High Frequency InGaN/GaN Micro LEDs for Optical Interconnect Applications

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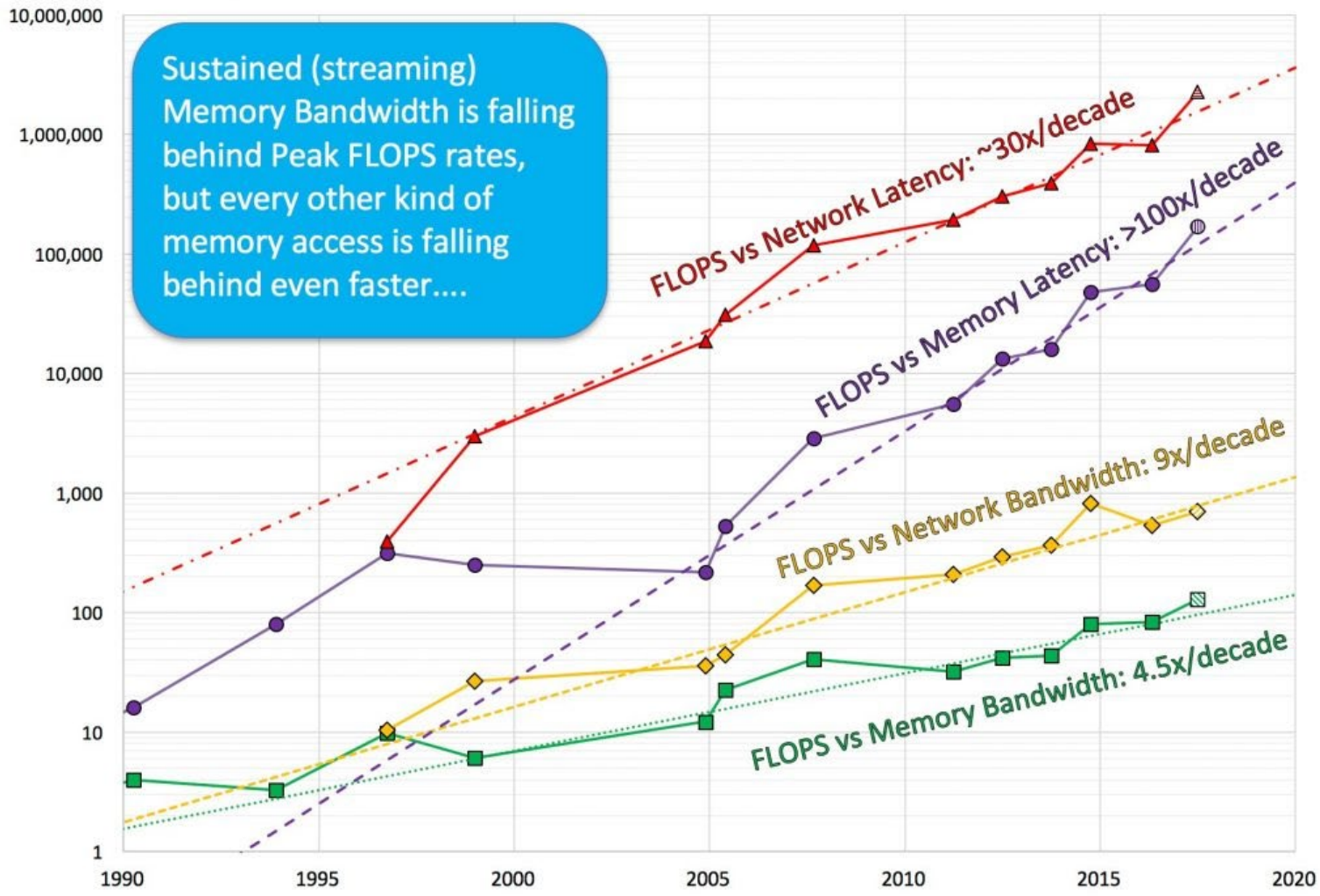
Motivation

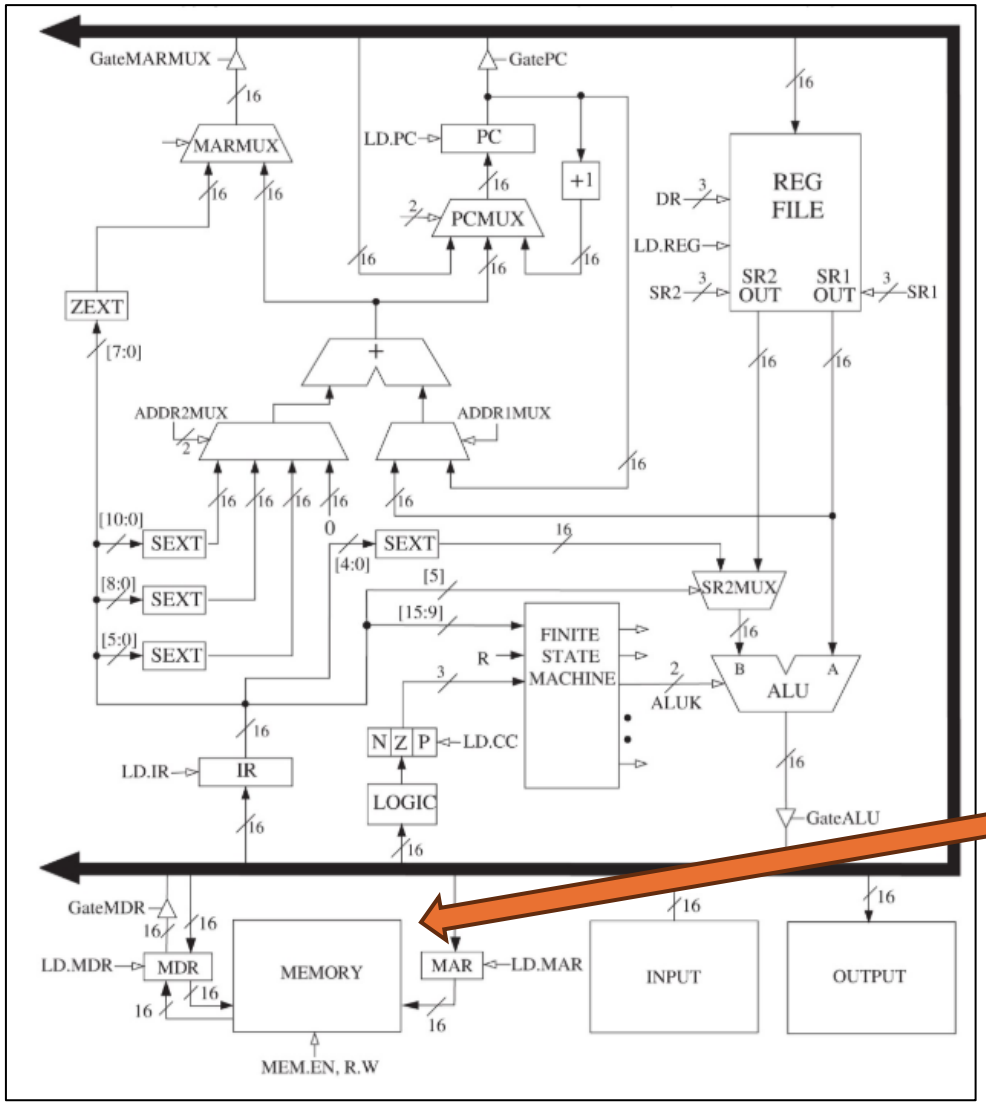
- **Memory and network speeds falling behind processing speeds**
- **Data transfers not keeping up**

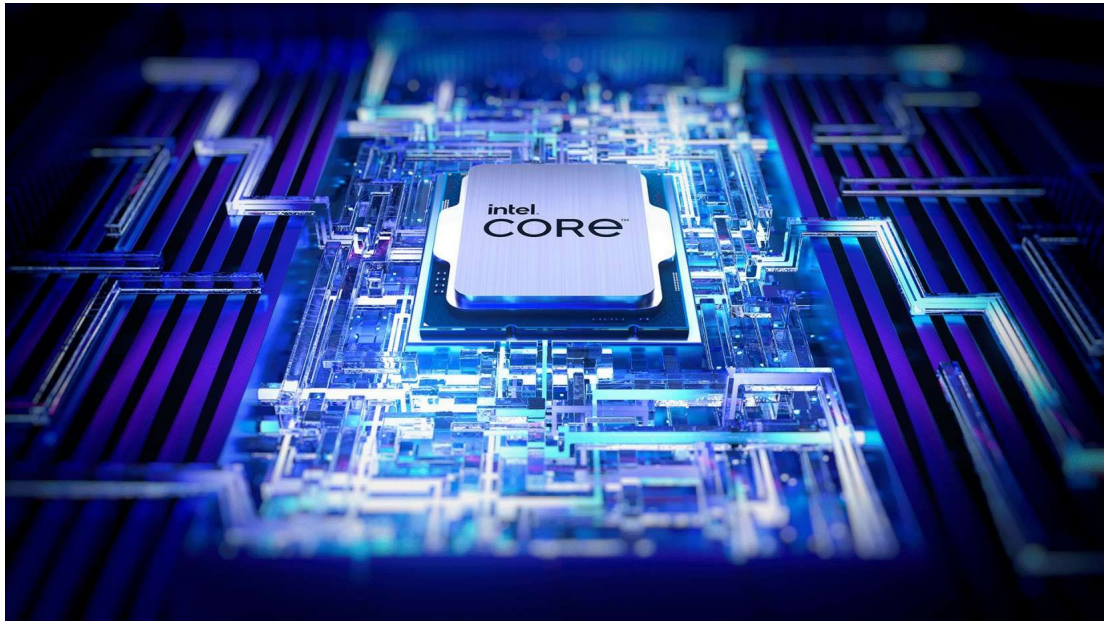


Flops versus data transfer speeds, John D. McCalpin 2016

https://sc16.supercomputing.org/2016/10/07/sc16-invited-talk-spotlight-dr-john-d-mccalpin-presents-memory-bandwidth-system-balance-hpc-systems/index.html

Motivation



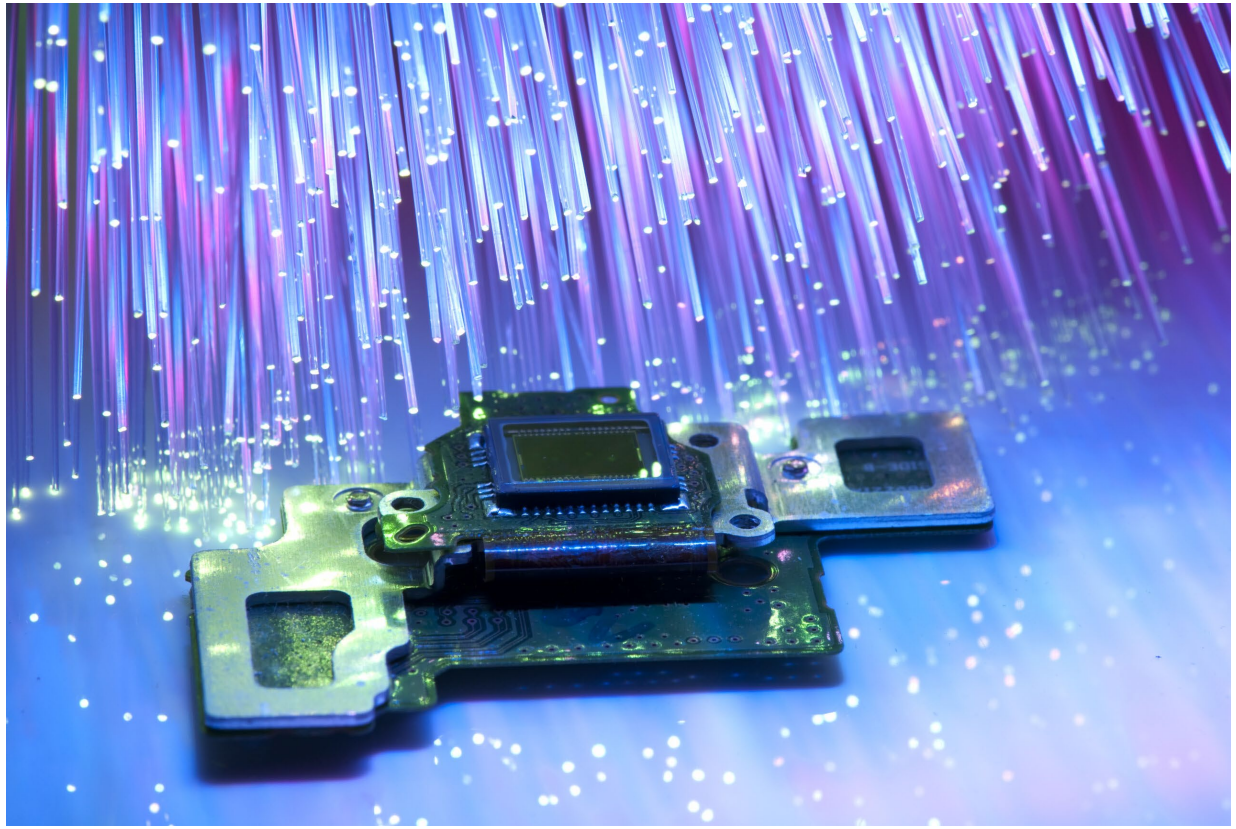


- **Processors lose efficiency waiting for data from memory**
- **Takes a lot of energy for chip-to-chip, board-to-board interconnects**

https://www.trustedreviews.com/explainer/what-is-a-cpu-2950255
https://lumetta.web.engr.illinois.edu/120-S19/slide-copies/131-lc-3-control-signals.pdf

Introduction and Background

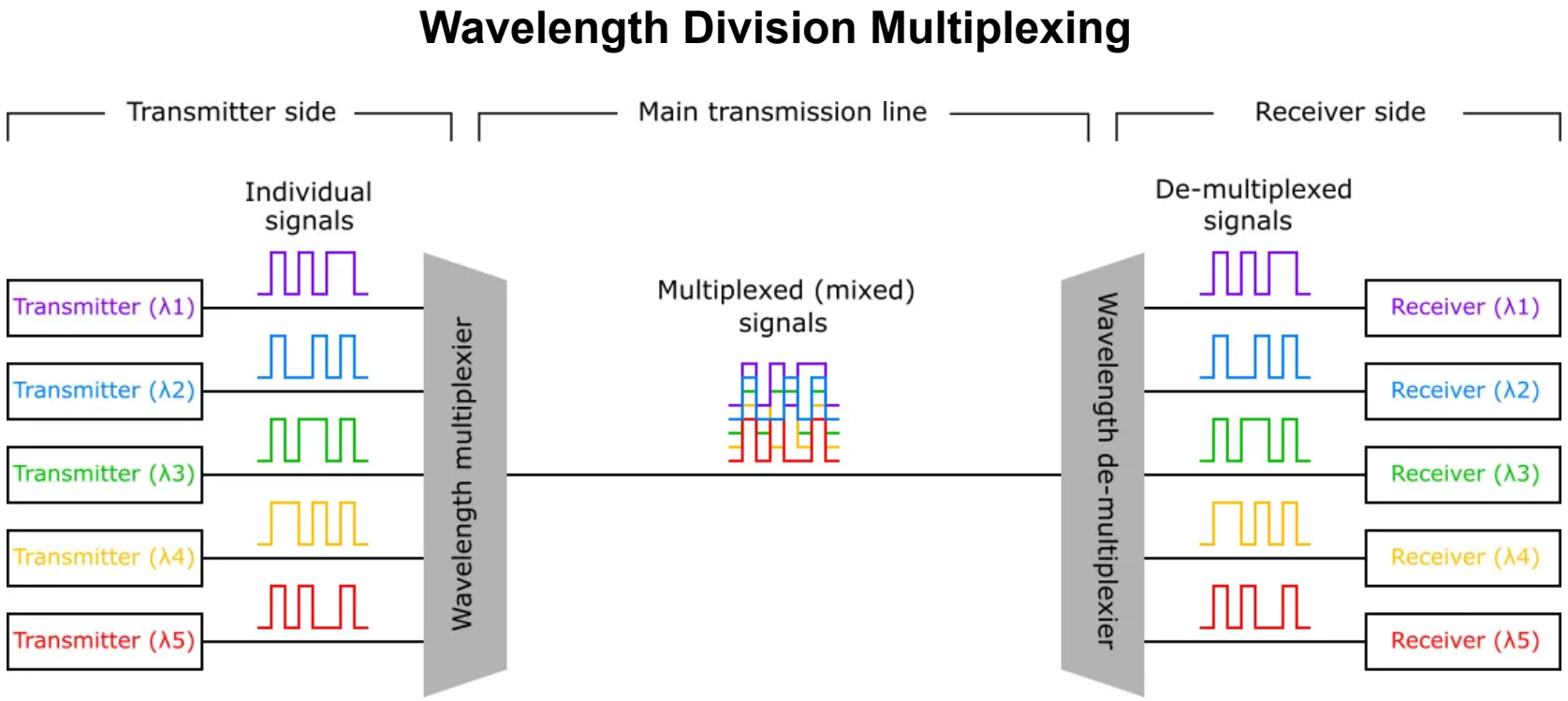
- **AI and computing have a large energy cost**
- **Increasing demand requires better data transfer methods**
- **Electrical interconnects are reaching theoretical limit**
- **Optical interconnects are potentially faster more robust**



https://www.nextplatform.com/2023/03/28/pushing-the-boundaries-of-web-scale-optical-dci-performance/

Introduction and Background

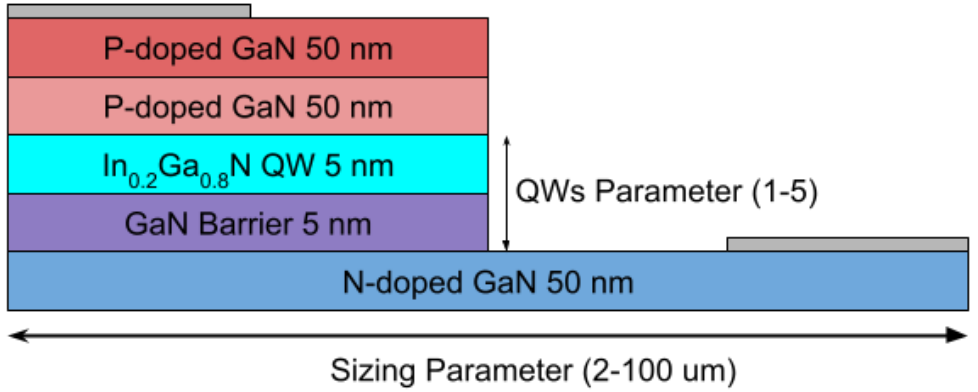
- **Properties of light allow for performance benefits**
  - **Separate wavelengths don't interfere, allows for WDM**
  - **Low attenuation over longer distances**

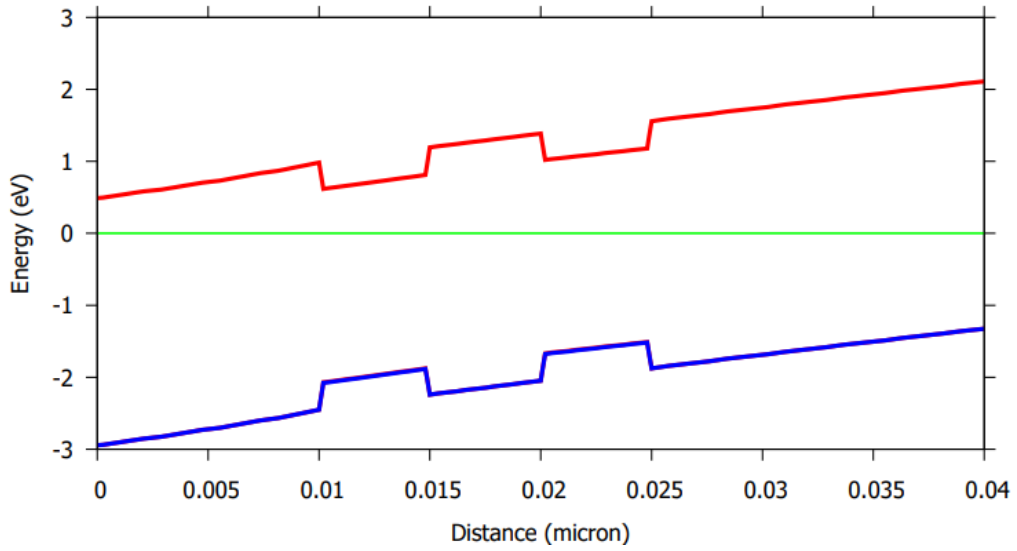


Fiberlands INC, Wavelength-Division Multiplexing (WDM), https://www.google.com/url?q=https://www.fiberlabs.com/glossary/wavelength-division-multiplexing/&sa=D&source=docs&ust=1713746267579693&usg=AOvVaw3xhhJqIp0XTh0RT1SzafhG

Micro LED Design

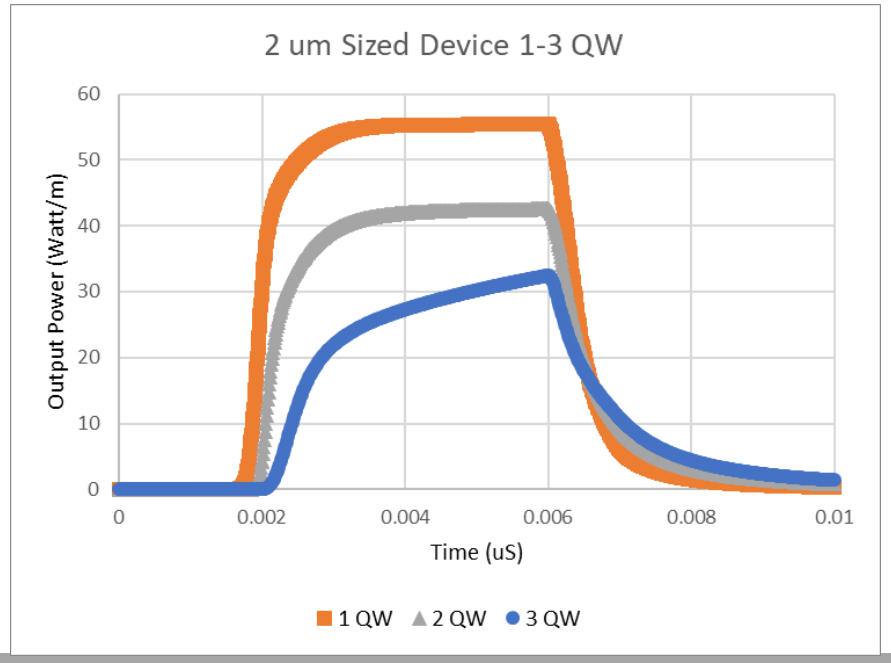
- **Target goal of 500 nm blue light**
- **InGaN/GaN quantum wells with doping**
- **Parameters:**
  - **Number of Quantum Wells**
  - **Sizing of device**
- **Important Metric:**
  - **Transient output power response time to input voltage pulse**

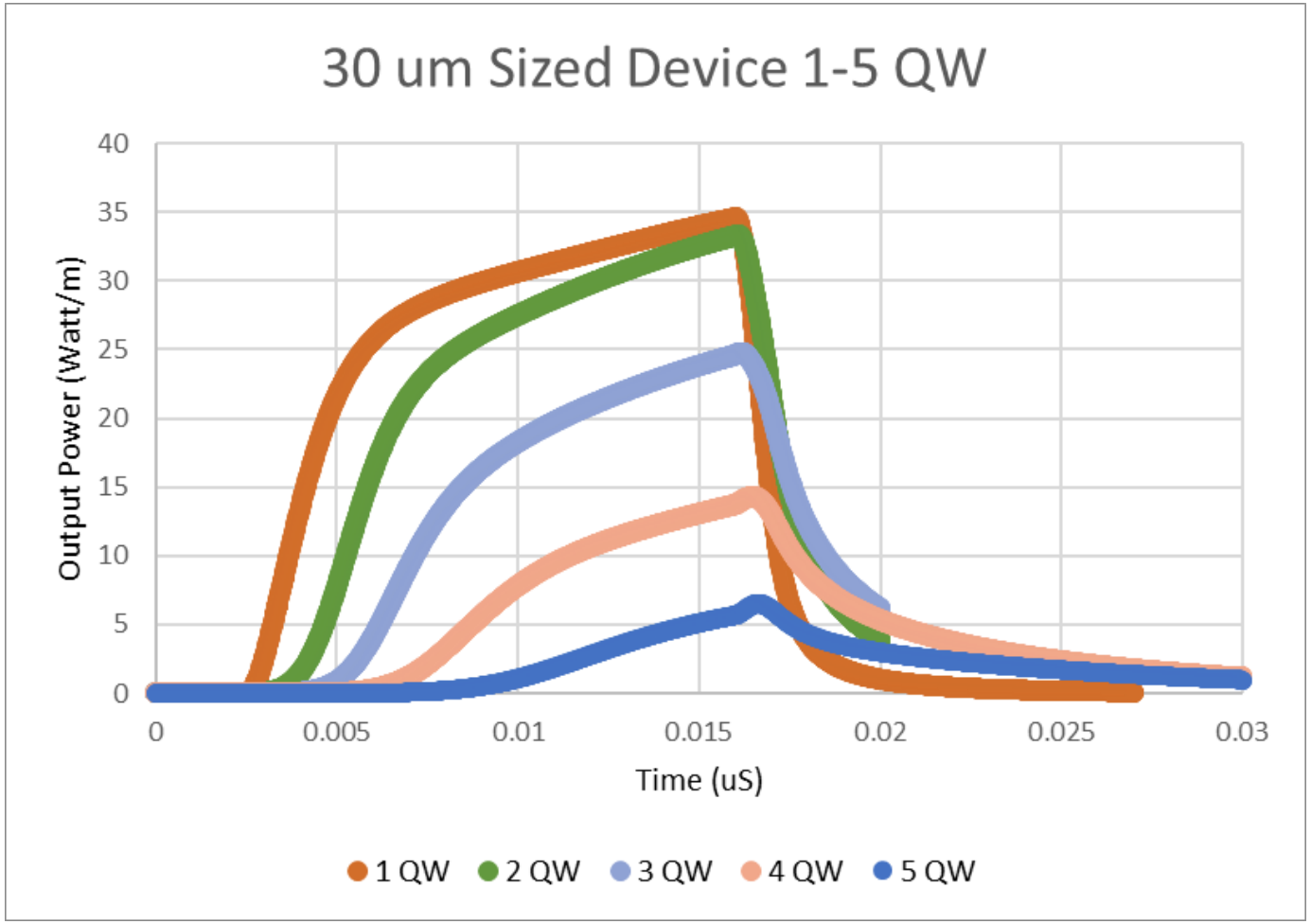




Simulation Results

- **Input voltage pulse on 30 um device with 1-5 QWs**
- **Input voltage pulse on 2 um device with 1-3 QWs**
- **Simulate transient output power**

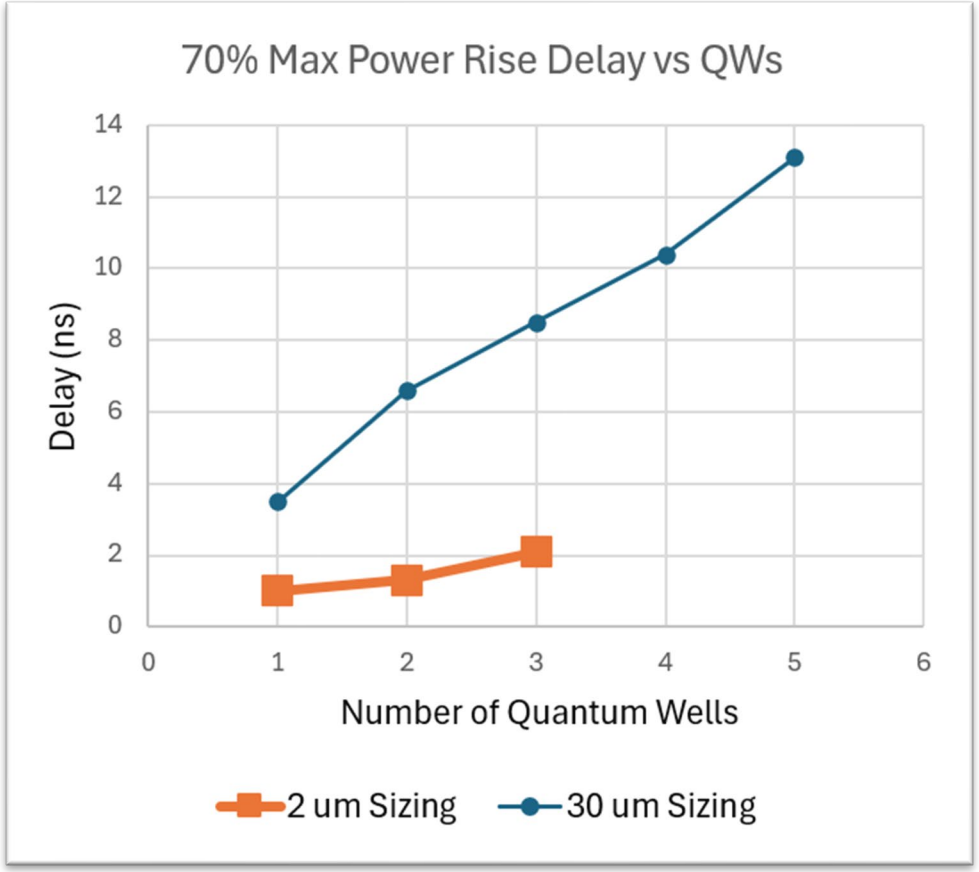




Simulation Results

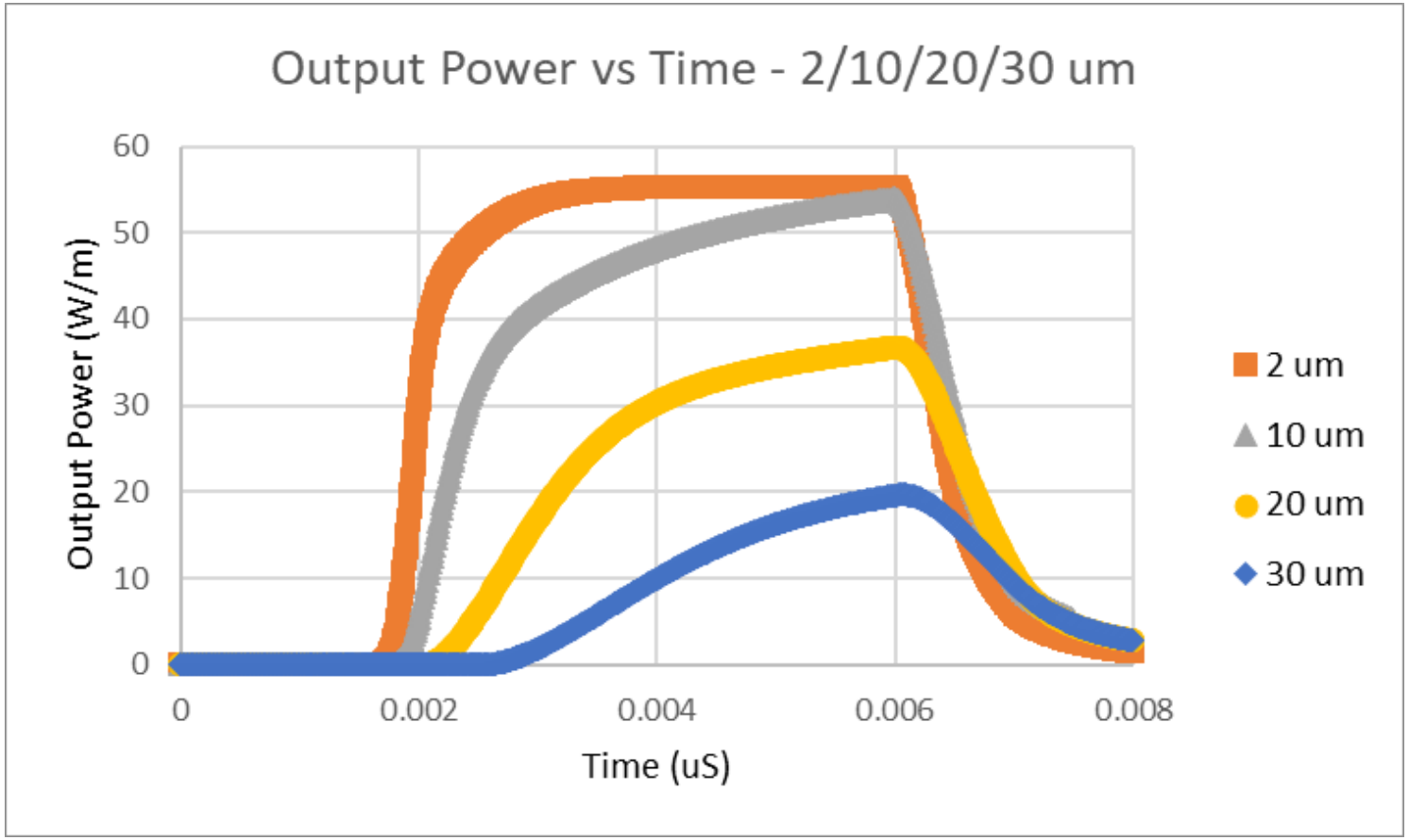
70% Rise Times	1 QW	2 QW	3 QW	4 QW	5 QW
2 um Size	1 ns	1.3 ns	2.1 ns	NA	NA
30 um Size	3.5 ns	6.6 ns	8.5 ns	10.4 ns	13.1 ns

- As the number of QWs increases, the rise time also increases
- Graphing rise time vs #QW reveals a linear relationship
- Decreasing QWs increases frequency performance
- Tradeoff of low IQE and more droop



Simulation Results

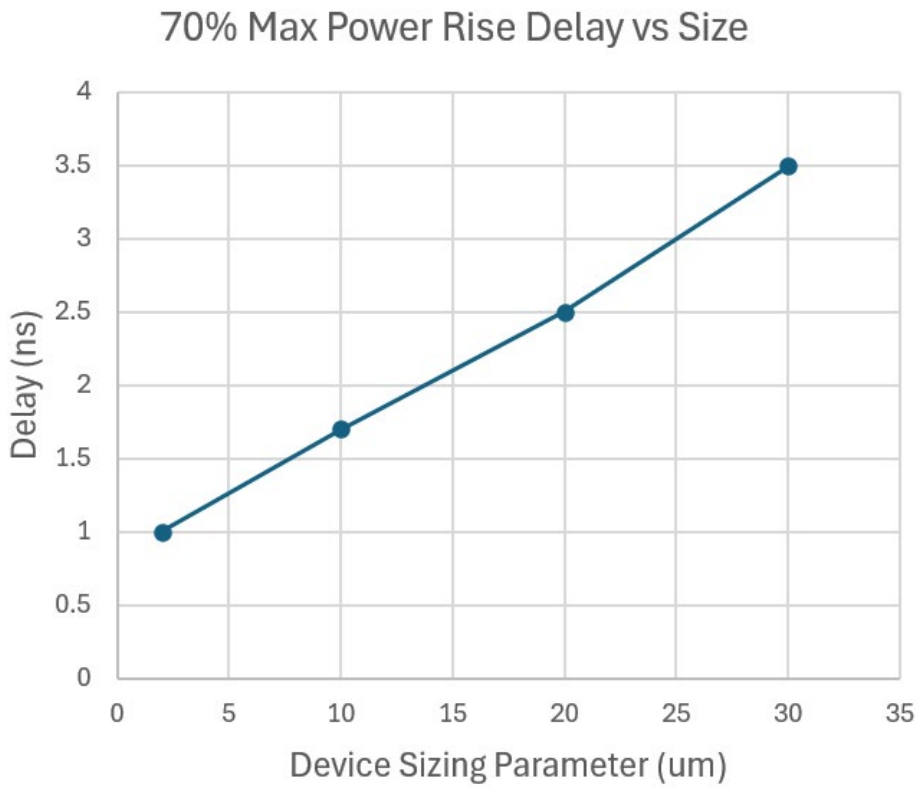
- **Input voltage pulse on 1 QW device**
- **Change sizing parameter from 2 um to 30 um**
- **Simulate transient output power**



Simulation Results

70% Rise Times	2 um Size	10 um Size	20 um Size	30 um Size
1 QW	1 ns	1.7 ns	2.5 ns	3.5 ns

- As the number device size increases, the rise time also increases
- Graphing rise time vs device sizing again reveals a linear relationship
- Decreasing device size increases frequency performance
- Tradeoff of low IQE from surface recombination effects



Conclusion

- **Decreasing the sizing of micro-LEDs and the number of quantum wells will increase frequency and switching ability**
- **There is a tradeoff with both approaches, leading to lower IQE and more droop inefficiency**
- **Micro-LEDs offer a new solution for data transfer if inefficiencies can be overcome, and operating frequencies can be increased**

Thank You!

Q & A

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