Wavelength Division Multiplexing Techniques for Enabling Complex Military Systems

Larry Lembo, James Leight, Brent Toland
TRW Space and Electronics Group, Redondo Beach, CA

DARPA/MTO Workshop on WDM for Military Platforms

April 18,2000

McLean, Virginia

The work described herein was sponsored in part by AFRL Rome Laboratory under Contract No. F30602-96-C-0026, James Nichter, COTR.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
18 APR 2000	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Wavelength Division Multiplexing Techniques for Enabling Complex Military Systems	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **TRW Space and Electronics Group Redondo Beach, CA**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
DARPA/MTO, WDM for Military Platforms Workshop held in McLean, VA on April 18-19, 2000, The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Overview

TRW

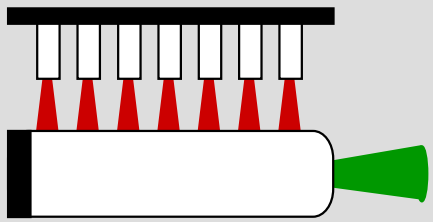
- **WDM techniques as enablers for complex military systems.**
- **Optical bandwidth is the key that unlocks the potential of photonics in military RF systems ---- low transmission loss of fiber does not carry the same weight as for commercial systems.**
- **Archetype: Large-scale phased-array antennas**
  - **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

TRW

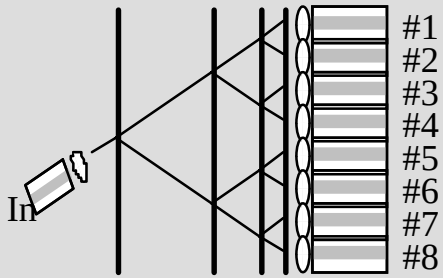
Sources



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

Issues/Drivers
Amp/Phase Noise
Multi-λ

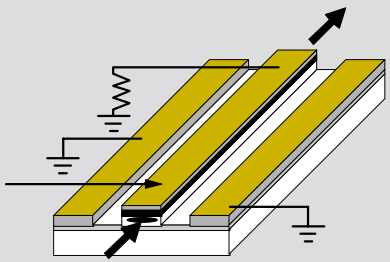
Optical Switching



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

Issues/Drivers
Insertion Loss, Speed,
Isolation

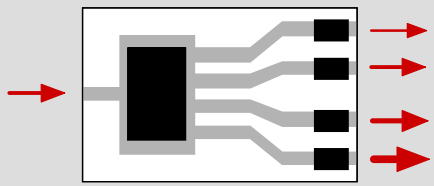
Modulators



Candidates
EAM, Mach-Zehnder,
Fiber Based

Issues/Drivers
Large Bandwidth
High RF Gain
High Optical Power

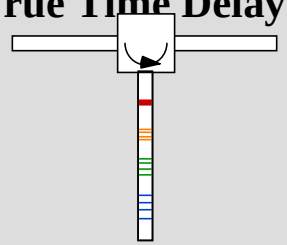
Amplified Distribution



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

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

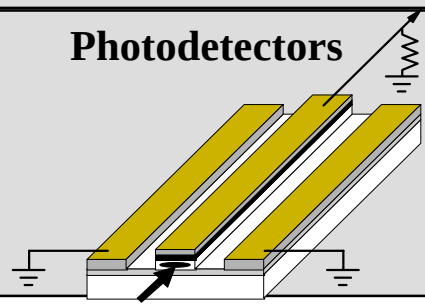
True Time Delay



Candidates
Discrete/Chirped Braggs,
Opt. Switched, AWG

Issues/Drivers
Losses, Complexity,
Environment

Photodetectors



Candidates
PIN, Waveguide, MSM

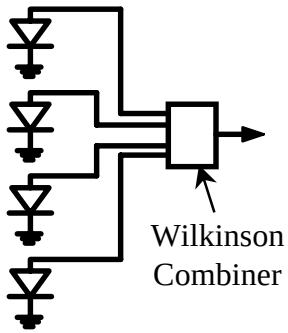
Issues/Drivers
High Power Handling &
Responsivity
Bandwidth, Efficiency

Signal Combining: A Critical Photonic Beamforming Issue

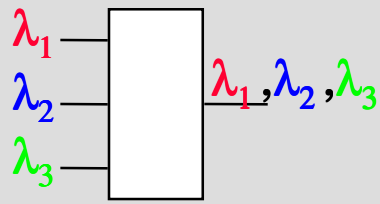
TRW

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

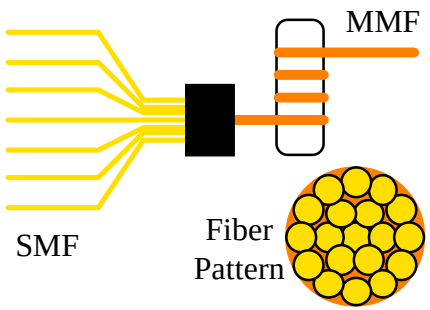
Photodetector Array Matched RF combiner



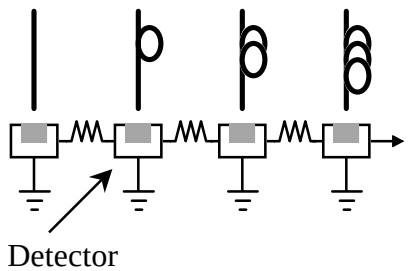
WDM Multiplexing



Multi-Mode Fiber-Optic Combiner



Traveling Wave Discrete-Element Detector

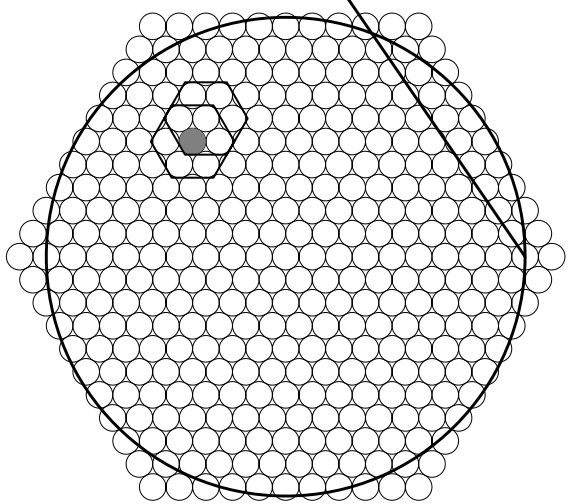


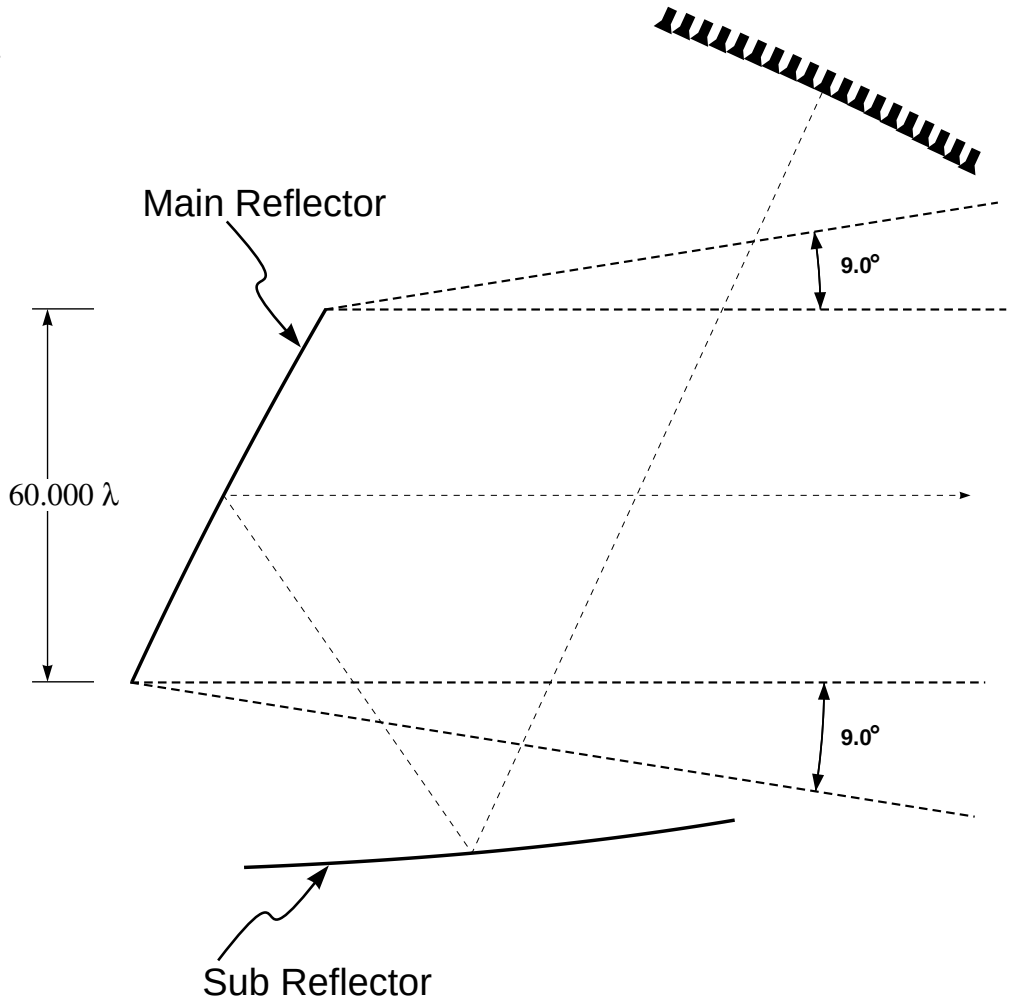
Spacebased Receive Antenna: Attractive for Geosynchronous SATCOM

TRW

- **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**

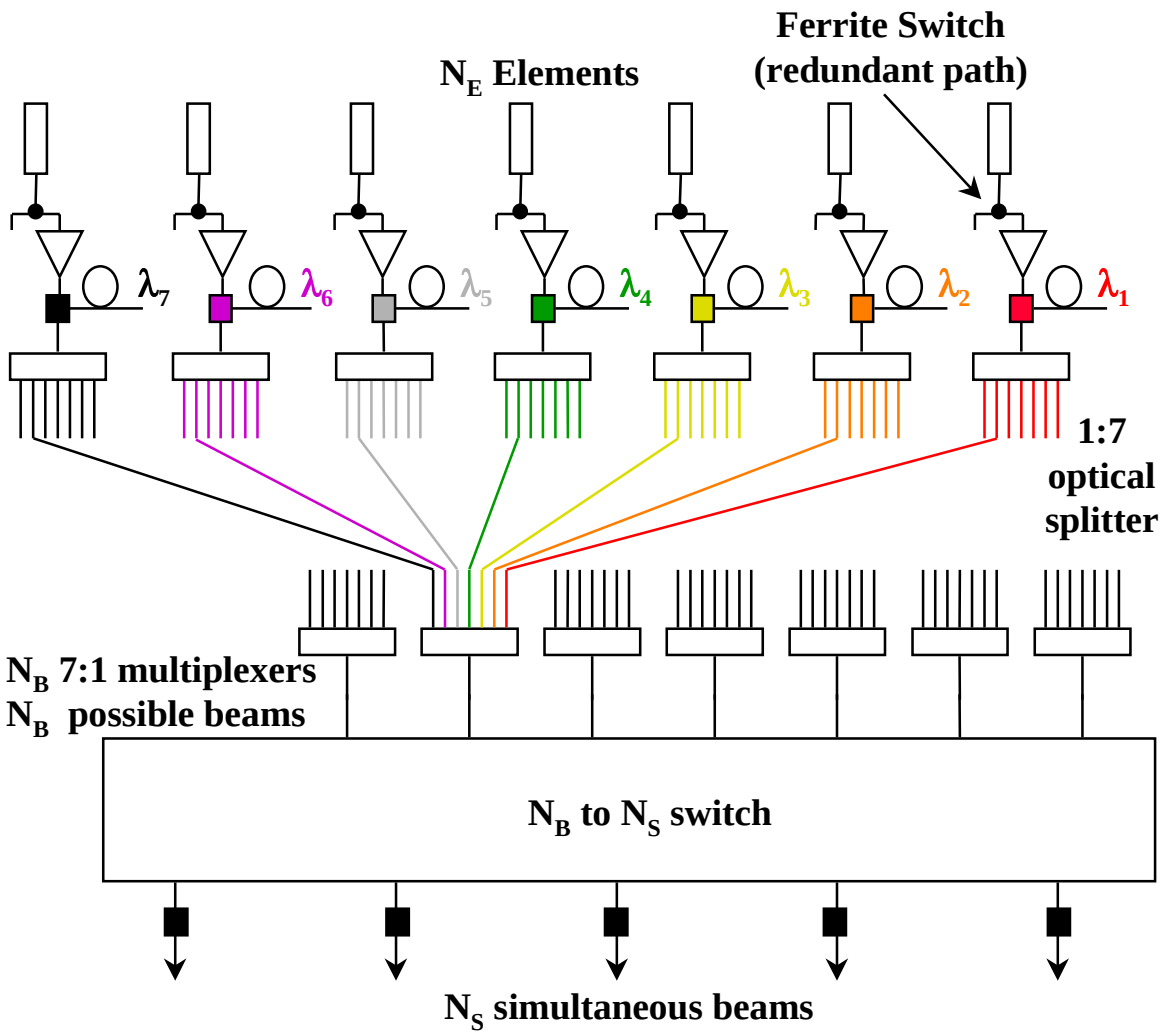
⇒ Significant advantage for combining, switching, redundancy

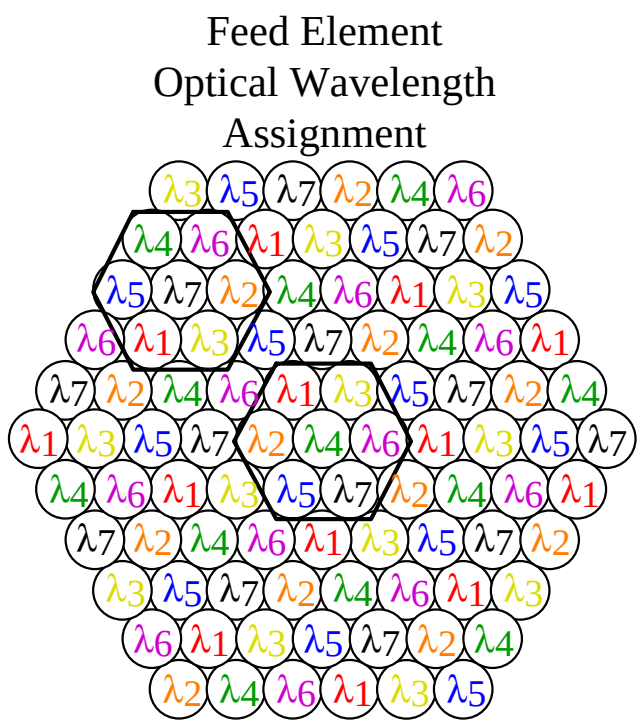




Array-Fed Reflector Beamformer with WDM Combining

TRW

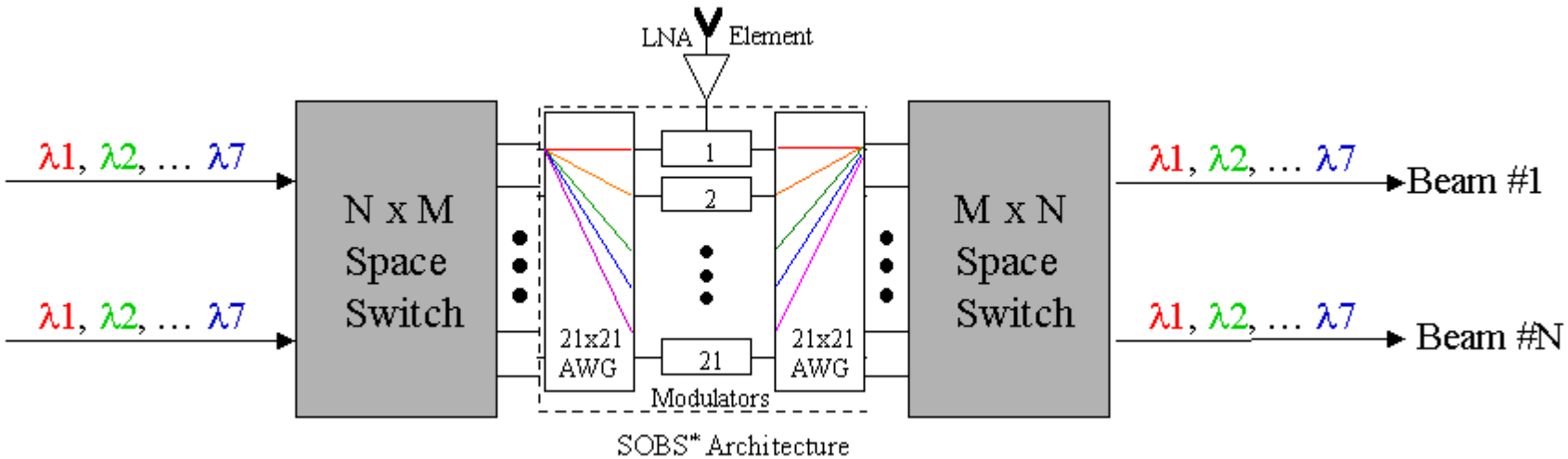




Array-Feed Reflector Beamformer: WDM and Space Switching for Beam Selection

TRW

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

TRW

- **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**