# Wavelength Division Multiplexing Techniques for Enabling Complex Military Systems

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# Overview

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- **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

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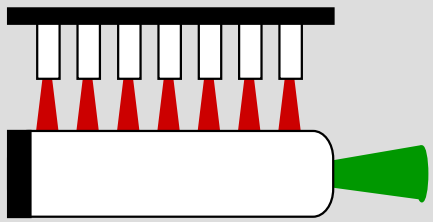
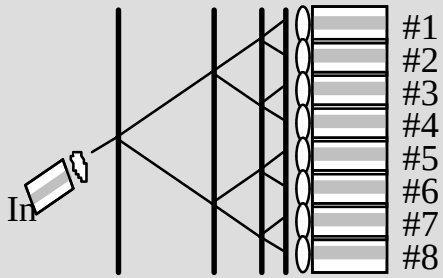
## Sources



**Candidates**
DFB, DBR,
Nd:YAG,
Ext. Cavity Tunable

**Issues/Drivers**
Amp/Phase Noise
Multi-λ

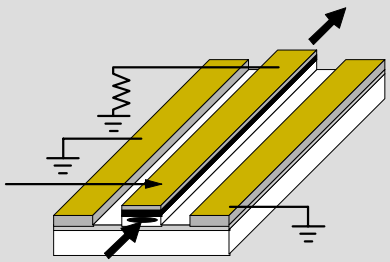
## Optical Switching




**Candidates**
Switched Gratings,
MEM's Digital Mirror,
Interferometric, Fiber
Optic Mechanical

**Issues/Drivers**
Insertion Loss, Speed,
Isolation

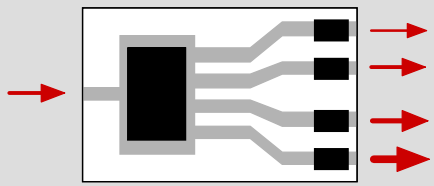
## Modulators



**Candidates**
EAM, Mach-Zehnder,
Fiber Based

**Issues/Drivers**
Large Bandwidth
High RF Gain
High Optical Power

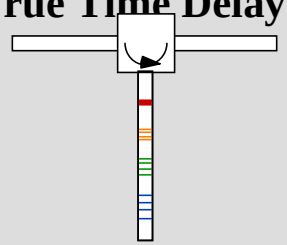
## Amplified Distribution



**Candidates**
Talbot, Er Doped WG, Er
Doped Fiber, Active Y Branch

**Issues/Drivers**
Splitting Losses => NF, Opt.
saturation, Dynamic range
System integration
Amplitude control

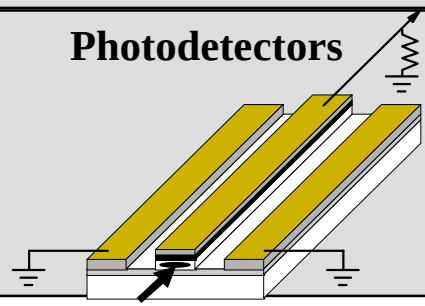
## True Time Delay



**Candidates**
Discrete/Chirped Braggs,
Opt. Switched, AWG

**Issues/Drivers**
Losses, Complexity,
Environment

## Photodetectors



**Candidates**
PIN, Waveguide, MSM

**Issues/Drivers**
High Power Handling &
Responsivity
Bandwidth, Efficiency

# Signal Combining: A Critical Photonic Beamforming Issue

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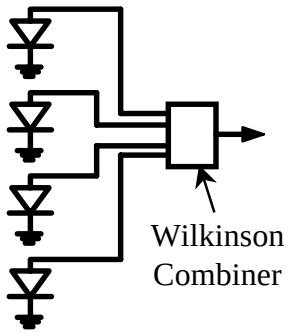
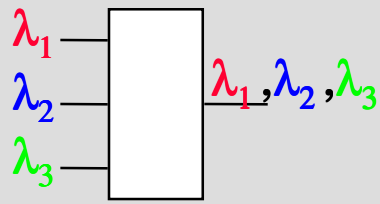
The need for low-loss combination of many elements while maintaining adequate amplitude control will require hybrid techniques.

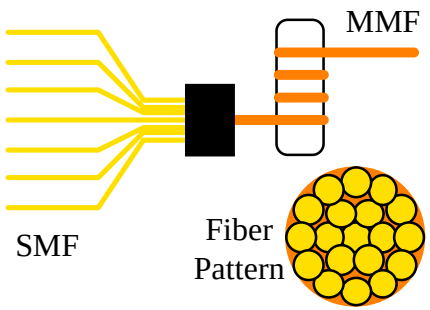
**Photodetector Array Matched RF combiner**



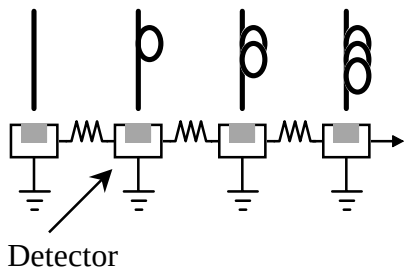

**WDM Multiplexing**




**Multi-Mode Fiber-Optic Combiner**




**Traveling Wave Discrete-Element Detector**



# Spacebased Receive Antenna: Attractive for Geosynchronous SATCOM

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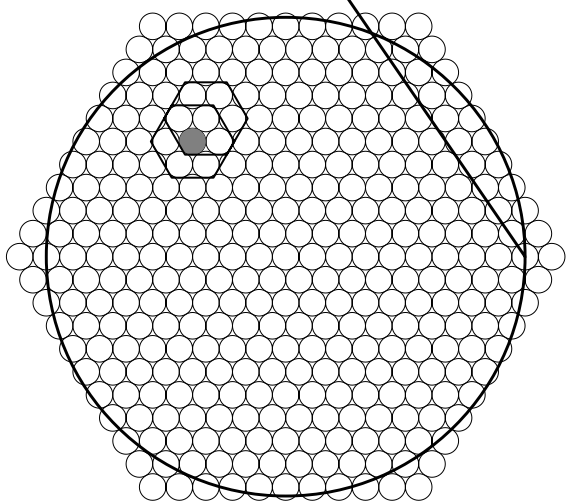
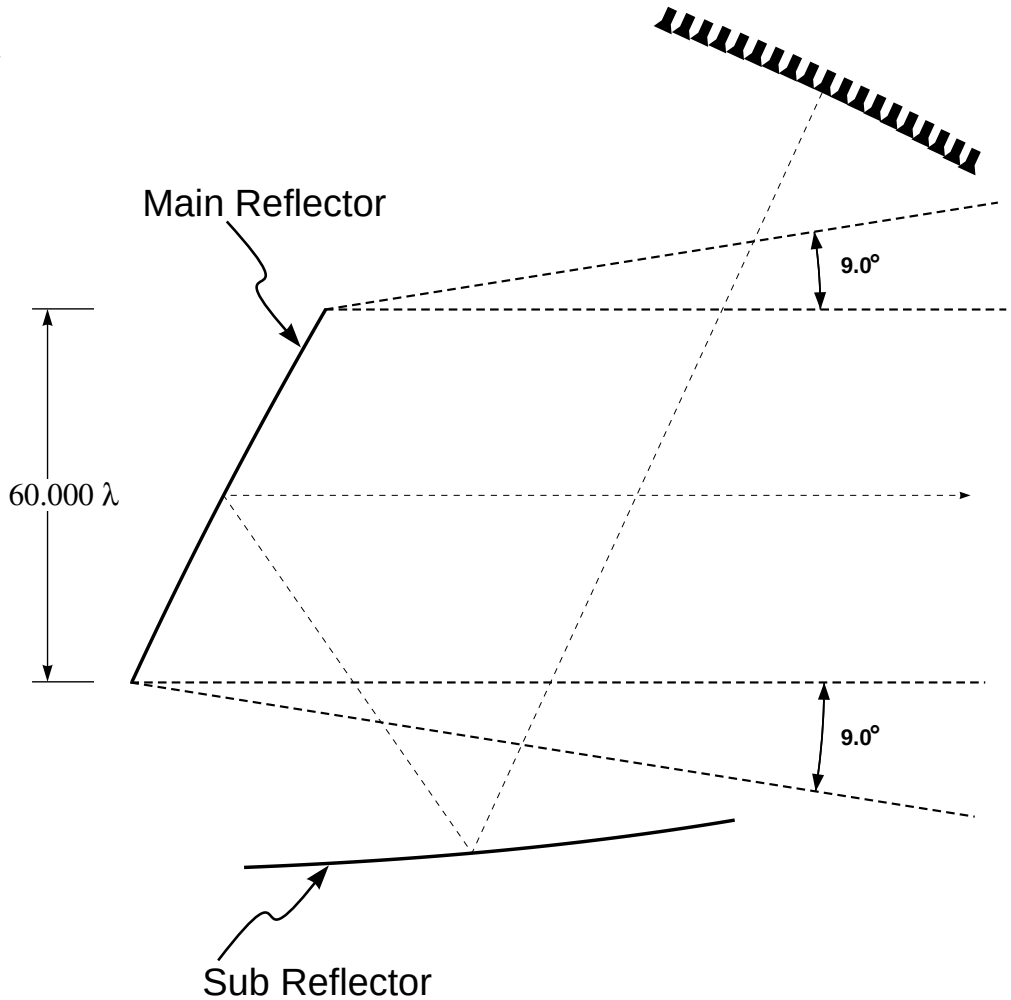
- **Reduced element count relative to direct radiating array**
  (331 vs. 547 elements)
- **Clusters of 7 elements form beams**
  via phase and amplitude weights
- **Weighting is the same for all beams**

⇒ Significant advantage for combining, switching, redundancy





# Array-Fed Reflector Beamformer with WDM Combining

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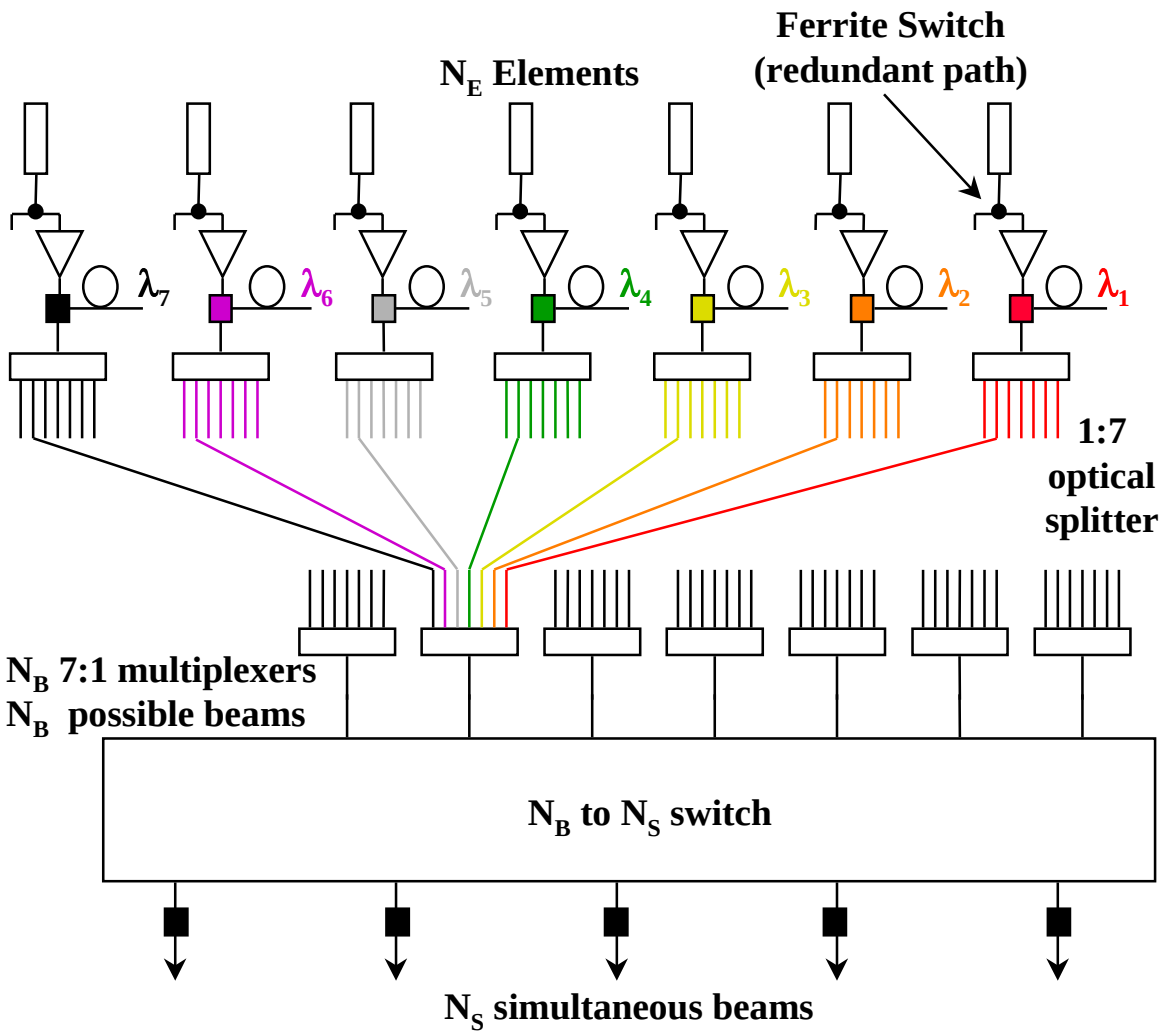


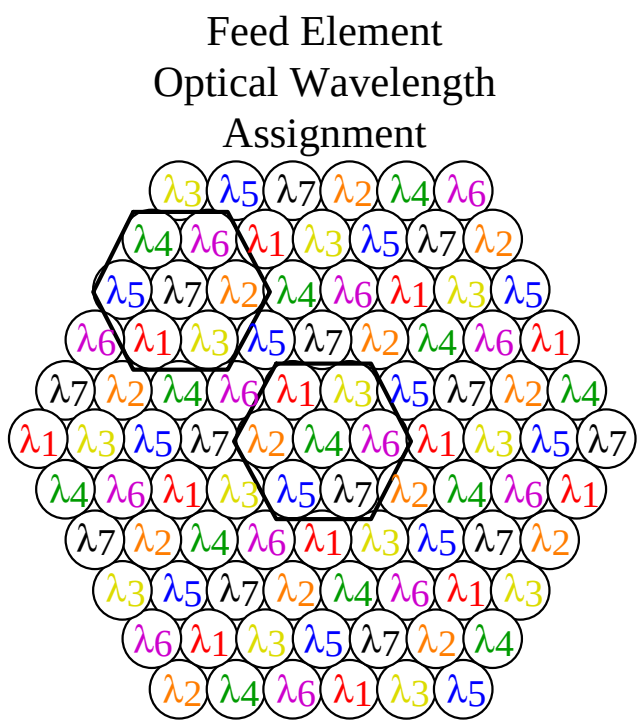

# Array-Feed Reflector Beamformer: WDM and Space Switching for Beam Selection

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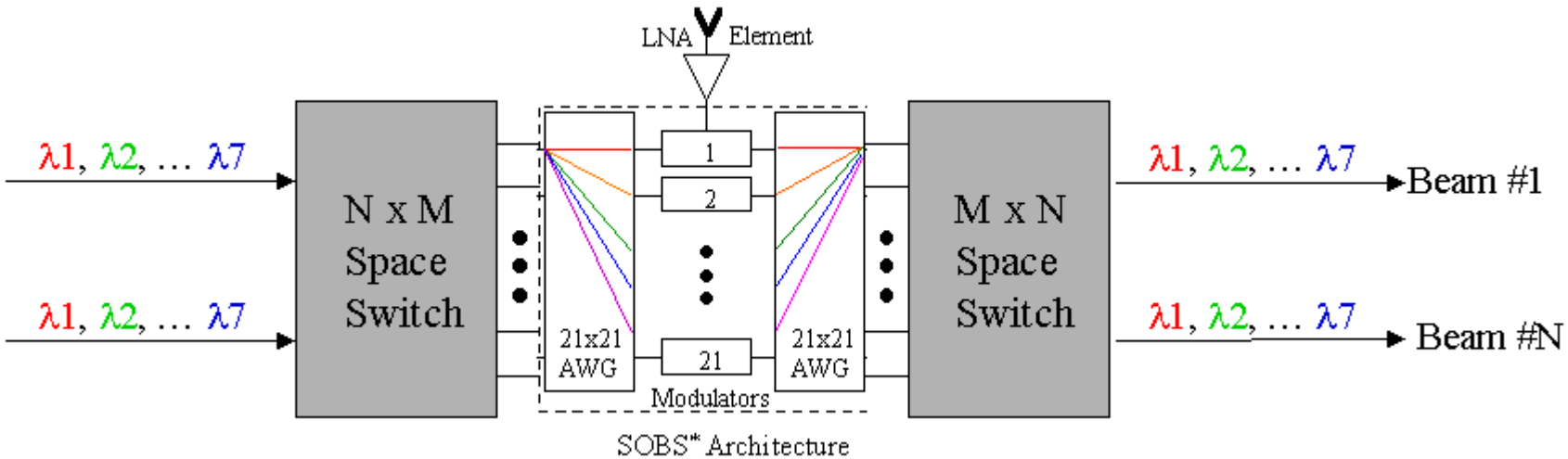
WDM routing techniques allow more efficient utilization of laser sources.




- 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

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- **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**