LIGHTWAVE LOGIC®

Silicon photonics foundry compatible EO polymer hybrid modulators: From material to high reliability products ready for prime time

ECOC Product Focus

September 29th, 2025

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NASDAQ

LWLG

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LWLG: At A Glance

LIGHTWAVELOGIC®

Strong platform and favorable market dynamics to enable the utilization of electro-optics polymers for high speed, low power AI and Data Center applications

Unprecedented, Accelerating Demand

- Market expected to grow to ~$100B by 2030
- Driven by in Capex to address AI, quantum, datacomm & space comm requirements

Innovative EO Polymer Technology

- Disruptive technology enabling future speed upgrades in data bandwidth
- Relieves key bottlenecks in AI infrastructure

Strong Patent Portfolio

- Protected by broad IP portfolio with over 70 patents
- Numerous patents pending

Deeply Experienced Leadership

- Management, Board of Directors and advisory board have over 200+ years of conceiving and launching products

Robust Balance Sheet

- Critical for execution
- Strong cash position provides significant optionality and execution runway

Entering a New Stage for Lightwave Logic

LIGHTWAVELOGIC®

Seizing growth opportunities presented by AI

Stage 1
(Completed)

Technology & Materials Development

Patents/IP, Polymers, Factory, Process

Stage 2
(2025 – 2026)

Customers & Products

Product Design-ins,

Silicon Photonics Foundries,

AI Ecosystem Integration

Stage 3
(Starting in 2026)

Scale-up & Diversification

Production infrastructure
+
New markets and applications

Silicon Photonics for AI Scale Up and Scale Out
200G and 400G speeds needed for $15B Opportunity in 2030

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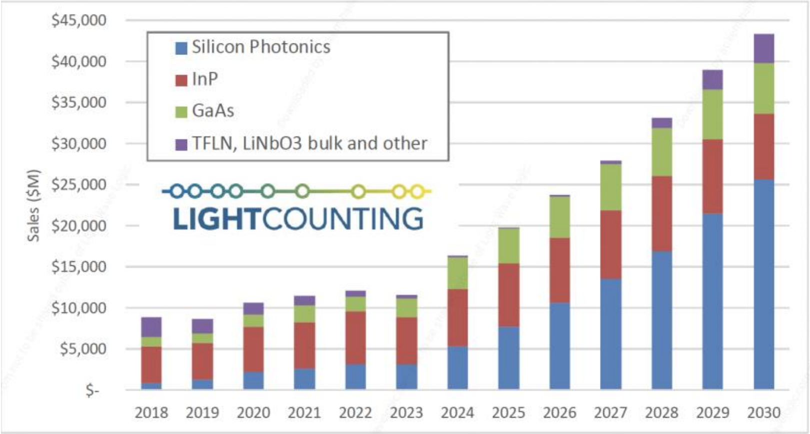
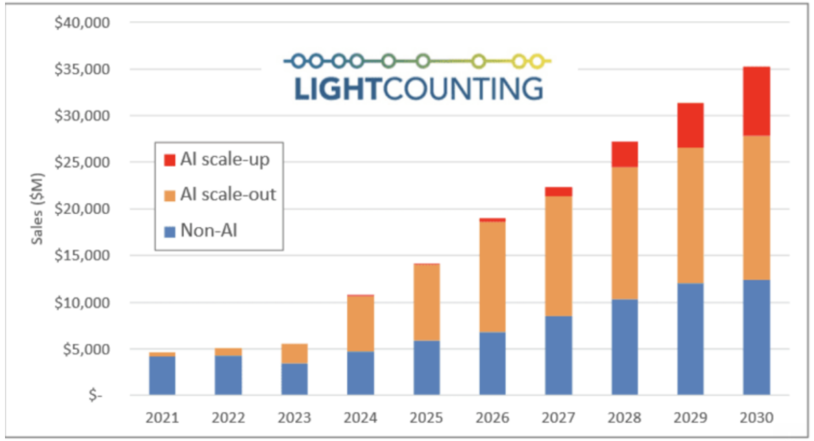
Sales of optical transceivers by technology

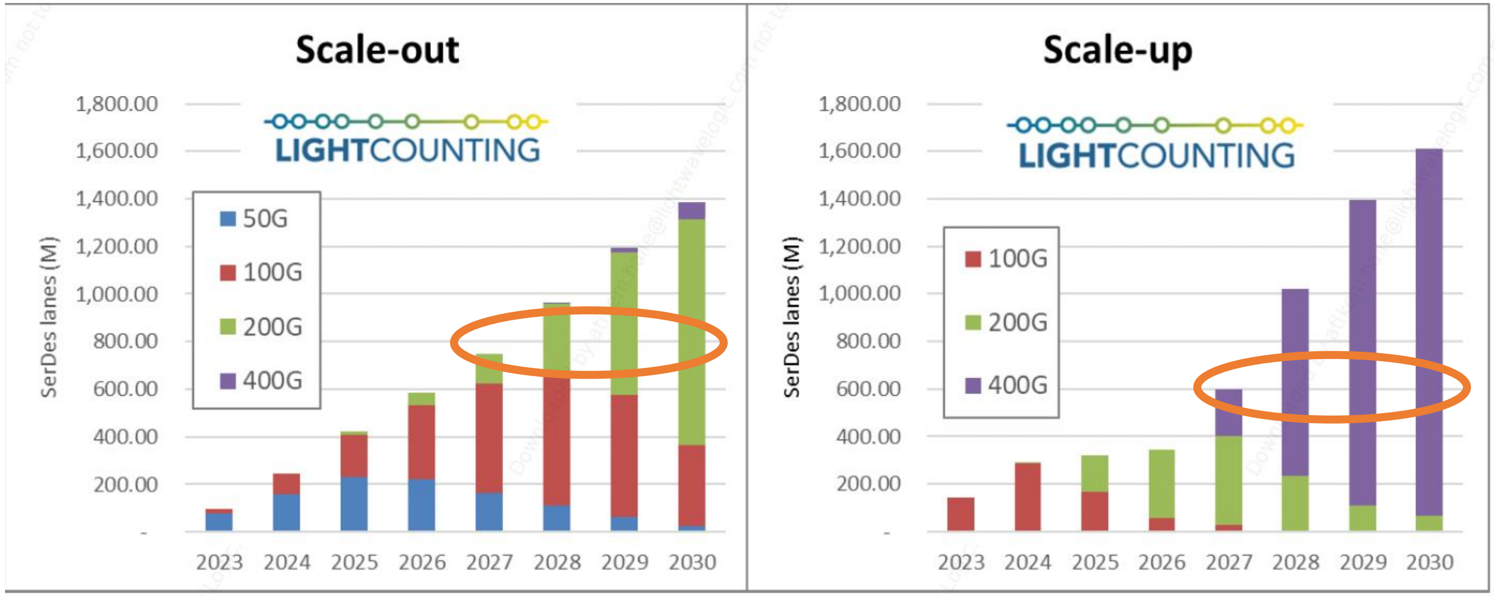


Source: LightCounting



Source: LightCounting

SERDES Speeds Transition



Source: LightCounting

- 200G Scale out and 400G Scale up Photonics needed in 2027 timeframe
- Traditional SiPh needs to be augmented to reach 400G – and improve 200G performance
- EO Polymers offer viable path compatible with standard CMOS processing and assembly

Electro-Optic Polymers (EOPs) - Perkinamine®

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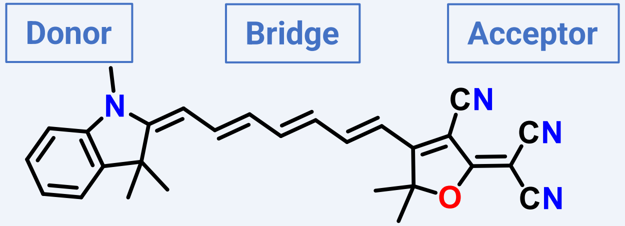
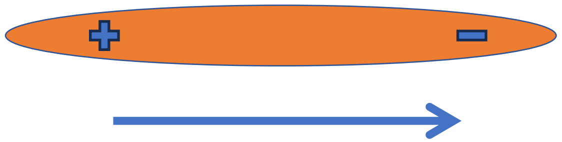
General chromophore structure

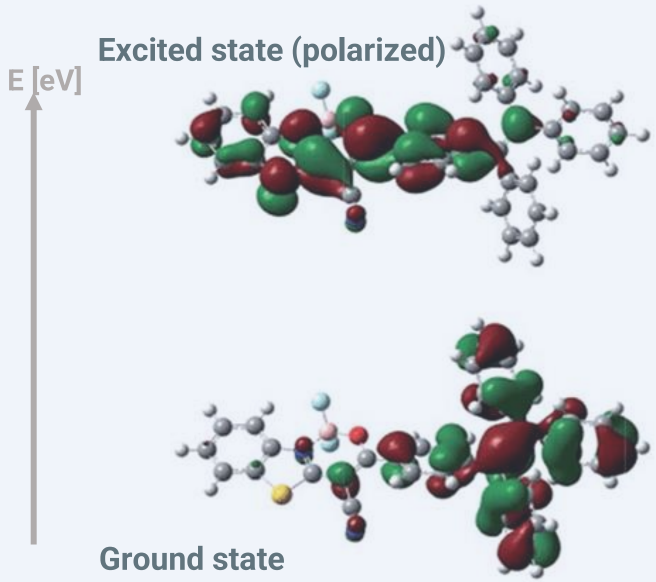


Chromophores are dipolar molecules



Pockels Effect:

- Linear electro-optic effect with the fastest response time
- Refractive index change directly proportional to applied electric field
- Occurs in non-centrosymmetric materials

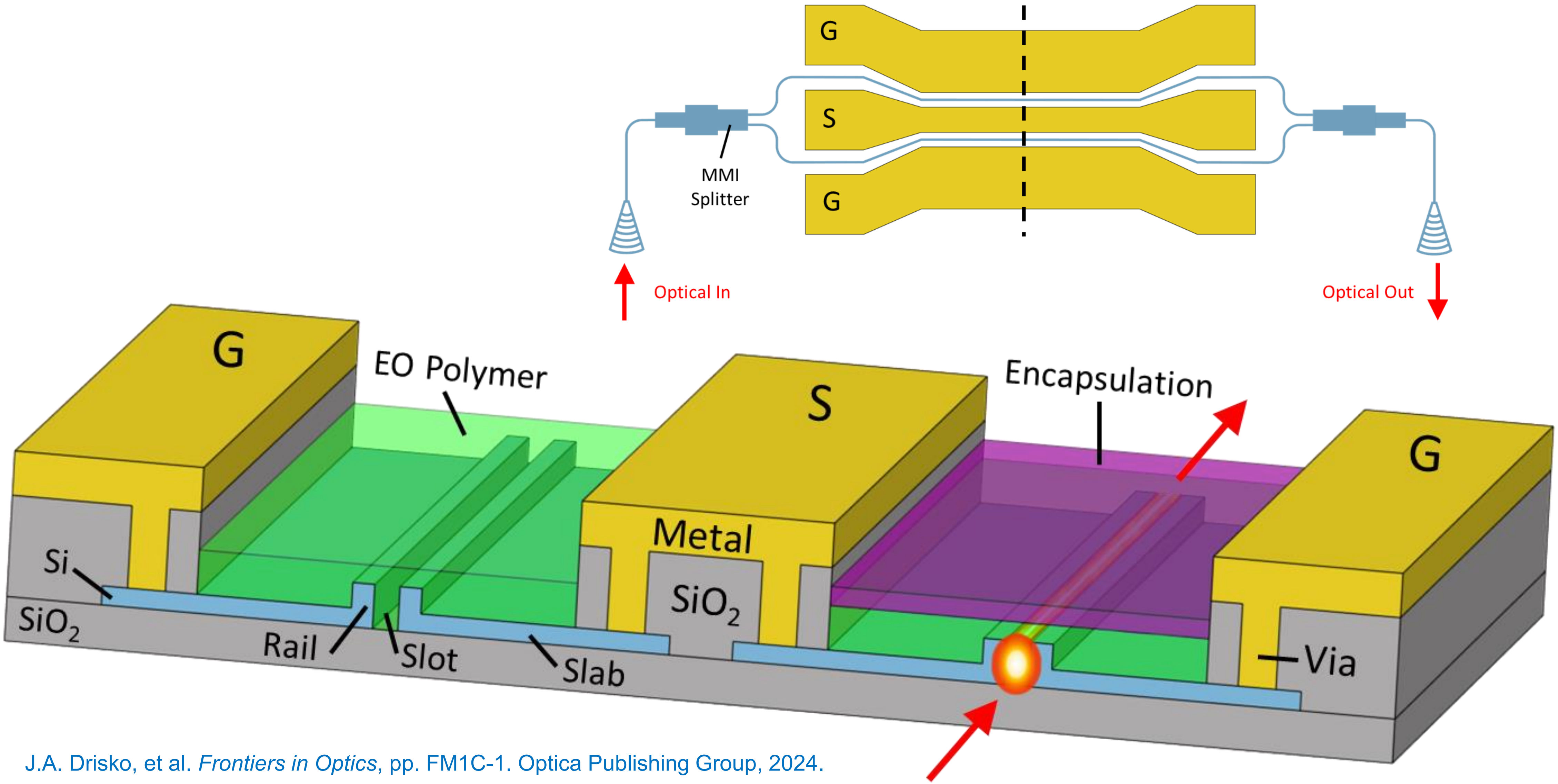


The electric field shifts the electron cloud to the excited-state molecular orbitals.
This alters the refractive index of the electro-optic material, which in turn causes a phase change to any transiting optical signal

EOPs: Index change proportional to applied field with the fastest response time

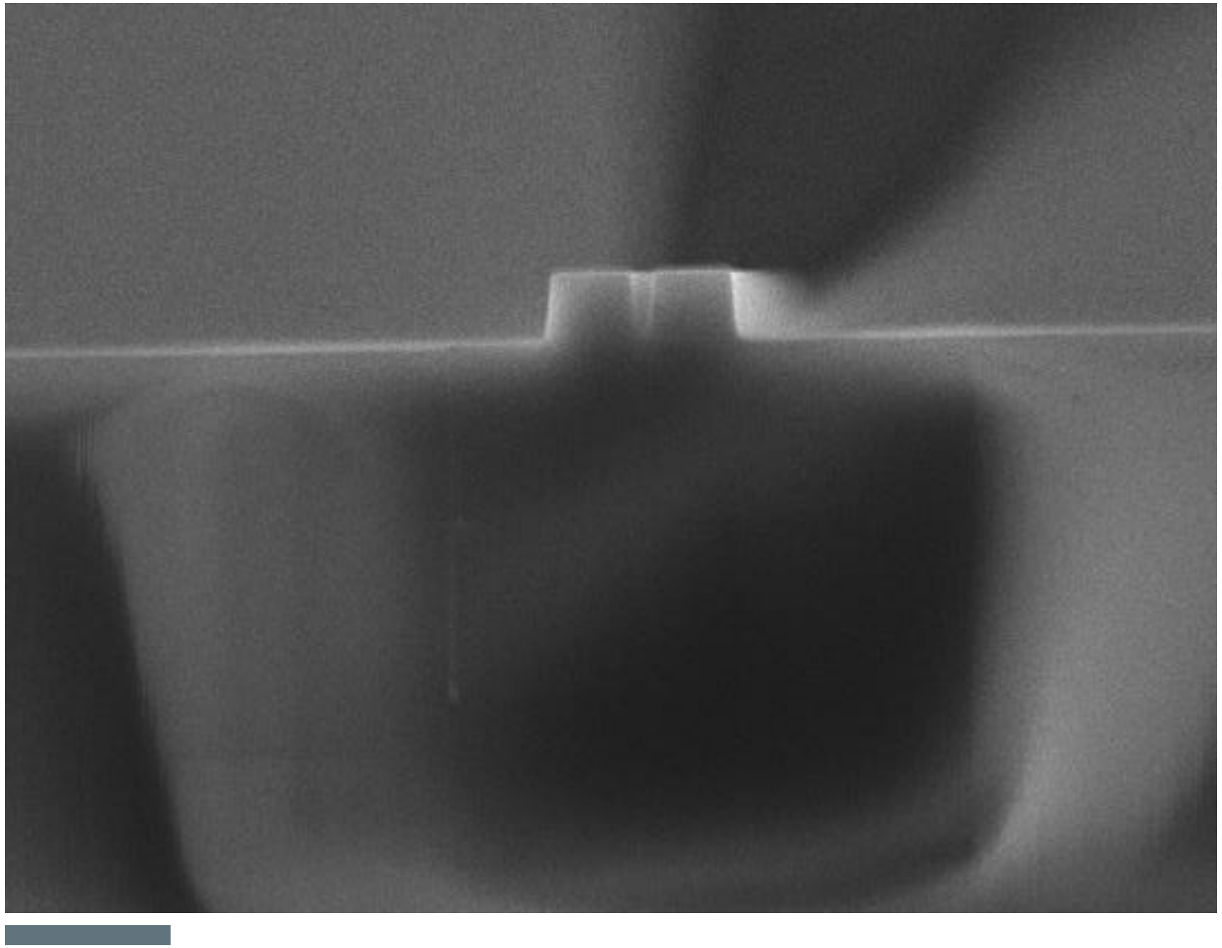
RSC Adv.. 7. 1348-1356. 10.1039/C6RA25871A.

Polymer Slot Modulators

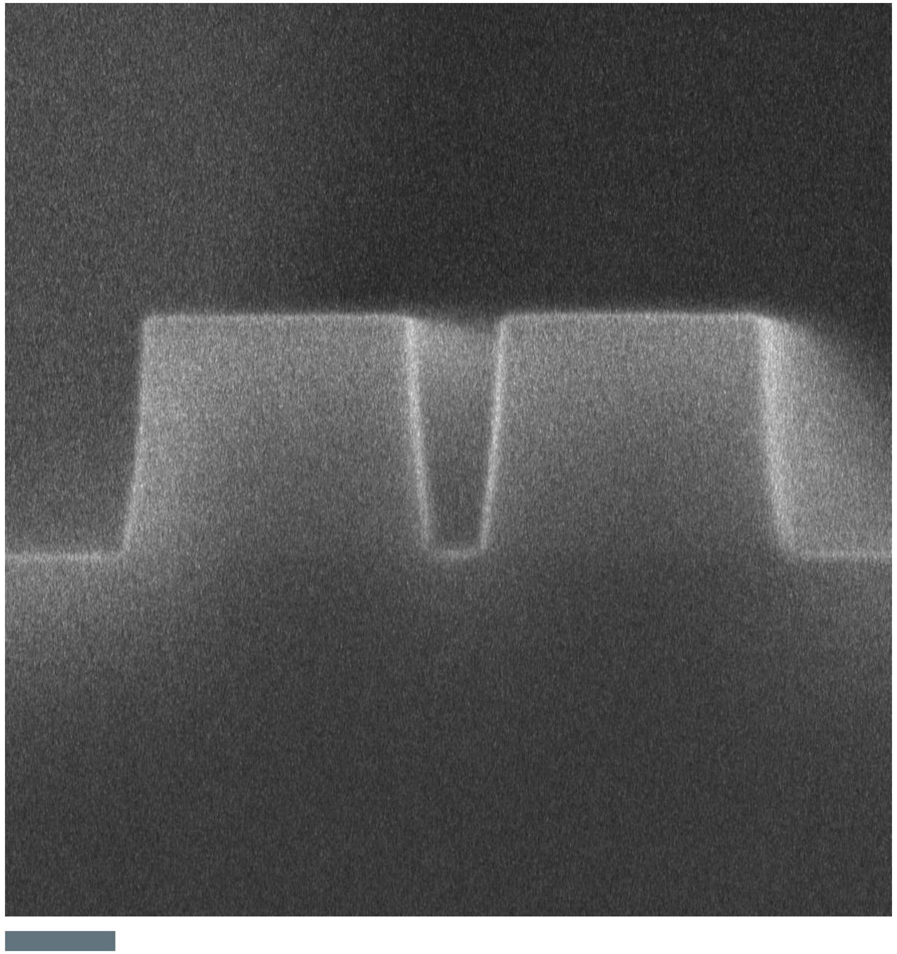


J.A. Drisko, et al. *Frontiers in Optics*, pp. FM1C-1. Optica Publishing Group, 2024.

Si Slot Waveguide Cross Sections



500 nm



100 nm

Clean, sharp, and smooth Si slots

Simulations

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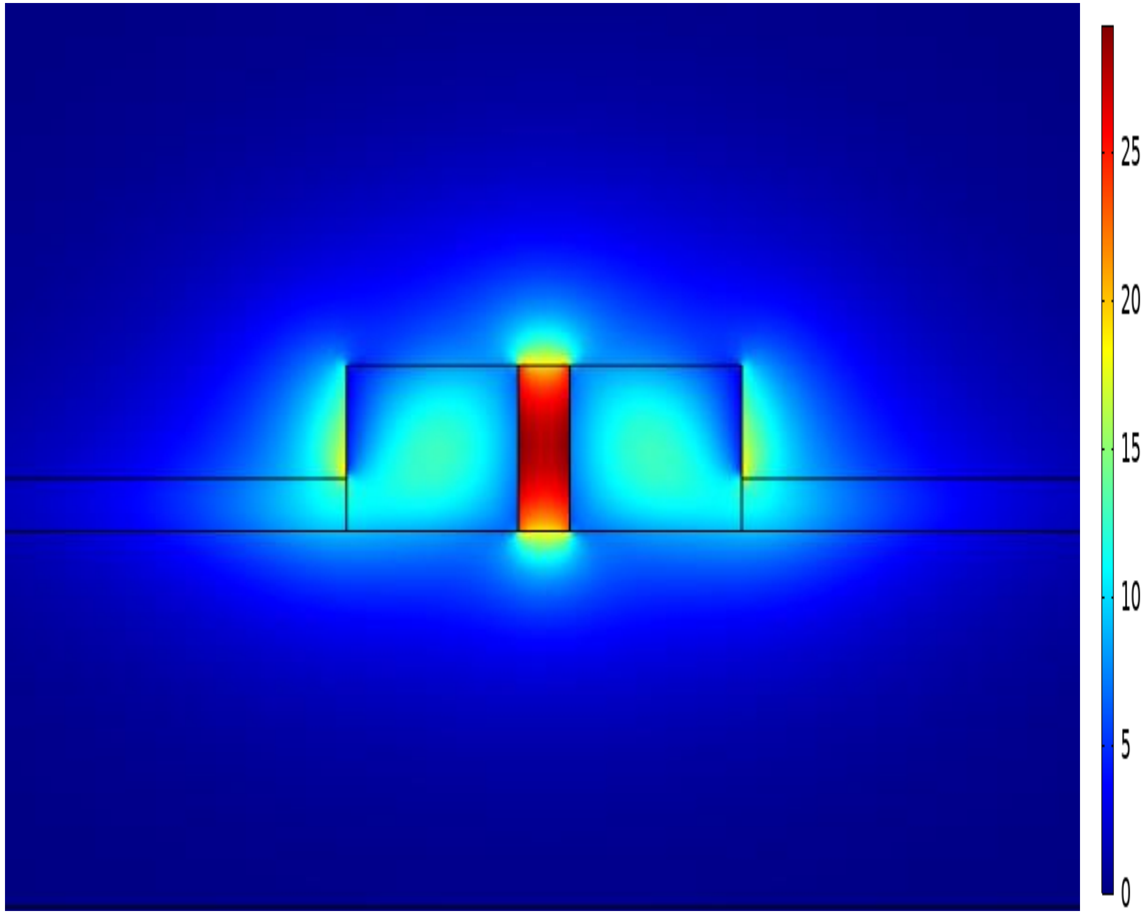
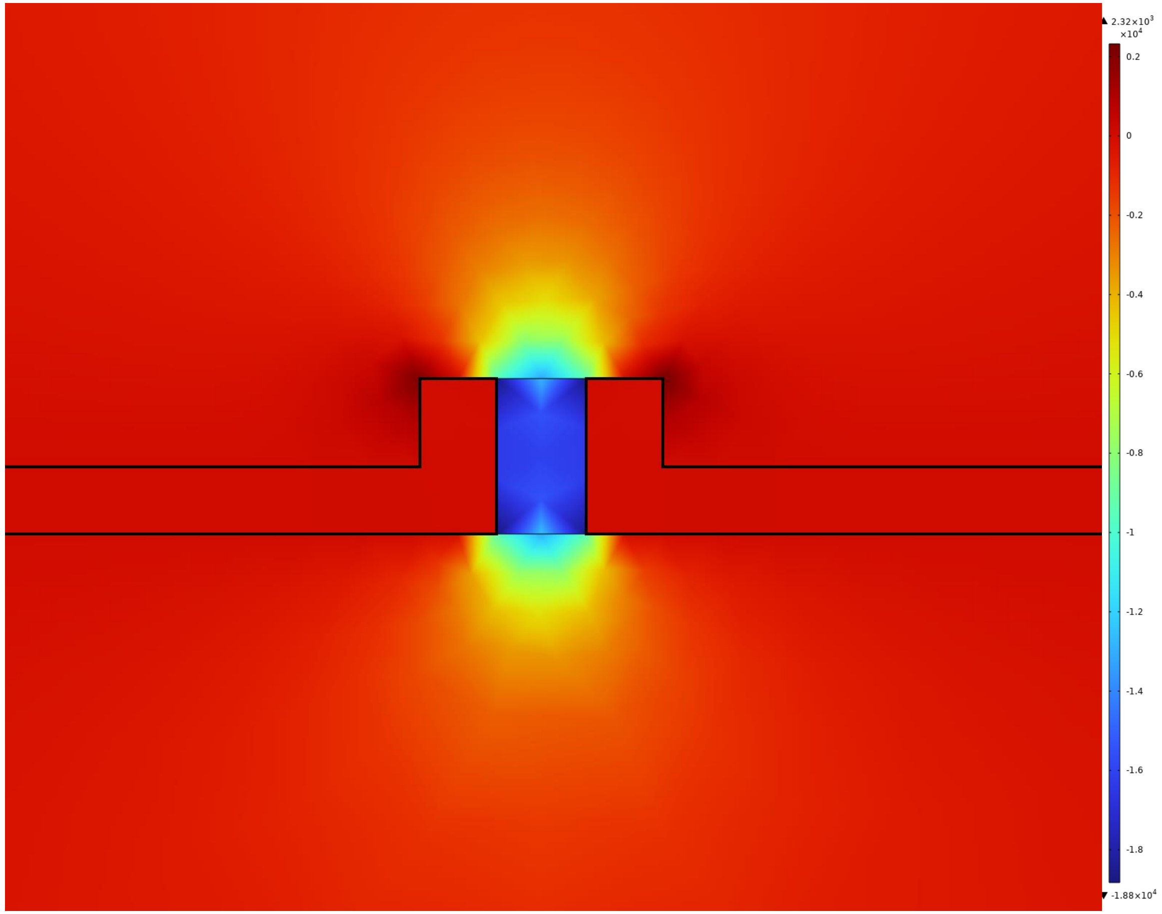
Optical Field (229 THz)



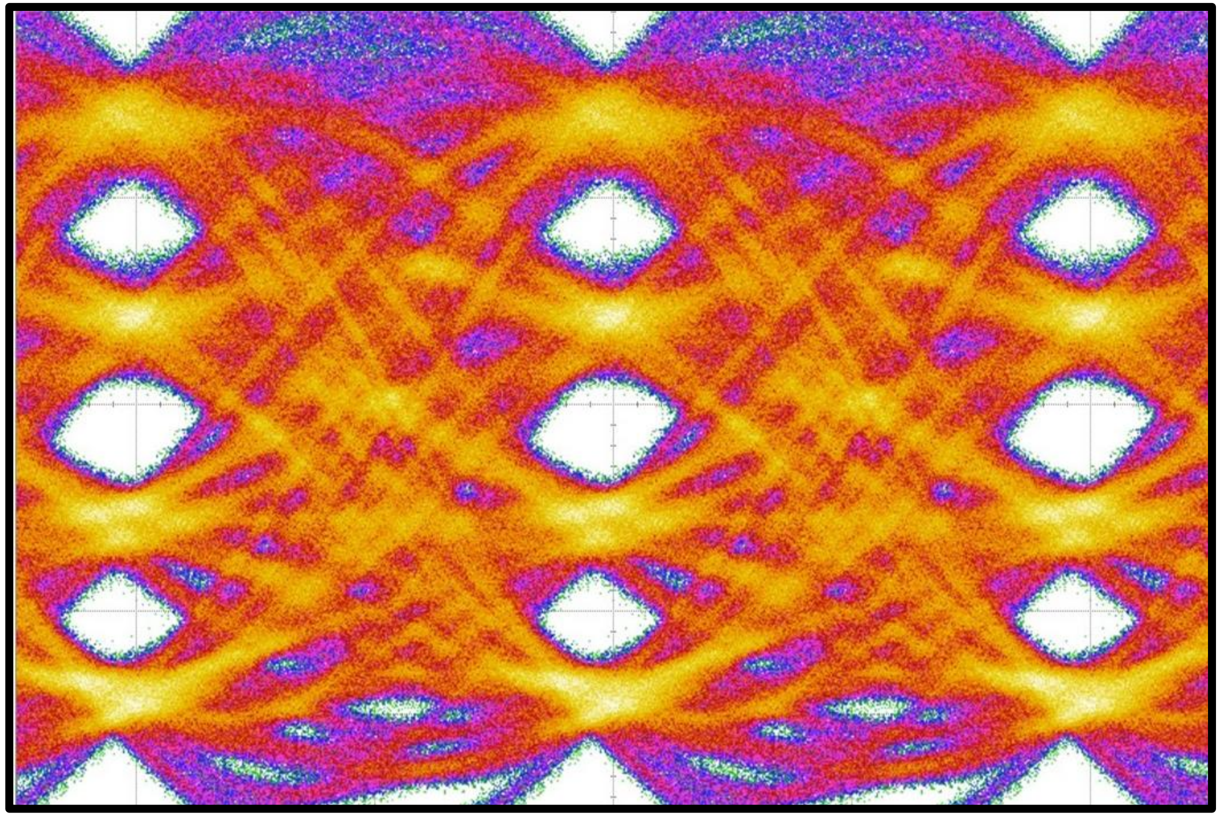
RF Field (~0-120 GHz)



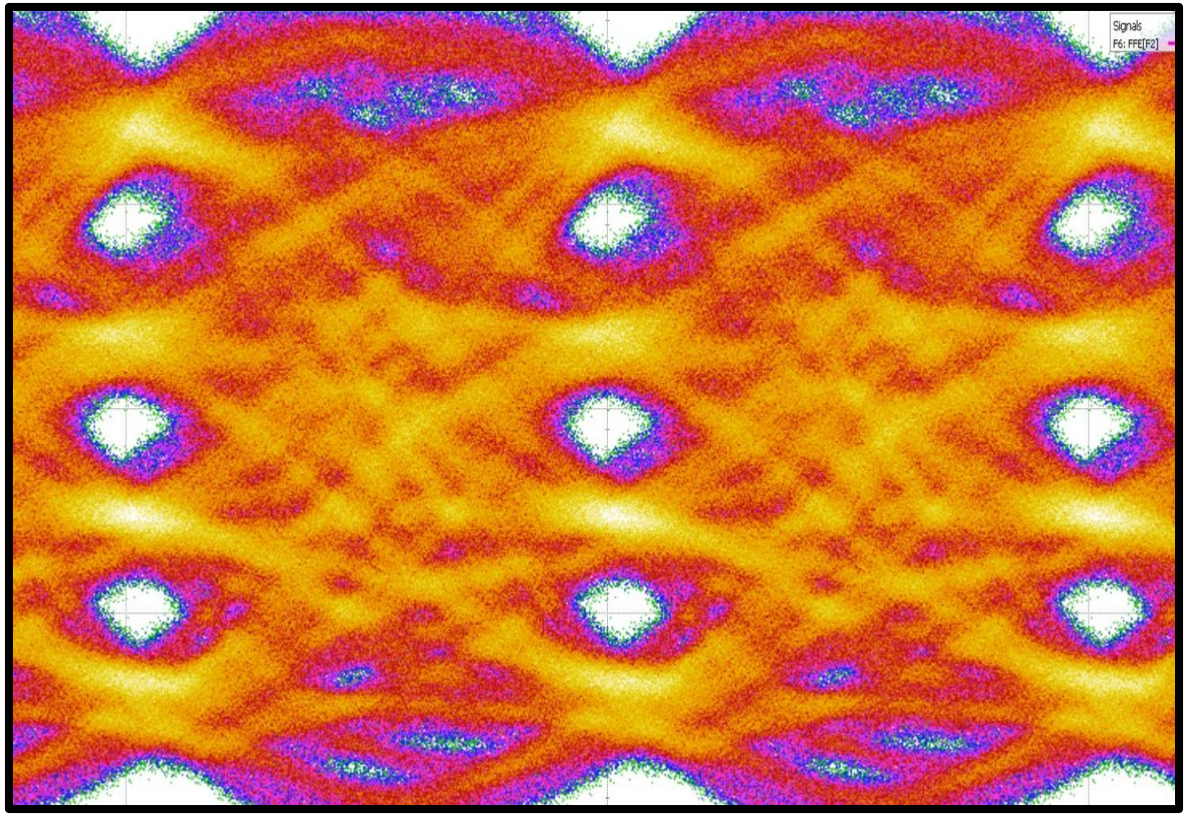
Strong overlap between optical mode and E-field → Very efficient modulation

Technology Demonstration Results

100 Gbaud, 200 Gbit/s, V_{drive} = 0.8 V



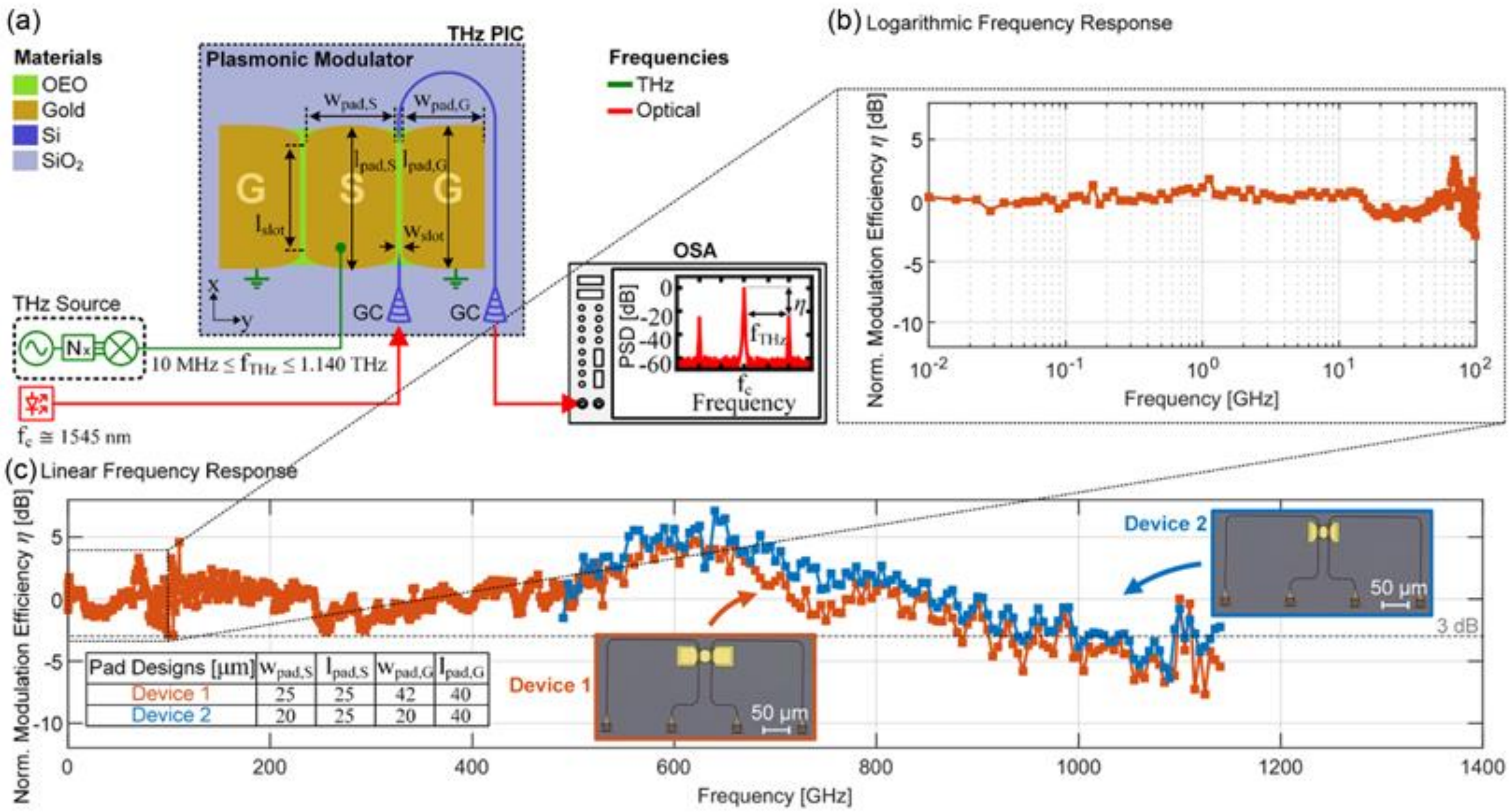
120 Gbaud, 240 Gbit/s, V_{drive} = 0.9 V



Clear, open, PAM4 eyes at > 200 Gbit/s with V_{drive} < 1 V

J.A. Drisko, et al. *Frontiers in Optics*, pp. FM1C-1. Optica Publishing Group, 2024.

400Gbps … and beyond



Polariton packaged products with Lightwave Logic EO polymer engine

A.H.: Y. Horst et al., Optica, vol12(3):325-8 (2025)

Material Parameters and Comparison

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Thin-Film $LiNbO_3$ (TFLN)	Electro-Optic Polymers
Performance: • r_{33} intrinsically capped at ~ 31 pm/V at 1310 nm • n = 2.2, ε_r = 30 (high dispersion across frequencies)	**Performance:** • No intrinsic cap on r_{33} (> 200 pm/V at 1310 nm easily achieved) • n ≈ 1.9, ε_r ≈ 3-6 (low dispersion across frequencies)
Integration: • Integration with Si/SiN very low yielding & basically still in R&D stage • Limited wafer size (150 mm) • Large device footprint (sub-cm scale) • High material cost w/ limited supplier base	**Integration:** • Fully Si compatible • Easily scalable to 300 mm wafer • Very small device footprint (sub-mm scale) • Low material cost
Processing: • Thin film uniformity becomes difficult as wafer size scales up • Specialized processing/tools needed – leads to higher costs associated with processing, QC, etc.	**Processing:** • Spin-coating produces films with high uniformity • No specialized processing/tools needed (completely compatible with existing Si foundry processes/tools) – reduces costs associated with processing, QC, etc.

LWLG EO polymers have inherently high performance and are fully Si-foundry compatible

Comparison of Key Modulator Technologies

Lightwave Logic assessment based on available public information

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Parameter	Silicon Photonics (SiPh)		Silicon Organic Hybrid (SiPh+EOP)	TFLN	Indium Phosphide (InP)	
Modulator Type	Ring	Mach-Zehnder (MZ)	MZ or Ring	MZ	DFB-MZ	Diff EML
Modulation Speed	200 Gbit/s	200 Gbit/s	**>>400 Gbit/s [1]**	400 Gbit/ s	400 Gbit/s	400 Gbit/s
Power Consumption	Low	Medium	Lowest	Medium	High	High
Drive Voltage (at 200G)	2V	3V	<1V	3V	<3V	<3V
Linear/ LPO/ DSP less compatible	No	Yes	Yes	Yes	Yes	No
Size	<0.2mm	<5mm	<0.5mm [1]	10mm	1mm	0.2mm
Differential $V_{pi}L$	<1V*mm	5V*mm	<1V*mm	20V*mm	3V*mm	n/a
Bias Drift / Control complexity	High	Medium	No bias needed; high linearity	Very high; poor DC stability and linearity	Medium; additional circuitry needed	Medium; additional circuitry needed
Thermal Stability	Low	High	Very high; polymer compensates dn/dT	Difficult due to high CTE mismatch	Requires TEC for laser	Requires TEC for performance
Ease of Integration/ Scalability / HVM	High	High	High	Complex Hybrid Integration; small wafer	Limited compatibility with SiPh; no FR4 integration	Limited compatibility with SiPh; no FR4 integration
3D Packaging/ 300mm Compatible	Yes	Yes	Yes	6" in production, 200mm piloting	6"	6"
Cost	Lowest	Lowest	Low	High	High	High
Reliability	No production yet	High (200G)	In Progress	In Progress	In progress	400G in progress

[1] >1THz Bandwidth and much smaller size with POH

Backend Process: Introduction

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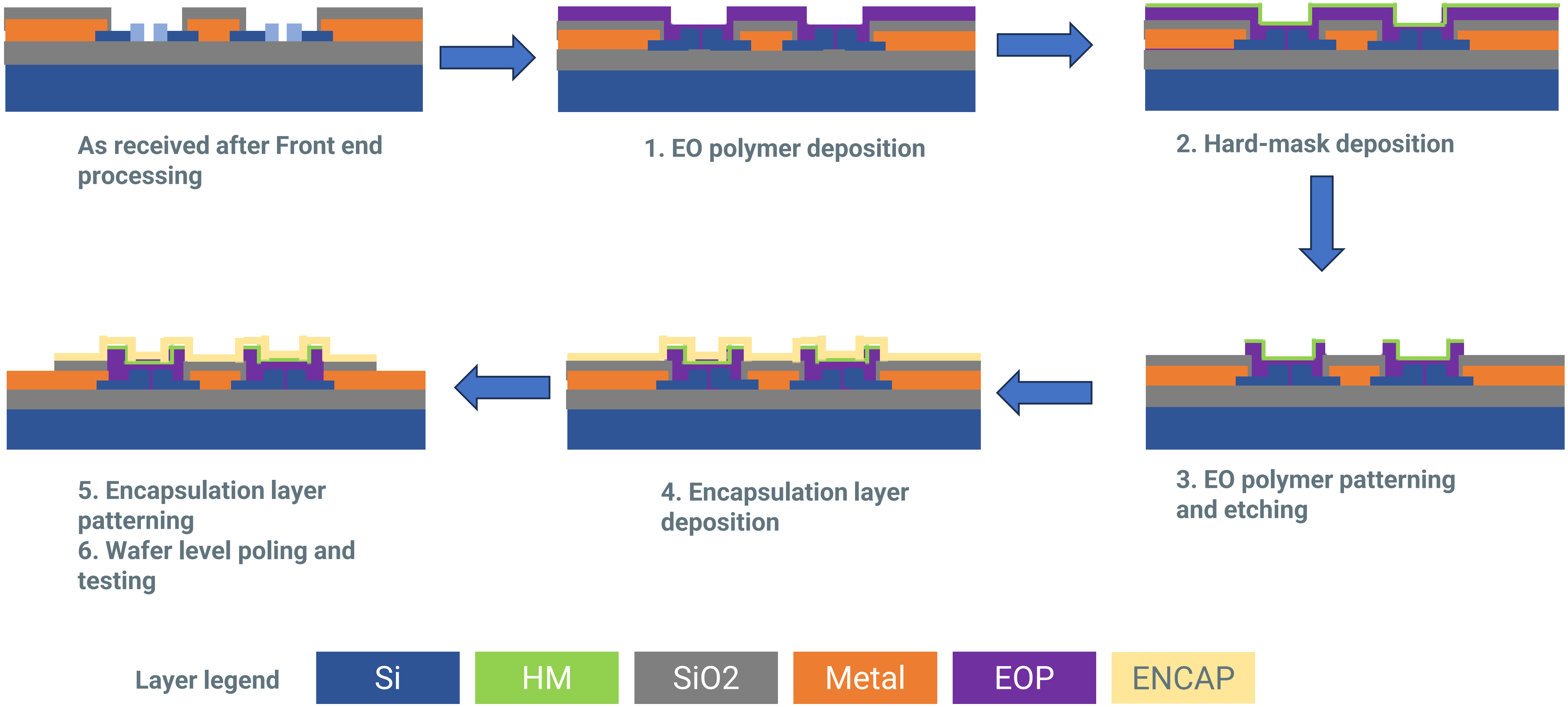
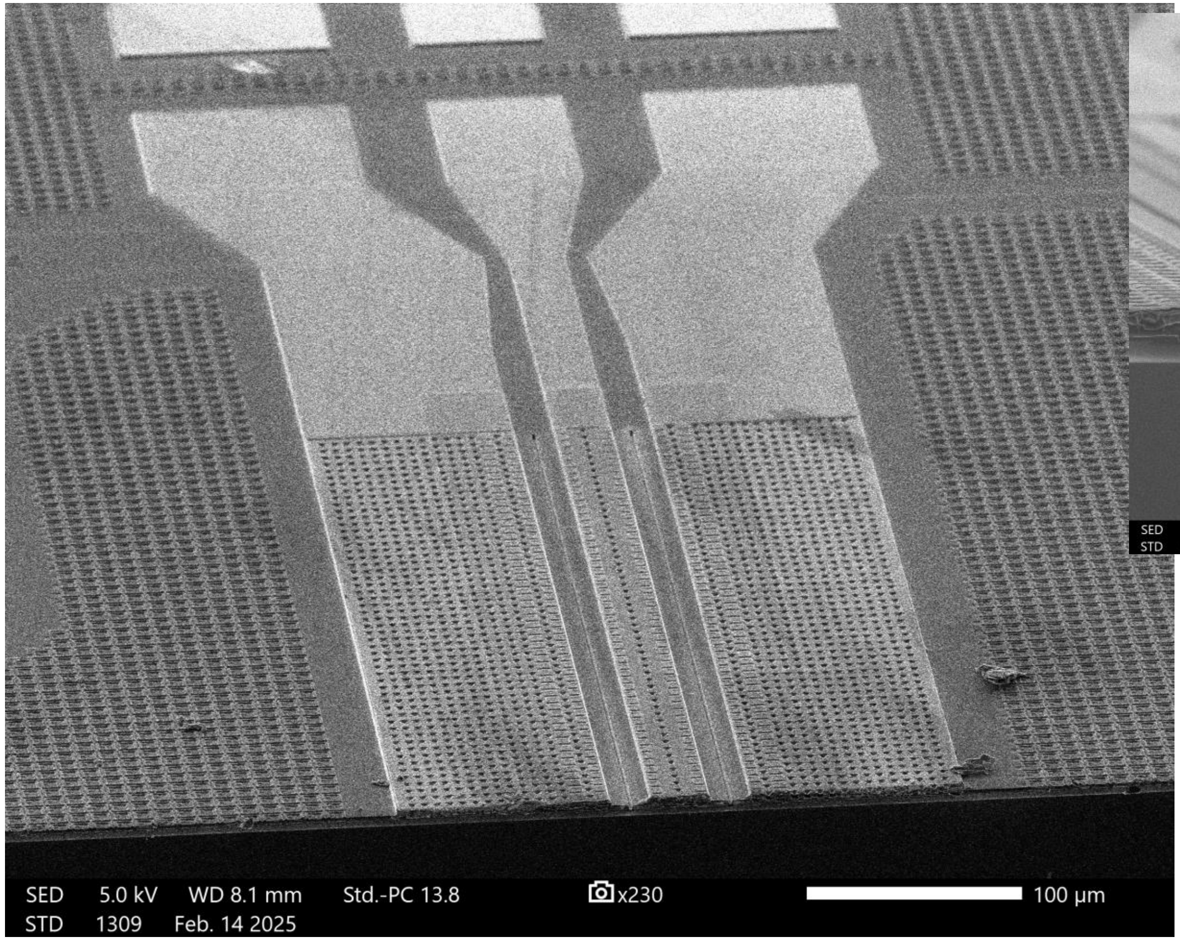
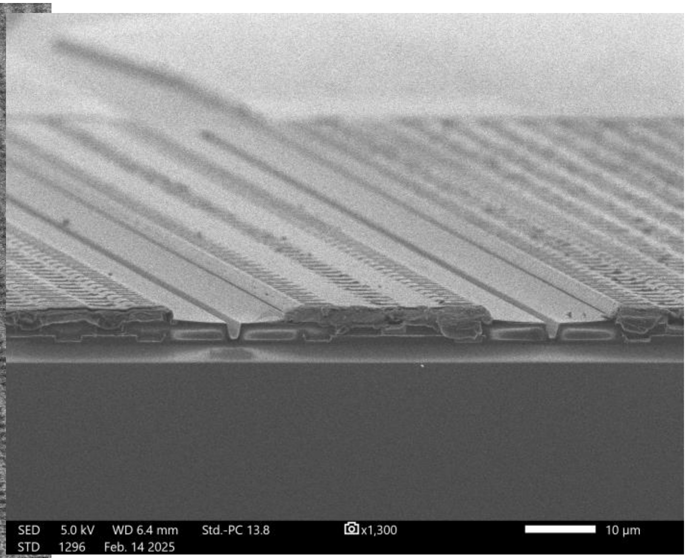
- The backend PDK is developed for applying EO polymers on the modulator device fabricated by a standard silicon photonics process (not foundry-specific)
- Key PDK steps
  - EO Polymer Deposition
  - EO Polymer Patterning and Etching
  - Encapsulation
  - Contact Pad Opening
- Wafer Level Poling and Test
- The manufacturing process is compatible with semiconductor fabrication lines using standard high-volume tools

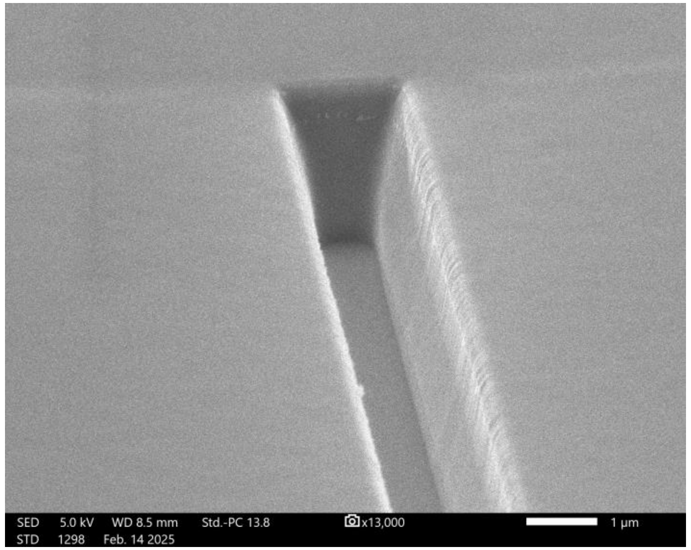
Simplified Backend Process Overview

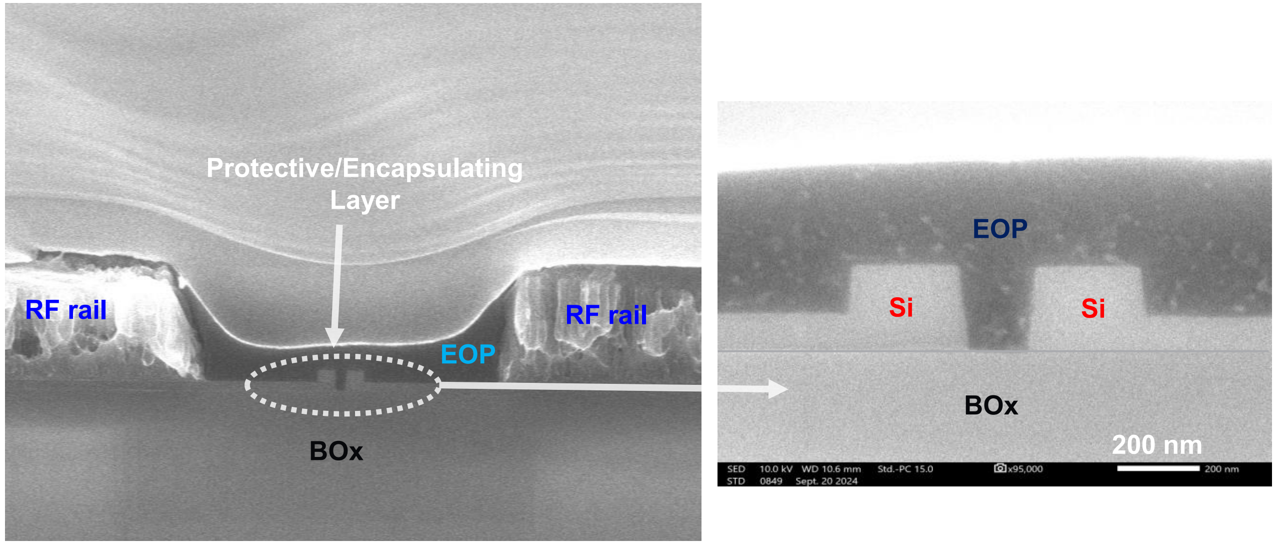


Example Device SEMs after EO Polymer Integration









Poling of EOPs

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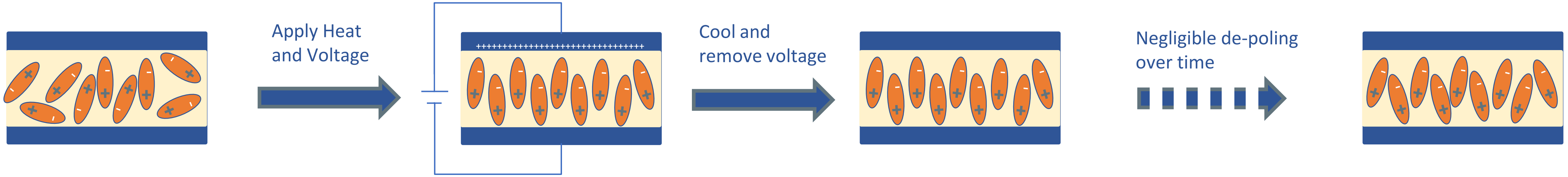


The electro-optic coefficient r_{33} of an unpoled material is zero since all chromophores are randomly oriented

Material is heated to T_g (glass transition temperature) and an electric field is applied to align the chromophores

Polymer is quickly cooled to freeze alignment

Chromophores may re-orient over time if heated to temperatures close to T_g

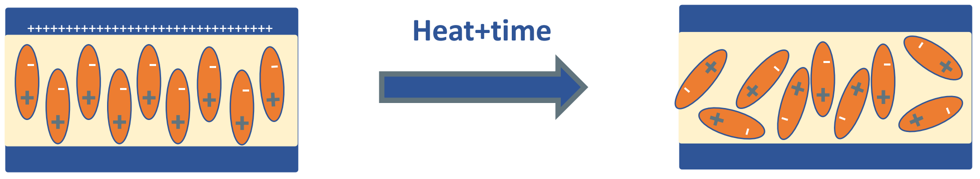
Key Requirements for EO Polymers:

- Negligible de-poling at 85°C continuous operation (stable r_{33})
- High photo-stability

Poled LWLG EO polymers have r_{33} values above 200 pm/V at poling fields of 100 V/um

Mechanism of De-Poling

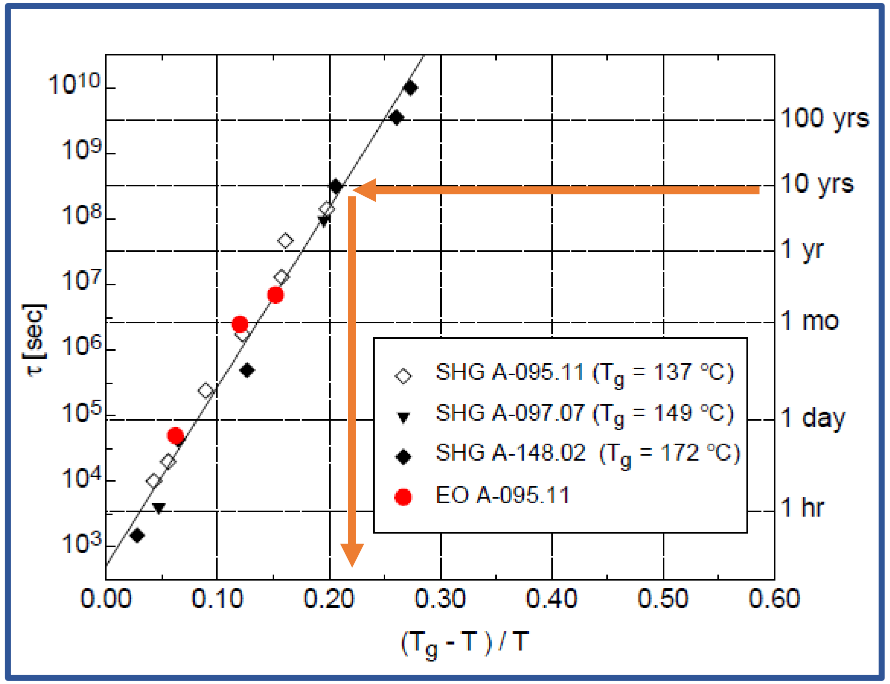
As the polymer temperature approaches T_g, the chromophore alignment gets lost (de-poling)



A high T_g (close to 100°C above operating temperature) is essential for long EO Polymer lifetimes

$$Depoling\ speed = \frac{1}{\tau_g} * e^{-\frac{E_{aAG} * (1 - \frac{T}{T_g})}{k * T}}$$

(Adam-Gibbs equation on viscosity of frozen liquid)



Based on theory, T_g of >164°C is required *
for 10+ years lifetime at 85°C operation

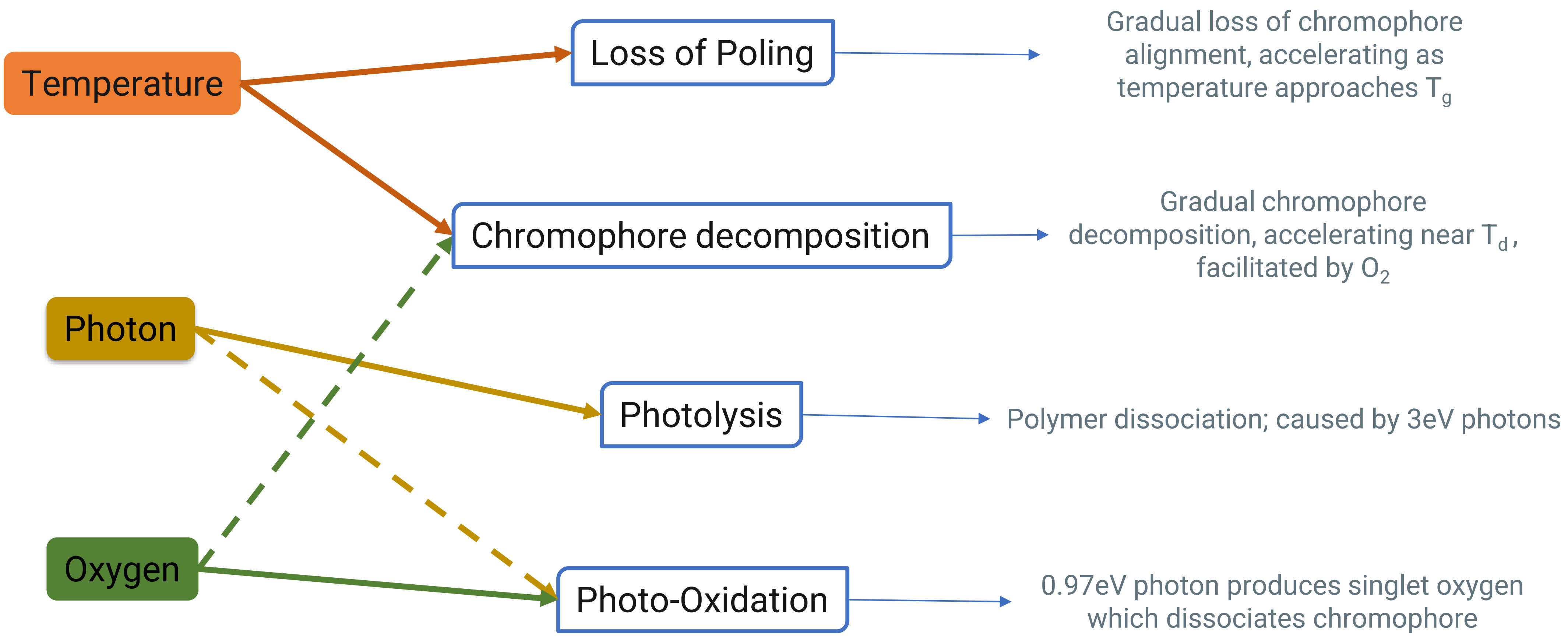
$* \ \frac{164 - 85}{273+85} = \sim 0.22$

Mechanisms for de-poling are well understood and follow an Arrhenius relationship

Martin Bösch, Diss. ETH No. 14192, Electro-Optic Polymers: Photochemical Stability and In-Line Modulator

Understanding Reliability Challenges

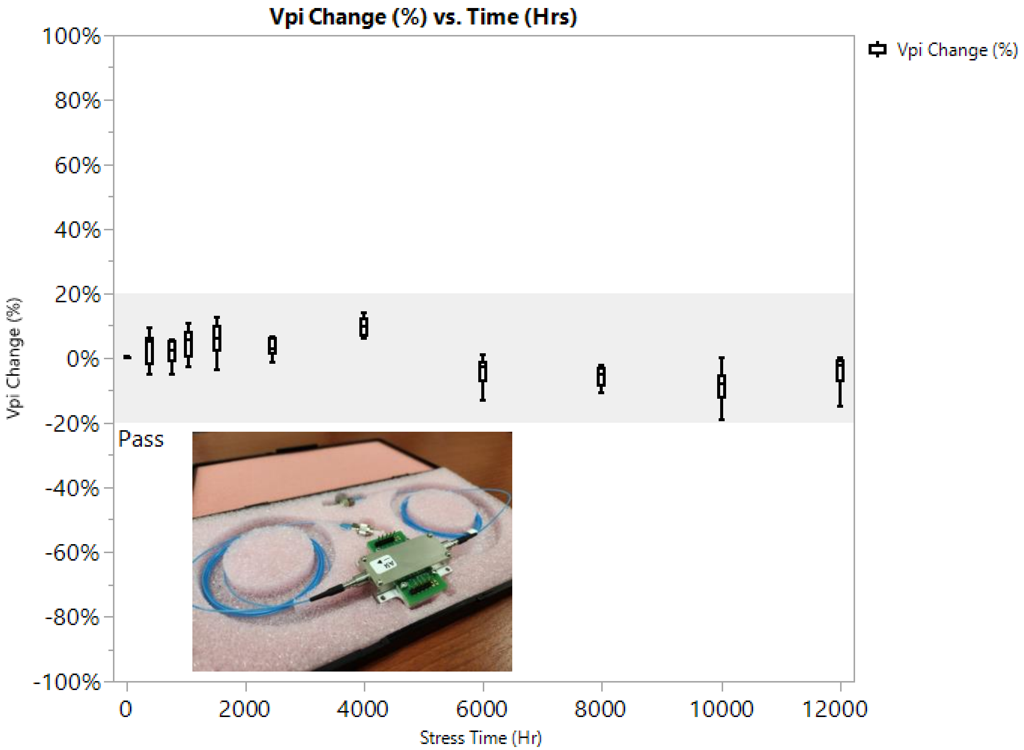
LIGHTWAVELOGIC®



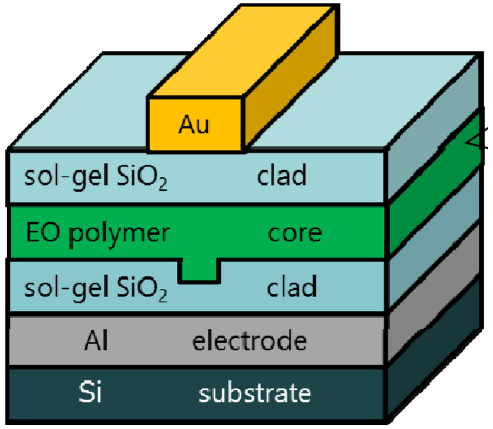
Oxygen is the primary stressor

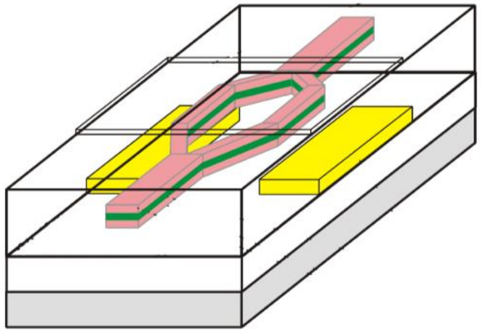
Thermal Aging of Devices

Temperature



3-Layer Stack





Mach-Zehnder Modulator

- No degradation in V_π over 12,000 hrs (1.4 years)
- Observed variation within margin-of-error of test setup
- Demonstrates LWLG Polymers have excellent thermal stability

Modulator devices show stable V_π over 12,000 hrs

Stress Condition: 3 Layer devices. N=20, N_2 purged oven at 85°C

Basics of Photostability

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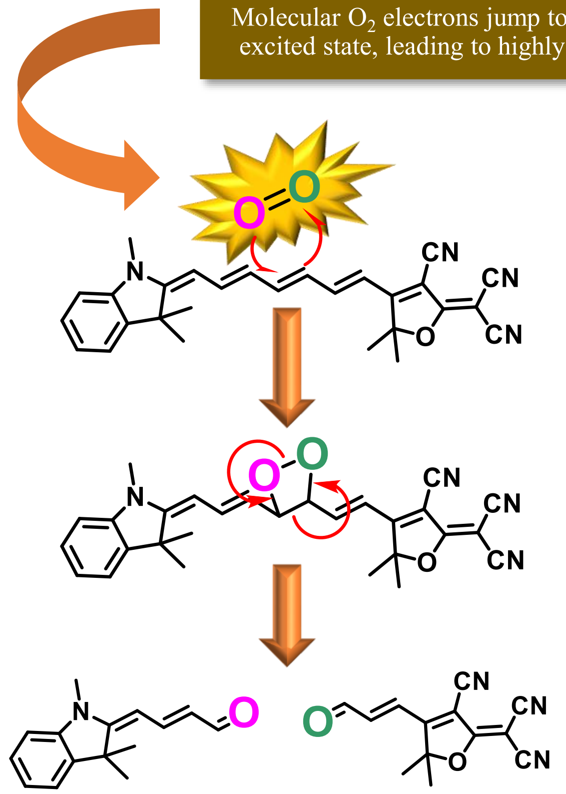
Photon

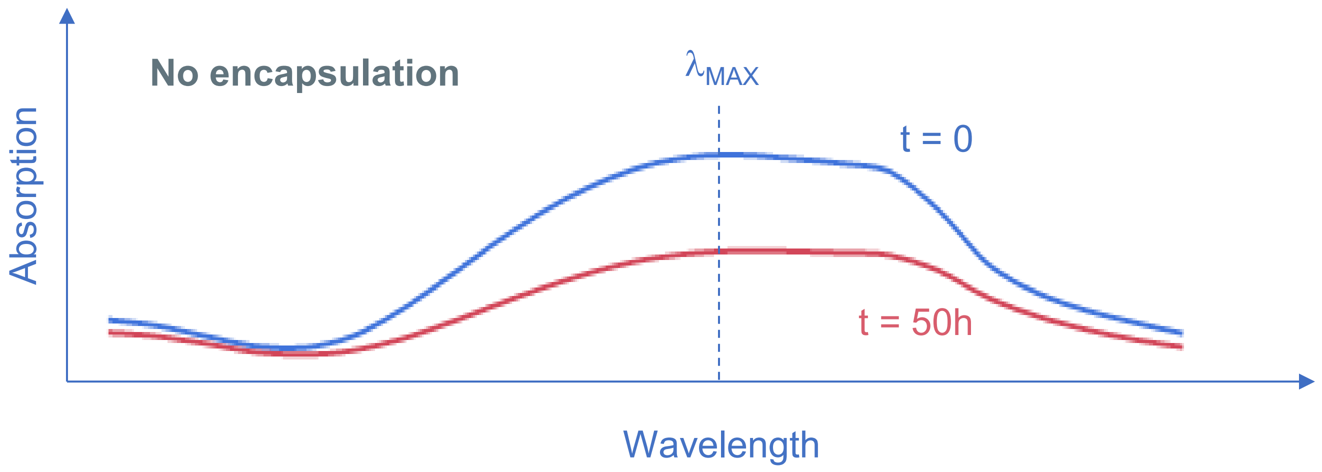
Chromophore absorbs light energy (1310 nm/~1eV)

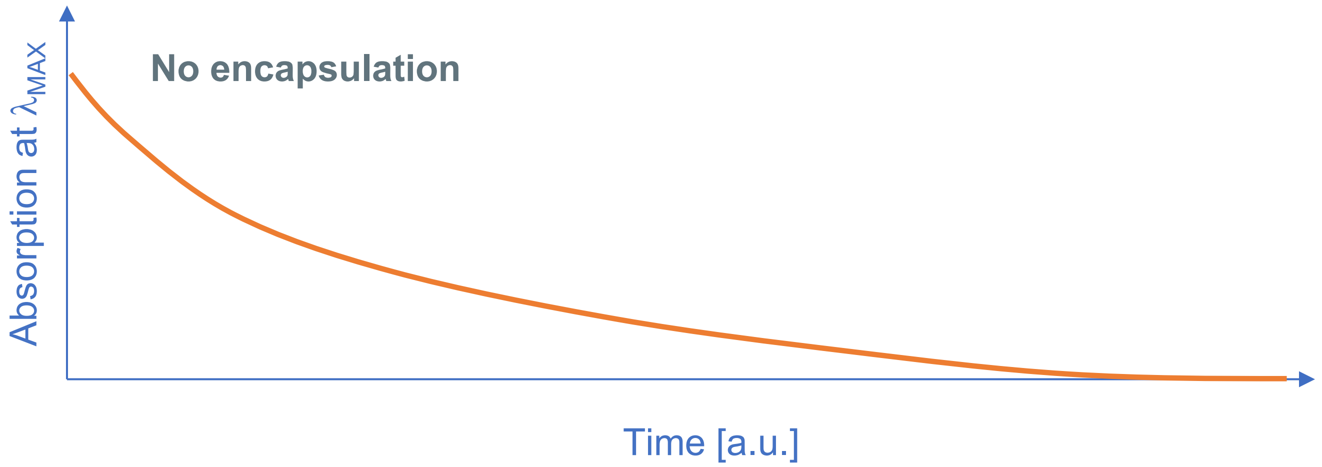
Energy transfer from "excited-state" chromophore to nearby molecular oxygen

Molecular O_2 electrons jump to high energy excited state, leading to highly reactive O_2

Photostability



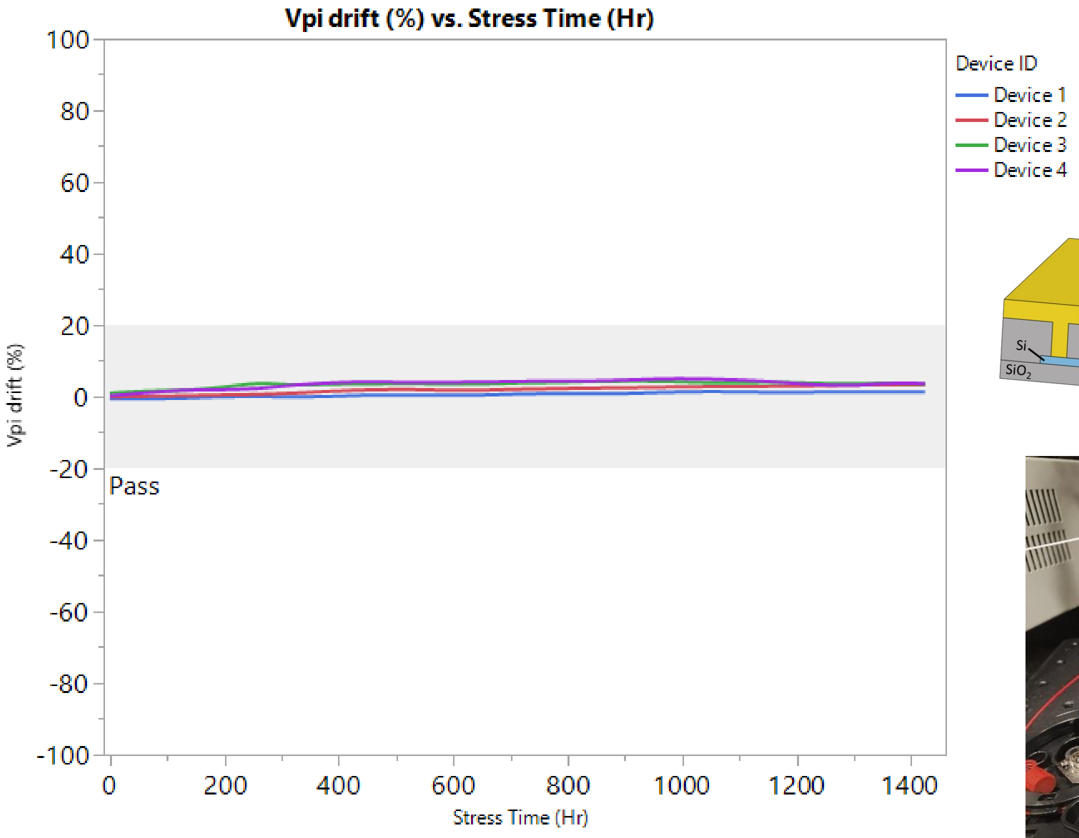


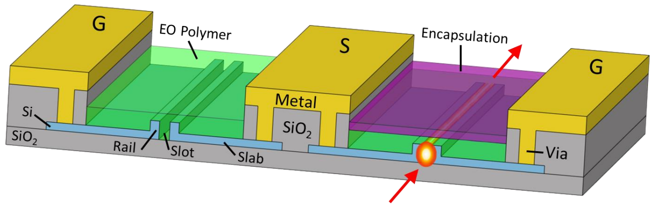


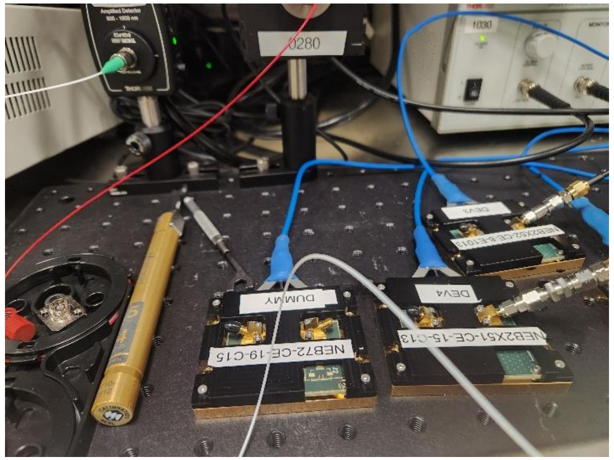
Organic chromophores will degrade in the presence of oxygen without appropriate encapsulation

Photostability on Devices without Oxygen

Photon







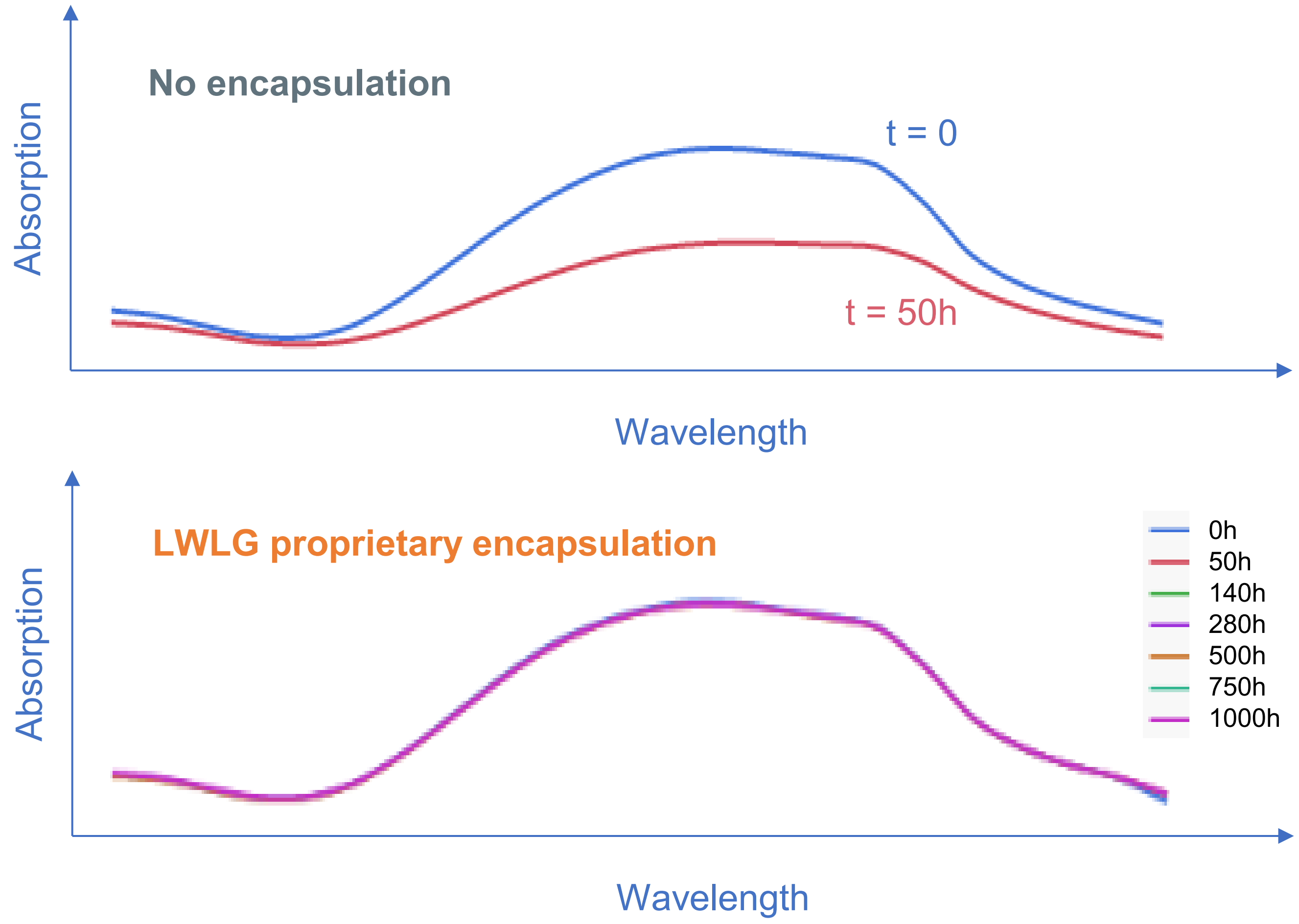
- High optical input power stress test (20dBm)
- The V_π on 4 modulators is stable over 1400 hrs
- The average shift over ~1400 hrs is 2%

No photodegradation in packaged devices

Stress Condition: Slot device, RT, 20dBm at 1550nm, N_2 purge

Photostability on Films with Encapsulation

Photon



- Proprietary encapsulation protects EO polymer from oxygen (and humidity)
- No photodegradation observed with latest encapsulation process

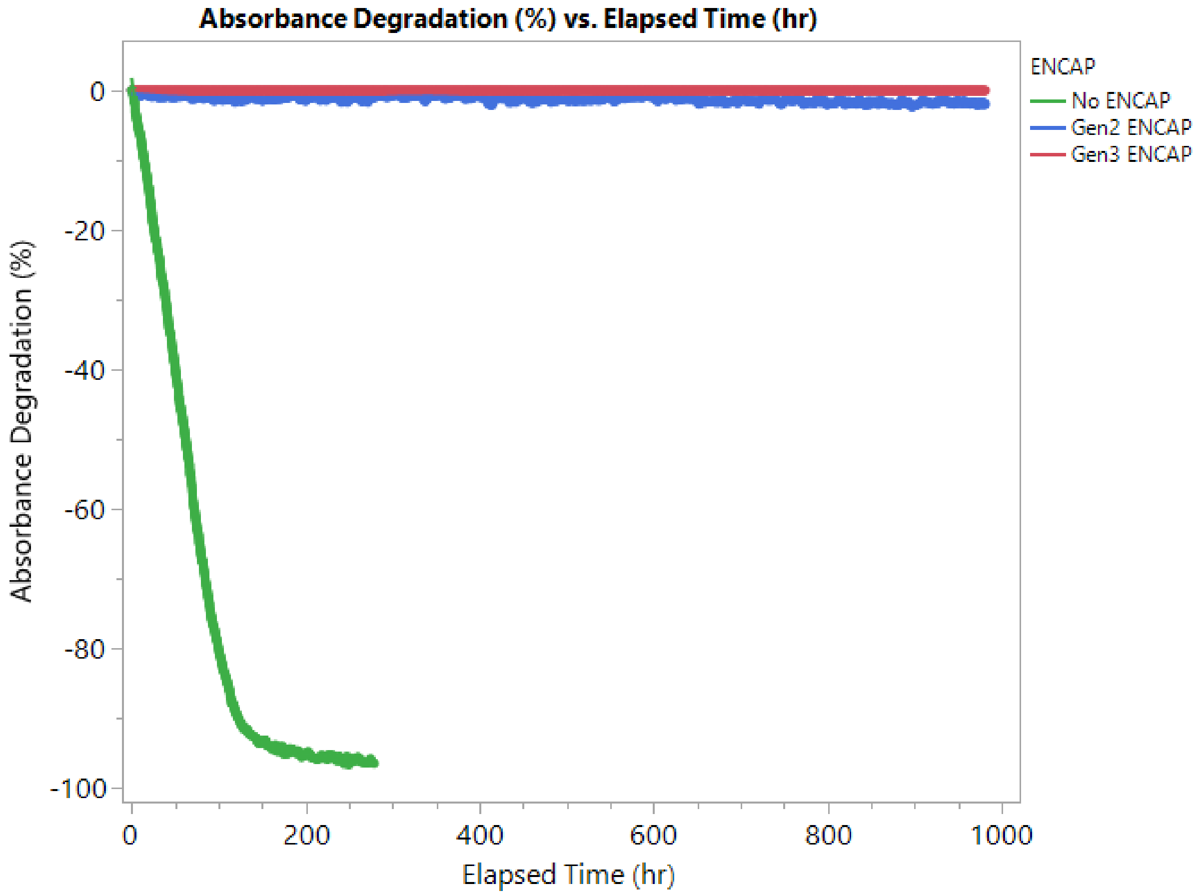
No photodegradation on film with appropriate encapsulation

Stress Condition: Thin film, high power broadband light source, RT, ambient

Broadband Photostability in Thin Film

LIGHTWAVELOGIC®

Photon



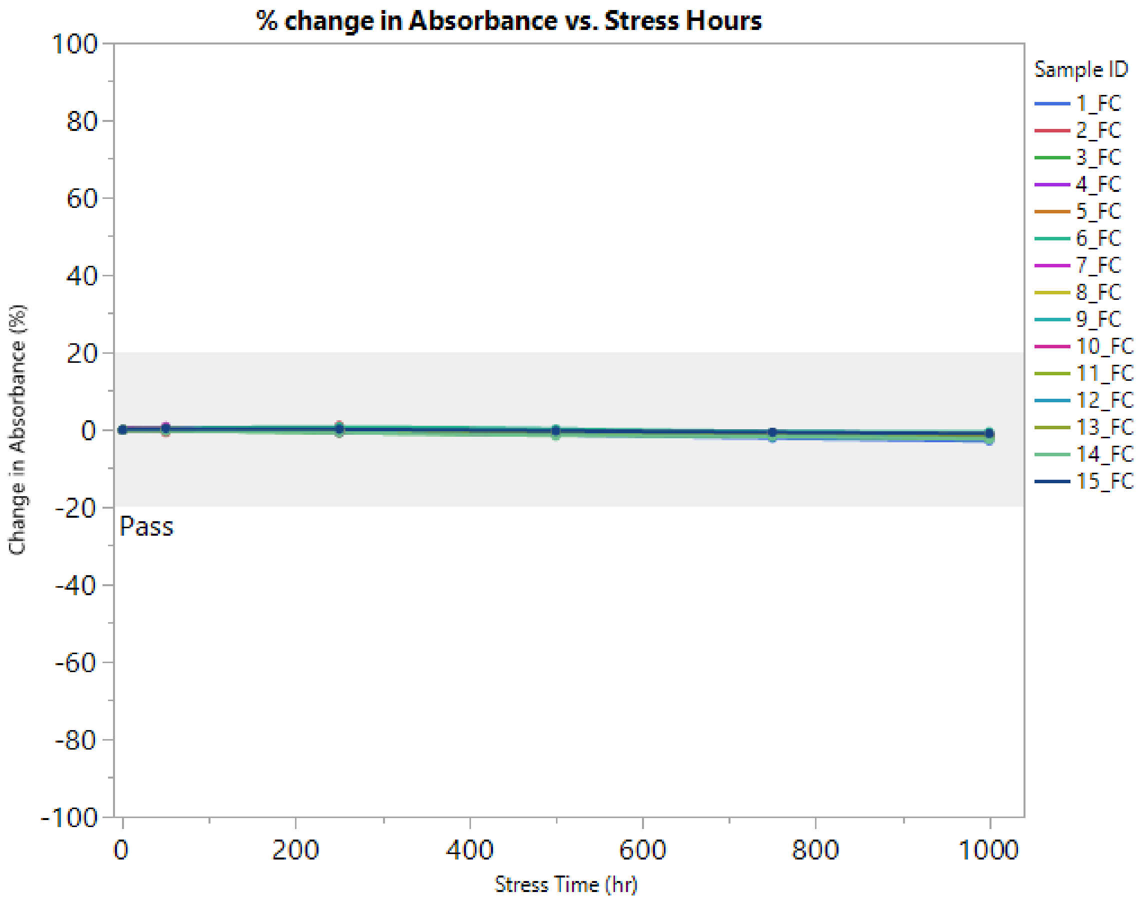
- 1000hrs at RT air environment with constant broadband light exposure
- Absorbance at λ_{MAX} is tracked
- After 1000hrs, previous generation Gen2 ENCAP shows less than 2% chomophore degradation
- Lastest Gen3 ENCAP shows zero chomophore degradation

Stress Condition: Thin film, high power broadband light source, RT, ambient

Temperature Humidity Stress on Thin Film

Temperature | Oxygen

Gen2 ENCAP

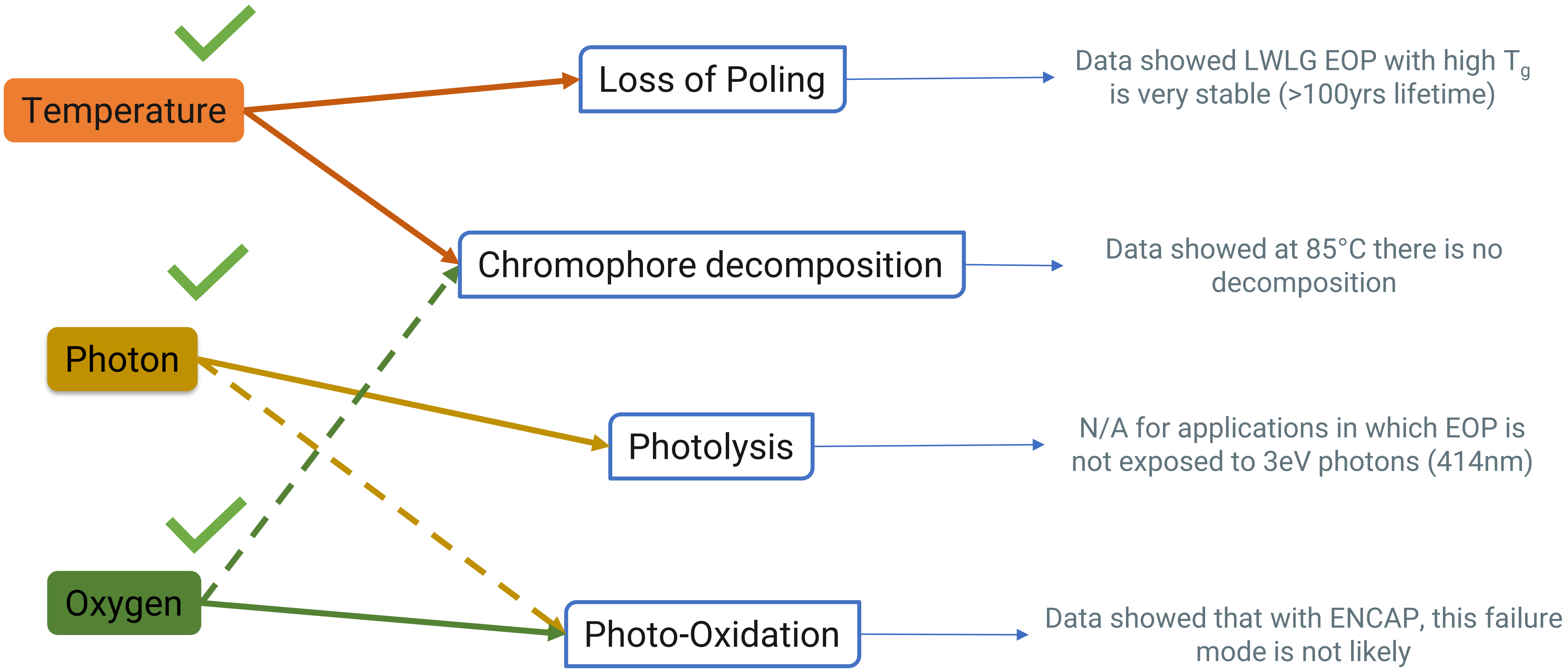


- Using sample size (15) and damp heat stress condition (85%rh-85°C)
- All thin film samples with GEN2 ENCAP protection have very little degradation
- UV-Vis samples show on average 1.6% decay after 1000 hrs
- Passing Telcordia requirements (1000 hrs) with more than 11 samples by a wide margin

Thin film EO Polymer with ENCAP passes Telcordia damp heat stress

Stress Condition: EOP thin film. 85%rh-85°C

Reliability Data Summary



All Key Reliability Challenges Addressed

Summary

LIGHTWAVELOGIC®

- Perkinamine®- Lightwave Logic proprietary material is most reliable organic EO polymer today
- Breakthrough inventions on material chemistry and protection from oxygen
- Key reliability risks addressed with demonstrated results such as 85/85 test
- Ongoing campaign to expand reliability results on raw materials
- Partnering now with customers to qualify materials in PICs/devices made in commercial silicon photonics foundries

Perkinamine® Ready for Deployment