LIGHTWAVELOGIC®

Faster by Design

Commercializing electro-optic polymers

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NASDAQ
LWLG

Photonics Enable Cloud Computing
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Safe Harbor

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Market Dynamics...

As anticipated, G-AI is driving rapid deployment of 800G+ solutions

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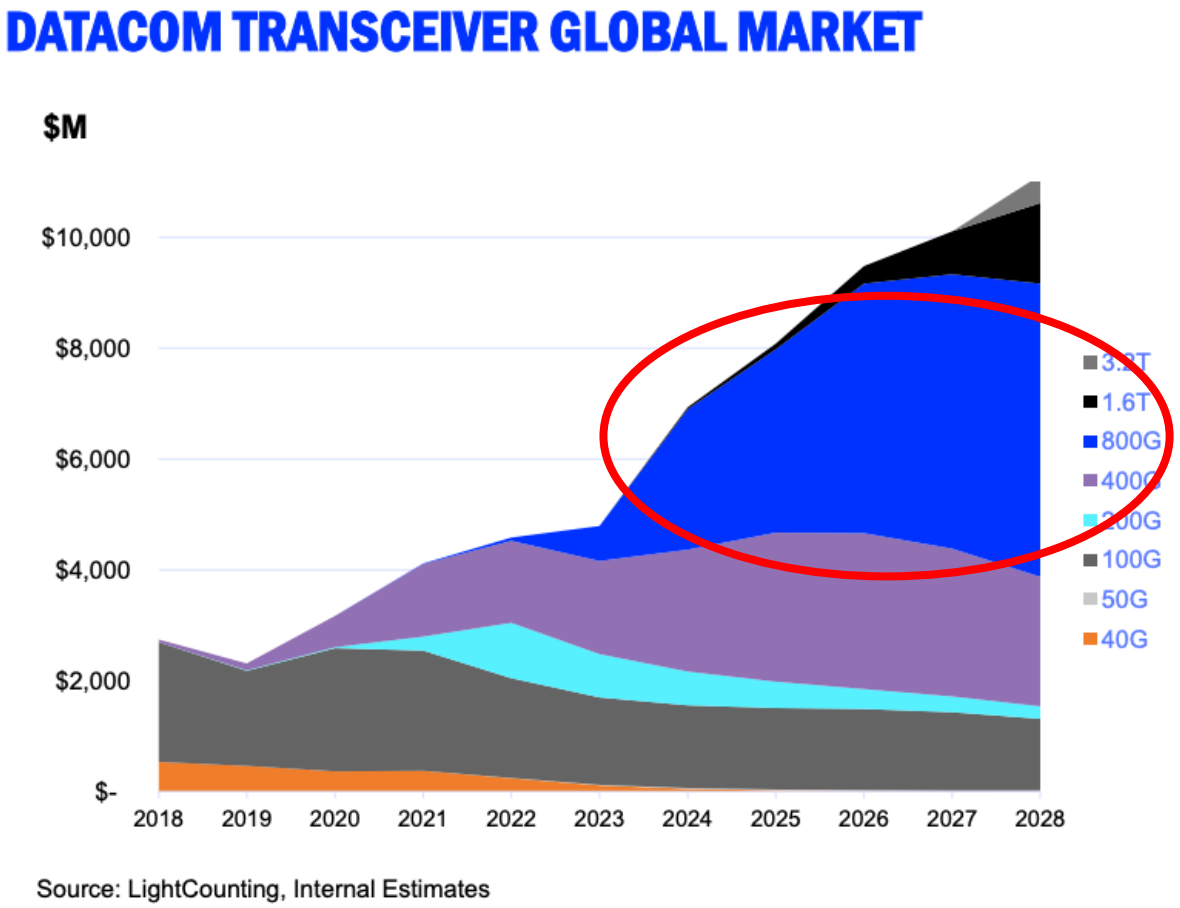
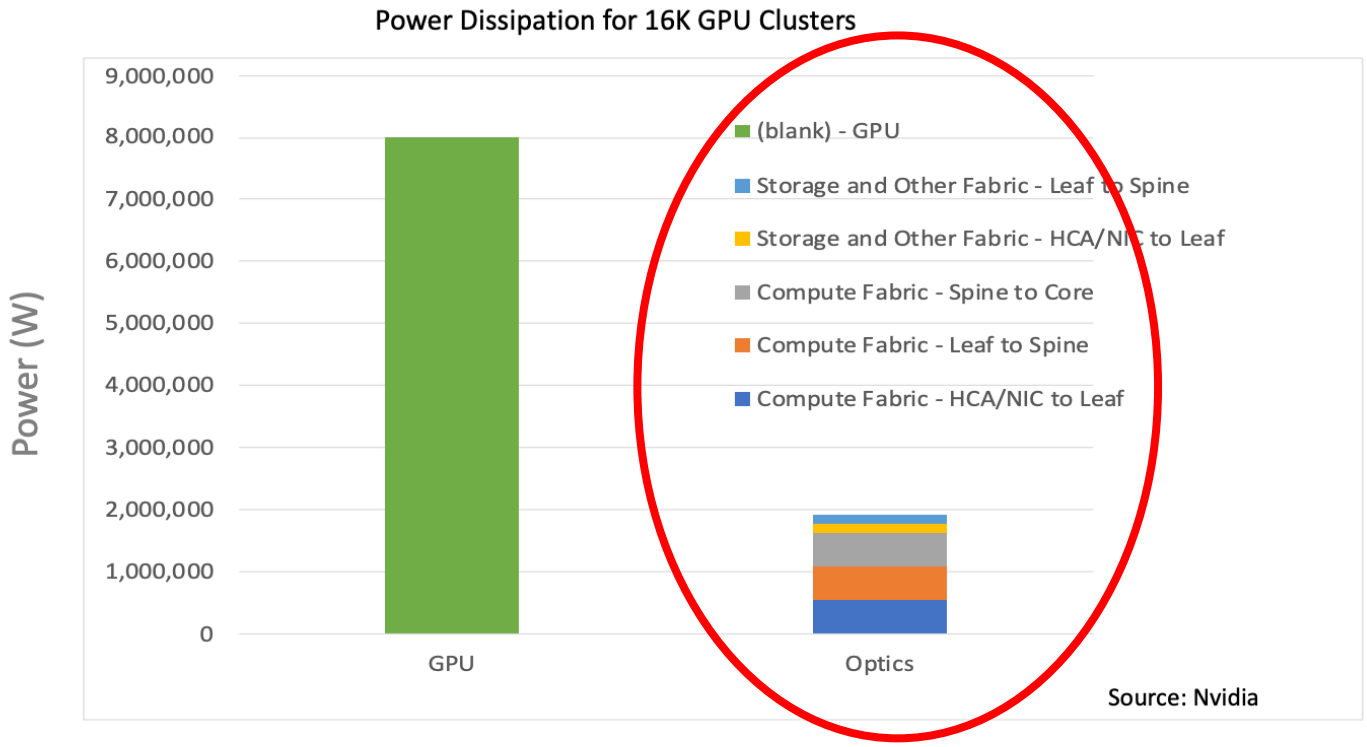


800G is expected to be a huge market in datacom and telecom

Source: Publication: Coherent (2023)

Optics is No Longer A “Minor” Contributor to Datacenter G-AI Power Issues



Large language models requires large GPU clusters (ChatGPT 4 training requires ~25,000 GPUs)

For 16,000 GPU clusters, optics consume ~2MW (equivalent to 4000 GPUs) – source: Nvidia, CIOE, Song, 2023)

Power dissipation for AI cluster optics showing optical network power dissipation share increasing…

Source: Silicon Photonics Solutions for AI/Data Center Applications Rang-Chen Yu, Dong Pan SiFotonics Technologies, ECOC 2023


What we do...

Perkinamine® Electro-Optic polymers

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Our polymers are world-class and proven by third parties

Electro-optic polymers can be used to fabricate optical modulators which enable:

- High material-level thermal and photostability
- Long-term storage and operational durability
- >3x faster modulation than existing products
- ~10x lower power than existing products

EO polymers → Fast, stable, reliable, low power consumption, and very small in size

Source: Lightwave Logic (LWLG)

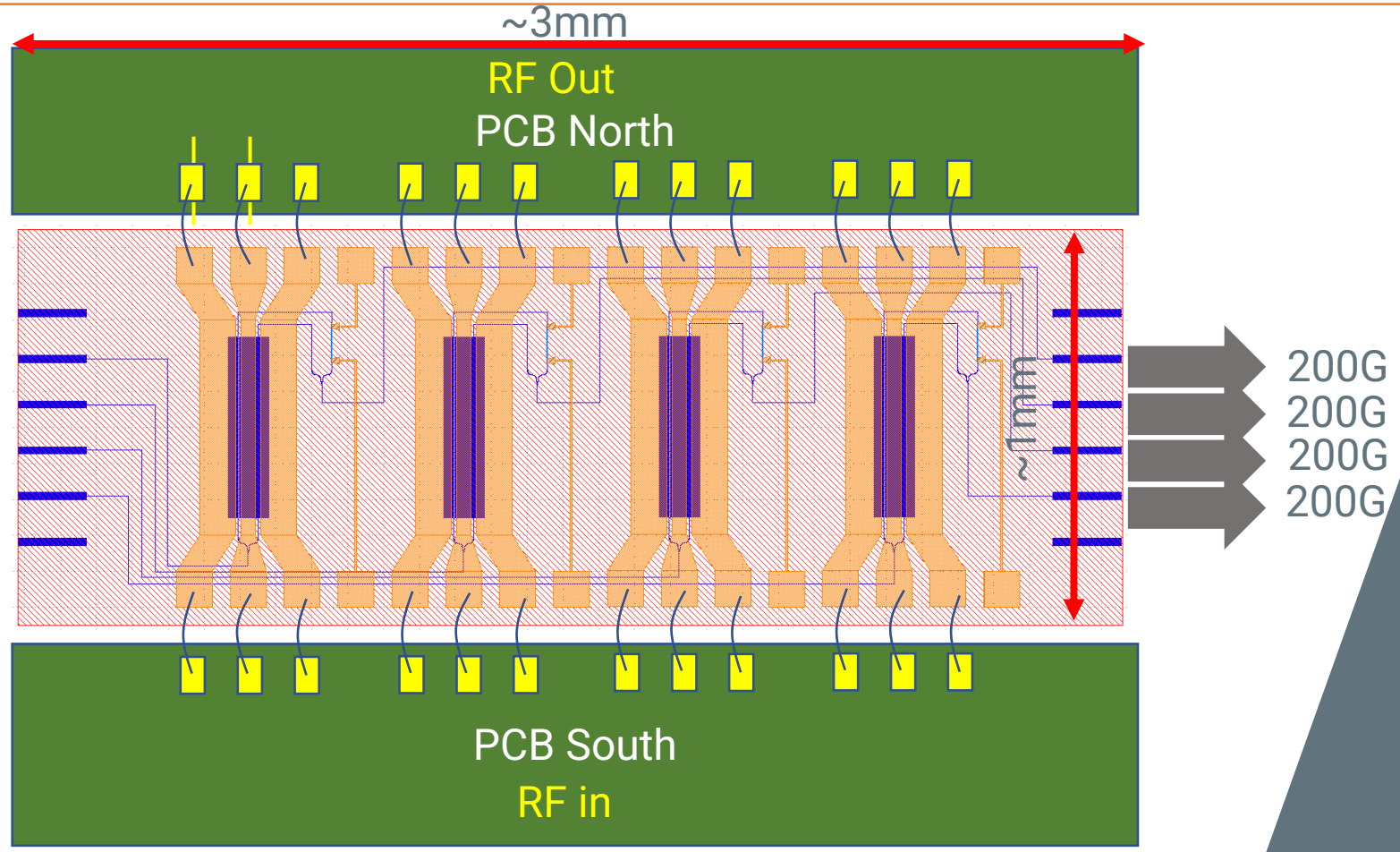
3rd Party Use of Perkinamine®

- **EO polymer** used in different device designs
- Silicon slot, plasmonic slot, plasmonic ring resonator
- All produced **world class** results*
- Presentations at industry conferences globally

Sources*: Nature Photonics: Resonant plasmonic micro-racetrack modulators with high bandwidth and high temperature tolerance (ETH Zurich, Polariton and LWLG EO polymer material)

Sources*: KIT, SilOriX, EU Horizon 2020, ETH Zurich, Polariton, CAU University Kiel (post deadline paper published at ECOC2022 using LWLG EO polymers)

800G integrated polymer modulators



- Optical 4 channel Polymer PIC layout with Mach Zehnder Interferometers (MZI) arrays
- Fiber array to be connected on both East and West side using Edge couplers
- Electrical CPW transmission length ~1mm

*Using EO S21 3dB bandwidths in excess of 150GHz, with the potential for >250GHz

Source: Lightwave Logic (LWLG)

In development → 4 channel polymer PIC chip as part of our P²IC platform

Potential for 300G and even 400G per lane*


Reliability and stability...

Optimized for reliability & stability

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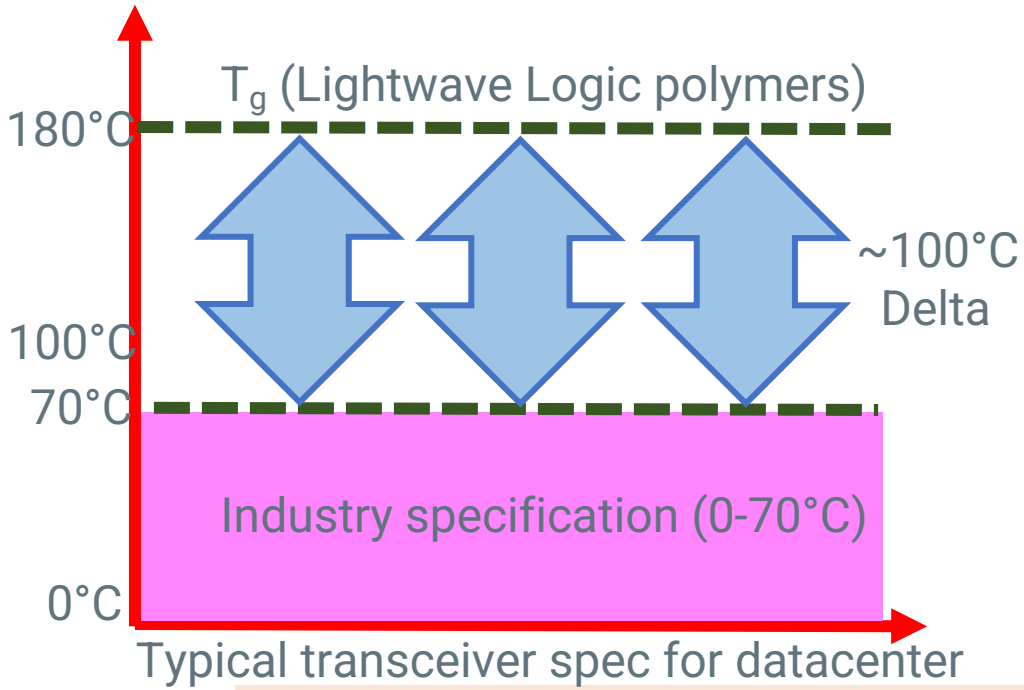
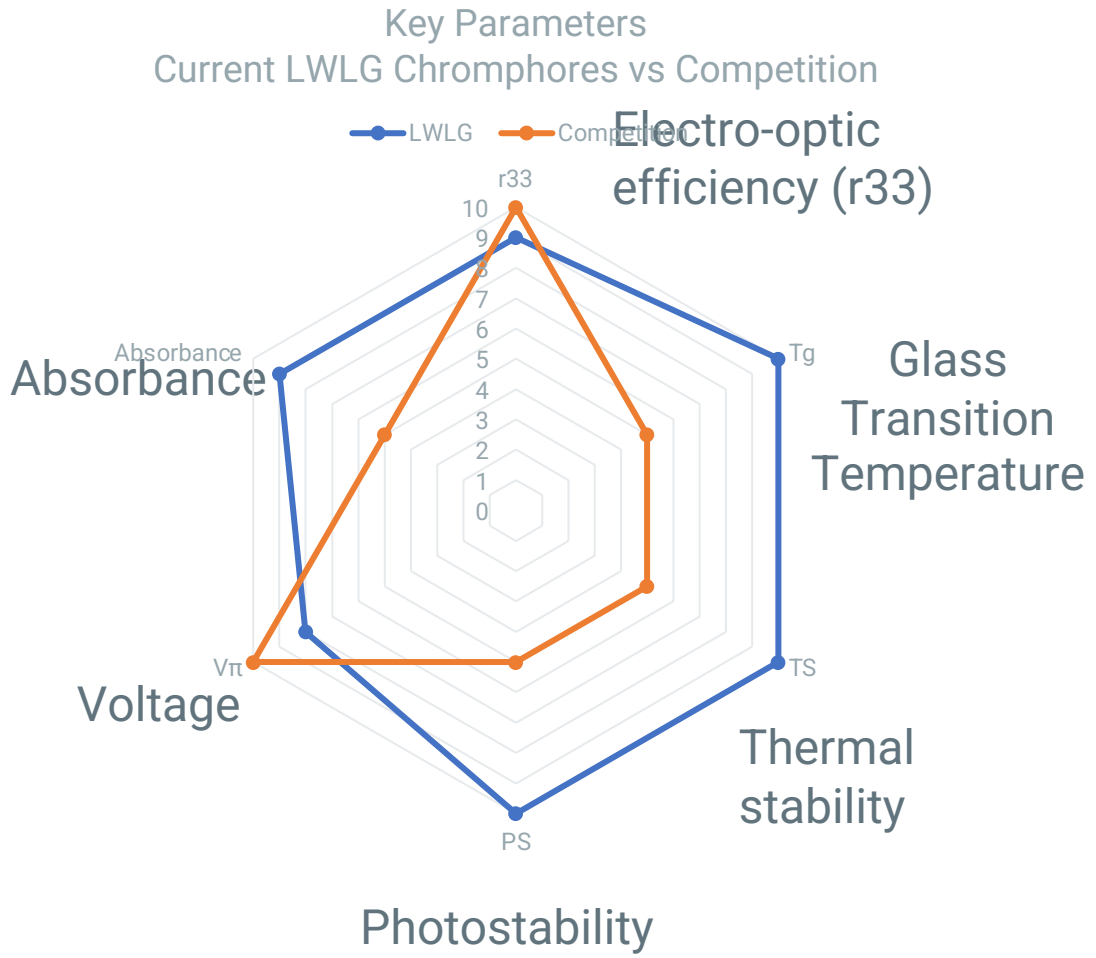
- **World class chromophore design**
  - Very high glass transition temperature (T_g)
  - ~100°C delta between industry spec and T_g
  - Eliminates need for cross-linking
  - Protects material from de-poling (occurs when T_g is close to industry specification high limit)



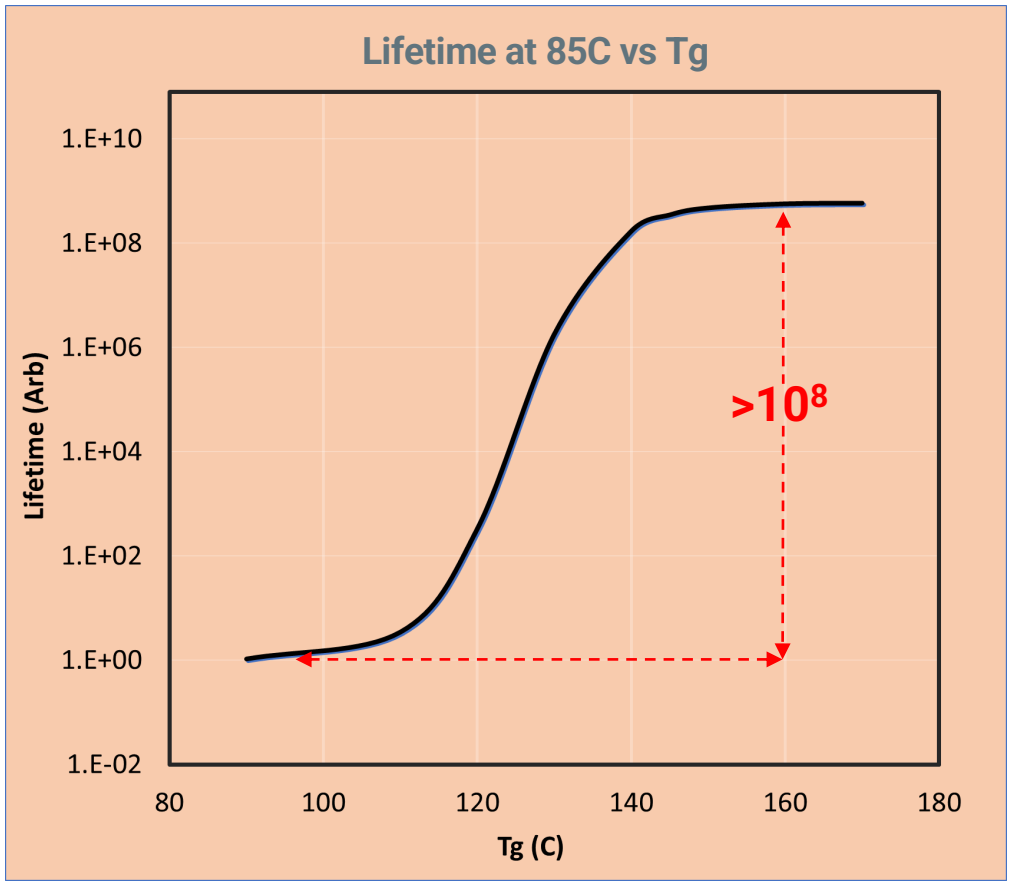


Electro-optic material designed for reliability, stability, and overall operational performance

NB: These are *qualitative* analyses only: i.e. on a scale of 1-10, how "good" is the material in terms of the particular parameter.

*Source: Lightwave Logic (LWLG), *best estimates of public data*

How important is glass transition temperature (T_g)?



The thermal lifetime of an EO-polymer material at 85C will increase with increasing Tg

The lifetime at 85°C for a polymer with **T_g =160°C is >10^8 times greater than** the lifetime for a polymer with **T_g= 90°C**

Increasing Tg → means much higher lifetime in electro-optic materials

Using the widely quoted Lindsay's time constant formula which is found in ***Polymer 48 (2007) 6605-6616***

$$\ln(\tau/\tau_P) = E_R\left(1+\tanh\left[(T_c-T)/D\right]\right)/2RT + E_p/RT$$

Source: Lightwave Logic (LWLG), Lindsay et al (2007)

How have EO polymers improved over the last 6 years?

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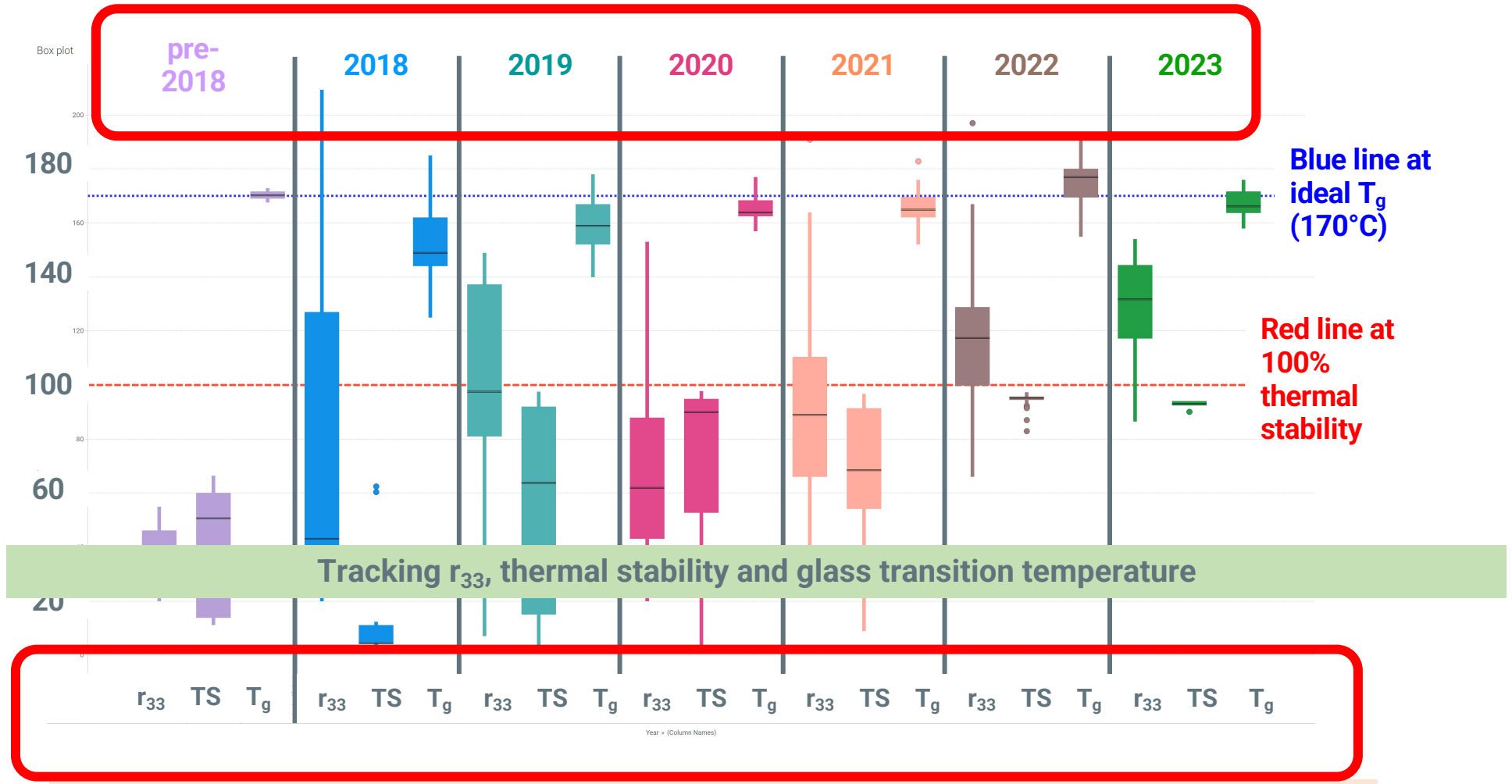
Box plot of Perkinamine®



Tracking r_{33}, thermal stability and glass transition temperature

Tracking r_{33}, thermal stability and glass transition temperature

A box plot or boxplot is a method for graphically demonstrating the locality, spread and skewness groups of numerical data through their quartiles

*Source: Lightwave Logic (LWLG), *best estimates;*

Tracking r_{33} improvements

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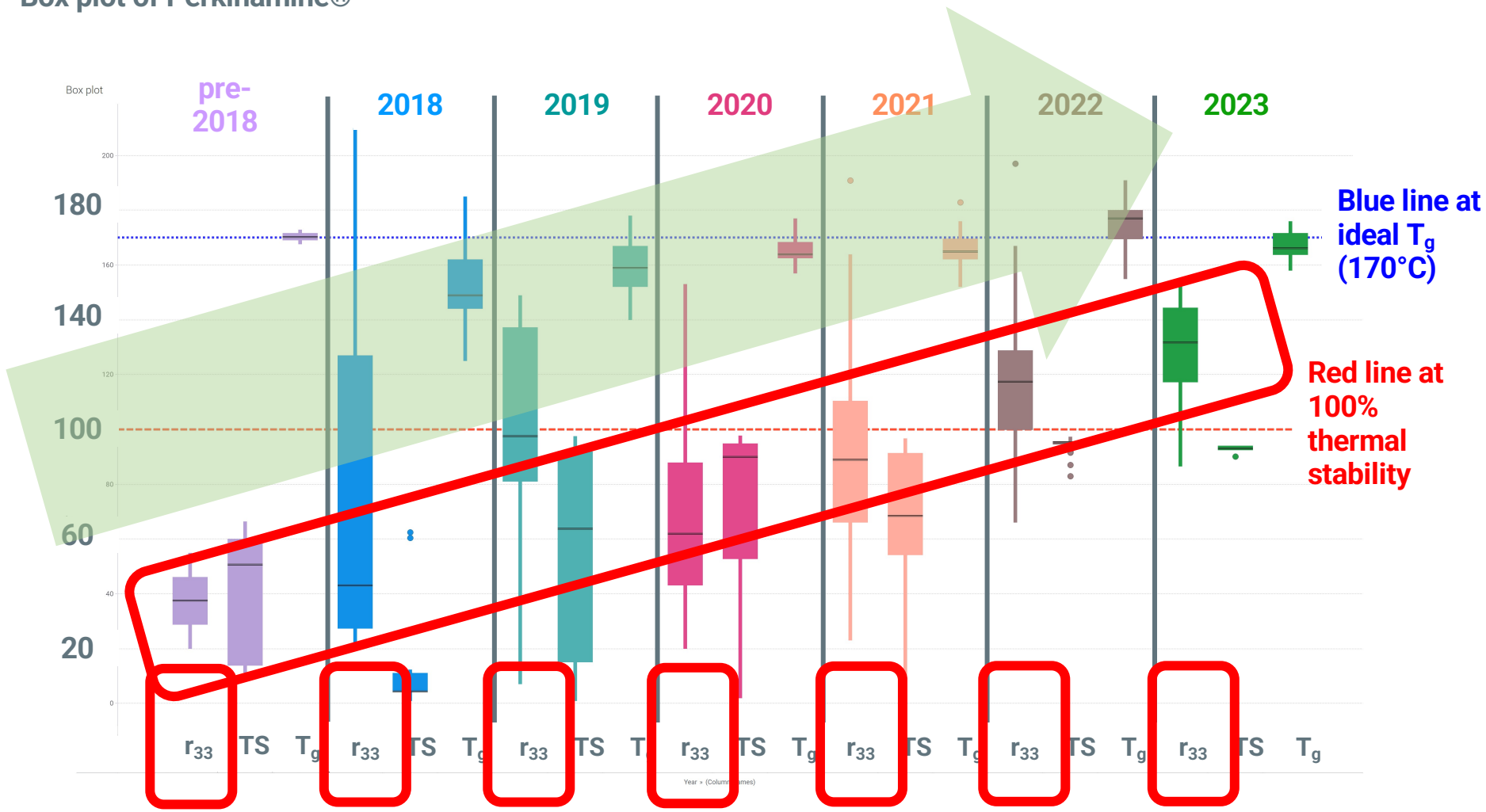
Box plot of Perkinamine®



r_{33} improved 5X over past 6 years; and now very stable in testing

*Source: Lightwave Logic (LWLG), *best estimates*

Tracking TS (Thermal Stability) improvements

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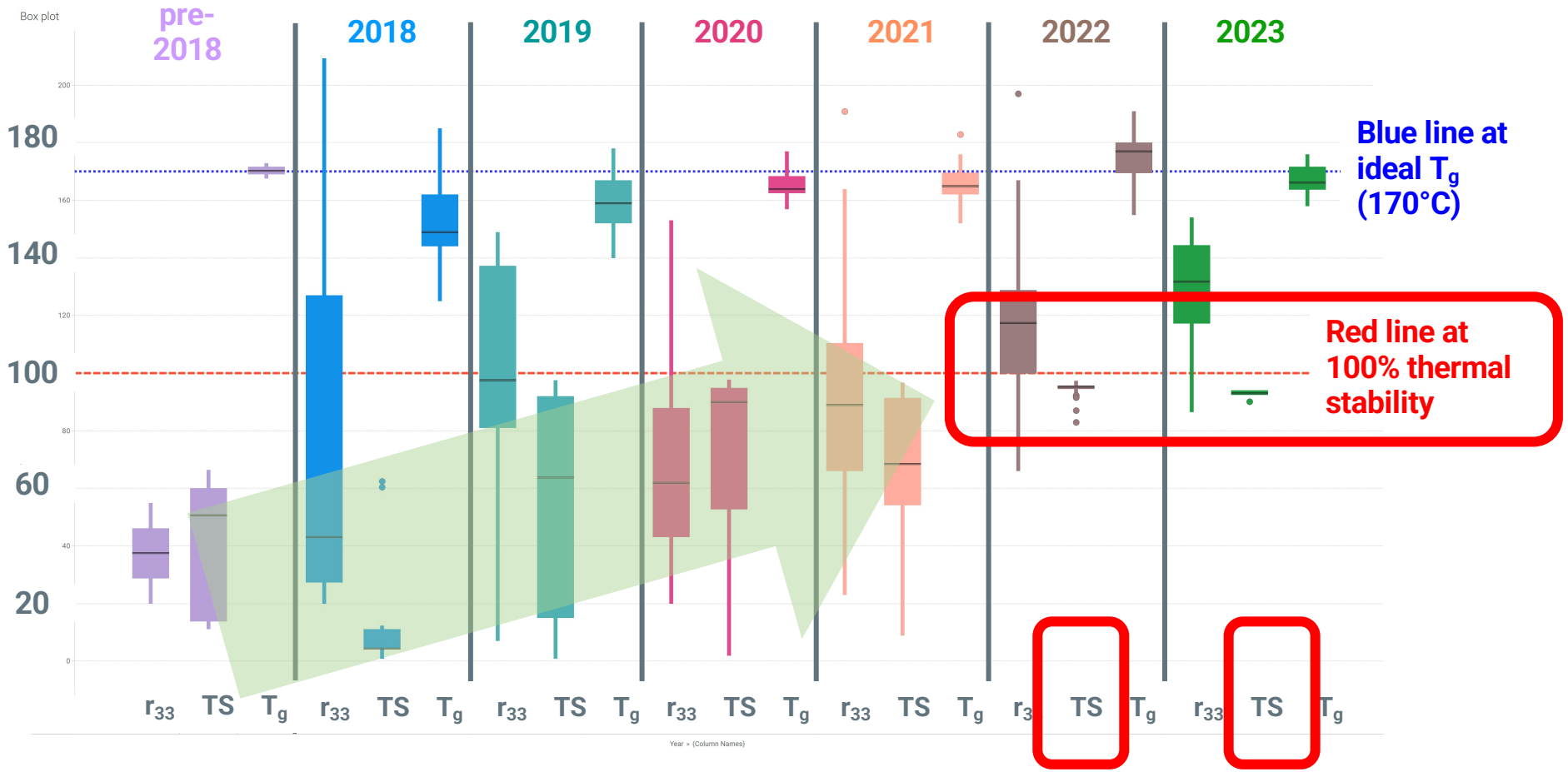
Box plot of Perkinamine®



Super performance of material thermal stability in last 2 years (approaching 100%)

*Source: Lightwave Logic (LWLG), *best estimates*

Tracking glass transition temperature (T_g)

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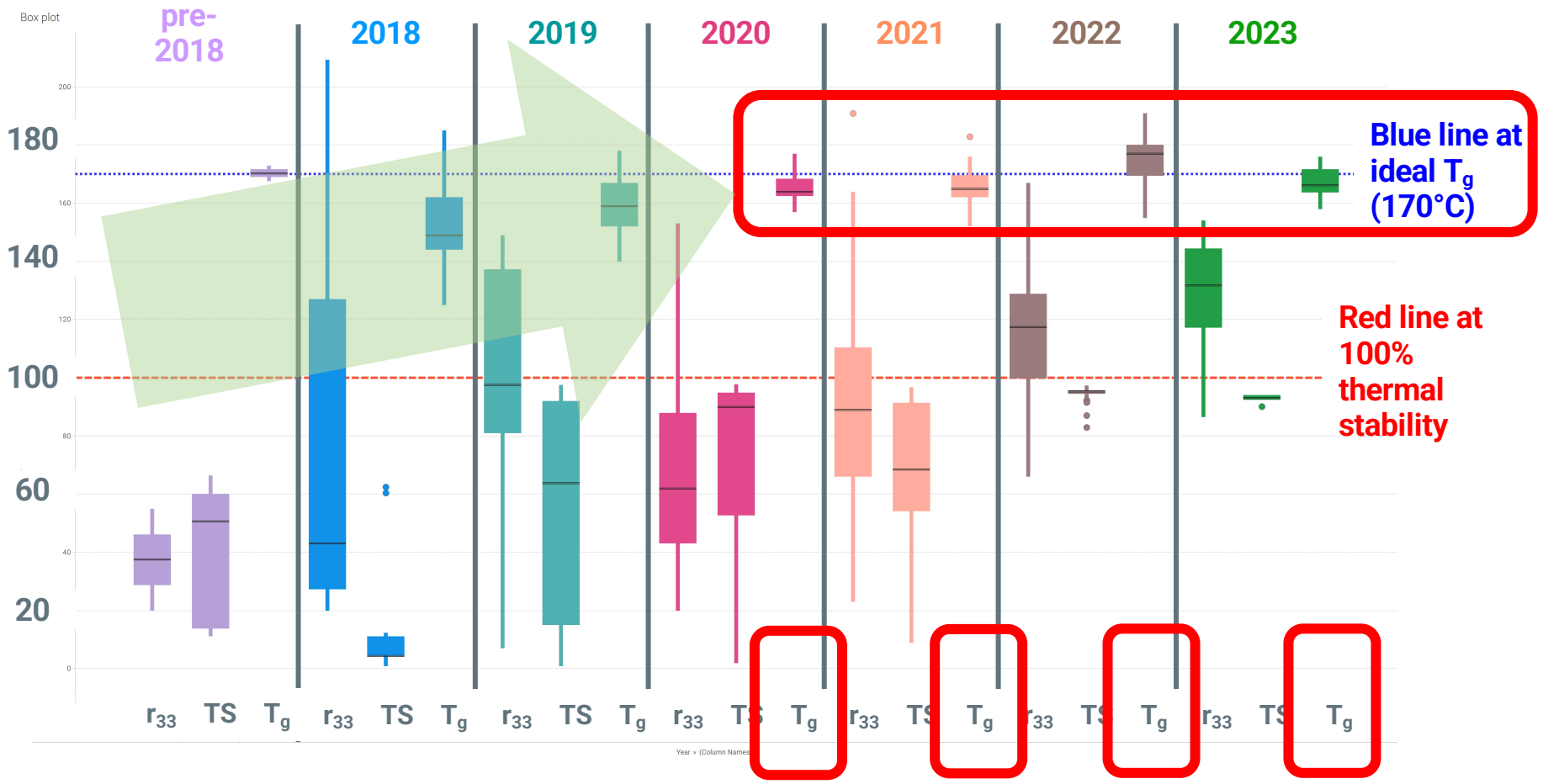
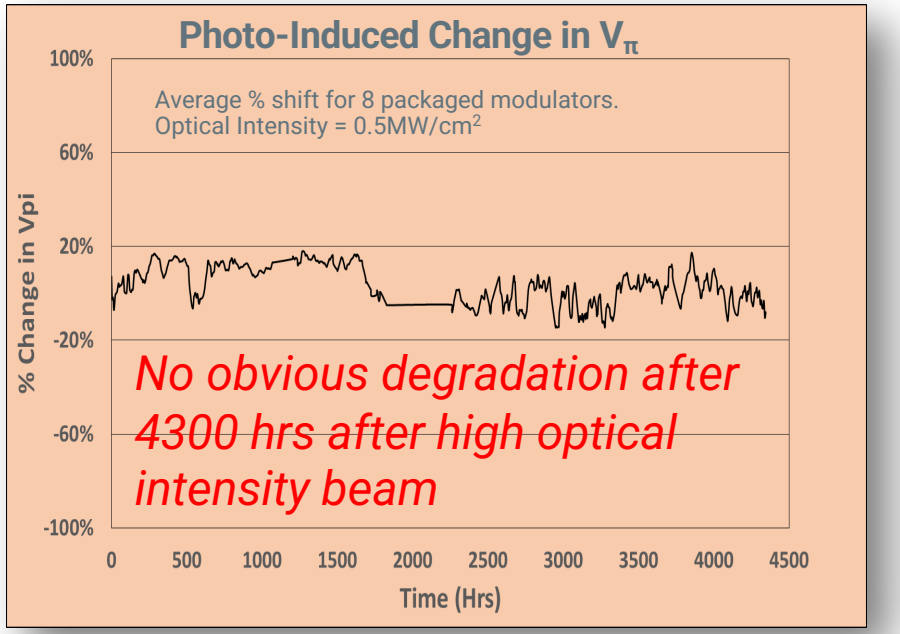
Box plot of Perkinamine®

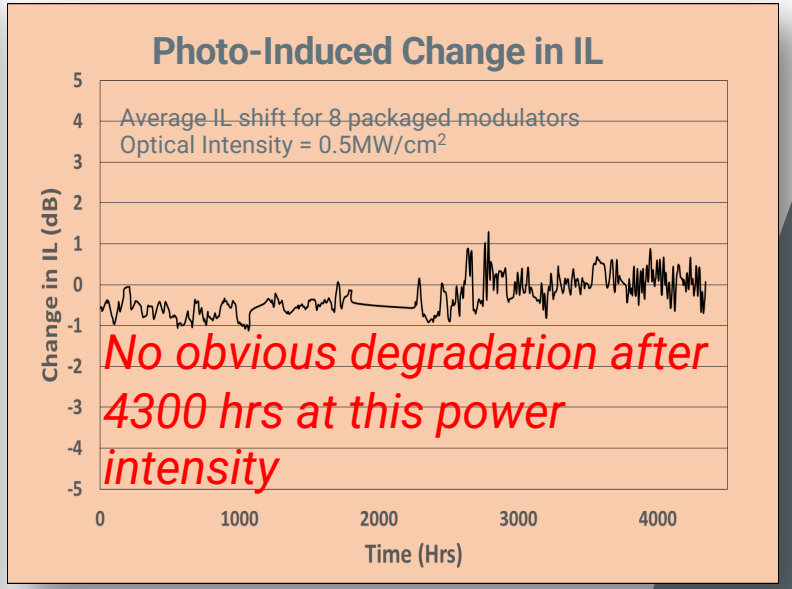


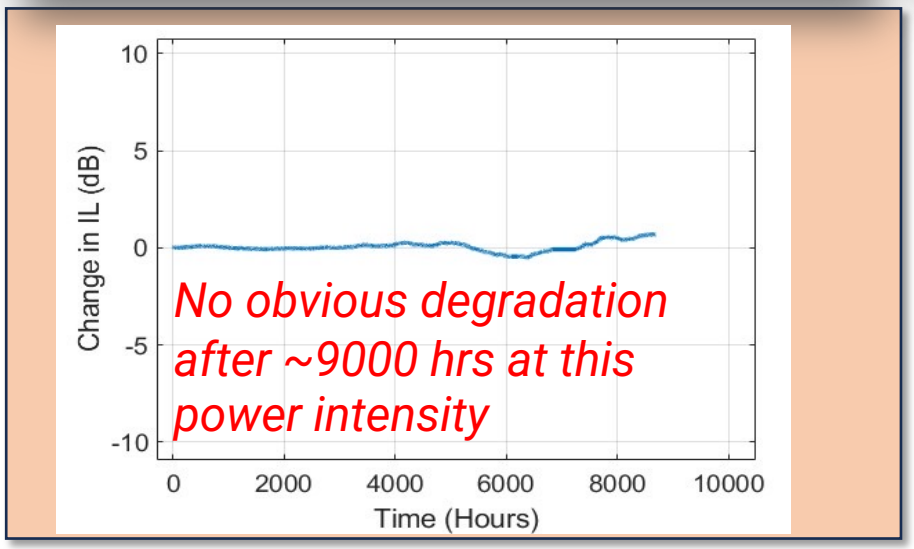
Tight control of materials with extremely high T_g at 170C

*Source: Lightwave Logic (LWLG), *best estimates*

Photostability vs Voltage and Insertion Loss



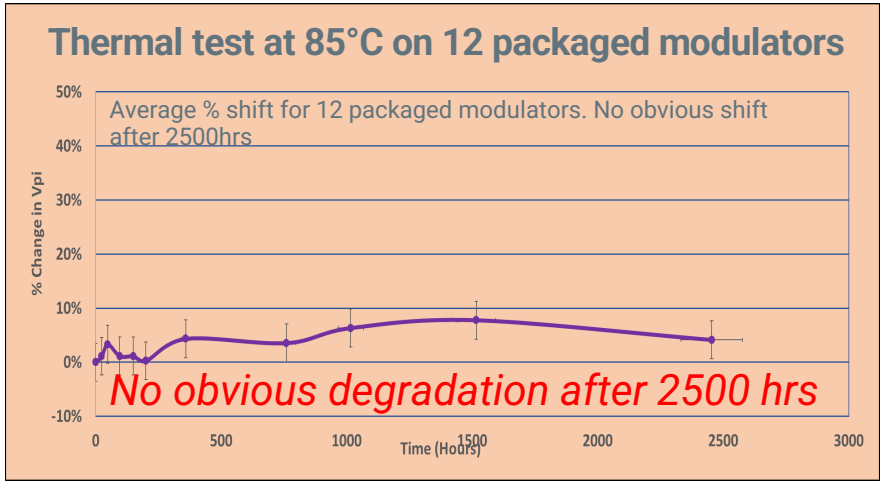




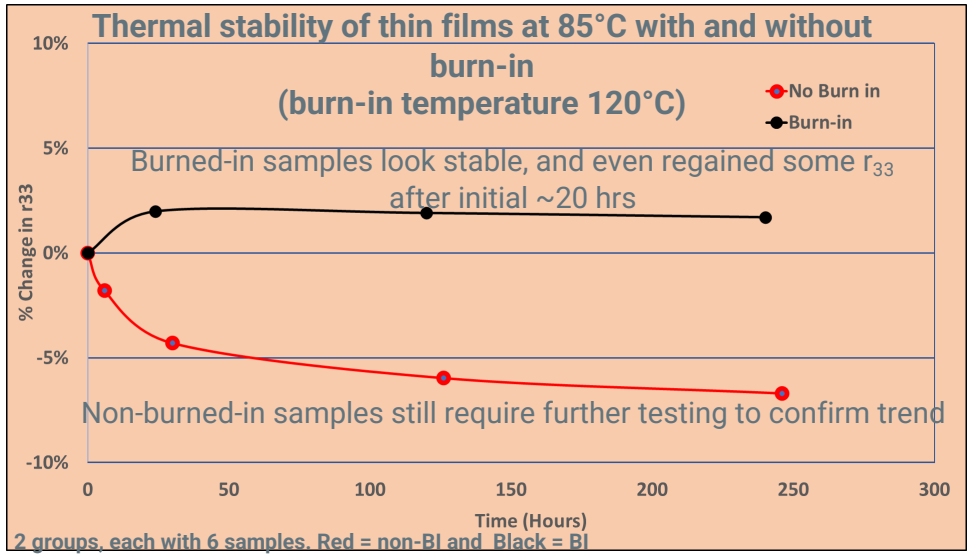
Source: Lightwave Logic (LWLG)

Long and short-term photostability does not seem to be an issue with LWLG electro-optic chromophores

Device Thermal Stability (TS) against change in voltage



The 12 parts continue to show fluctiations and variations in the V_{π} readings, but there is no obvious trend.



Source: Lightwave Logic (LWLG)

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Thermal stability does not seem to be an issue with LWLG packaged modulators or burn-in against change in r_{33}


Trying electro-optic polymers…

Implementing a new technology platform…

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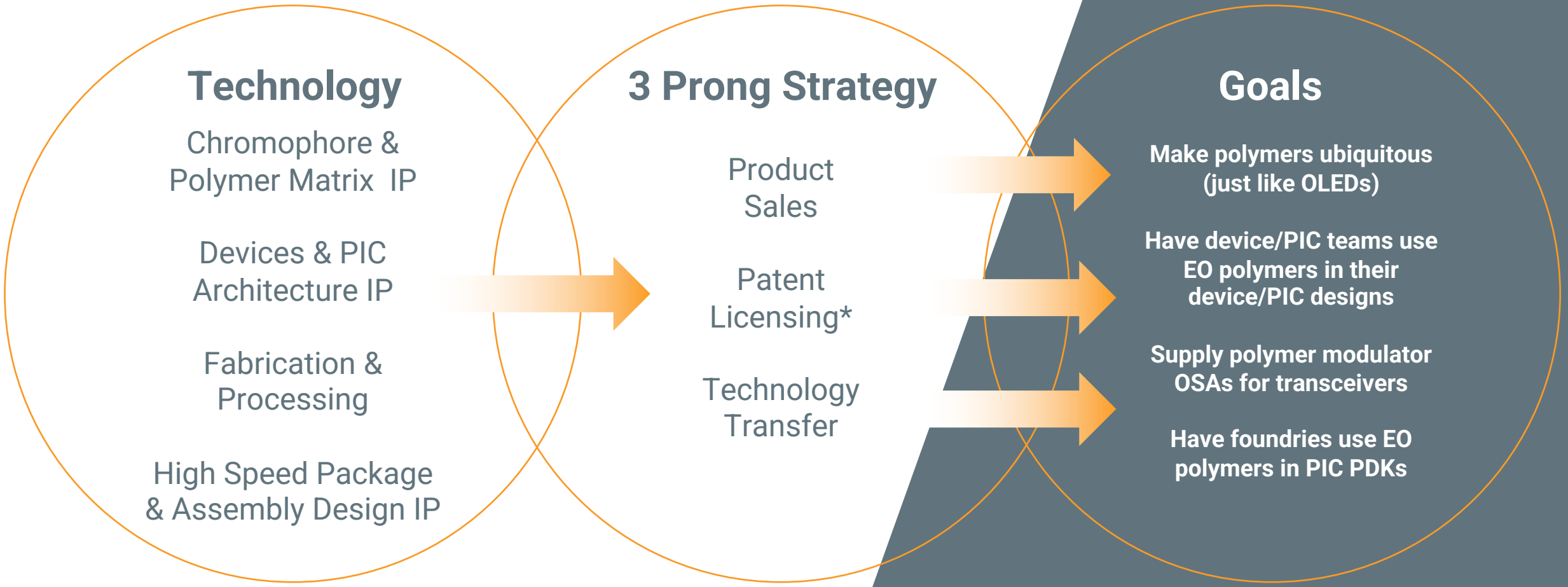
Licensing model provides inherent scalability



***1st commercial material supply license agreement 2Q23 → market acceptance**

Source: Lightwave Logic (LWLG)

Summary…

Takeaways

- Electro-optic polymers have *superior performance…*
- We continue to increase our *technical progress with reliability and stability…*
- We can scale polymer materials today, and are positioning to have *polymer modulators scale using foundries/OSATS…*
- We are developing prototypes for trial and reliability testing.

Source: Lightwave Logic (LWLG), OSAT – Outsourced semiconductor assembly and test

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Thank you for listening

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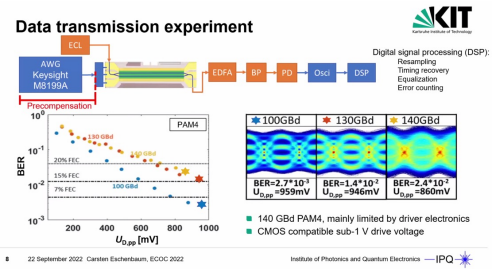
BACK-UP


3rd party verification...

3rd party use of Perkinamine®

- *EO polymer* used in different device designs
- Silicon slot, plasmonic slot, plasmonic ring resonator
- All produced *world class* results*
- Presentations at *industry* conferences



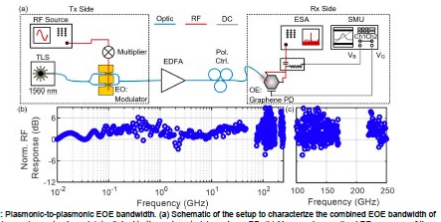
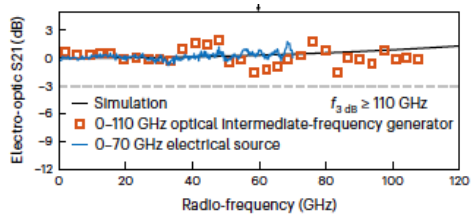
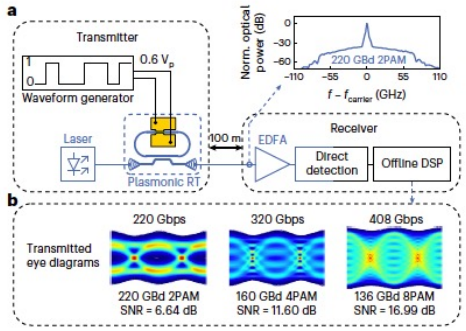


Fig. 3: Plasmonic-to-plasmonic EOE bandwidth. (a) Schematic of the setup to characterize the combined EOE bandwidth of the plasmonic racetrack modulator linked to the metamaterial graphene PD. (b) Measured normalized RF response of the system showing an EOE bandwidth of 250 GHz and (c) the response visualized from 100 to 250 GHz on a linear scale.



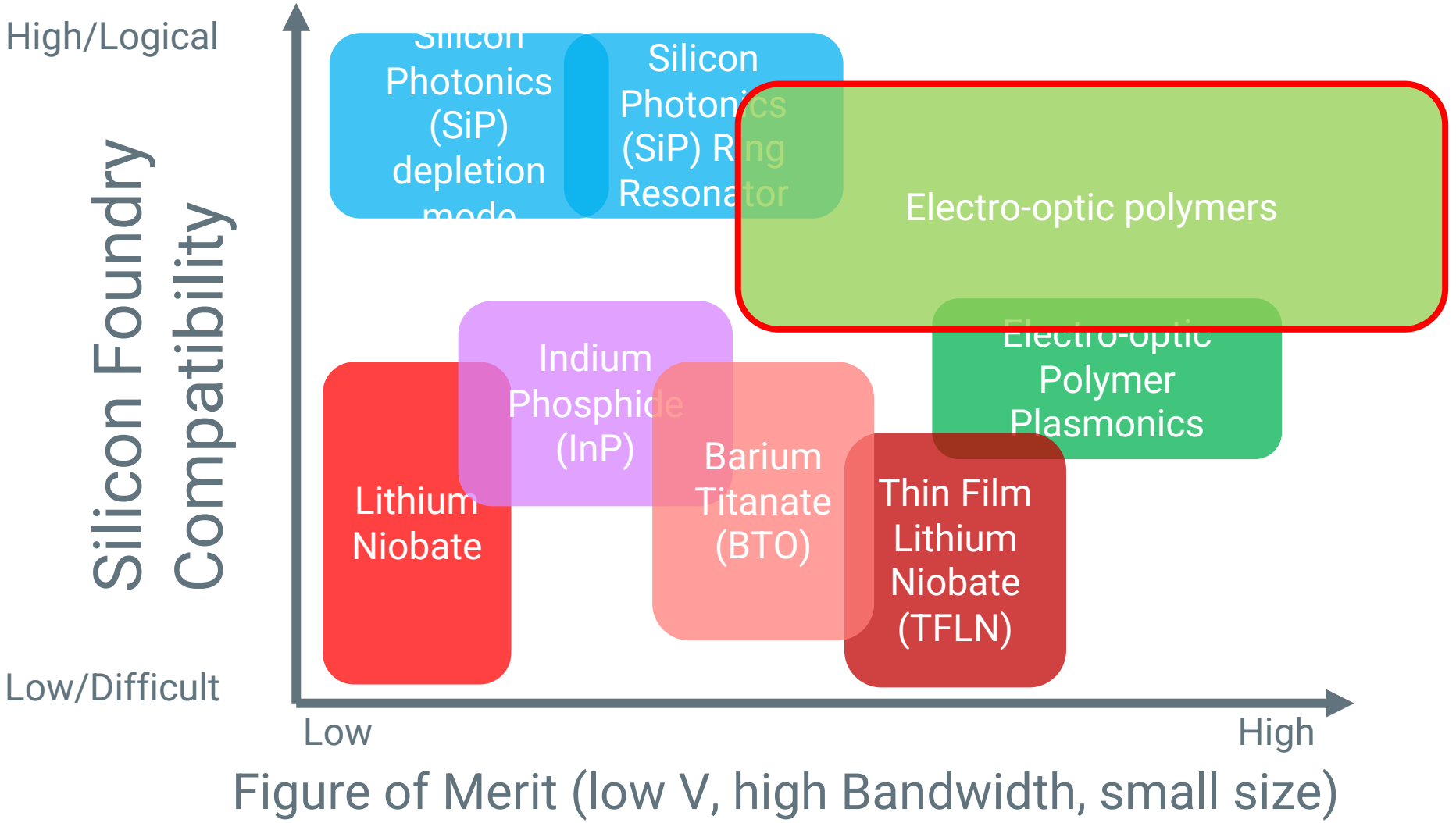


Sources: Nature Photonics: Resonant plasmonic micro-racetrack modulators with high bandwidth and high temperature tolerance (ETH Zurich, Polariton and LWLG EO polymer material)*

Sources: KIT, SilOriX, EU Horizon 2020, ETH Zurich, Polariton, CAU University Kiel (post deadline paper published at ECOC2022 using LWLG EO polymers)*


EO polymers are competitive with semiconductor modulators…

Competitive polymer positioning



Polymer modulators outperform competitive semiconductor technologies

Source: Lightwave Logic (LWLG) research showing target metrics for polymers

Polymer attributes are impressive…

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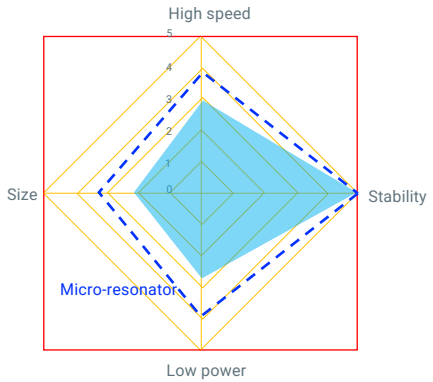
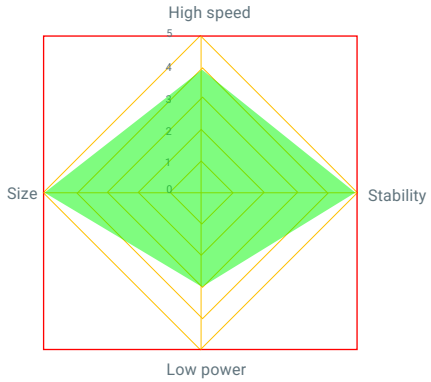
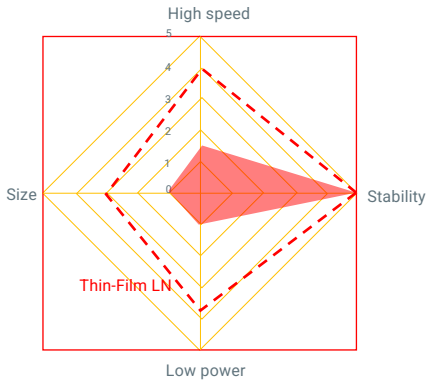
Silicon*



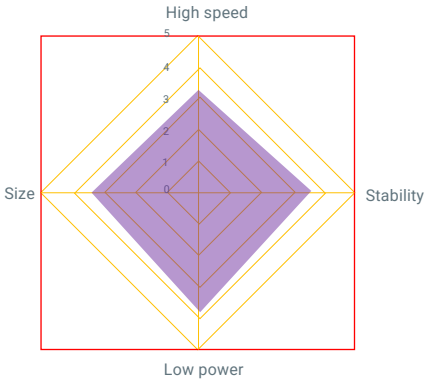
Indium Phosphide*



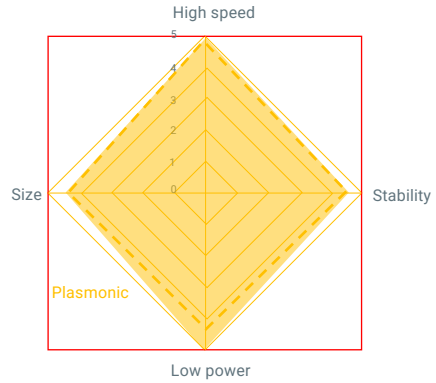
Lithium Niobate*



Barium Titanate*



Polymer Slot*



Technology spider chart → polymers have strong coverage → excellent performance

*Source: Lightwave Logic (LWLG), *best estimates*


END