Silicon Photonics Photo-Detector Announcement

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Agenda

- Intel's Silicon Photonics Research
- 40G Modulator Recap
- **40G Photodetector Announcement**
- Vision of Future Terascale Platforms
- Summary

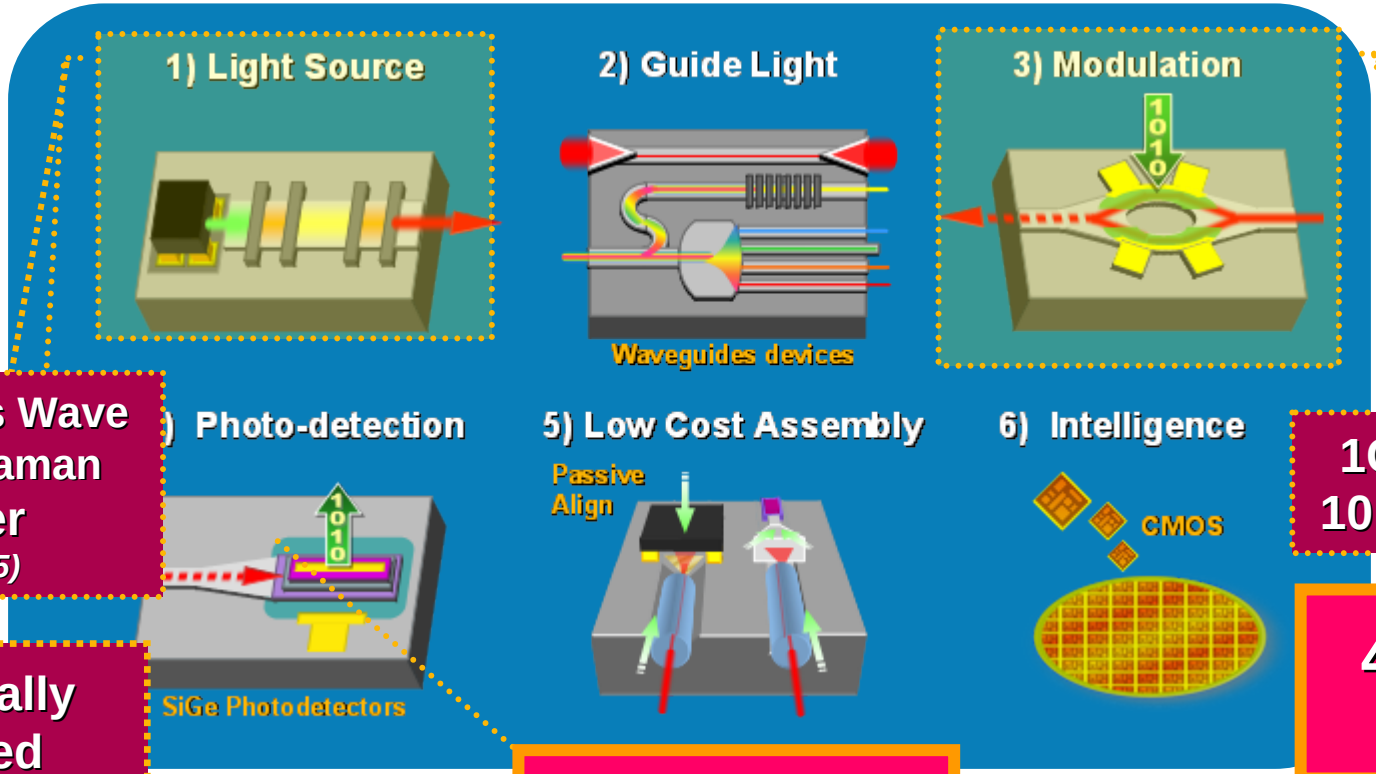
Photonics: ***The technology of emission, transmission, control and detection of light (photons) aka fiber-optics & opto-electronics***

Today: ***Most photonic devices made with exotic materials, expensive processing, complex packaging***

Silicon Photonics Vision: ***Research effort to develop photonic devices using silicon as base material and do this using standard, high volume silicon manufacturing techniques in existing fabs***

Benefit: Bring volume economics to optical communications

Intel's Silicon Photonics Research



Continuous Wave Silicon Raman Laser *(Feb '05)*

Electrically Pumped Hybrid Silicon laser (September 2006)

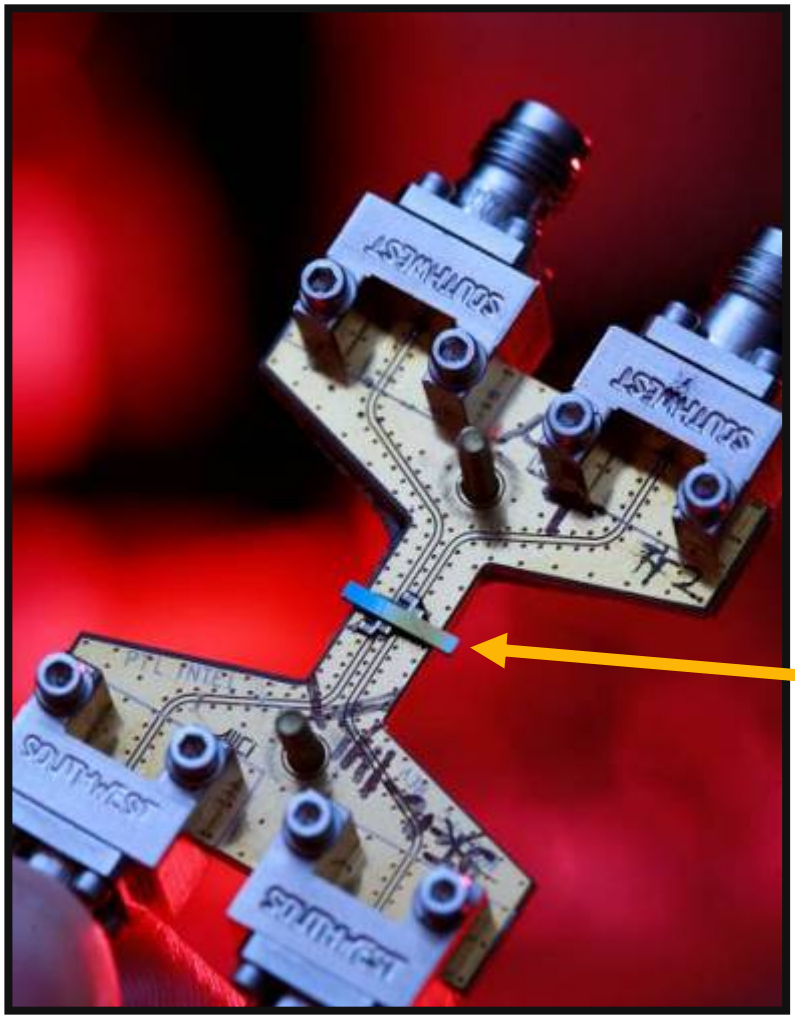
1GHz *(Feb '04)*
10 Gb/s *(Apr '05)*

40 Gb/s (Jul '07)

40 Gb/s TODAY

Achieved 40 Gb/s for most devices
Next: Focus on integration

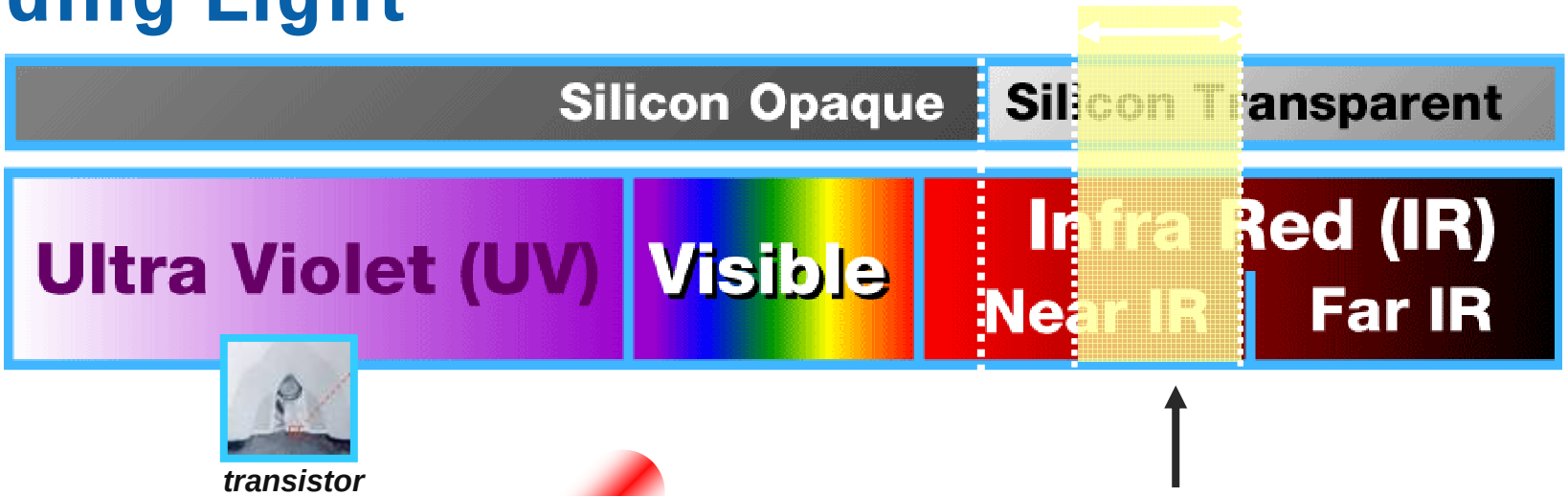
40Gb/s Silicon Laser Modulator

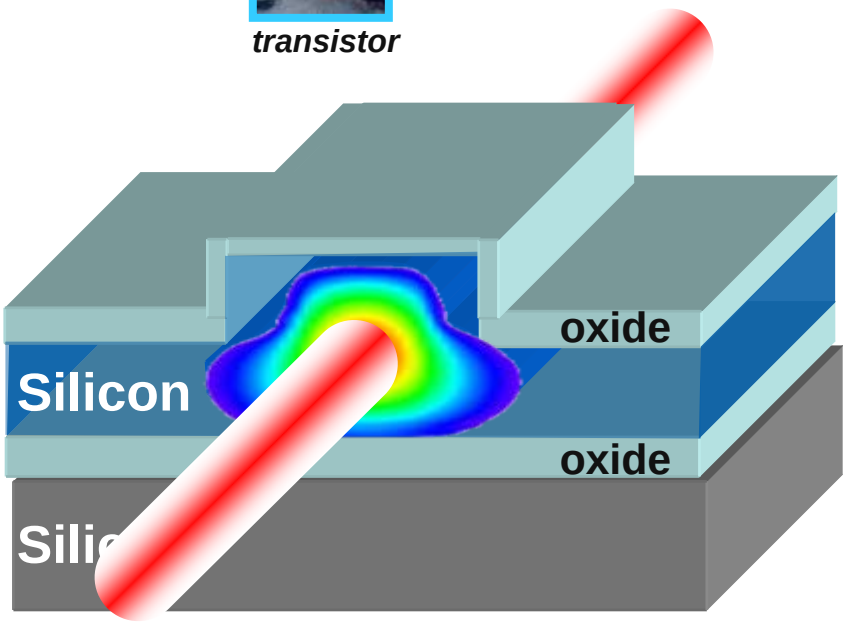


- Encodes data on a light beam at 40Gbps
- Fastest Si modulator

– on par with fastest modulators available commercially

Guiding Light





Ex: Rib waveguide

Silicon is Transparent
to infra Red light ($\lambda > 1.1um$)

Can guide light in Silicon

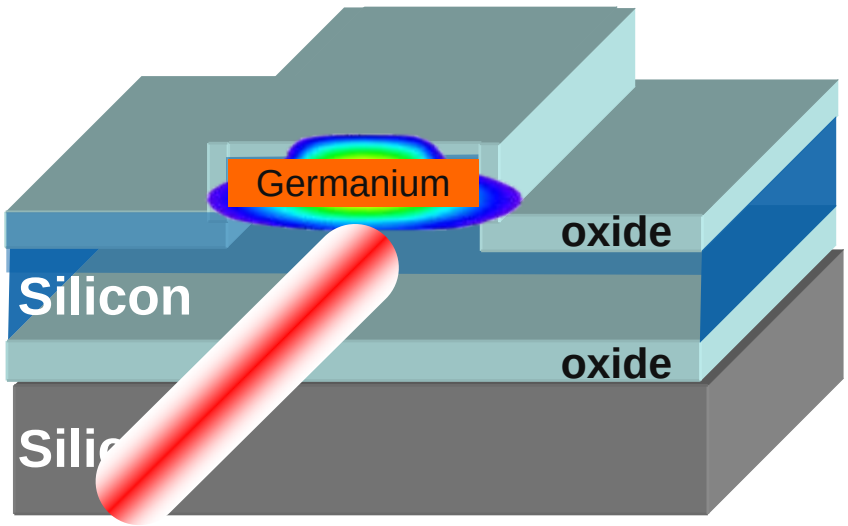
But does not absorb / detect

How do we absorb light: Use Germanium

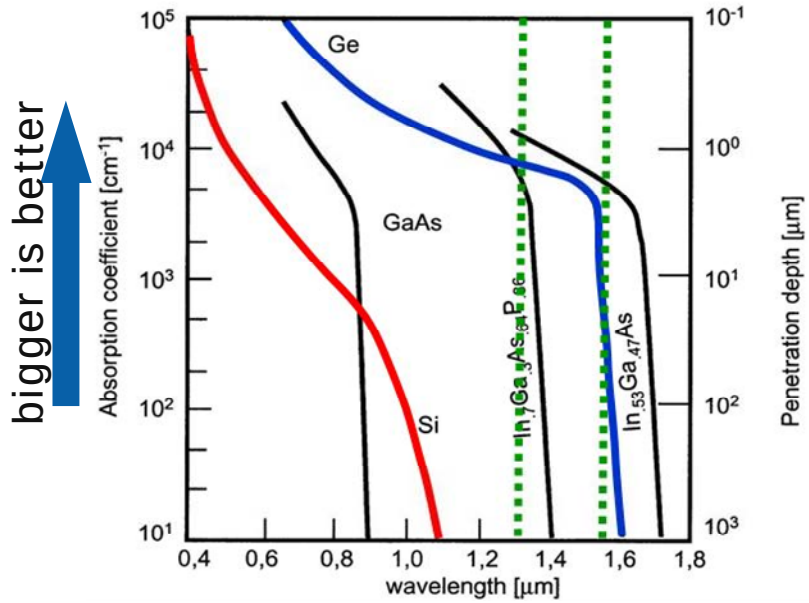
Bandgap engineering… i.e. add another material

Ge is the most promising candidate:

- High absorption for wavelengths of interest
- CMOS compatible

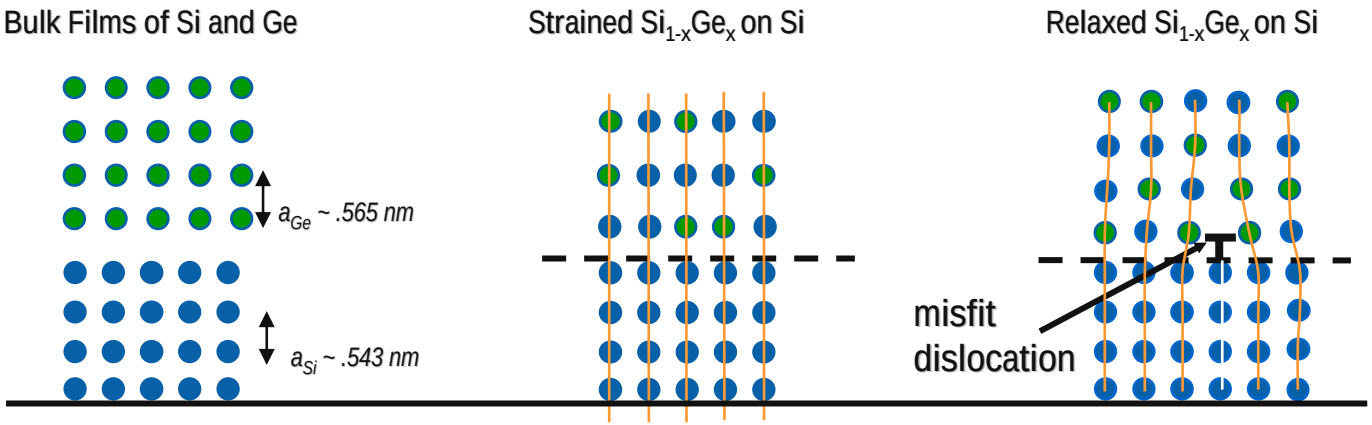


Ex: Rib waveguide



Challenge: Strain

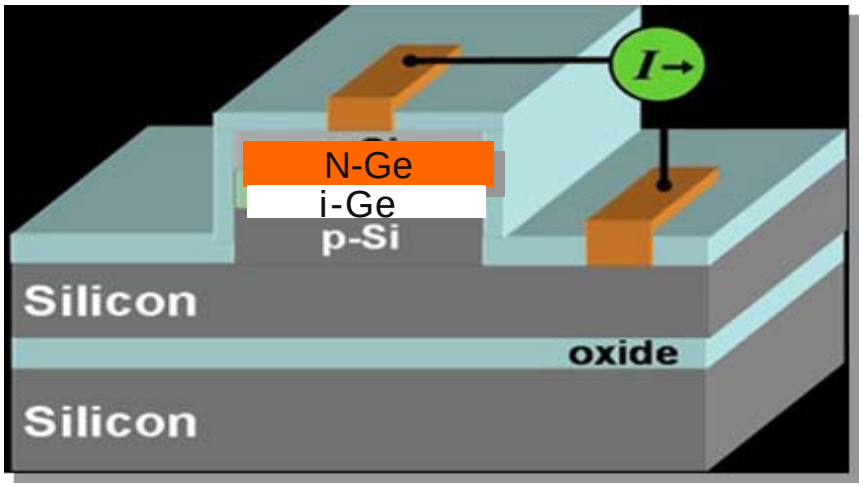
- Crystal structure of germanium is **4% larger** than silicon.
- This introduces strain when Ge is grown on Si.
- Result crystal lattice dislocations → excess noise



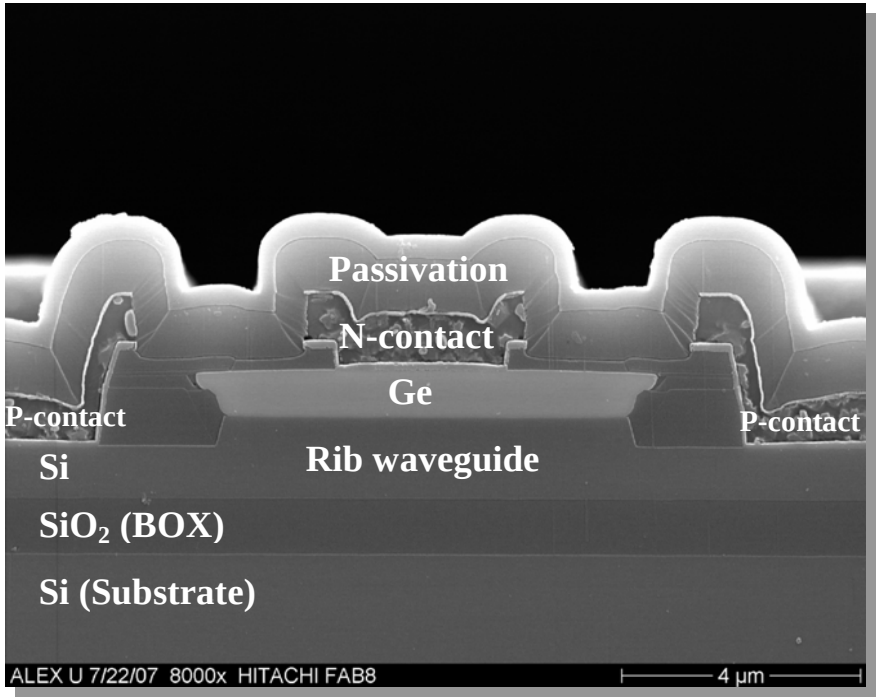
Misfit dislocations typically create threading dislocations which degrade device performance - *dark current (I_{dk}) goes up*.

By optimizing the thermal growth process parameters we can minimize defects impact.

Photodetector Design



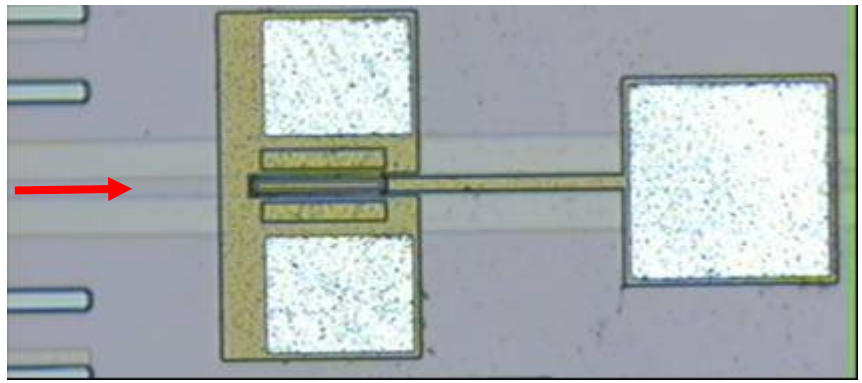
SEM Cross-Section



World's best Waveguide Photodetector Performance

Performance combines

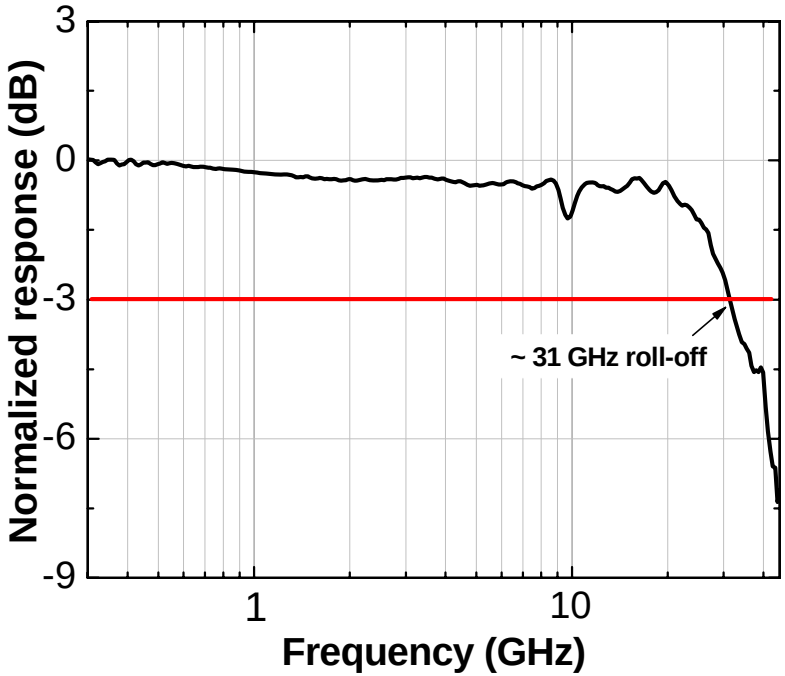
- **Speed**
  = bits per second
- **Efficiency**
  = % of photons detected
- **Noise**
  = "dark current")



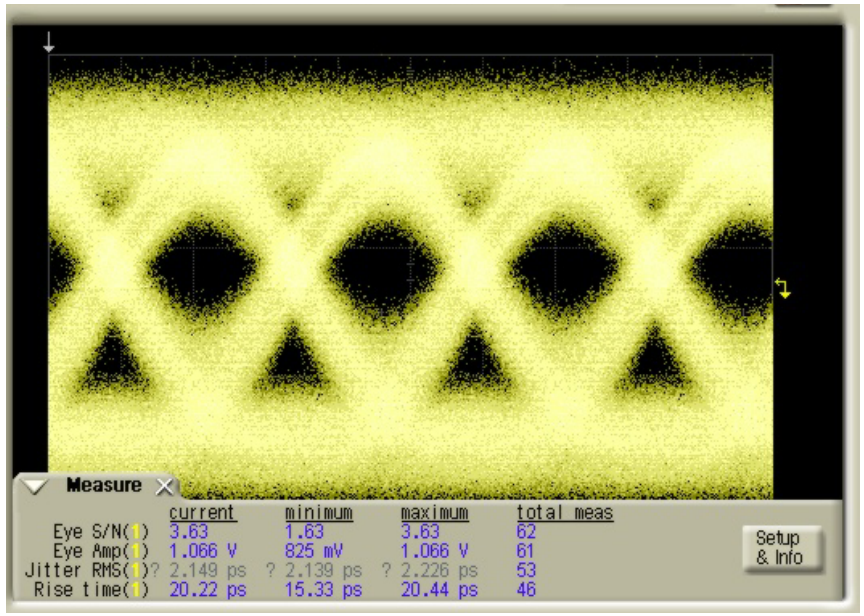
Results:

- 40 Gb/s operation
- 95% efficient (up to λ ~1.56um)
- < 200nA of dark current

Experimental Results:



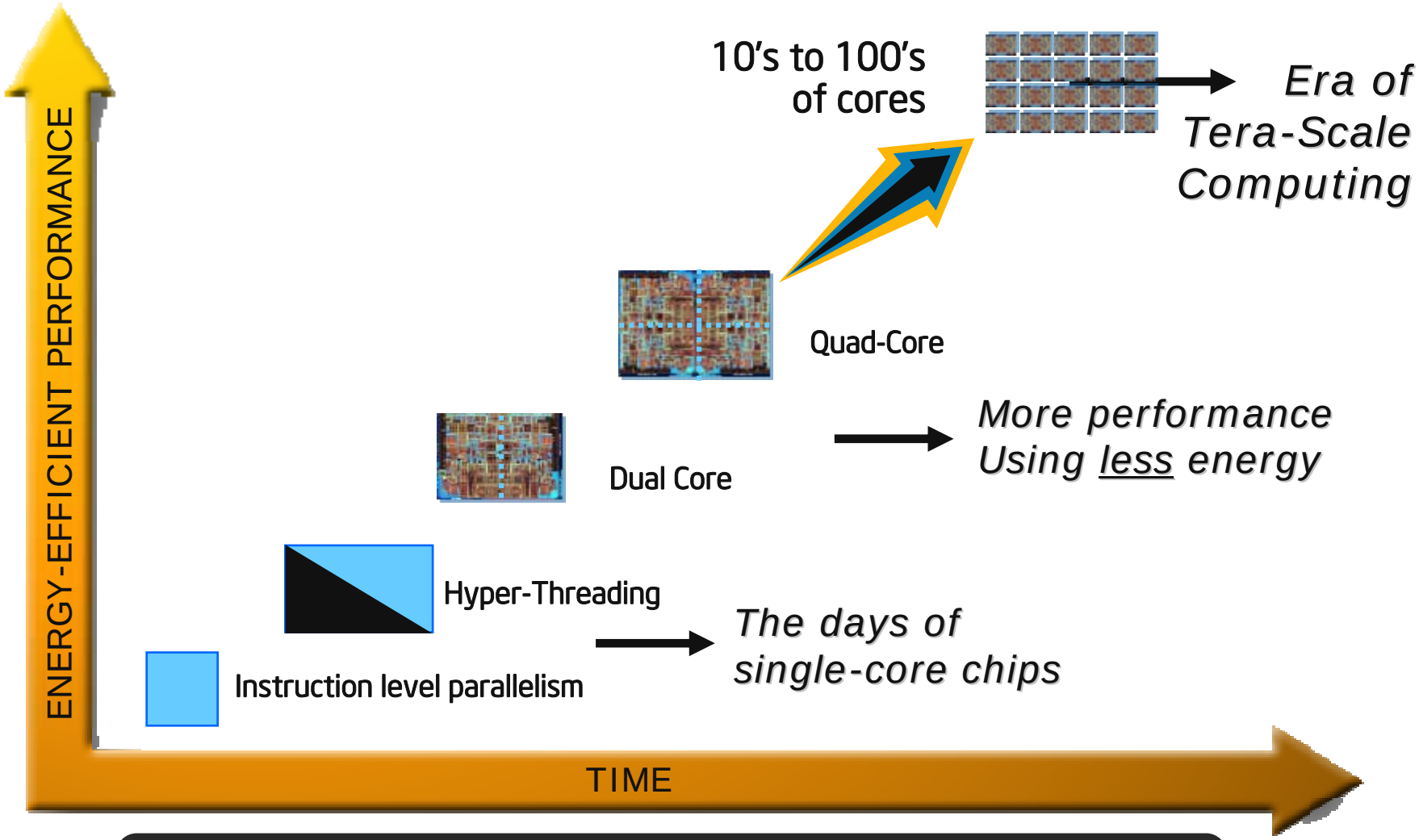
31 GHz Optical Bandwidth



40 Gb/s Data transmission

World's Best Performing Ge Waveguide Photodetector

Tera-leap to Parallelism:



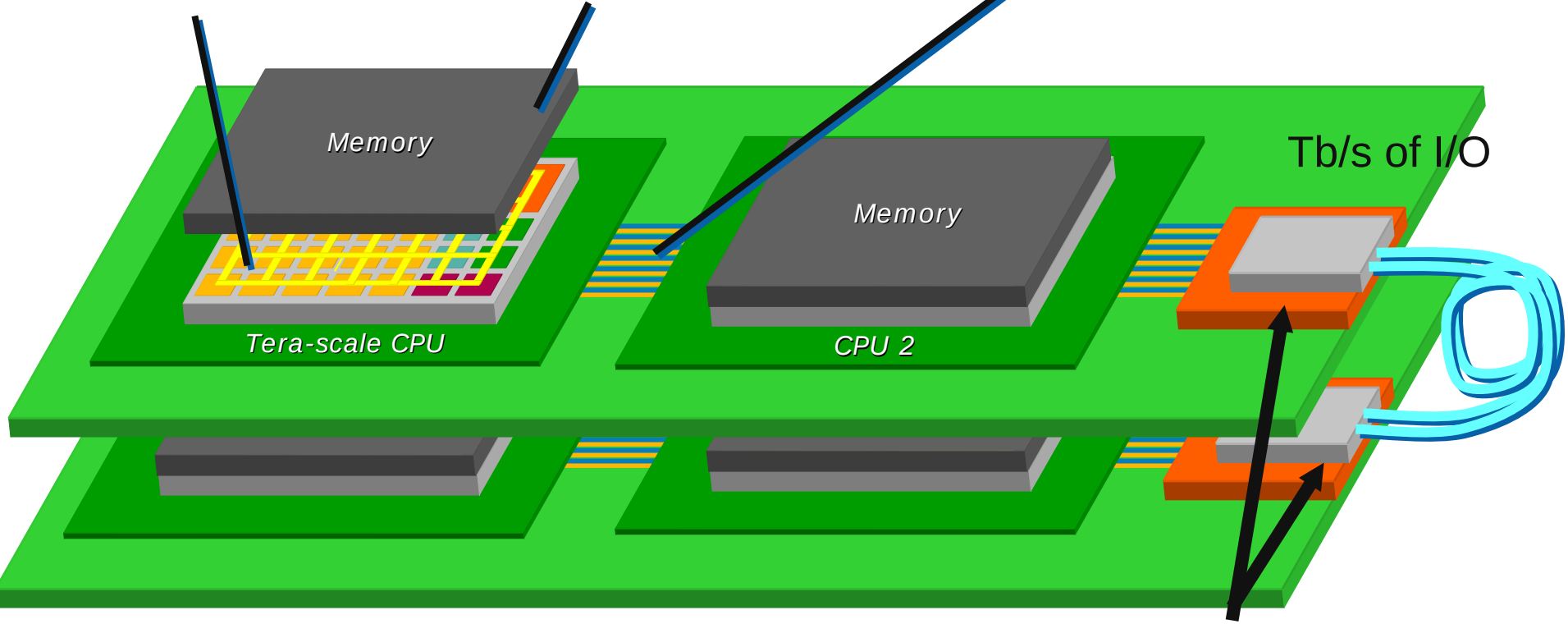
All this compute capability may require high speed optical links

Future Physical I/O for a Tera-scale Servers

Core-Core: On Die
Interconnect fabric

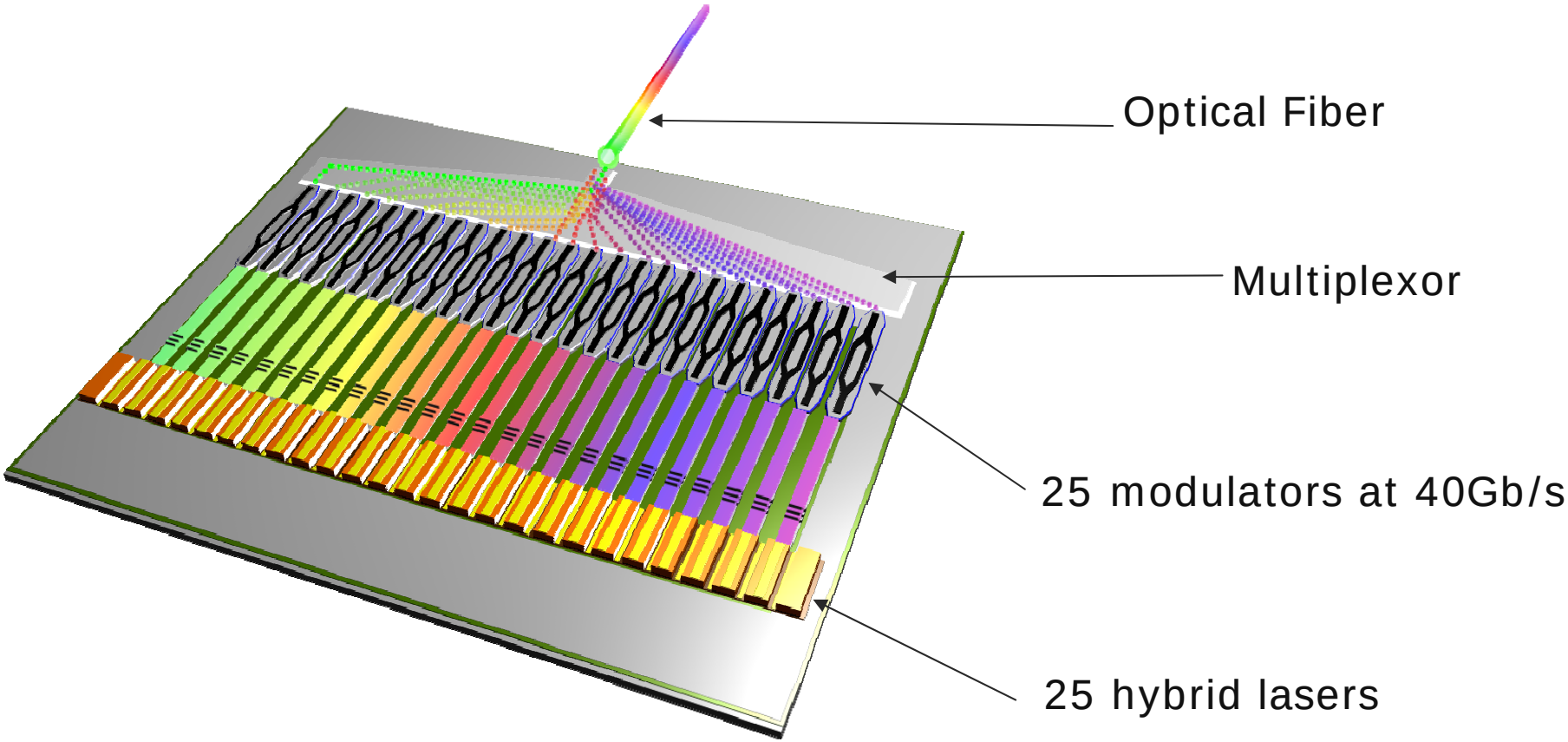
Memory: Package
3D Stacking

Chip-Chip: Fast Copper
FR4 or Flex cables



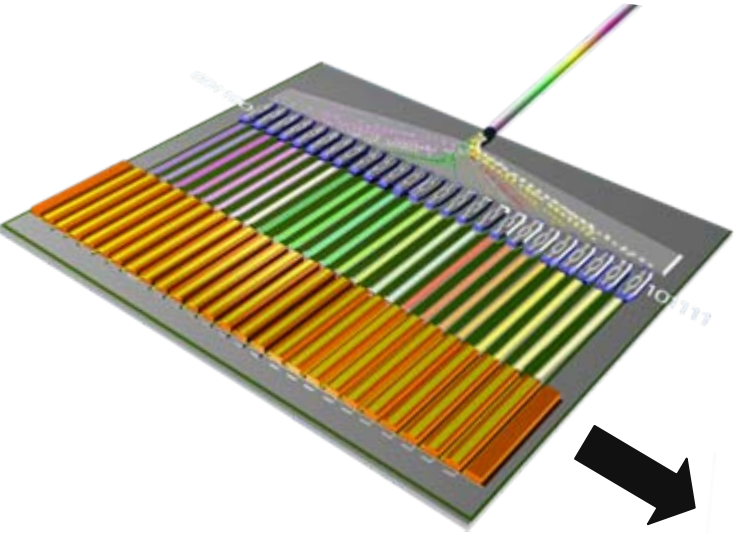
Integrated Tb/s Optical Chip

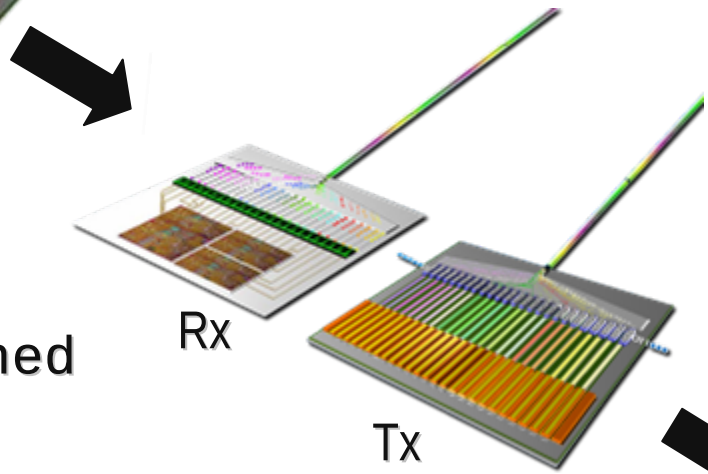
Future: A Terabit Optical Chip



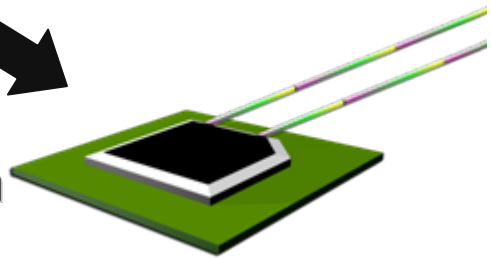
A future integrated terabit per second optical link on a single chip

Integrating into a Tera-scale System



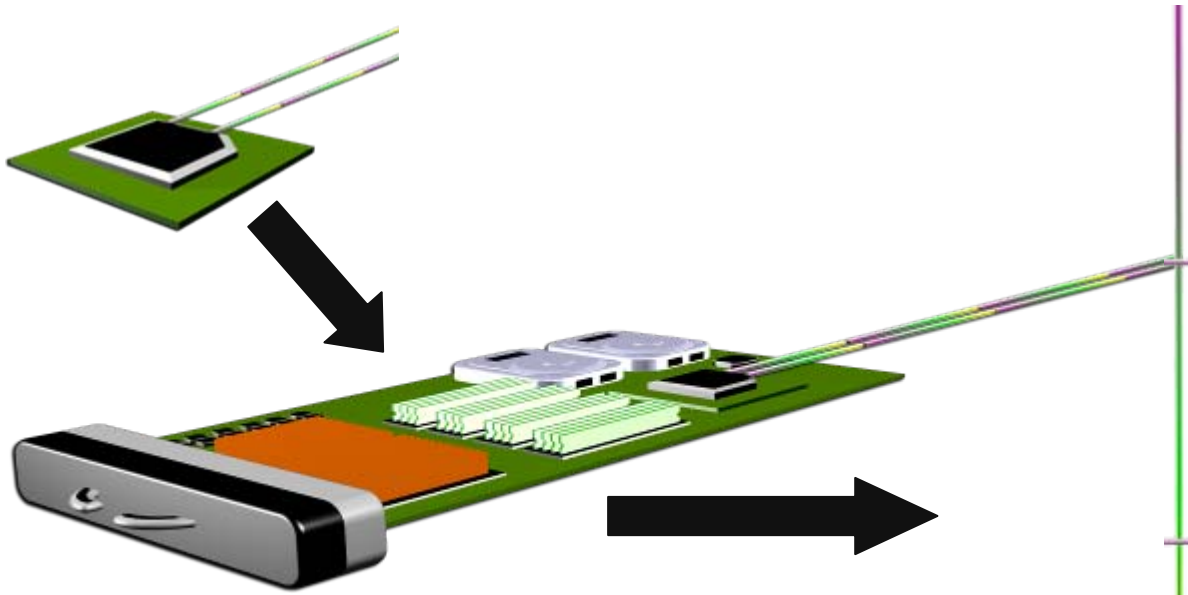


This transmitter would be combined with a receiver



Which could then be built into an integrated, silicon photonic chip

Integrating into a Tera-scale System



This integrated silicon photonic chip could then be integrated into computer boards

And this board could be integrated into a Tera-scale system

Integration of photonic devices will be critical in future applications.

Summary

Worlds Best performing Silicon Germanium Photo-detector

- Capable of operating at 40 Gbps
- Low dark current and great responsivity
- Details to be presented at Group IV conference Tokyo Japan Sept 20th

Background

- Silicon is transparent to Infrared light and good for routing light
- Germanium must be added to allow Silicon to absorb light
- Intel used a unique process to grow Germanium on Silicon and produce an efficient Silicon Germanium photo-detector

Vision

- Build highly integrated Si Photonics chips for optical communication
- Build using high-volume, low cost manufacturing processes
- Enables terabit optical links

Links

- Silicon Photonics at Intel site - http://techresearch.intel.com/articles/Tera-Scale/1419.htm
- Blog about recent modulator advance - http://blogs.intel.com/research/2007/07/40g_modulator.html

What We are Announcing

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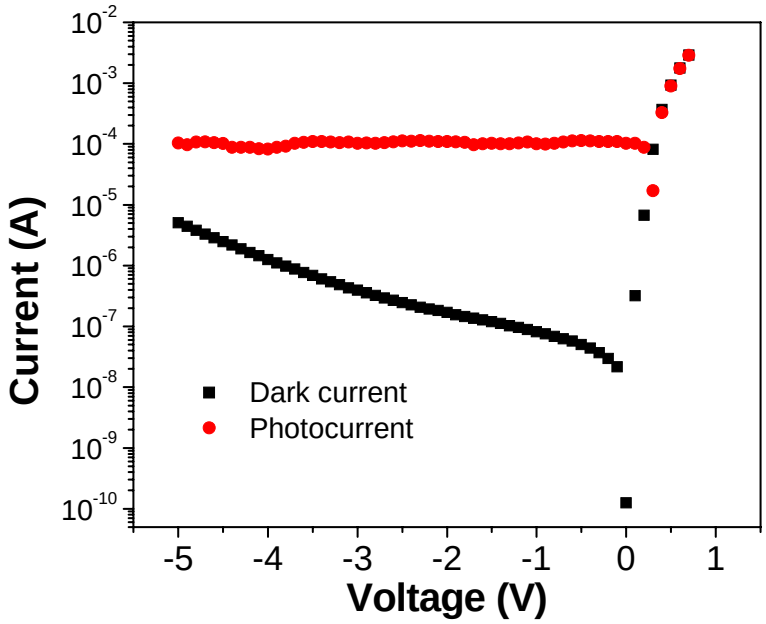
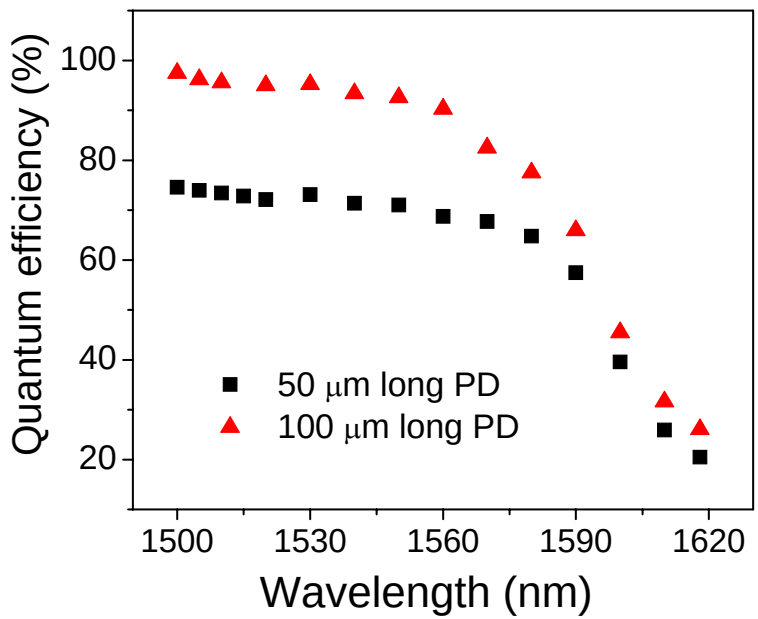
- Build using high-volume, low cost manufacturing processes
- Enables terabit optical links for tera scale platforms


intel
Leap ahead™

DC Photodetector Performance





- Dark current of photodetector is still below noise floor of amplification circuitry.
- Quantum efficiency is excellent at ~95%.