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Wavelength Division Multiplexing Techniques for Enabling Complex Military Systems

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DARPA/MTO Workshop on WDM for Military Platforms

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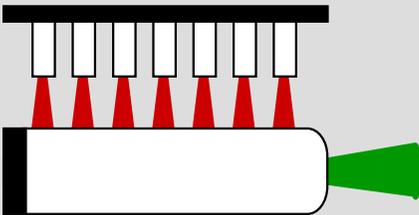
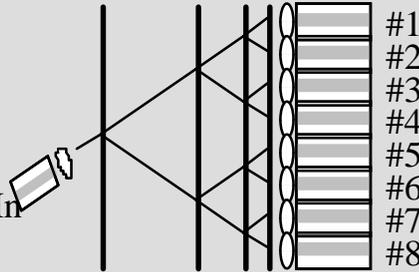
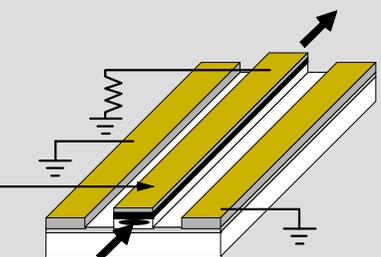
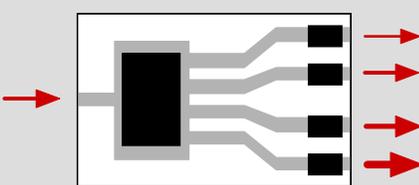
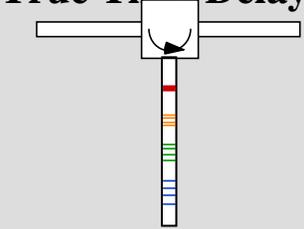
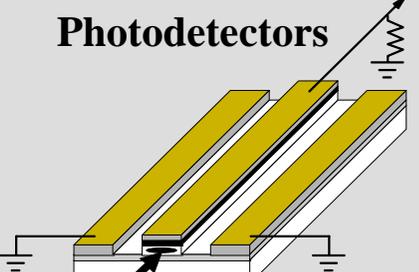
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Overview

- **WDM techniques as enablers for complex military systems.**
- **Optical bandwidth is the key that unlocks the potential of photonics in military RF systems ---- low transmission loss of fiber does not carry the same weight as for commercial systems.**
- **Archetype: Large-scale phased-array antennas**
 - **Challenge: Receive-mode signal combining**
 - **Solutions:**
 - Careful optical and RF subsystem design
 - Prudent use of existing WDM technology
 - Technology developments

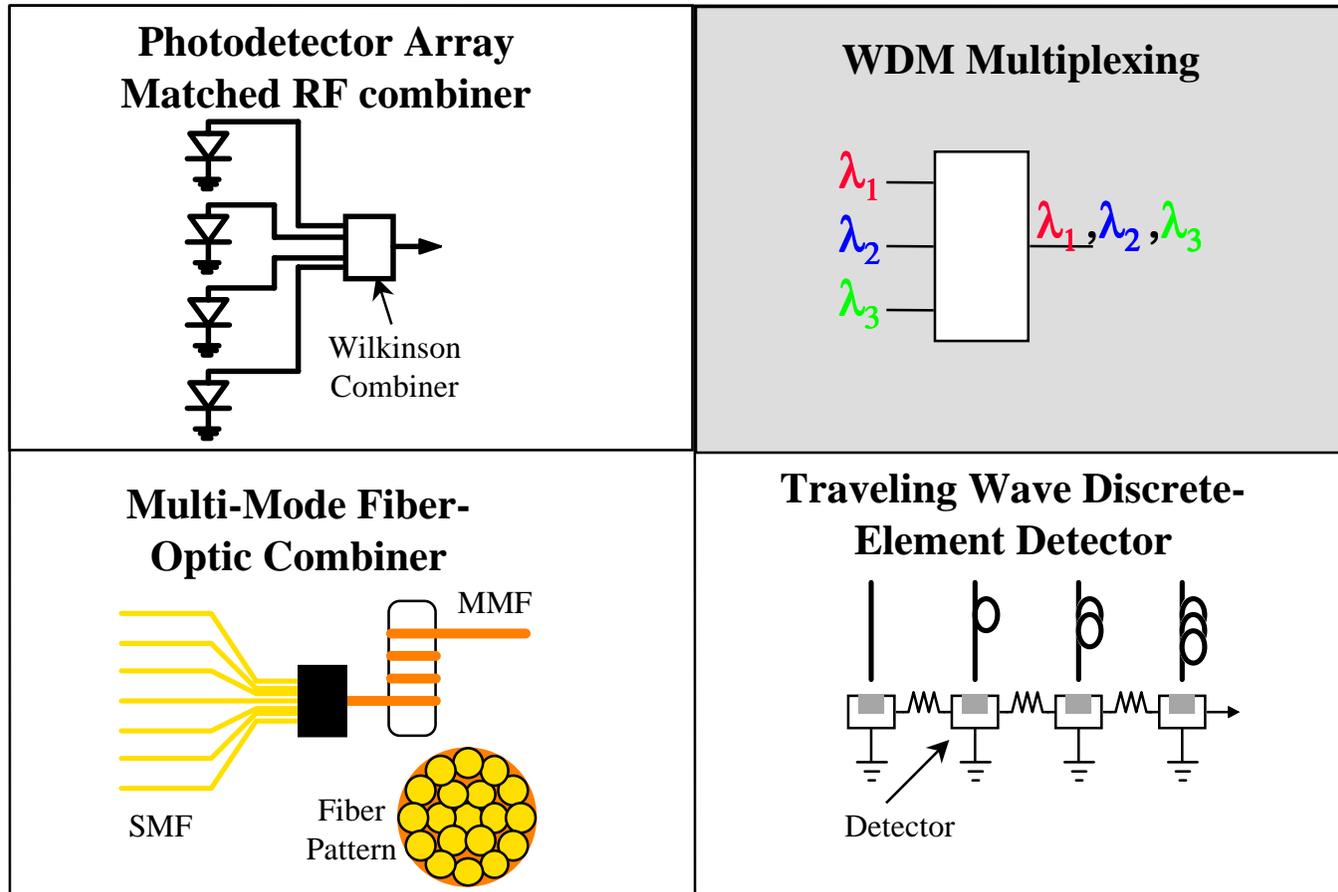
⇒ **Why we are here**

Phased Array Antenna Beamforming Networks: Requires Full Range of Photonics Technologies

| | |
|---|---|
| <p>Sources</p>  <p>Candidates DFB, DBR, Nd:YAG, Ext. Cavity Tunable</p> <p>Issues/Drivers Amp/Phase Noise Multi-λ</p> | <p>Optical Switching</p>  <p>Candidates Switched Gratings, MEM's Digital Mirror, Interferometric, Fiber Optic Mechanical</p> <p>Issues/Drivers Insertion Loss, Speed, Isolation</p> |
| <p>Modulators</p>  <p>Candidates EAM, Mach-Zehnder, Fiber Based</p> <p>Issues/Drivers Large Bandwidth High RF Gain High Optical Power</p> | <p>Amplified Distribution</p>  <p>Candidates Talbot, Er Doped WG, Er Doped Fiber, Active Y Branch</p> <p>Issues/Drivers Splitting Losses => NF, Opt. saturation, Dynamic range System integration Amplitude control</p> |
| <p>True Time Delay</p>  <p>Candidates Discrete/Chirped Braggs, Opt. Switched, AWG</p> <p>Issues/Drivers Losses, Complexity, Environment</p> | <p>Photodetectors</p>  <p>Candidates PIN, Waveguide, MSM</p> <p>Issues/Drivers High Power Handling & Responsivity Bandwidth, Efficiency</p> |

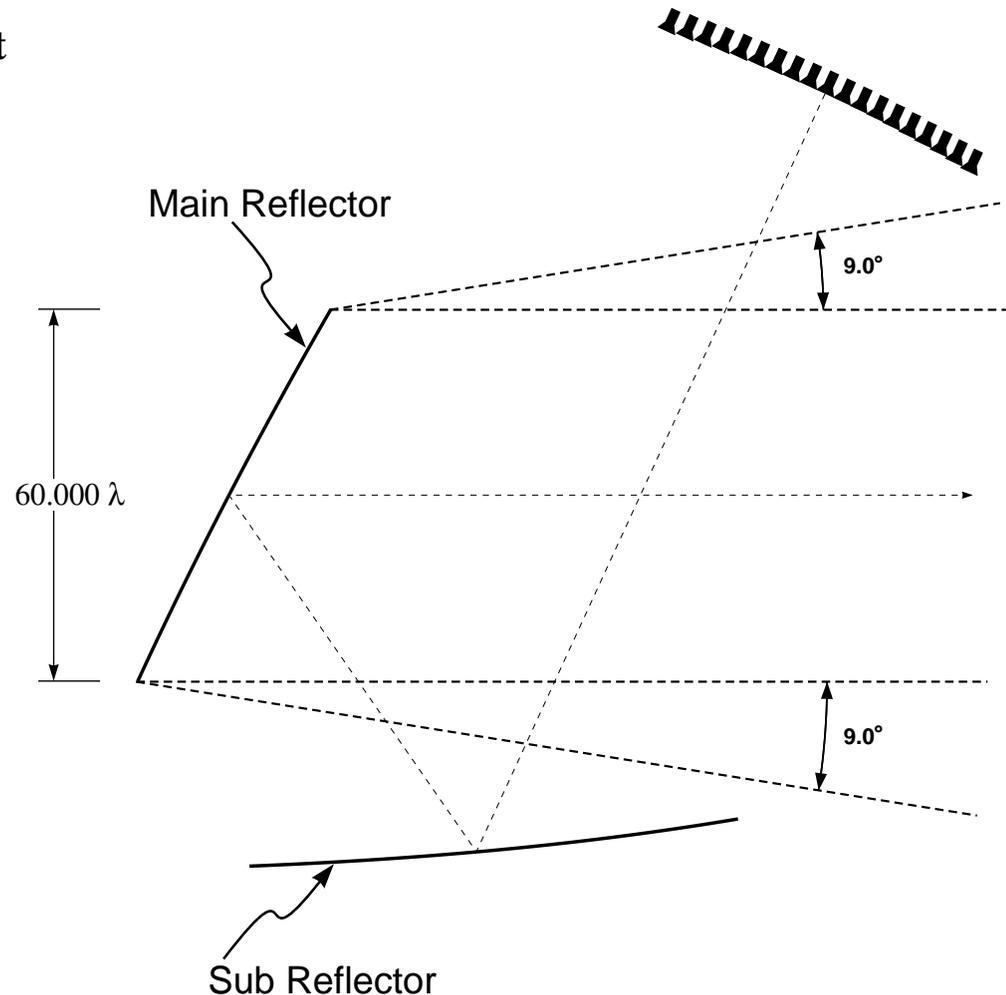
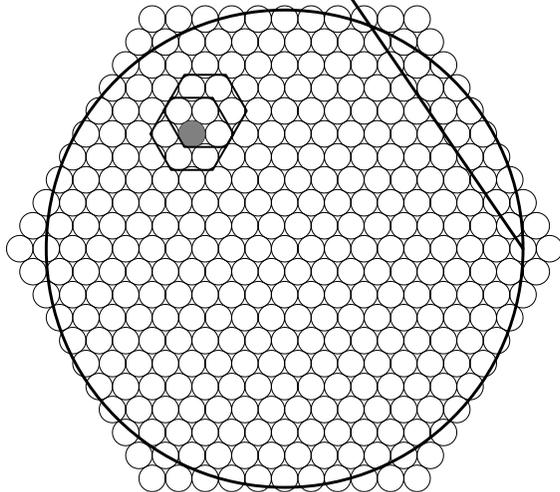
Signal Combining: A Critical Photonic Beamforming Issue

The need for low-loss combination of many elements while maintaining adequate amplitude control will require hybrid techniques.

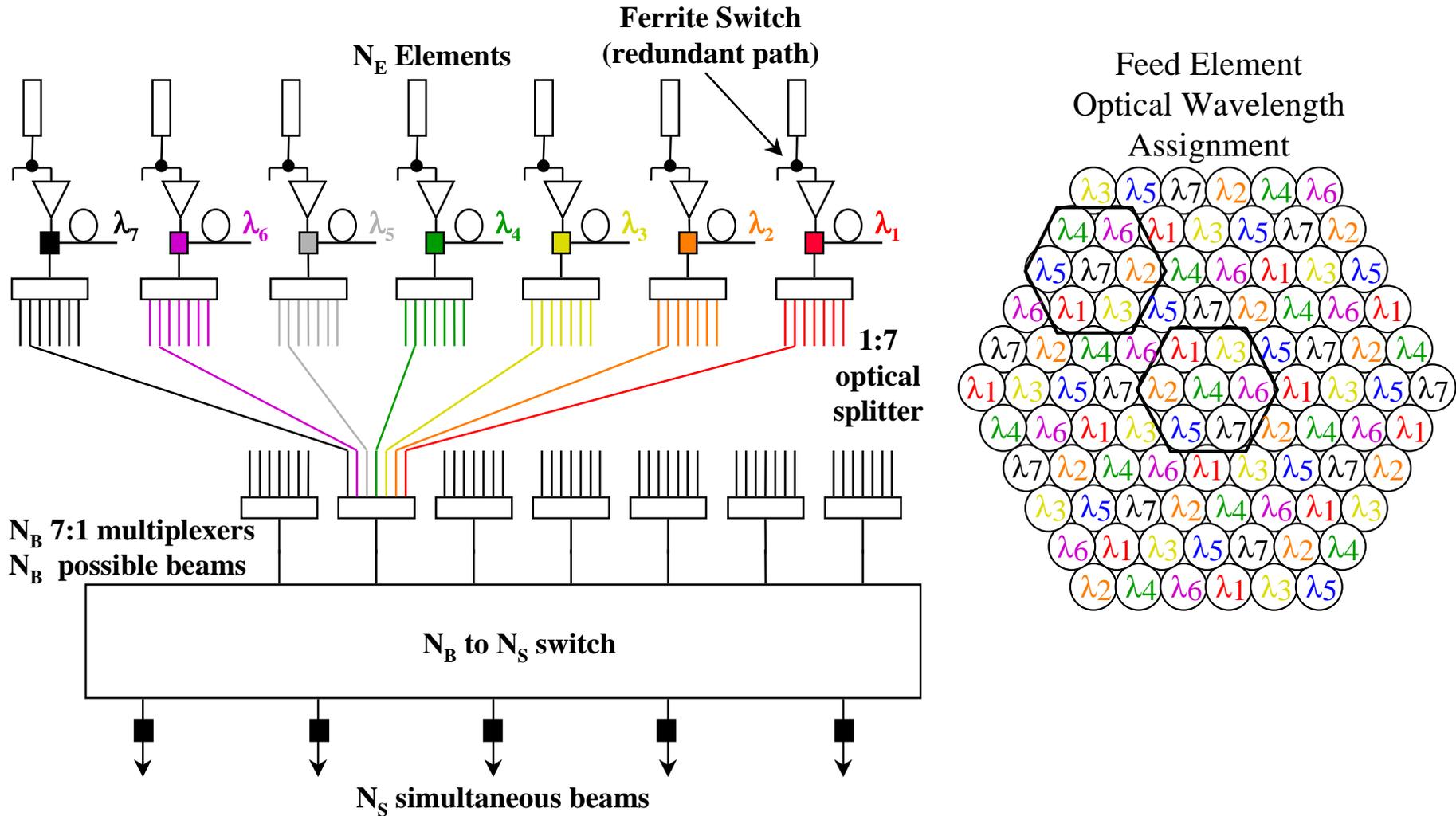


Spacebased Receive Antenna: Attractive for Geosynchronous SATCOM

- **Reduced element count relative to direct radiating array**
(331 vs. 547 elements)
- **Clusters of 7 elements form beams**
via phase and amplitude weights
- **Weighting is the same for all beams**
⇒ Significant advantage for combining,
switching, redundancy

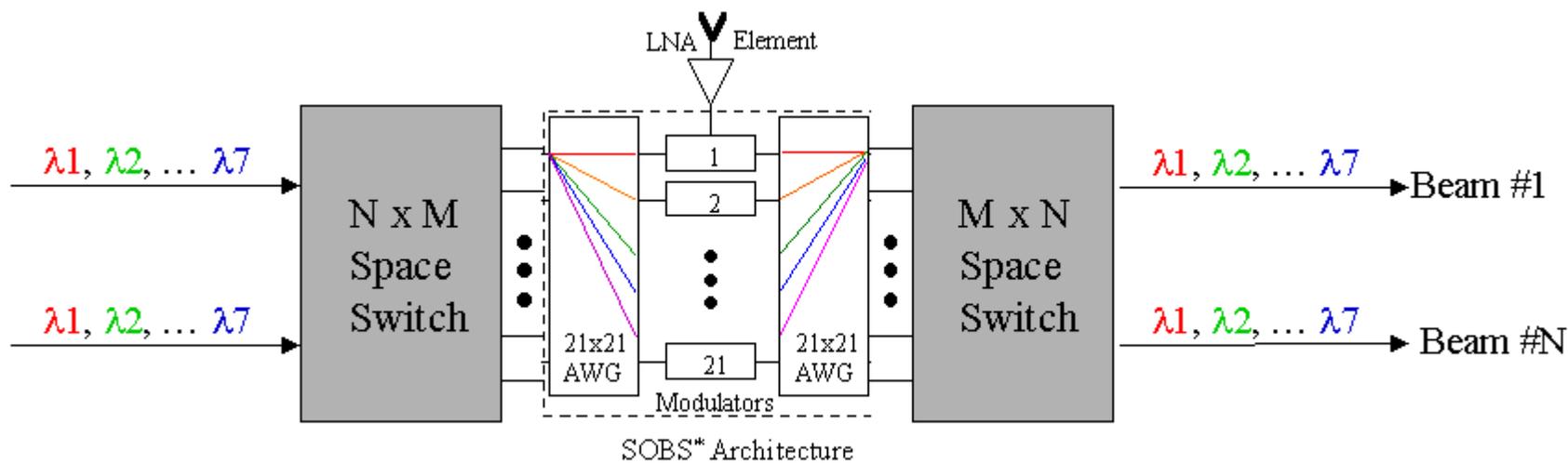


Array-Fed Reflector Beamformer with WDM Combining



Array-Feed Reflector Beamformer: WDM and Space Switching for Beam Selection

WDM routing techniques allow more efficient utilization of laser sources.



- Beamsteering may be accomplished through combination of space switching and wavelength tuning.
- Tunable, multi-wavelength, high-power, low-noise optical sources are an attractive technology.
- Integrated components (e.g., switches) needed for large-scale array packaging.

*Splitterless Optical Broadcast Switch, U.S. Patent # 5,870,216

Summary

- **WDM techniques can enhance / enable the capabilities of military systems**
- **WDM unlocks intrinsic optical bandwidth**
- **Increased bandwidth utilization enables realization of complex systems:**
 - **Large-scale phased-array / array-feed antennas**
 - **Data switching networks**
 - **Tunable delay lines**
 - **Signal processing**
- **Required technology development areas:**
 - **Novel system designs**
 - **Improved device performance**
 - **Modular integration techniques**