THE SHUNTED RING FAULT TOLERANT NETWORK PHYSICAL LAYER

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FIBER OPTIC RING TOPOLOGY

ADVANTAGES

- BEST SUITED TO OPTICS
- LARGE NUMBER OF TERMINALS POSSIBLE
- COMFORTABLE POWER BUDGET
- LOW SENSITIVITY AND DYNAMIC RANGE RECEIVERS
- LOW COST

ISSUES

- NODE AND CABLE FAILURES
- REQUIRES BYPASS MECHANISM
- POWER BUDGET FOR SUCCESSIVE BYPASSES
- DUAL COUNTER ROTATING TOPOLOGY LIMITATIONS
- DATA LOSS AND RESTORATION TIME
- WDM “ALL OPTICAL” IMPLEMENTATION

BYPASS SWITCH SPEED = LOST DATA

1 MILISECOND = 1,000 BITS @ 1MBPS
1 MILISECOND = 1,000,000 BITS @ 1GBPS
1 MILISECOND = 10,000,000 BITS @ 10GBPS

1 MICROSECOND = 1 BIT @ 1 MBPS
1 MICROSECOND = 1000 BITS @ 1GBPS
1 MICROSECEND = 10000 BITS @ 10GBPS

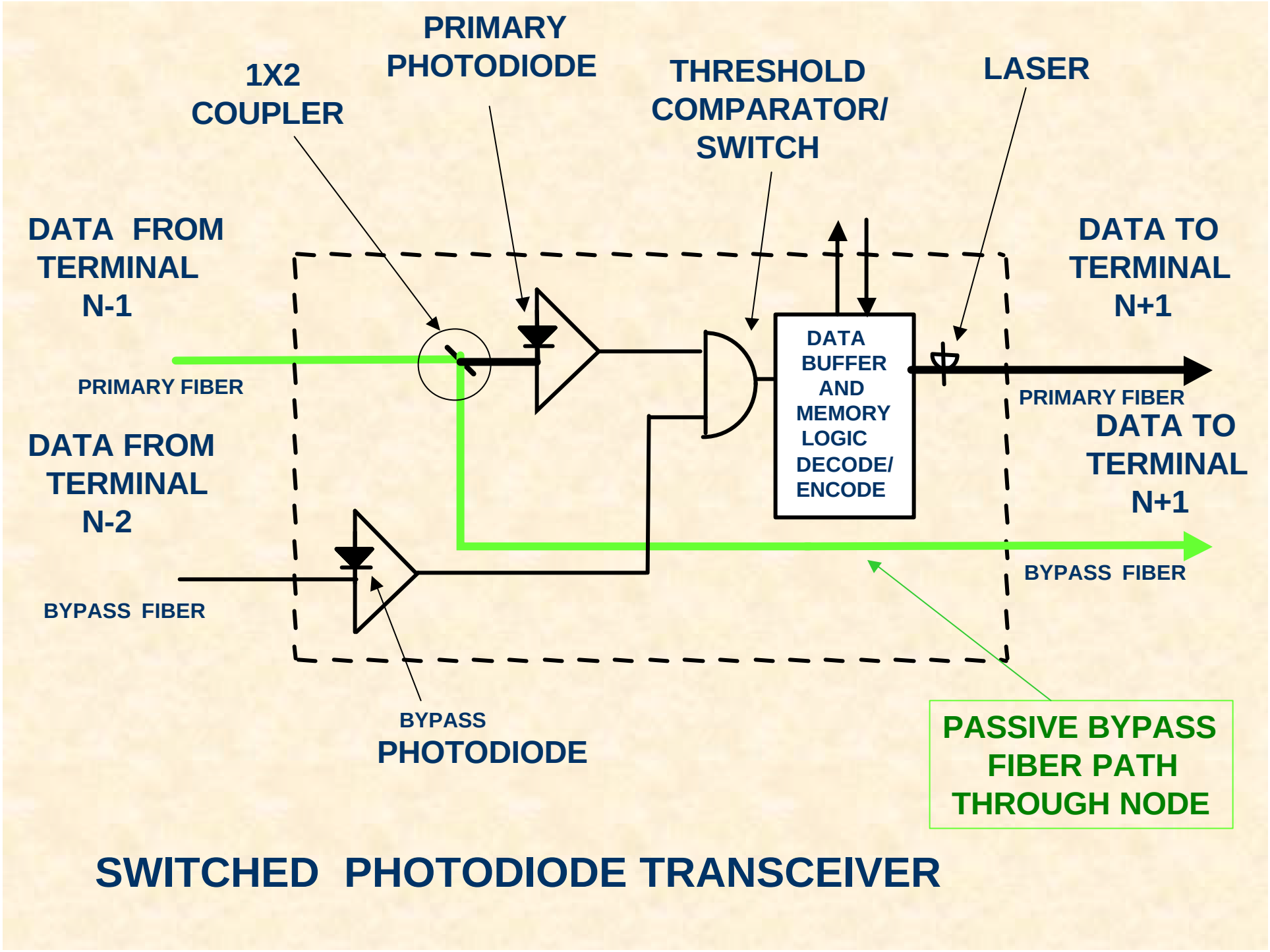
1 NANOSECOND = 1 BITS @ 1GBPS
1 NANOSECOND = 10 BITS @ 10GBPS

As Network Speeds Increase, Slow Bypass Switches Can Cause Significant Loss of Data During Reconfiguration

Speed and long Term Reliability of Electro-Mechanical Bypass Switches Can Adversely Impact Network Data Availability

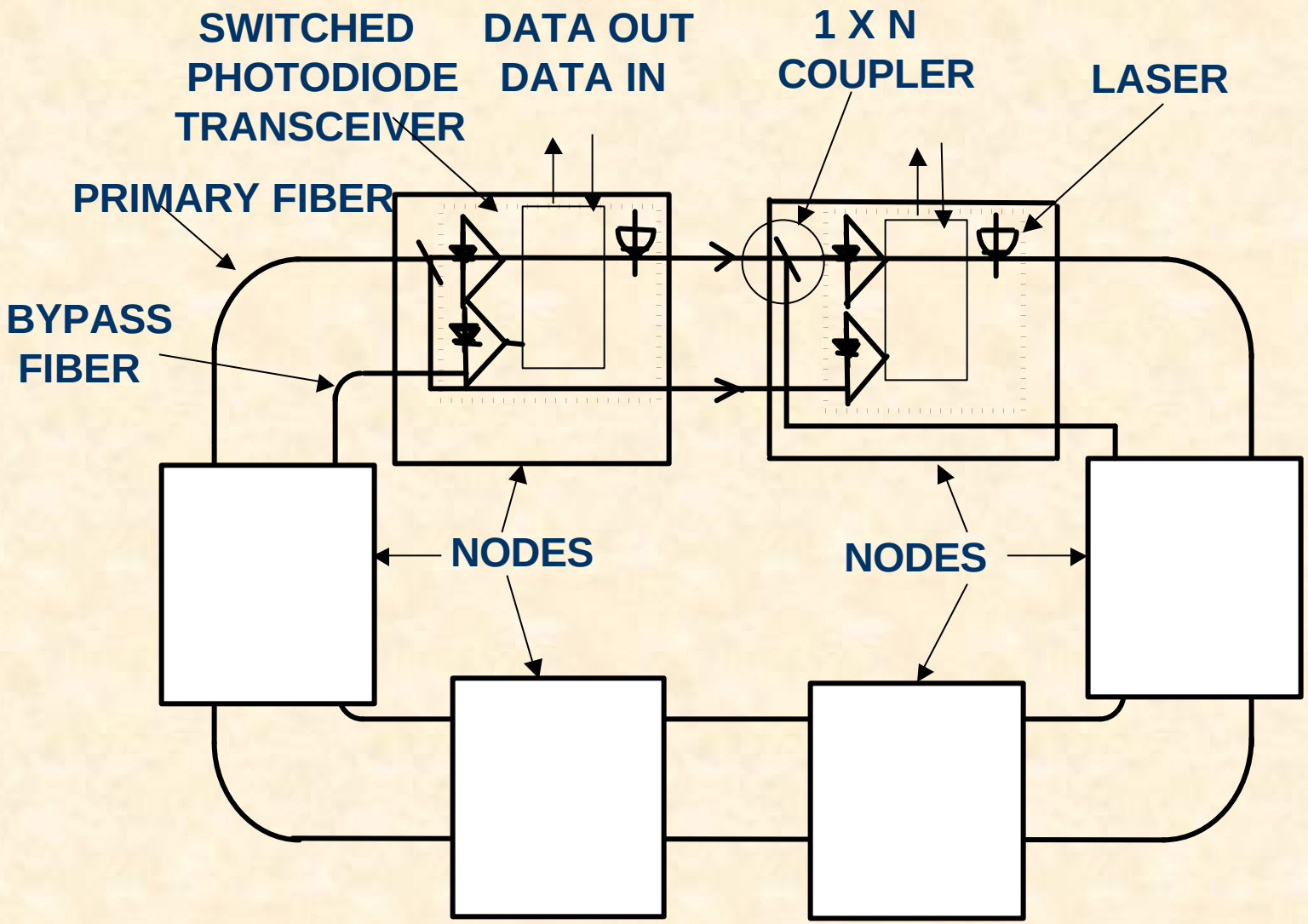
SHUNTED RING TOPOLOGY

- **The Shunted Ring Topology uses Passive Optical Fiber to Bypass Terminal Faults and high Speed Electronic or Optical Switching to Reconfigure the Network.**
- **Shunted Ring Networks can Eliminate or Minimize Data Loss without Disruption of Service With Reduced Reconfiguration Time**
- **Shunted Ring Networks Provide Fault Prediction, Detection, Isolation and Circumvention with Enormous Life Cycle Cost Savings.**
- **Shunted Ring Networks can Reduce Latency and Enhance Performance through Feedforward Options.**



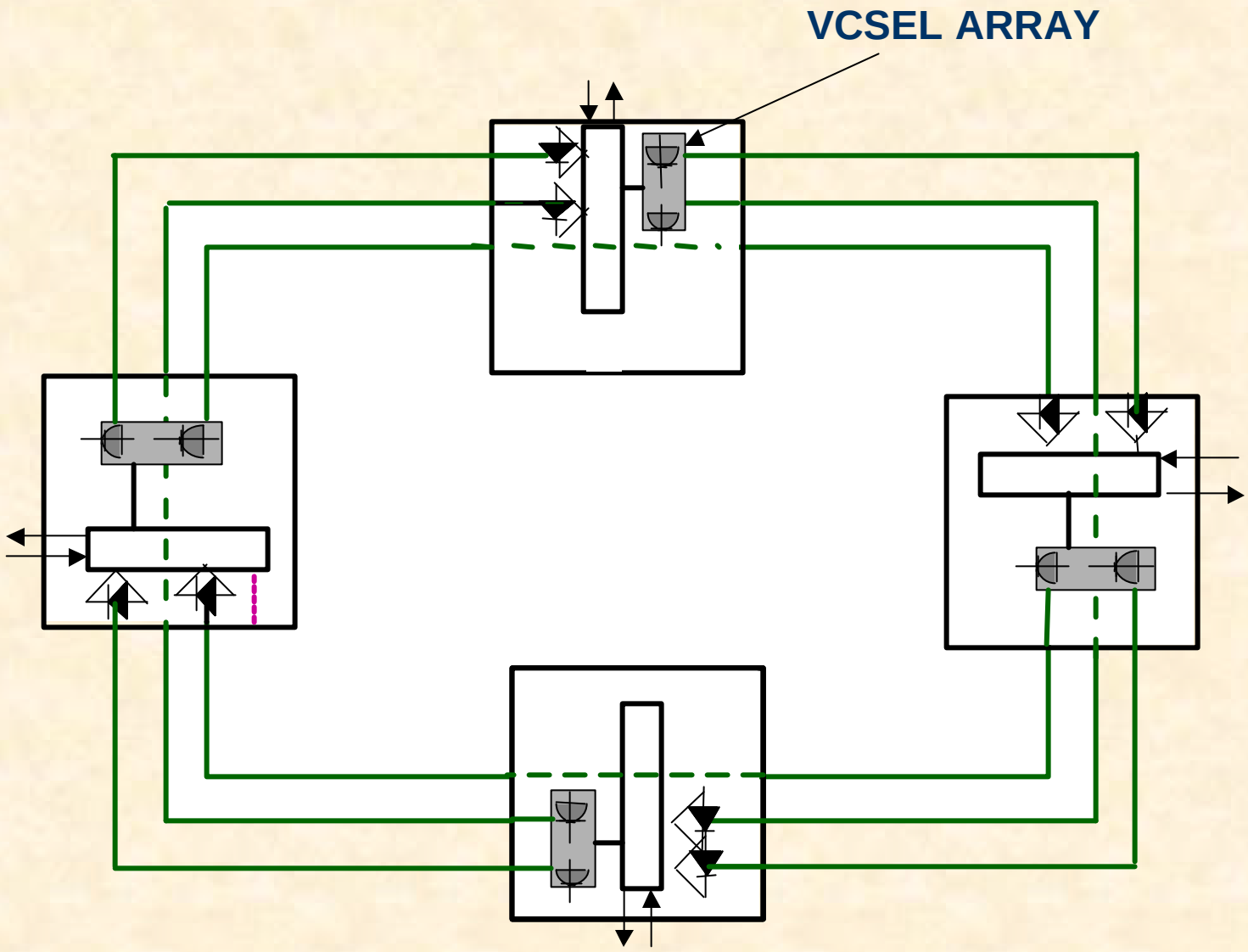
SWITCHED PHOTODIODE TRANSCEIVER

- DATA ARRIVES AT N+1 NODE VIA BYPASS NODE PRIOR TO ARRIVAL ON PRIMARY FIBER DUE TO REPEATER DELAY AT N^{TH} NODE
- THIS DATA CAN BE STORED IN A BUFFER (OR OPTICAL DELAY LINE) AT THE N+1 NODE
- IF THE N^{TH} NODE FAILS, THE BUFFERED DATA STREAM IS SWITCHED INTO THE N+1 ACTIVE CIRCUIT FOR TERMINAL USE OR REPEATERED TRANSMISSION
- THE FAULT DETECTION OCCURS DOWNSTREAM FROM THE ACTUAL FAULT
- PROVIDES A BUILT-IN- TEST MECHANISM AT THE PHYSICAL LAYER BASED ON DESIRED CRITERIA



SHUNTED RING NETWORK TOPOLOGY

Bypasses Node Failure - Including Power Loss At Node

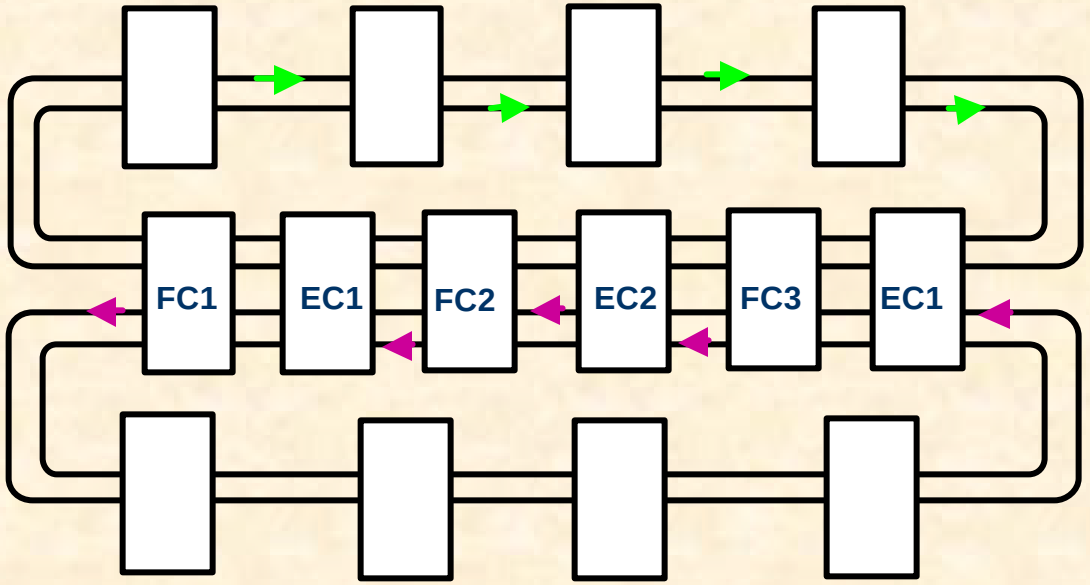


ALTERNATE “SKIP-A-NODE” IMPLEMENTATION

VCSEL Array Replaces Coupler

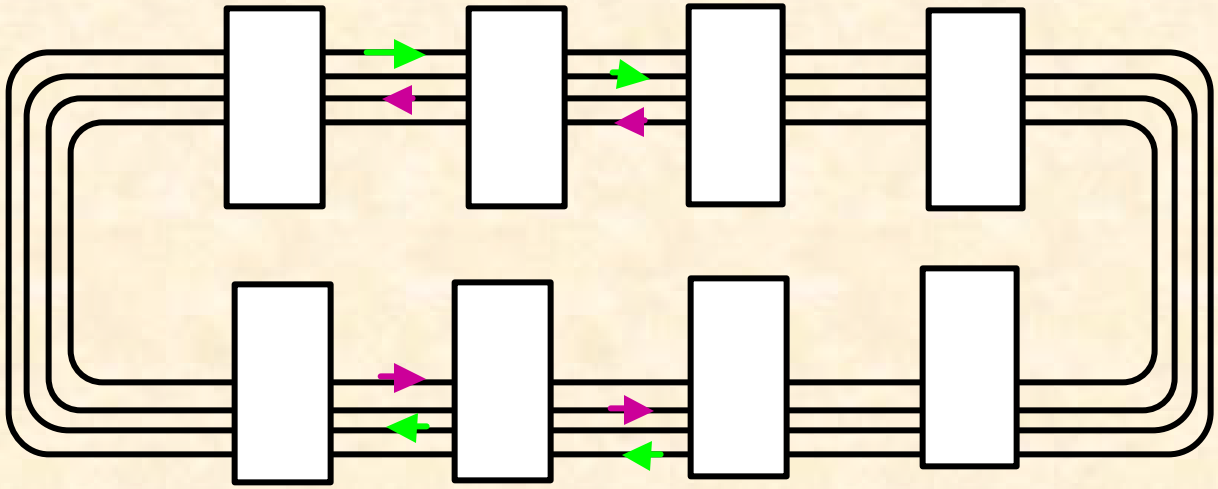
COUNTER-ROTATING SKIP-A-NODE RINGS

REDUNDANT CABLES

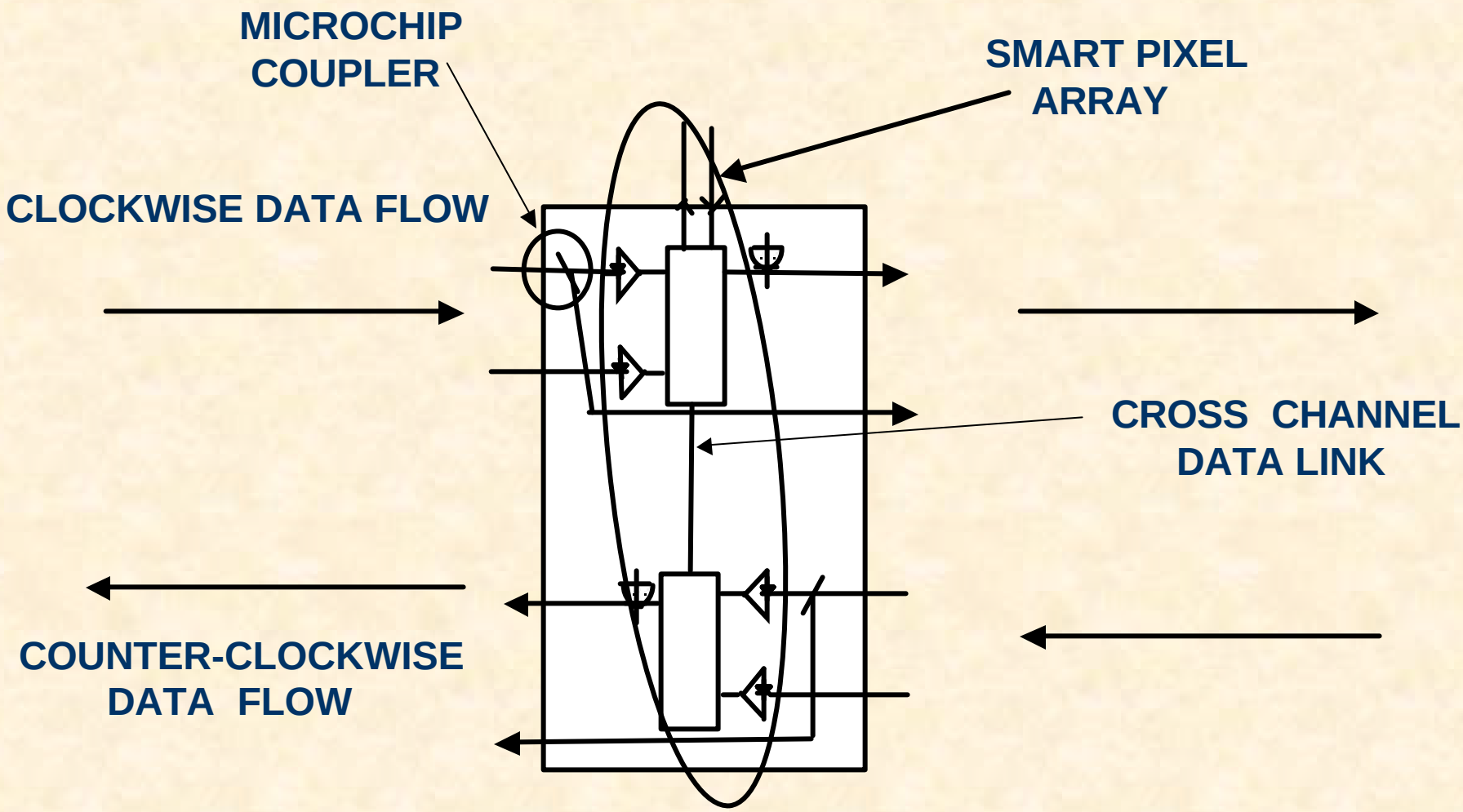


FC = FLIGHT CONTROL COMPUTER
EC =ENGINE CONTROL COMPUTER

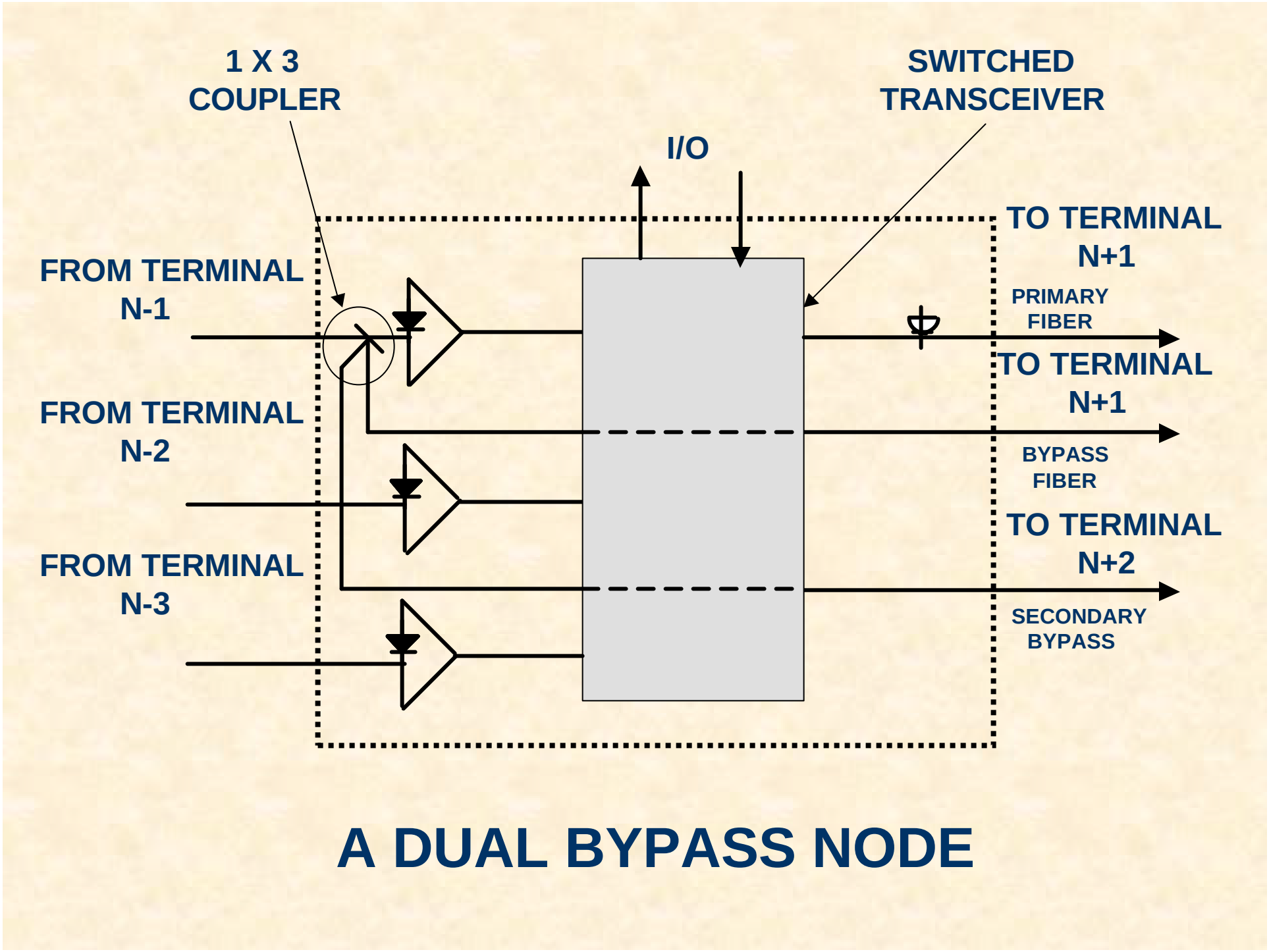
SINGLE CABLE



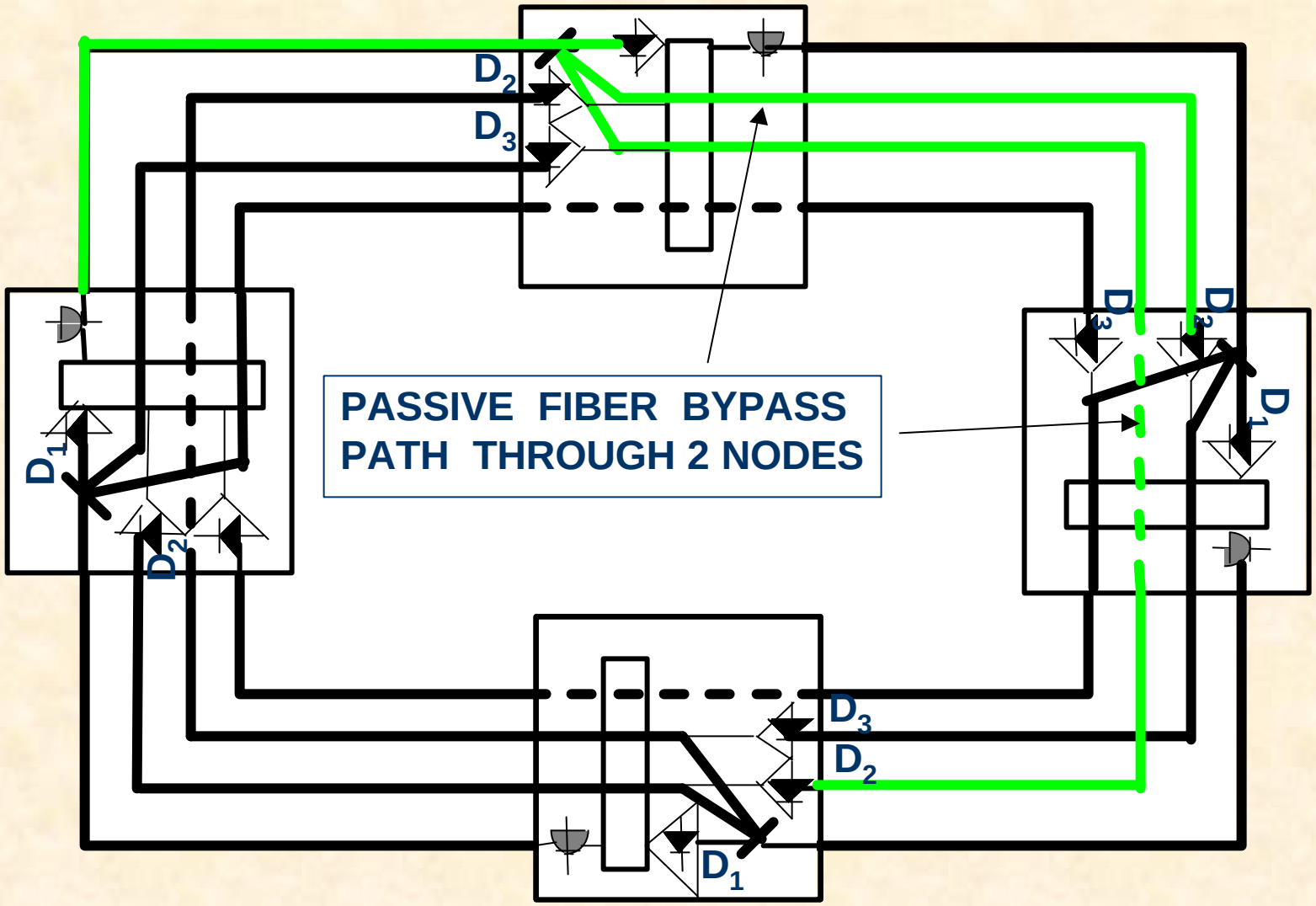
Bi-Directional Ring “Skip-A-Node” Ring



A SINGLE “SMART PIXEL” CHIP PROVIDES NETWORK RECONFIGURATION AND BYPASS CONTROL



A DUAL BYPASS NODE

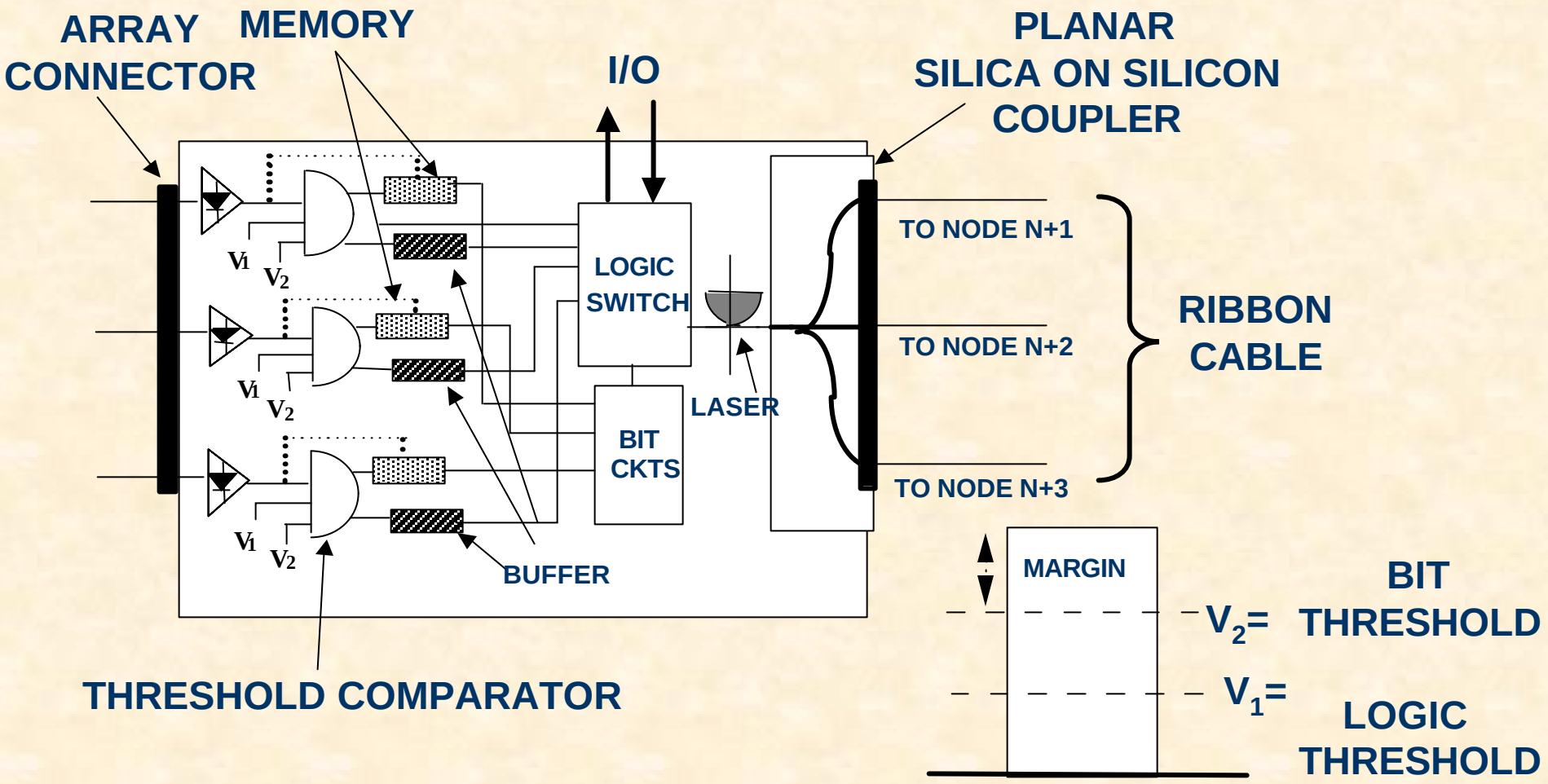


DUAL BYPASS RING TOPOLOGY

Worse Case Loss Budget ~ 1XN Star Topology Budget

- **Provides a Circuit-switched Subnet in a Packet Ring**
- **Provides a Switch Selectable Broadcast Option**

NOTIONAL "SMART" TRANSCEIVER



FAULT DETECTION AND PREDICTION

TERMINAL	D_1	D_2	D_3
T_{N-1}			
T_N	LOW		
T_{N+1}		LOW	
T_{N+2}			LOW

SIGNAL LEVEL

LASER DEGRADING

TERMINAL	D_1	D_2	D_3
T_{N-1}			
T_N	OFF		
T_{N+1}		OFF	
T_{N+2}			OFF

SIGNAL LEVEL

N-1 LASER FAILED

TERMINAL	D_1	D_2	D_3
T_{N-1}			
T_N	LOW		
T_{N+1}		NORMAL	
T_{N+2}			NORMAL

SIGNAL LEVEL

PRIMARY LINK N-1 to N DEGRADING

TERMINAL	D_1	D_2	D_3
T_{N-1}			
T_N	OFF		
T_{N+1}		NORMAL	
T_{N+2}			NORMAL

SIGNAL LEVEL

BROKEN PRIMARY FIBER N-1 TO N

TERMINAL	D_1	D_2	D_3
T_{N-1}	NORMAL		
T_N		OFF	
T_{N+1}			OFF
T_{N+2}			

SIGNAL LEVEL

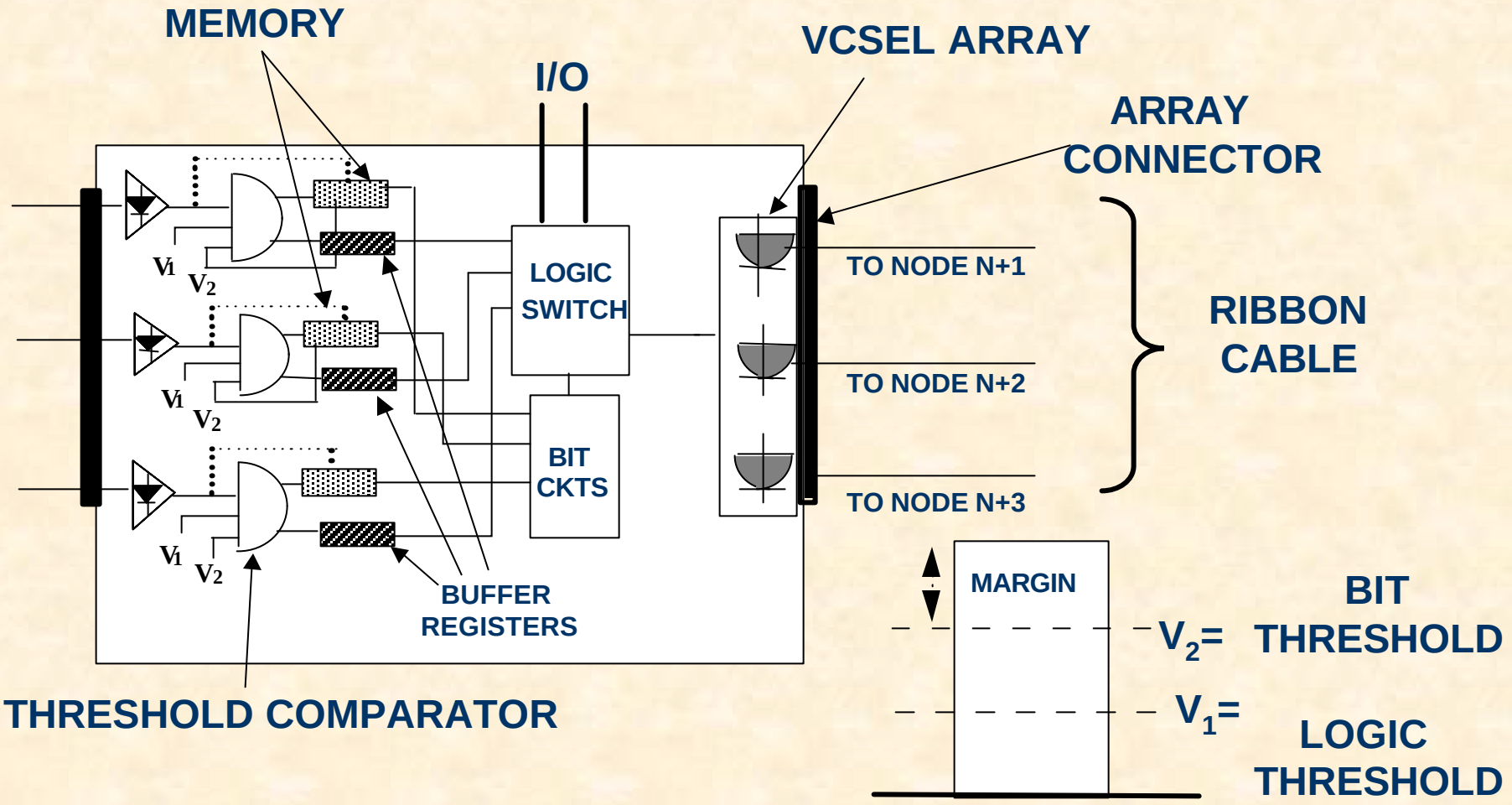
BROKEN PRIMARY FIBER N-2 TO N-1

TERMINAL	D_1	D_2	D_3
T_{N-1}			
T_N	NORMAL	LOW	
T_{N+1}			NORMAL
T_{N+2}			

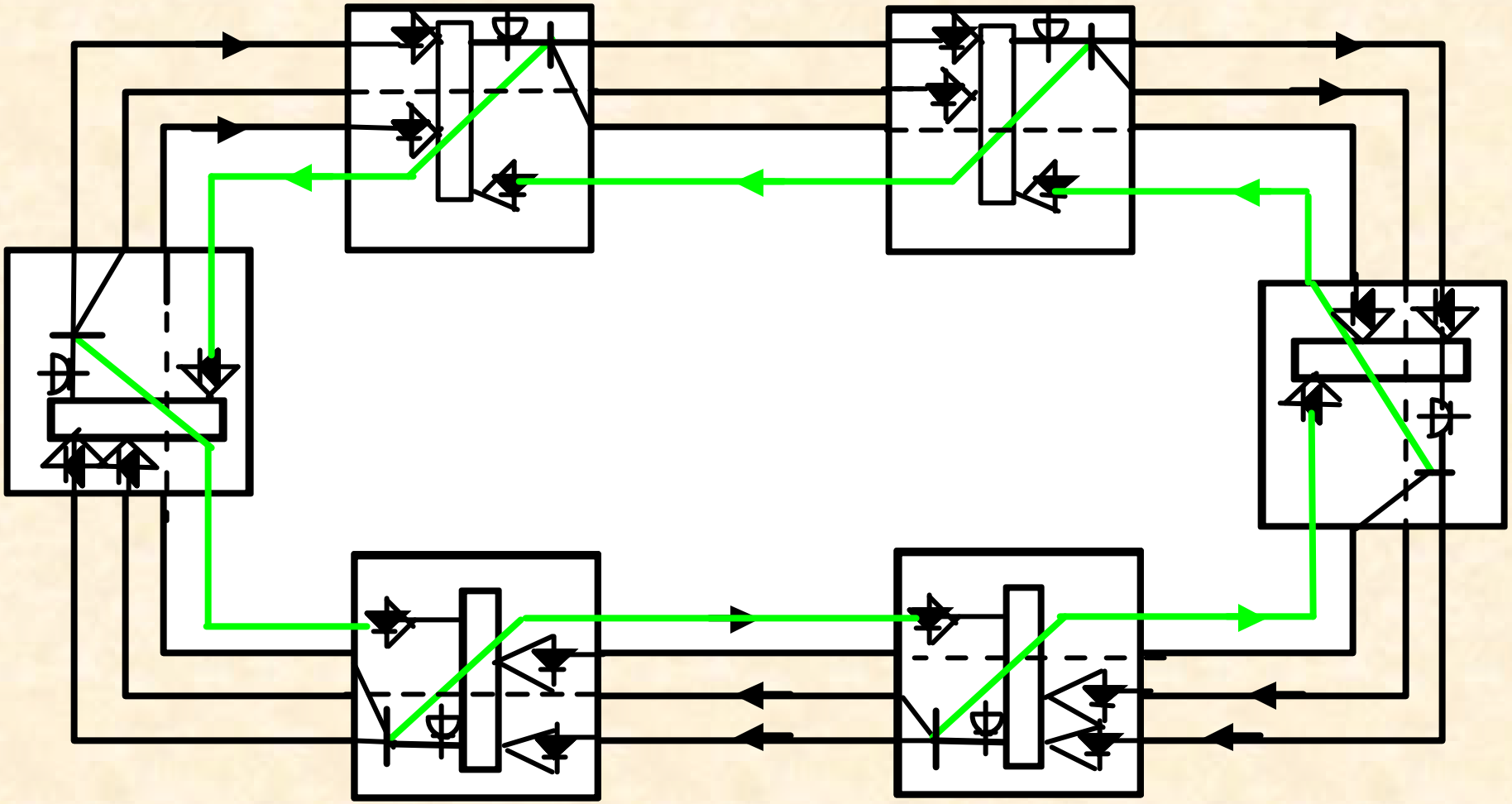
SIGNAL LEVEL

SECONDARY LINK DEGRADING N-1 TO N

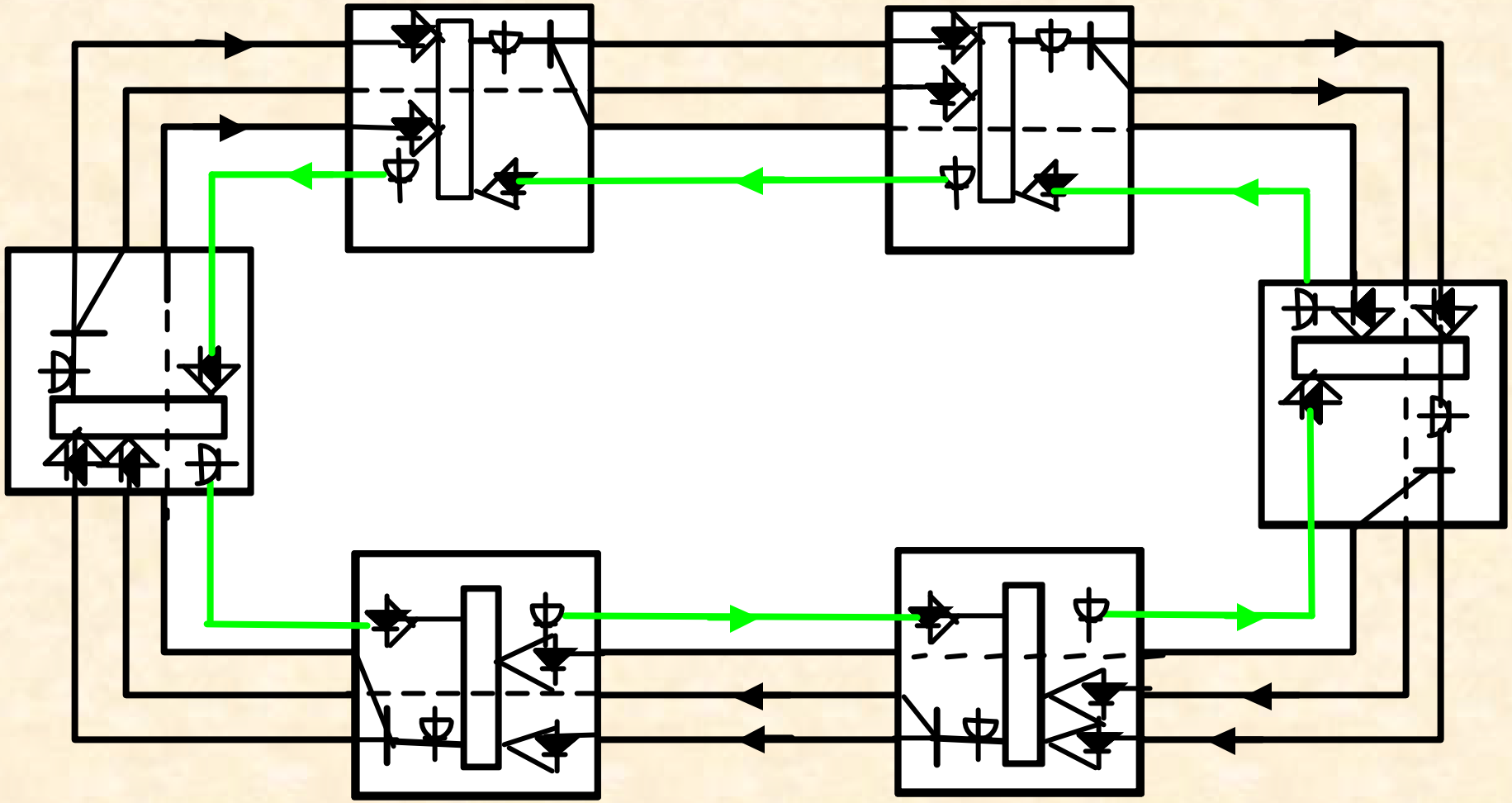
NOTIONAL "SMART" TRANSCEIVER



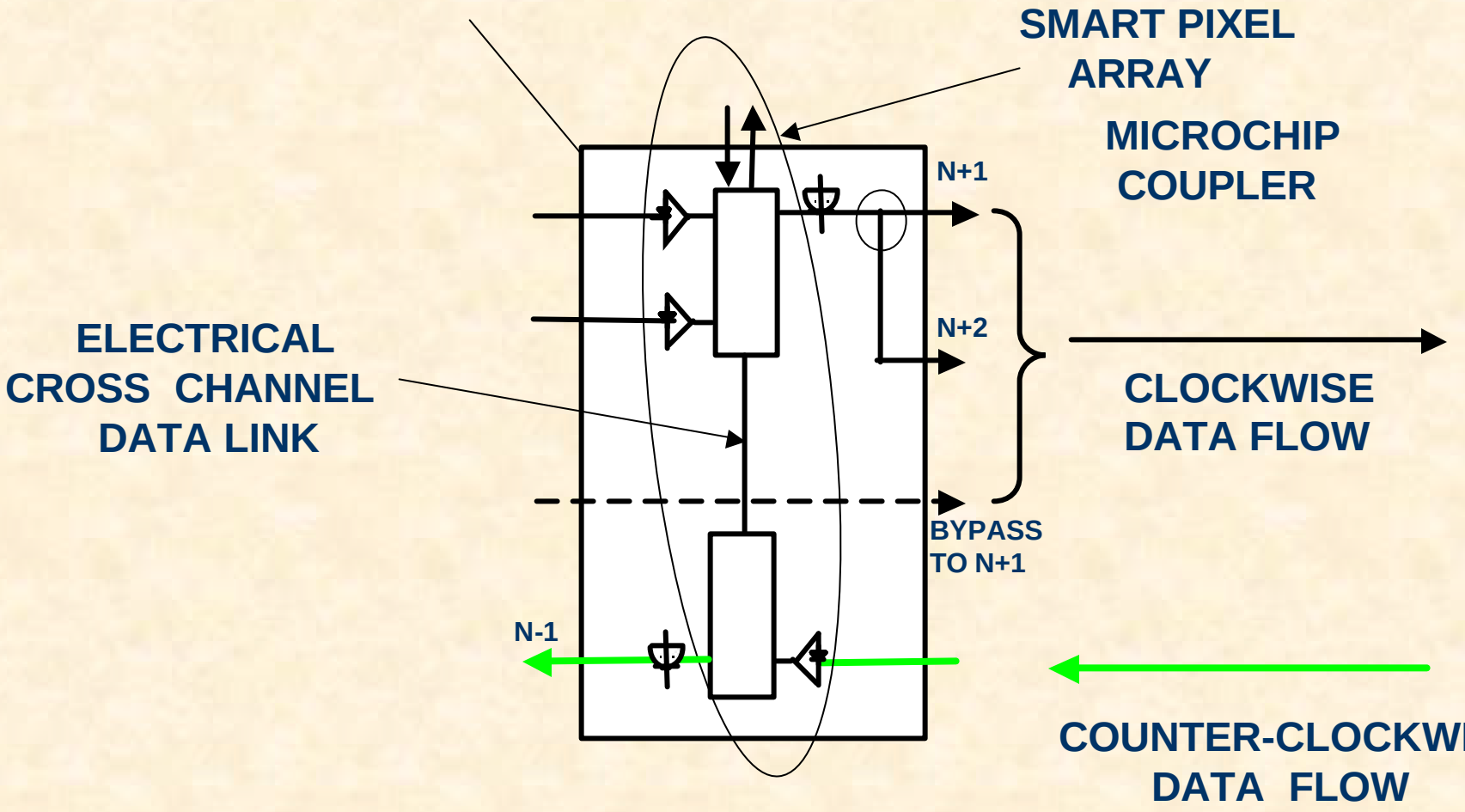
COUNTER-ROTATING RINGS
Single Bypass - One Source



Bi-Directional Single Bypass Ring

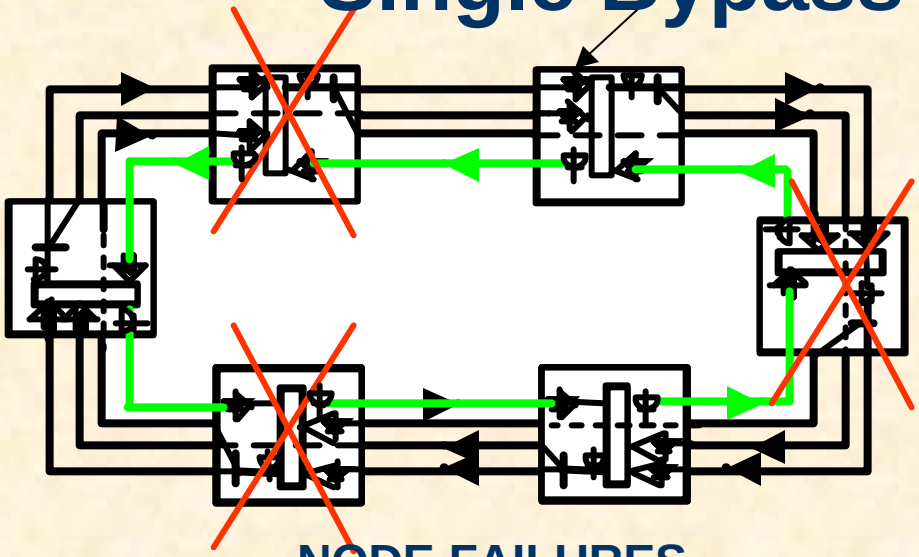


Bi-Directional “Skip-a-Node”Ring

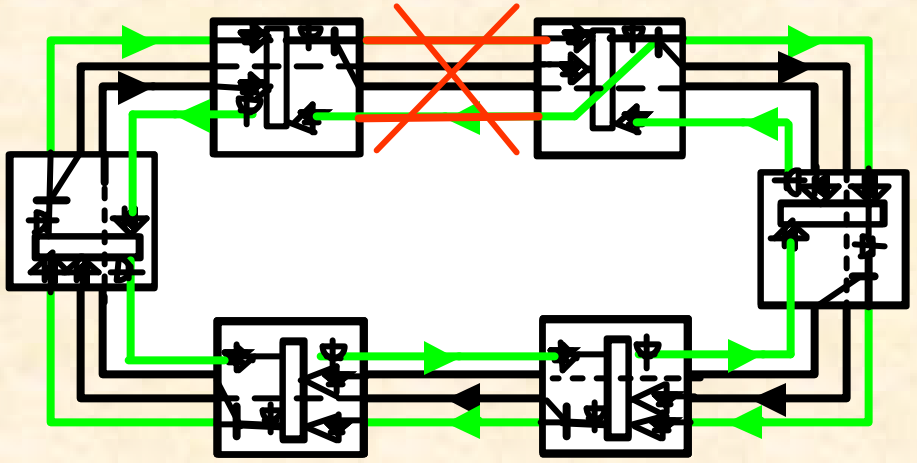


A SINGLE “SMART PIXEL” CHIP PROVIDES NETWORK RECONFIGURATION AND BYPASS CONTROL

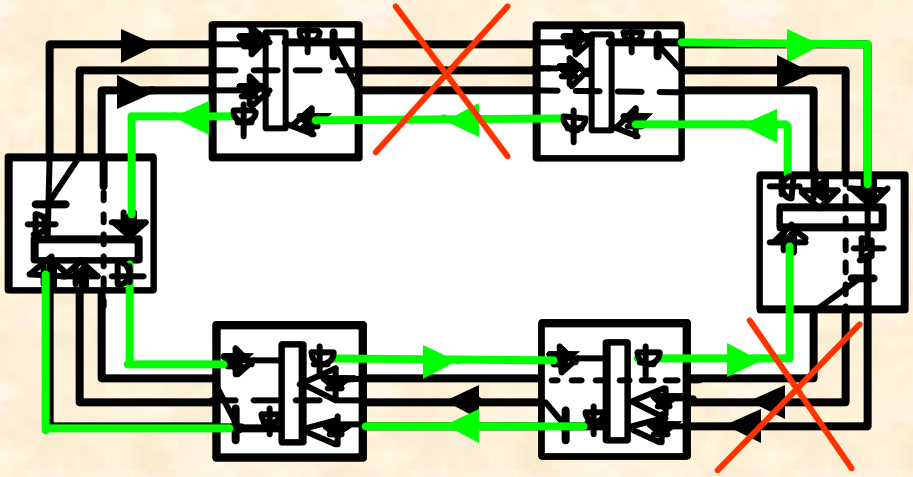
COUNTER-ROTATING RINGS
Single Bypass - Two Sources



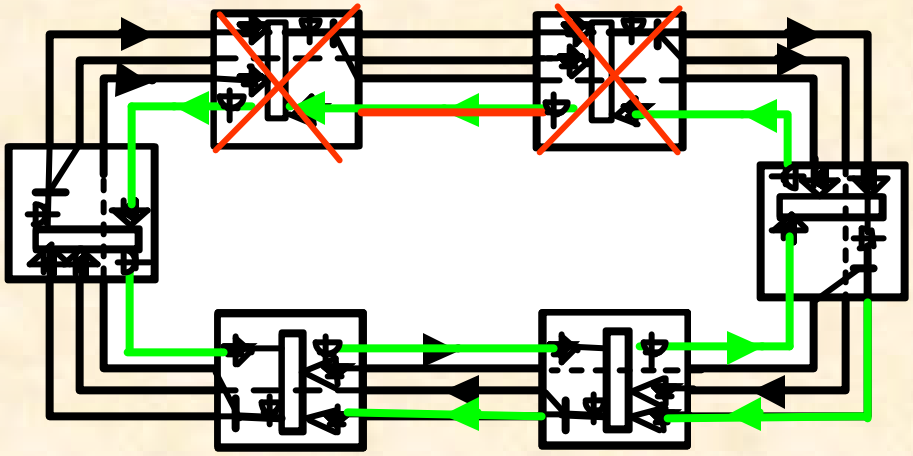
NODE FAILURES
AUTO-SWITCH TO BYPASS FIBER



BROKEN CABLE
AUTO-LOOPBACK

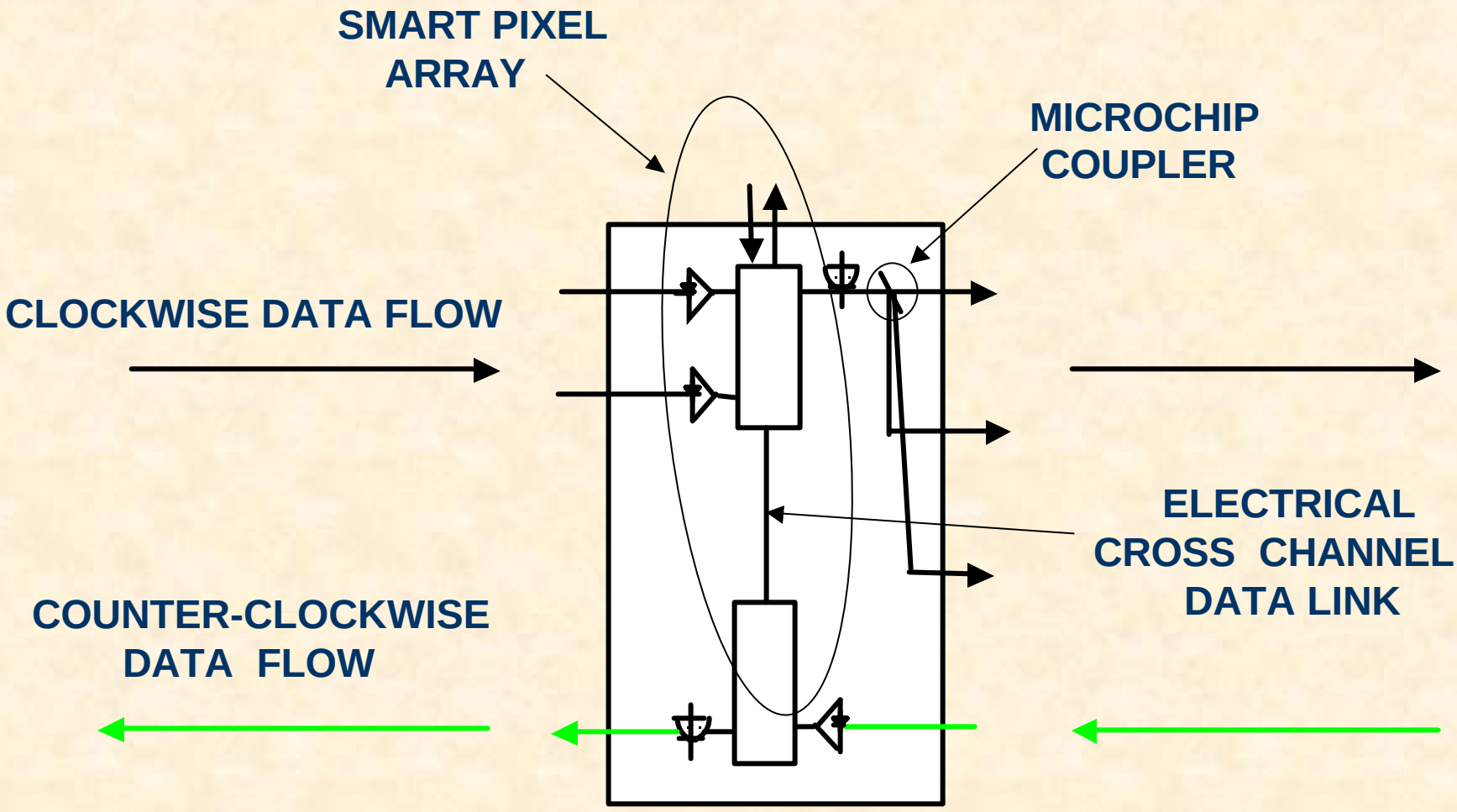


TWO BROKEN CABLES
TWO SEPARATED RINGS



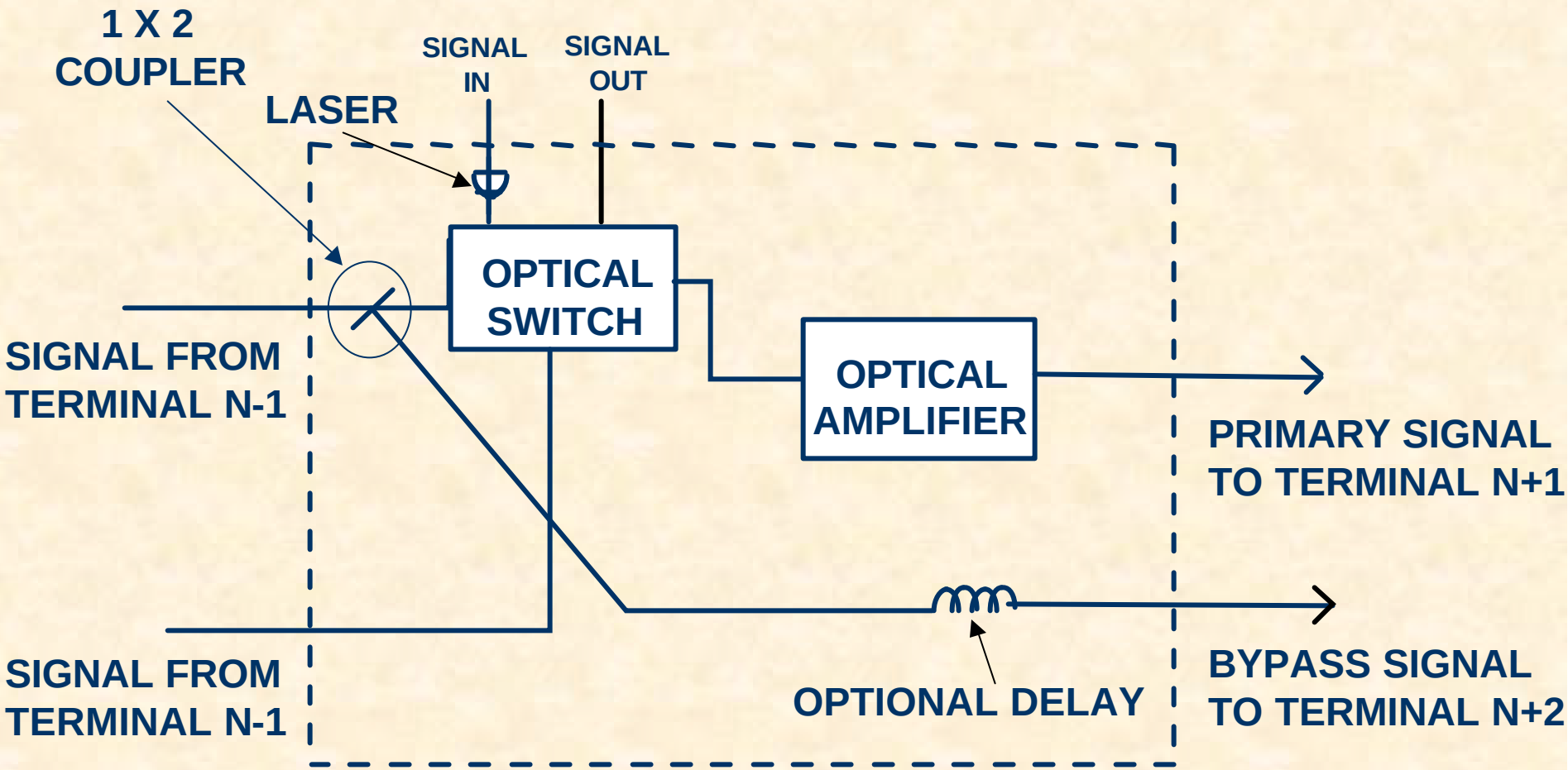
TWO SUCCESSIVE FAILURES
AUTO-LOOPBACK

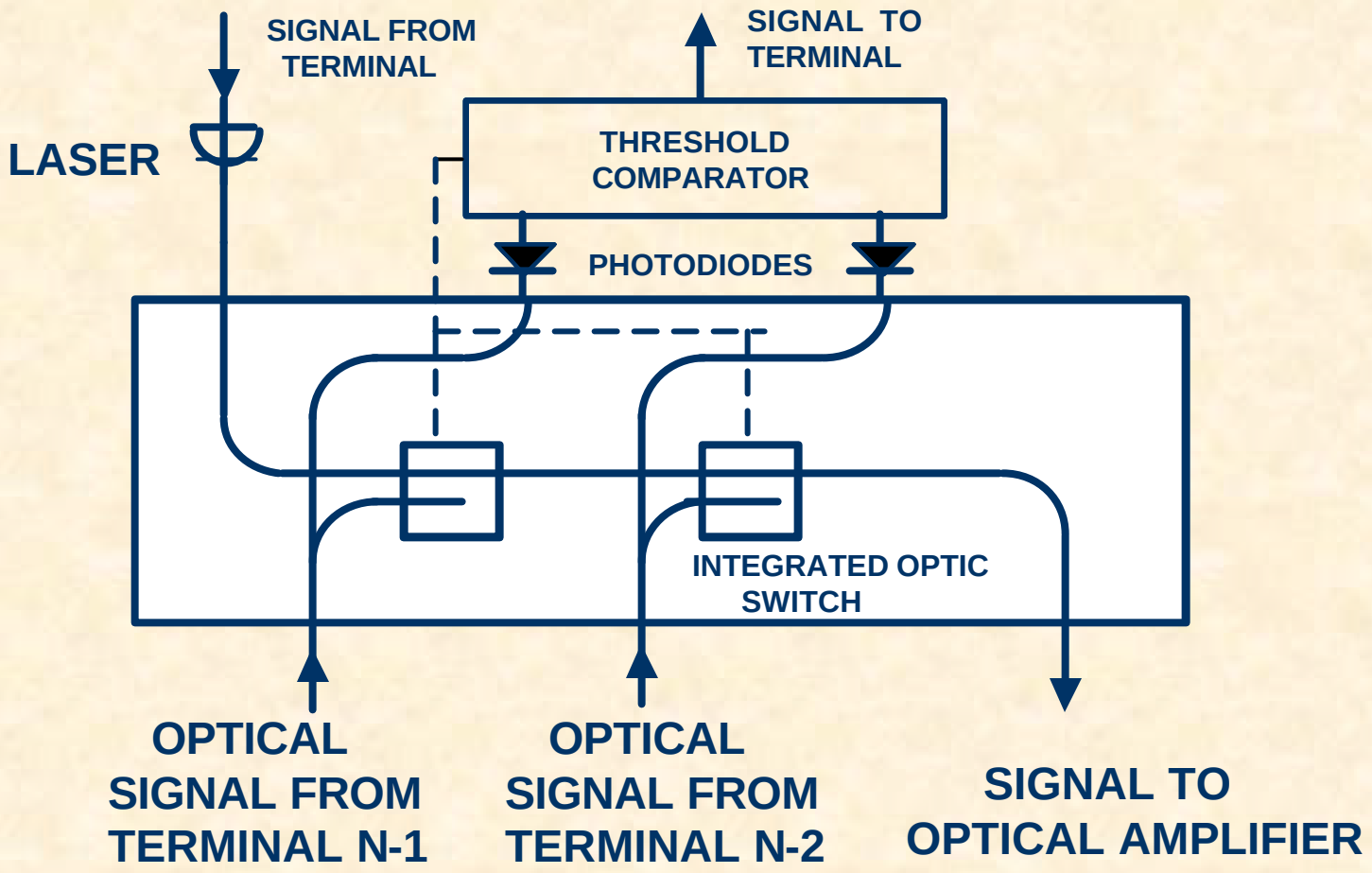
Bi-Directional Dual Bypass Ring



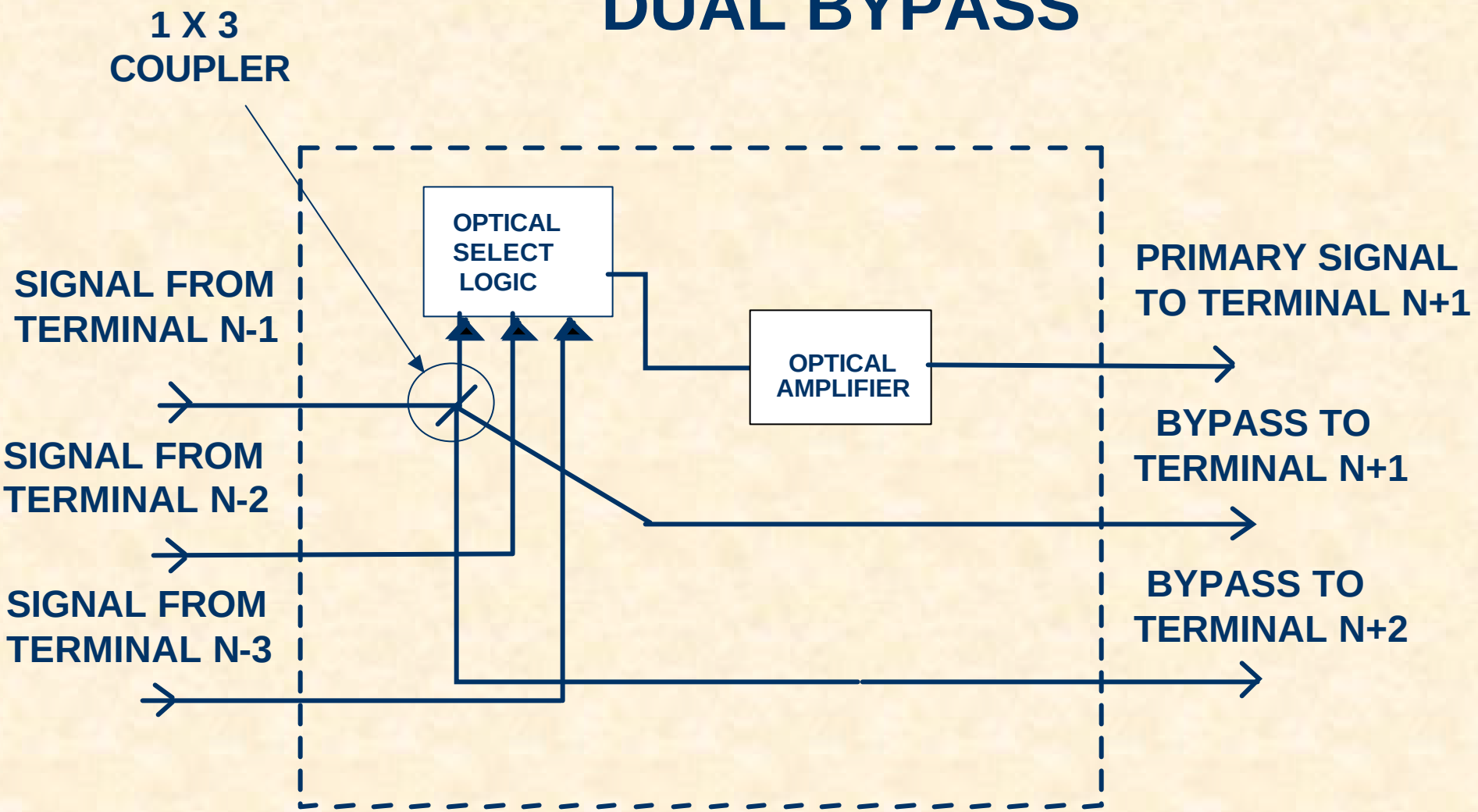
A SINGLE "SMART PIXEL" CHIP PROVIDES NETWORK RECONFIGURATION AND BYPASS CONTROL

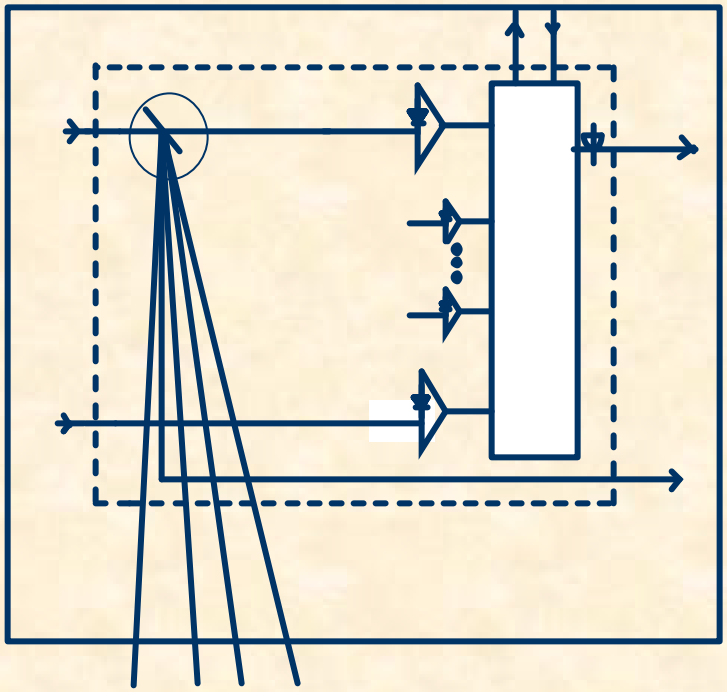
“ALL OPTICAL” TERMINAL

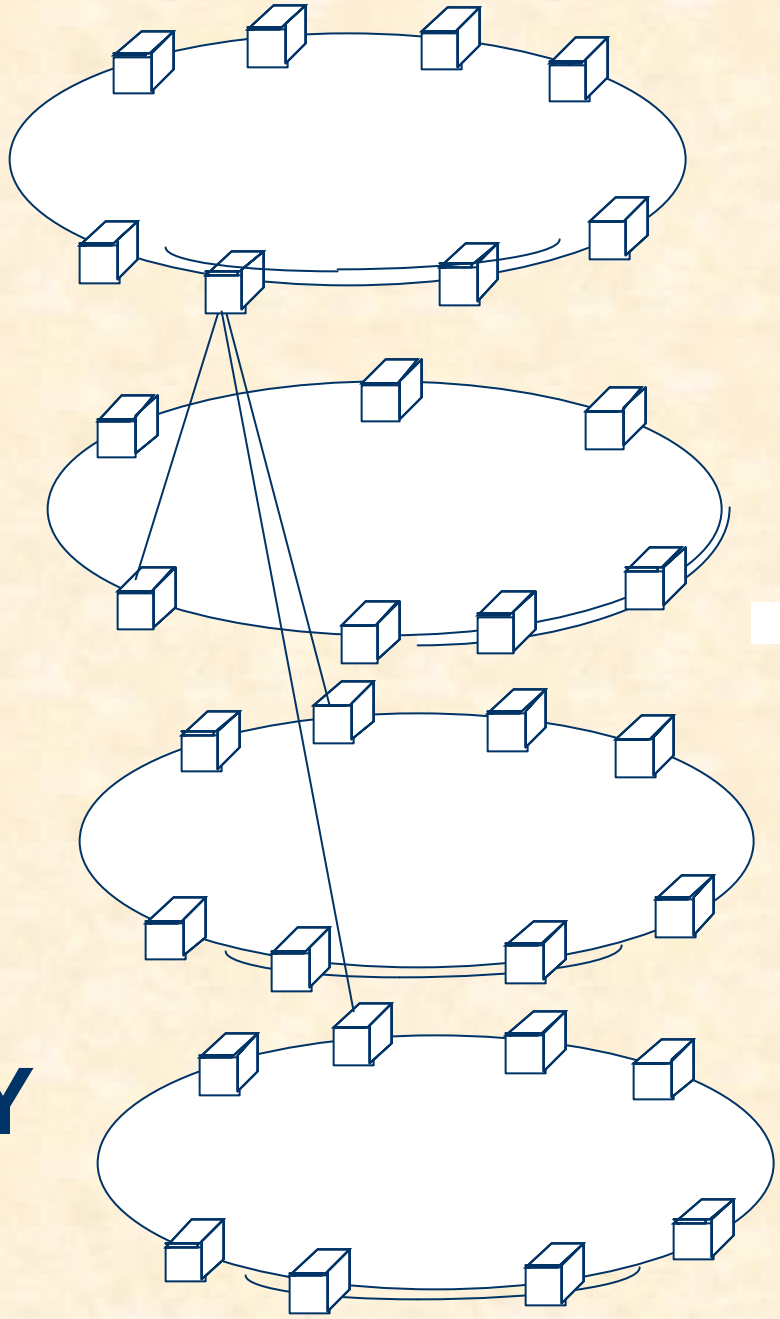



SIGNAL FROM TERMINAL
SIGNAL TO TERMINAL
LASER
THRESHOLD COMPARATOR
PHOTODIODES
INTEGRATED OPTIC SWITCH
OPTICAL SIGNAL FROM TERMINAL N-1
OPTICAL SIGNAL FROM TERMINAL N-2
SIGNAL TO OPTICAL AMPLIFIER

ALL OPTICAL TERMINAL DUAL BYPASS







MULTI-RING CONNECTIVITY

RELIABILITY BENEFITS

- Bypass Multiple Node or Cable Failures
- Detect, Isolate, and Circumvent Faults in Real Time
- Eliminate or Minimize Data Loss During Reconfiguration
- Circumvent Power Failure at a Terminal via the Passive Bypass Fiber
- Detect/Remove Babbling or "stuck-on" Terminals
- Built-in Failure Prediction of Active and Passive Components
- Diagnostics at the Physical Layer of the Network
- Auto - Loopback For Cable Cuts
- Reconfiguration Initiated Up or Down Stream from Failure

MAINTAINABILITY BENEFITS

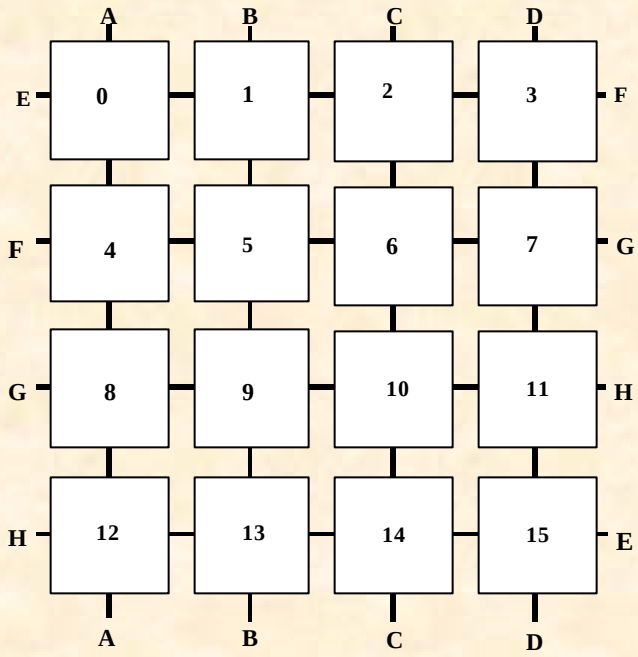
- Inherent Built-in-Test
- Preventive Maintenance Through Failure Prediction
- Hot Swap of Failed Terminal Modules
- Built-In Spare Fibers
- Minimal Loss of Service

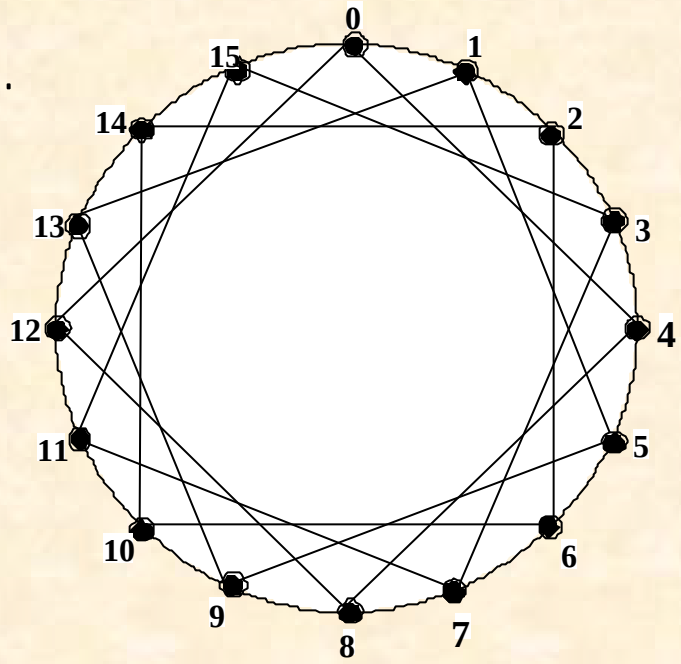
PERFORMANCE BENEFITS

- Topology Permits Distributed Bandwidth
- High Speed Recovery
- Single Mode or Multi-Mode
- Scalable to “All Optical” and WDM Implementation
- Accelerates Message Passing by Bypassing Intermediate Repeaters
- Uni-directional or Bi-Directional Transmission
- Analog or Digital Implementation
- In-line Bit Error Detection and Correction

PERFORMANCE BENEFITS

- Rapid Reconfiguration with Available Electrical or Optical Switch Technology
- Redundant Fiber Paths to Overcome Fiber Damage
- Feedforward/Feedback Paths for Congestion Control
- Anticipatory Decoding of Header Fields to Rapidly Configure Virtual Circuits
- Compatibility with Most Network Protocols
- Comfortable Power Budget for LAN Applications



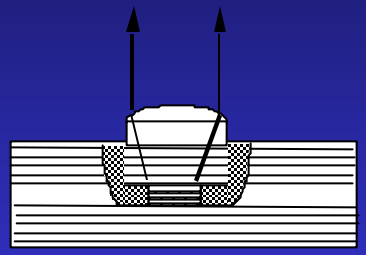


EQUIVALENT CONNECTIVITY

A RING CAN IMPLEMENT A MESH TOPOLOGY OR ANY SUBSET THEREOF

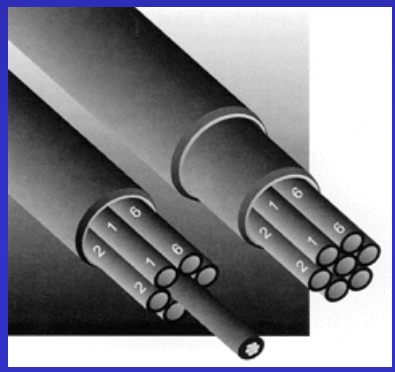
GENERATION II PHOTONIC HARDWARE IS THE AFFORDABLE ENABLER

GENERATION II HARDWARE
LOW COST ENABLERS

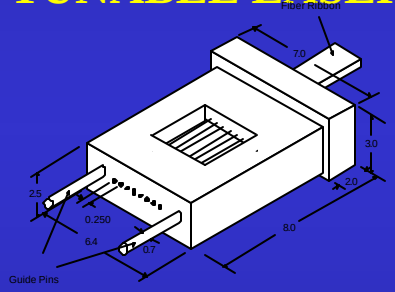


VERTICAL CAVITY/ TUNABLE LASERS

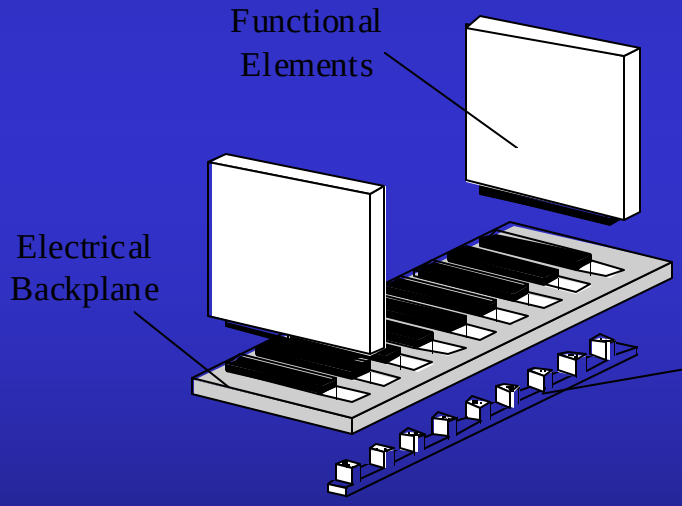
RIBBON CABLES



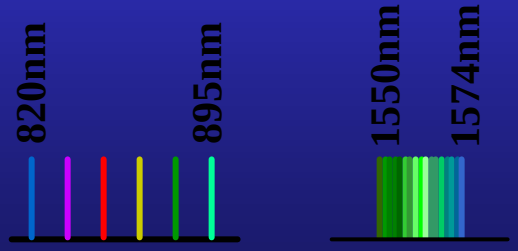
AIR BLOWN FIBER



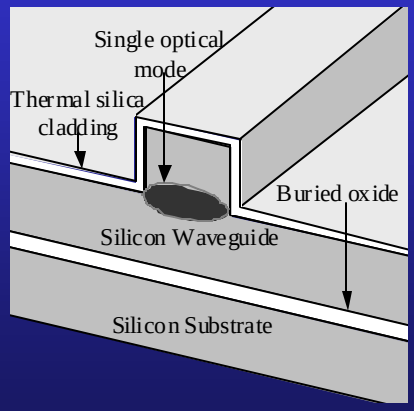
SMALL FORM FACTOR ARRAY CONNECTORS



OPTICAL BACKPLANES



COARSE WDM DENSE WDM



PLANAR WAVEGUIDES

REFERENCES

Glista, A.S. "Fault Tolerant Topologies for Fiber Optic Networks and Computer Interconnects Operating in the Severe Avionics Environment", IEEE Journal of Lightwave Communications Systems, February, 1991.

Glista, A.S.“A Shunted Ring Fiber Optic Network Topology Providing Fault Detection, Isolation and Circumvention”, IEEE NAECON, May 1993

Glista, A.S., “Optical Interconnects:Topology and Protocol issues”, SPIE OE/Lase ‘94, Jan,1994

Fault Tolerant Fiber Optic Coupler/Repeater for Use in High Speed Data Transmission and the Like (Grants Number 4,837,856 and 5,229,875.)