

WDM for Military Platforms Workshop
April 18-19, 2000

WDM Sensor Networks for Military Platforms

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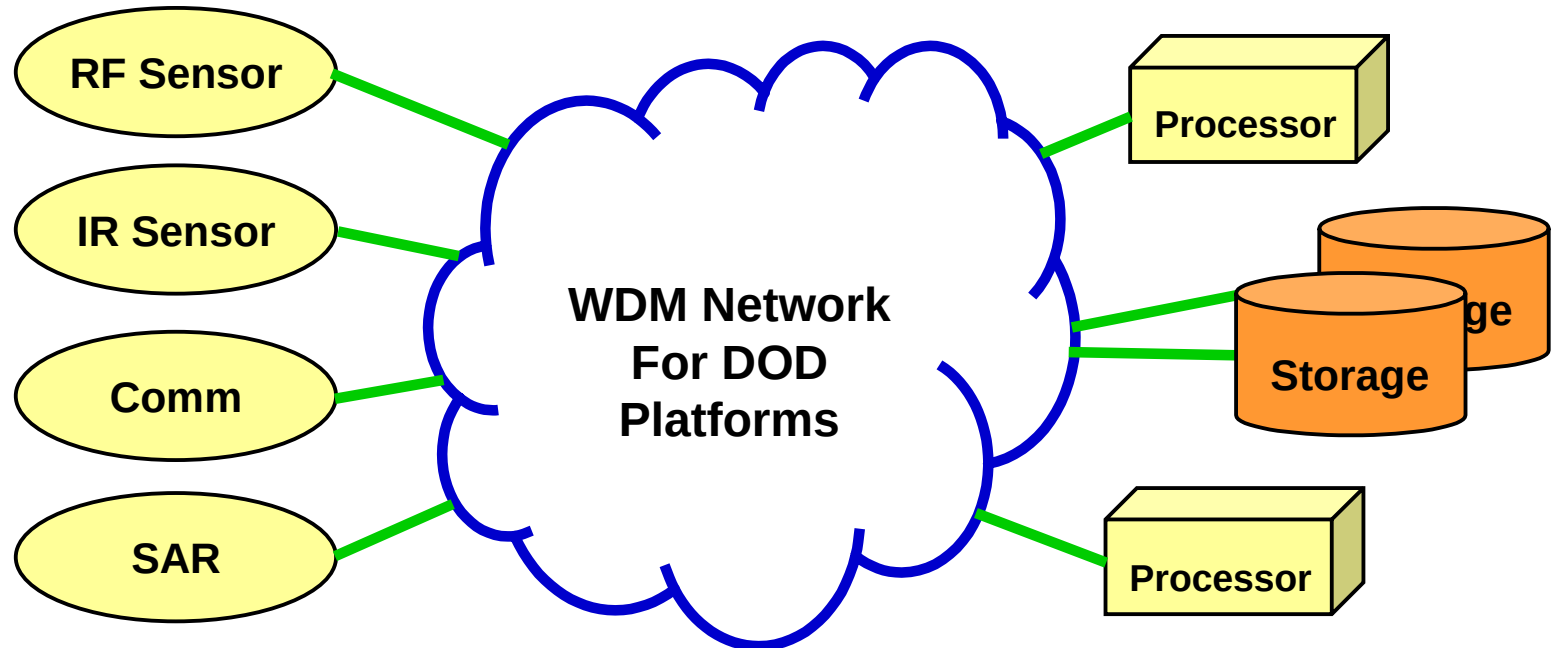
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OUTLINE

- **The emerging Optical Transport Networking (OTN) for telecom**
- **WDM sensor networks**
- **New components required**
- **New functions enabled by the network**

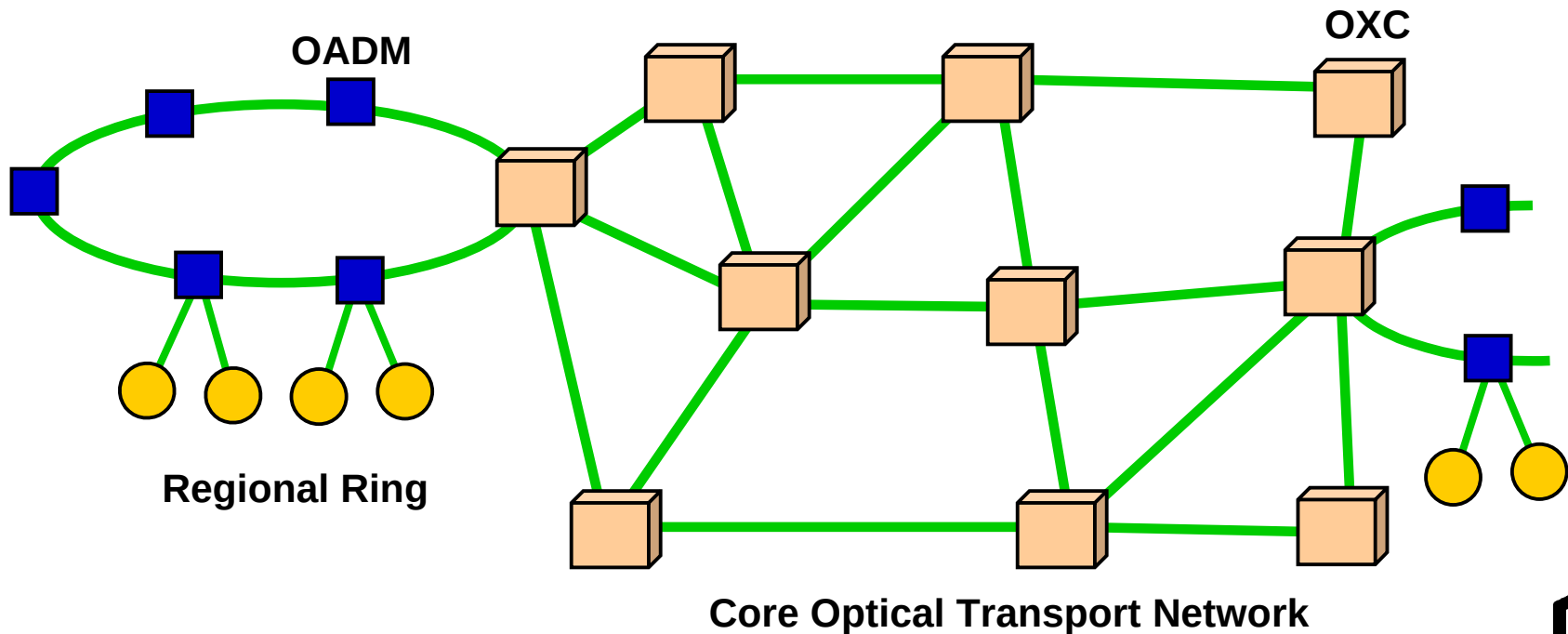
Ideal Sensor Networks for DOD Platforms



- Mixed RF/digital/analog signals
- Distributed sensors in all locations
- Connectivity (more than point-to-point)
- High survivability, fault tolerant
- Dynamic reconfigurable, wide instantaneous bandwidth

Telecom Optical Transport Networking

- WDM is quickly evolving from **point-to-point capacity expansion** to scalable and robust **optical transport networking (OTN)**
- Catering to an expanding variety of client signals with equally varied service requirement

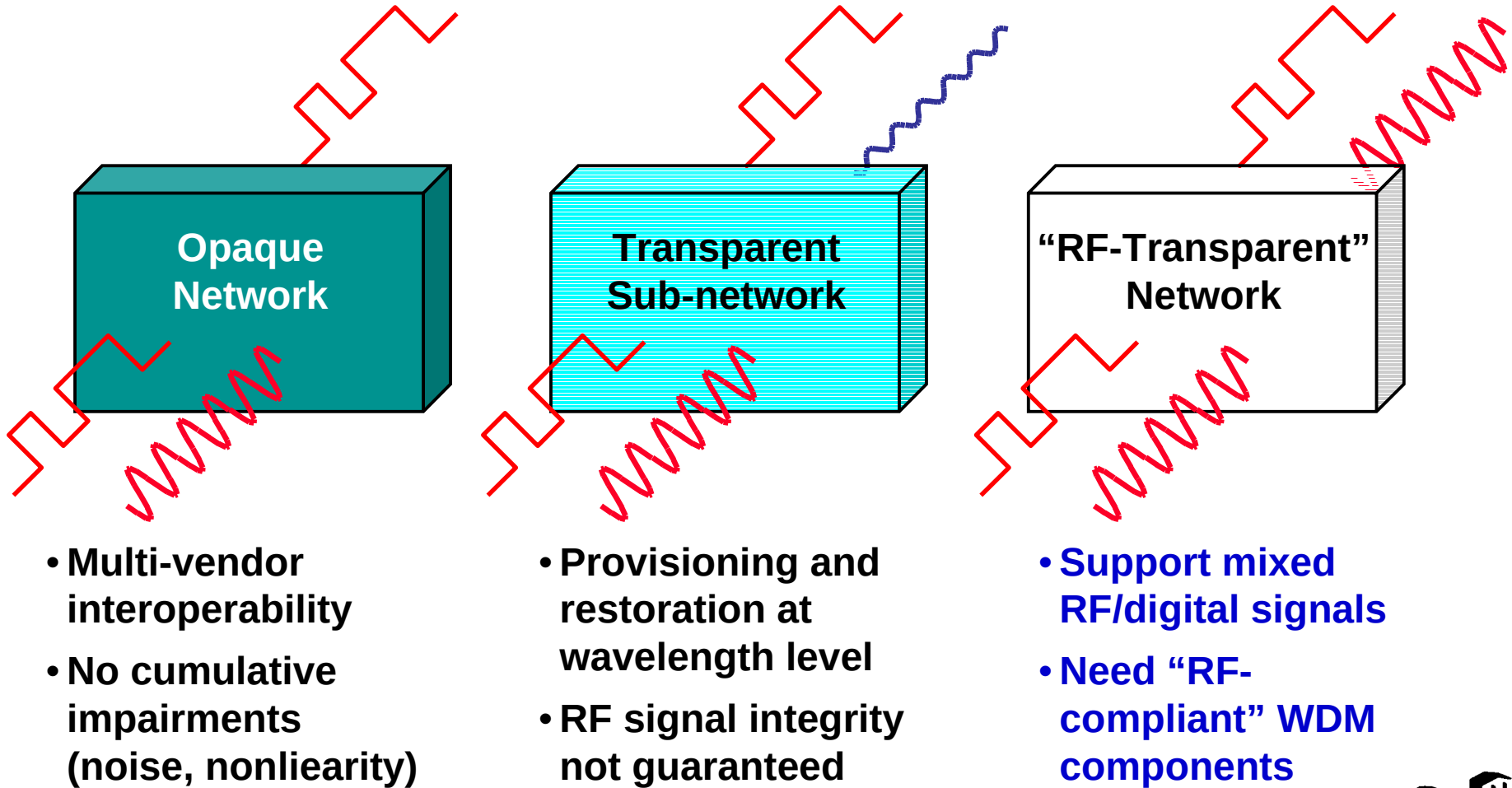


The Issue of **Optical Transparency**

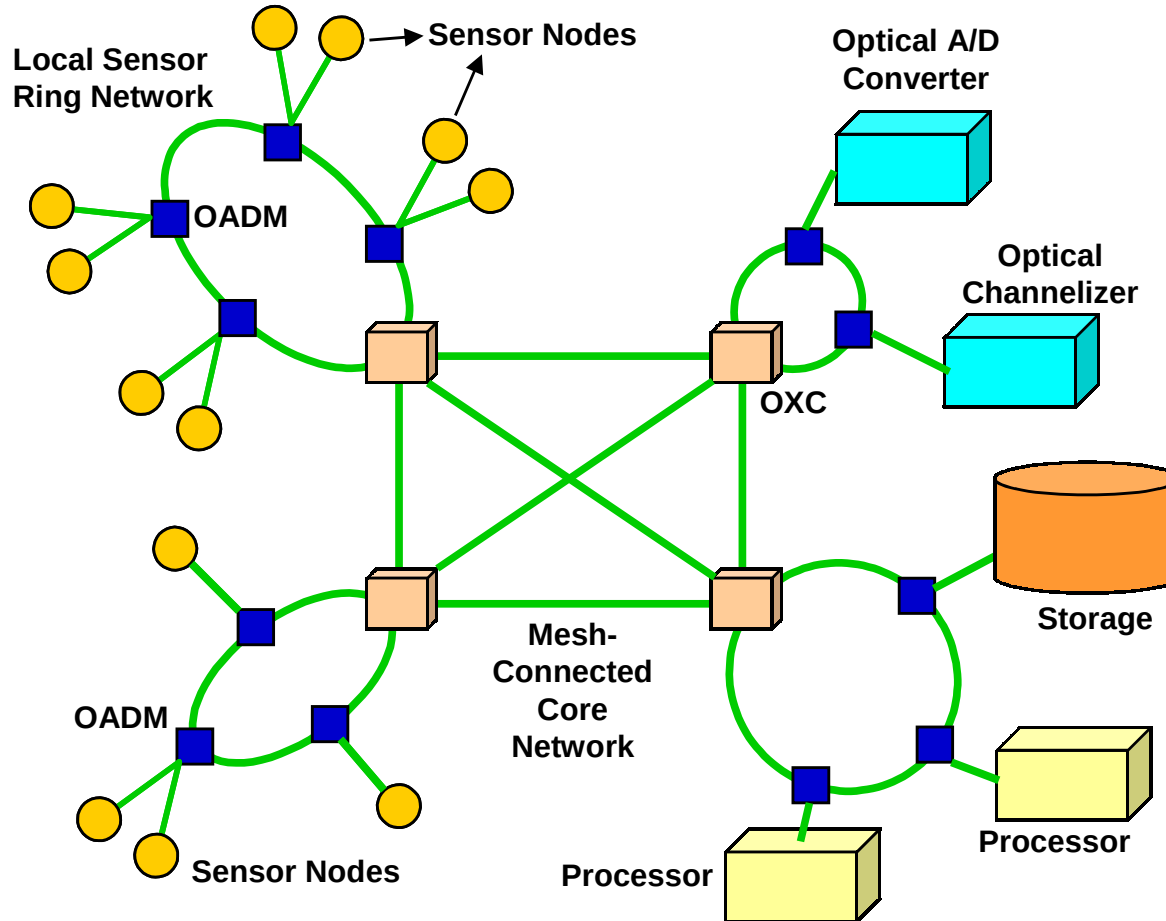
- Early visions of “**All-Optical**” Transport Networking
 - Any signal (digital or analog)
 - Anywhere
 - Anytime
- “Idealized” vision tempered by practical constraints – analog network engineering → “**Opaque networks**”
 - “Optoelectronics” (usually with 3R) required to mitigate analog noise accumulation and maintain the network
- Practical vision of OTN
 - **Optically transparent sub-networks** (islands) bounded by feature-enhanced optoelectronics
 - **Size and capability of the optically transparent sub-network grows as technology and standards matures**

Adapted from: P. Bonenfant, “Optical Networking Standards,” OFC 2000 Tutorial

Granularity of “Transparency”

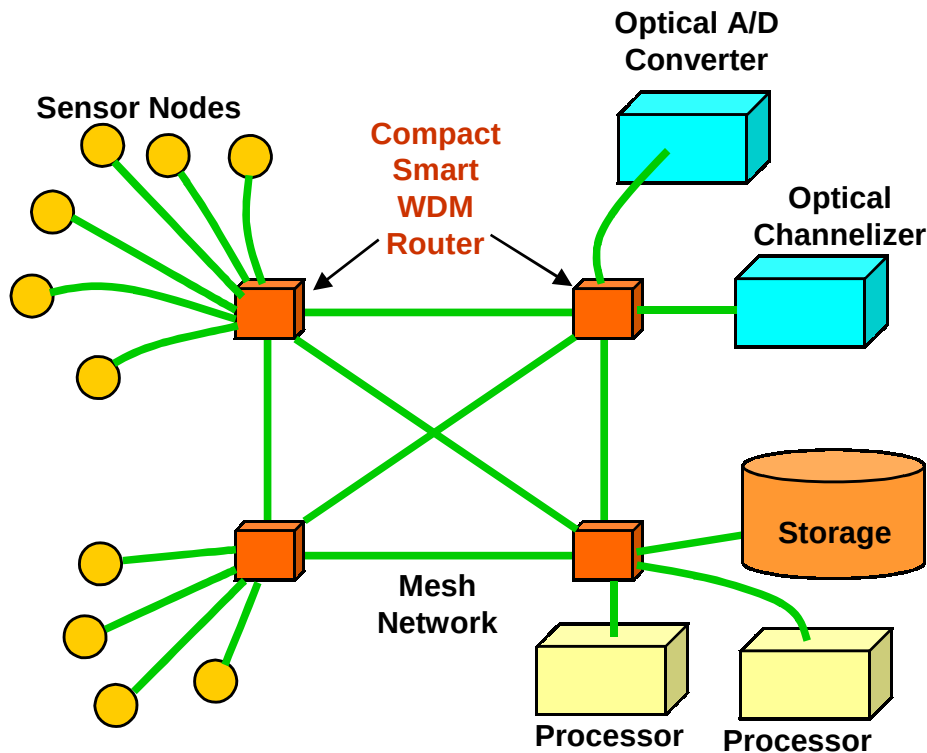


WDM Integrated Sensor Network



- **Highly survivable**
 - Built-in protection and restoration
- **Dynamically reconfigurable**
- **Provisioning at wavelength level (**Bandwidth on demand**)**
- **Support large number of nodes**
- **“Future-proof”**
 - Add more sensors
 - Add optical front-end preprocessors
 - Increase RF frequency
- **Pay as you grow**
 - Add more wavelengths when needed

OXC for WDM Sensor Network

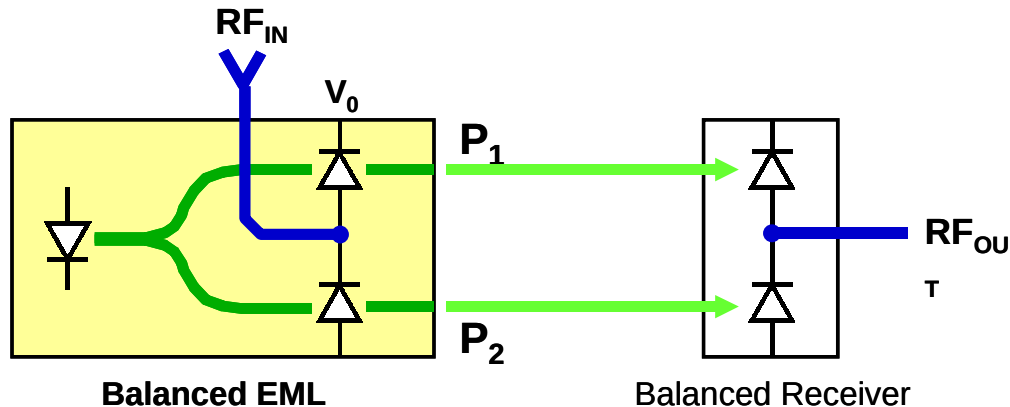


- Need much more compact OXC
 - Telecom OXC too big in size, weight, power, and capacity
- What can we do without?
 - Probably don't need wavelength conversion (?)
 - Use wavelength-selective cross connect (WSXC)
- Combine WSXC and OADM
 - Smart WDM Router

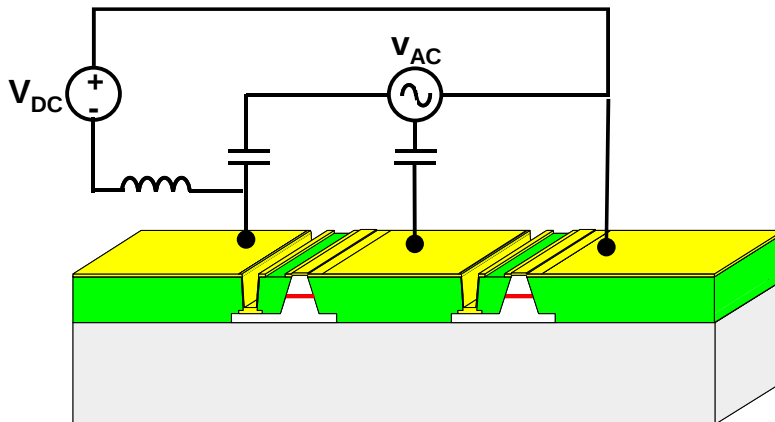
RF-Compliant Components

- WDM components with < -40 dB optical isolation
- Flat passband response
- Many RF-compliant optoelectronic components are being developed by RFLICS
- **Balanced EA modulator with high linearity and low noise**

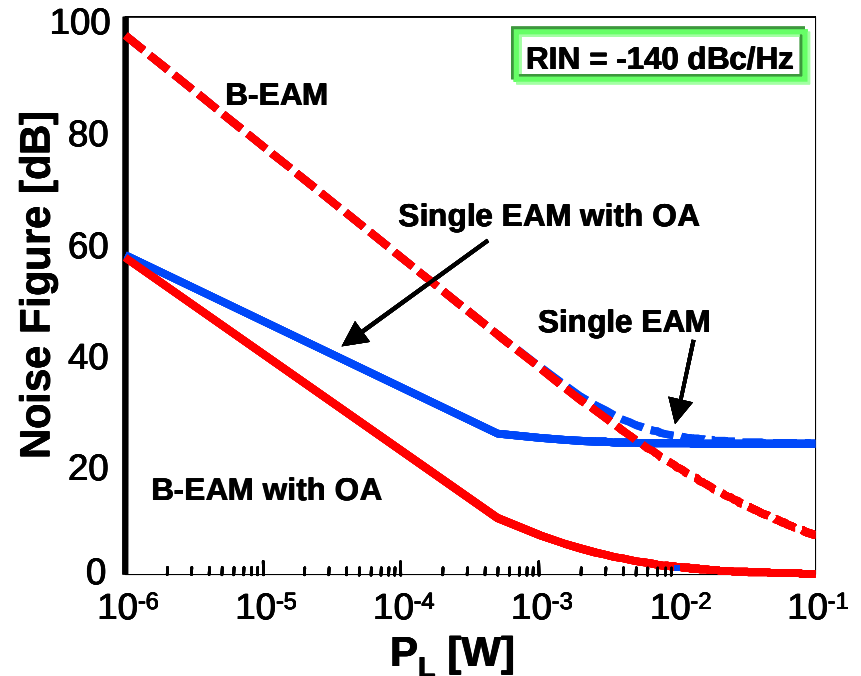
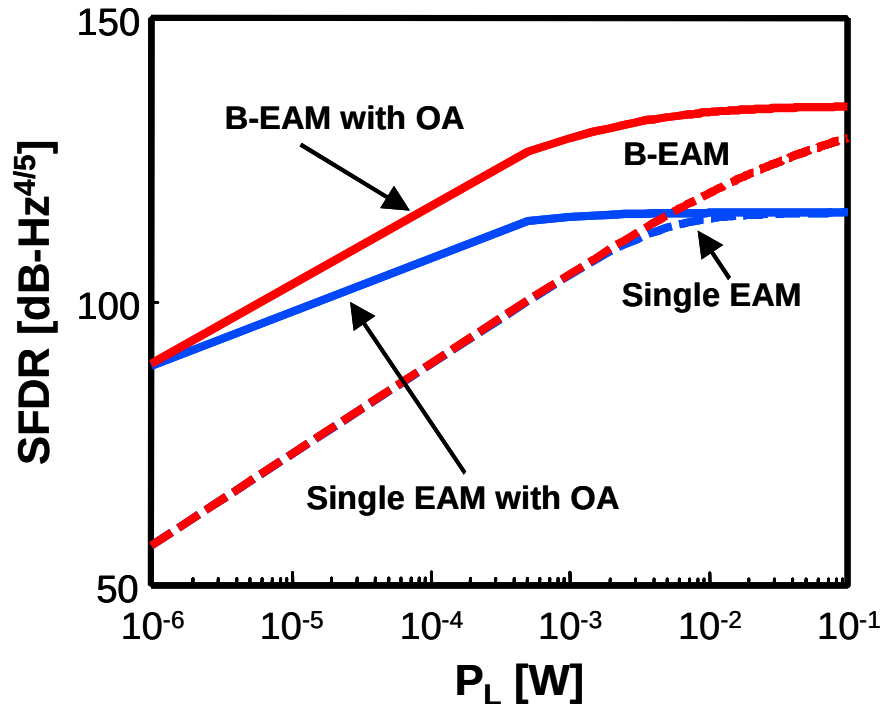
Balanced EA Modulator (BEAM) for “RF-Transparent” WDM Networks



- Complementary output at **all bias voltages**
- BEAM balanced link:
 - All even order distortions cancelled
 - 3rd order intermod nulled
 - RIN cancelled
 - Common ASE of SOA suppressed
- High fidelity link achieved with telecom-grade lasers and modulators
- Ideal for mixed mode (digital + RF) WDM networks

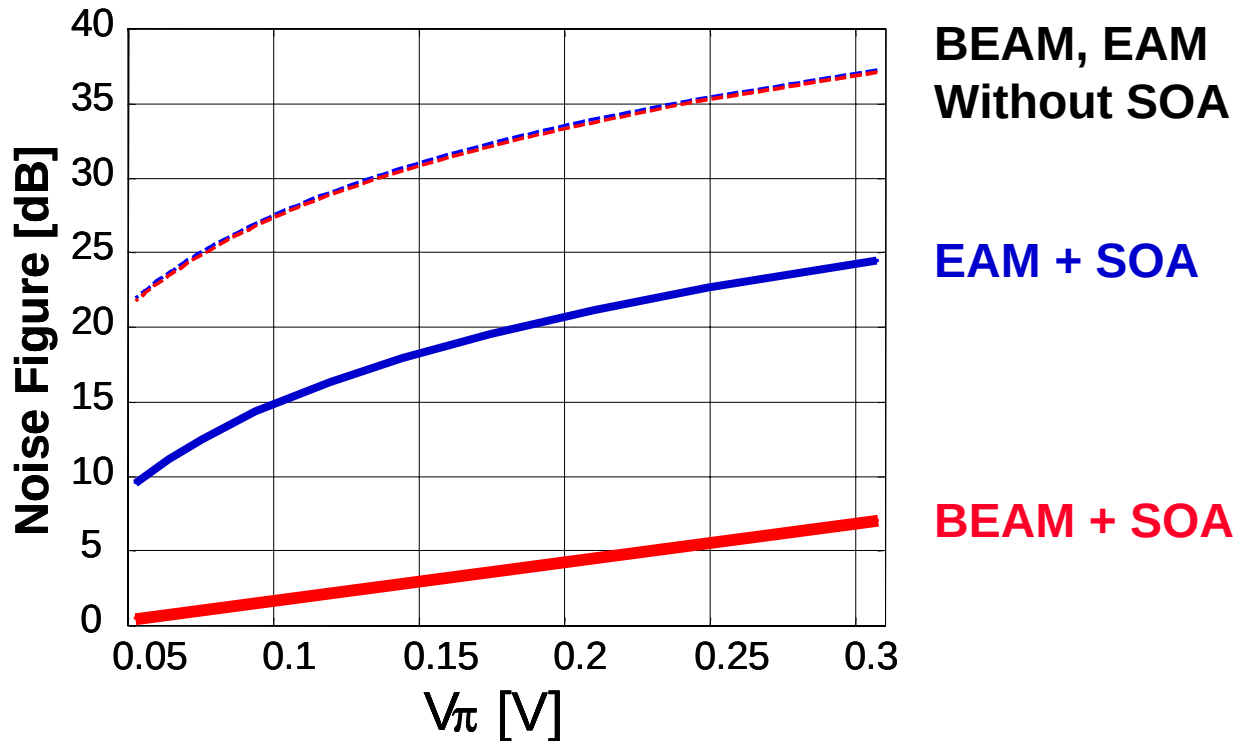


Calculated Spurious-Free Dynamic Range and Noise Figure of BEAM



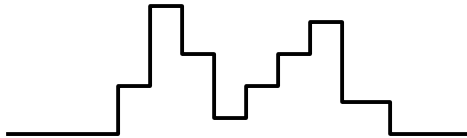
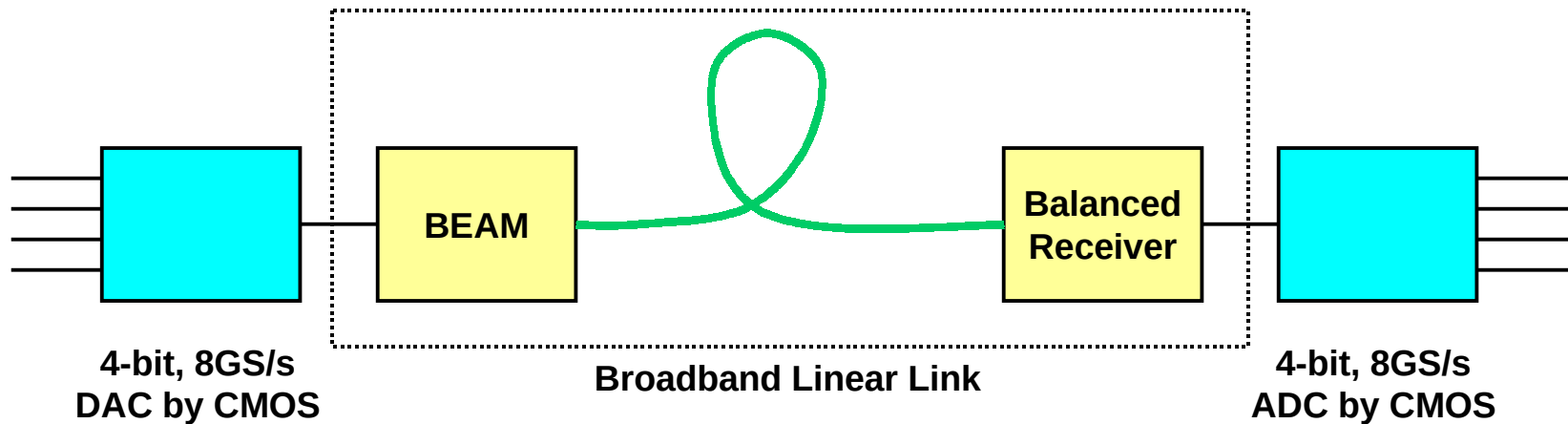
High SFDR and low NF can be achieved at moderate laser power and RIN

Comparison of BEAM and EAM

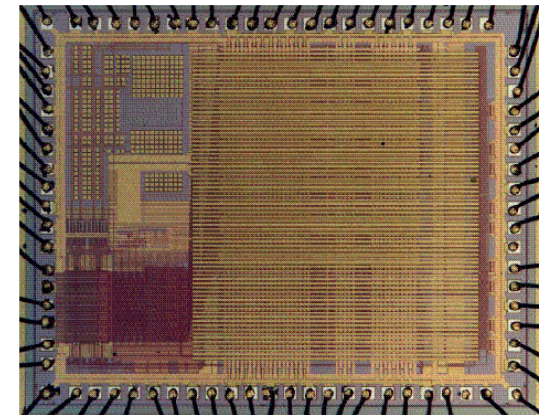


- Noise Figure of BEAM is lower than EAM with 5x lower V_π

Ultra-High Speed Link using CMOS Multi-Level Tx/Rx Chips

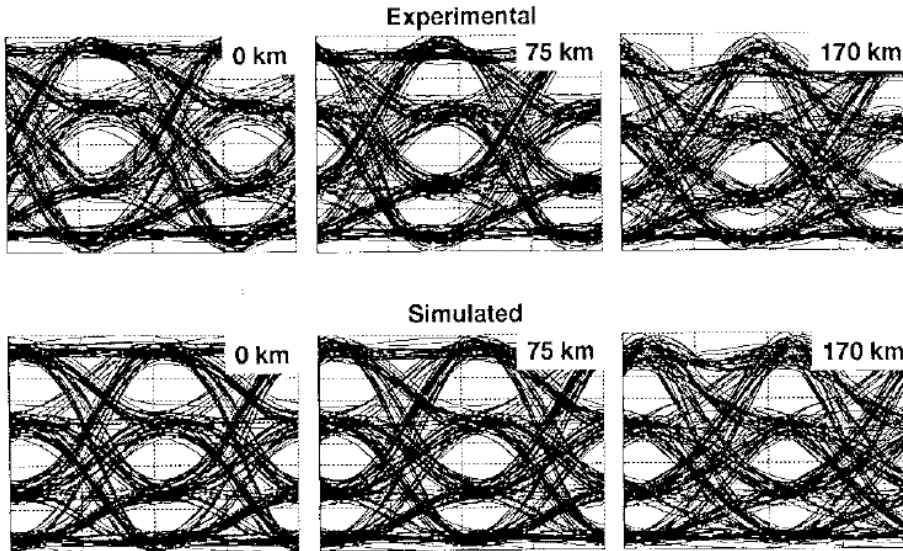


- 30 Gbps transmission by combining linear link with high speed CMOS DAC/ADC
- High spectral efficiency ($\gg 1$ bit/Hz)
- Prof. Ken Yang (UCLA), leader in high speed CMOS Tx/Rx design



0.25 μ m CMOS
Prof. Ken Yang (UCLA)

Multi-Level Signaling Digital Transmission



- **M-ary signaling**
 - **Reduced bandwidth**
(bandwidth $\sim$ symbol rate)
 - **Increased spectral efficiency** ($\gg 1$ b/sec/Hz)
 - **Resistant to dispersion**
 - **40 Gbit/s over 35 km standard single mode fiber demonstrated by Alcatel**
- **For large M**
 - **Need network with large SFDM**
 - **Need more optical power**

- Walklin, S.; Conradi, J. "Multilevel signaling for increasing the reach of 10 Gb/s lightwave systems. IEEE Journal of Lightwave Technology, vol.17, p.2235-48, 1999.
- Wedding, et al. (Alcatel), "40 Gbit/s quaternary dispersion supported transmission over 31 km standard single mode fiber without optical dispersion compensation," ECOC '98, p.523.

SUMMARY

- **“RF-transparent” WDM network for sensor networks for military platforms**
- **Compact Smart WDM Router**
- **Balanced electro-absorption modulator (BEAM) for mixed RF/digital signals**
- **Multi-level signaling for possible 40 Gbit/sec WDM in CMOS**