lightwave Logic Inc. 369 Inverness Parkway, Suite 350 Englewood, CO 80112

# Contact

Michael Lebby michael@lightwavelogic.com

lightwavelogic.com