JDS Uniphase

Thin Film Products Group Capabilities Overview

Eric Kurman
Science & Technology Division
JDS Uniphase Thin Film Products Group
Santa Rosa, California

2004 DOE/EPRI High Efficiency Thermoelectrics Workshop
17 – 20 February, 2004

JDS Uniphase is a worldwide leader in optical technology.

We design and manufacture products for fiberoptic communications, as well as for markets where our core optics technologies provide innovative solutions for industrial, commercial and consumer applications.

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JDS Uniphase at a glance

FY2003 Sales	$676 million
Employees	5,200
Headquarters	San Jose, California
Locations	16 mfg sites worldwide
Nasdaq	JDSU
Website	www.jdsu.com

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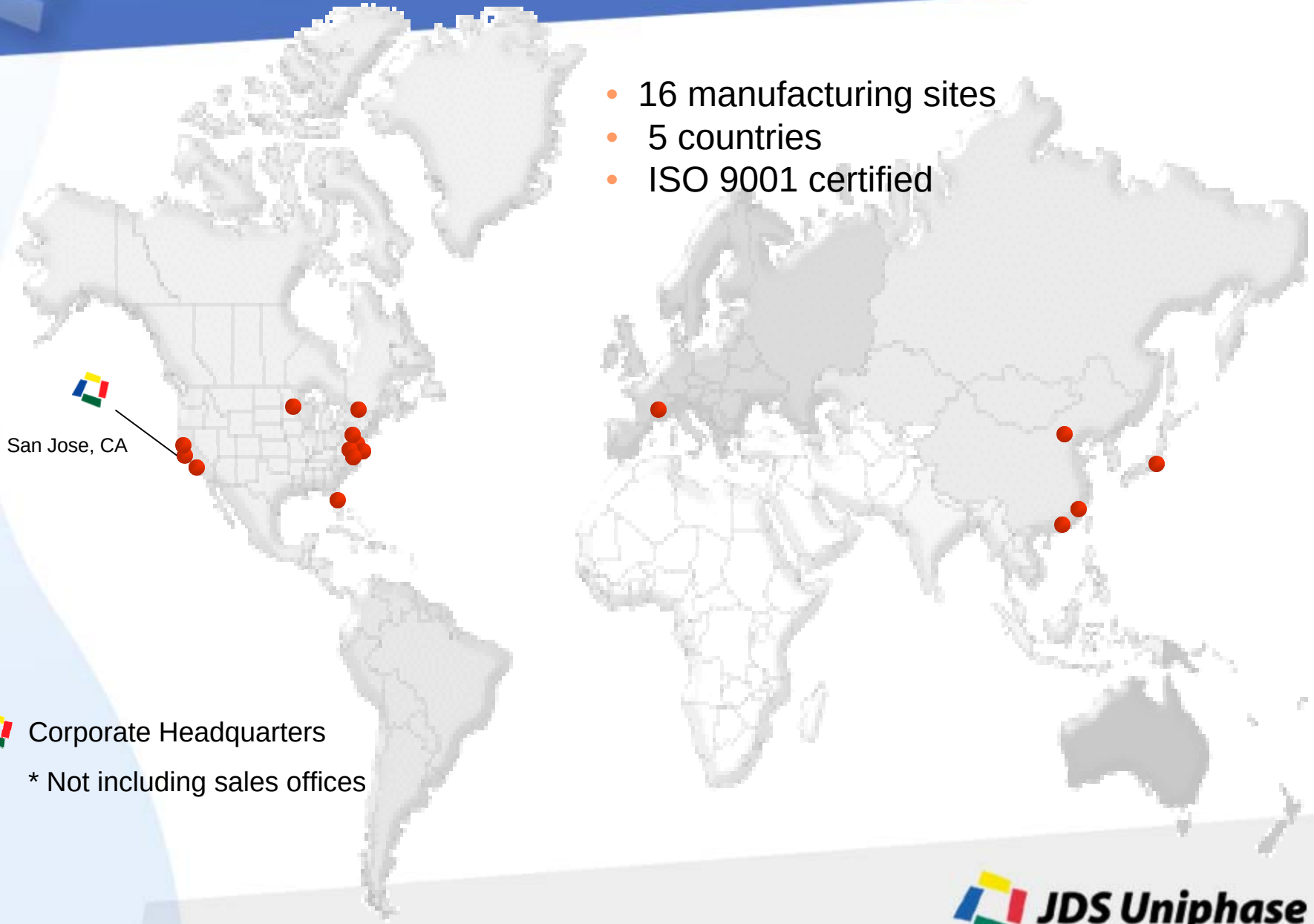
Worldwide locations*

- 16 manufacturing sites
- 5 countries
- ISO 9001 certified



Corporate Headquarters

* Not including sales offices

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Company strategy

- Maintaining close customer relationships
- Maintaining technology leadership
- Increasing the level of integration and functionality in our communications products
- Strengthening and developing opportunities for our optical technology businesses
- Focusing on continuous quality improvement
- Structuring our manufacturing capabilities for maximum efficiency and quality
- Pursuing complementary mergers and acquisitions
- Developing our people

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Organization

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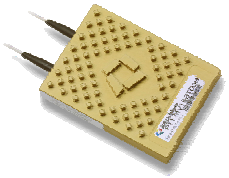
A world leader in fiberoptic communications

Subsystem Products

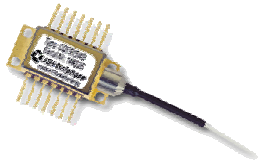
Instrumentation, Network Ready Products, amplifiers, card-level products

Transmission Products



Telecom and datacom modules, CATV & specialty products

Component Products



High power lasers, waveguides, transmission components, passive components

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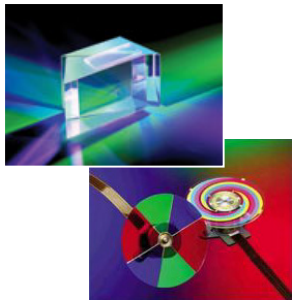
Commercial Lasers

Solid-state, gas, fiber and diode lasers used in biotechnology, biohazard detection, graphics and imaging, semiconductor, and materials processing

Flex Products

Light interference pigments for color shifting characteristics used in security products & decorative surface treatments

OCLI Products



Optical components and front surface mirrors for displays

Optical filters for medical instruments

Infrared filters, beam splitters a optical sensors for aerospace

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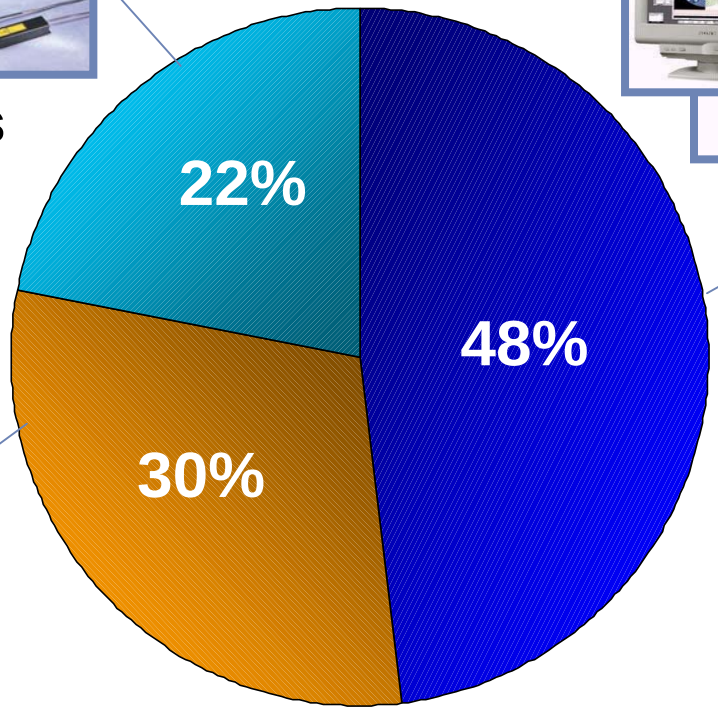
TFPG Markets & Products

Commercial Lasers

OCLI Products

Flex Products



Flex Products Inc.
A JDS Uniphase Company

OCLI
A JDS Uniphase Company

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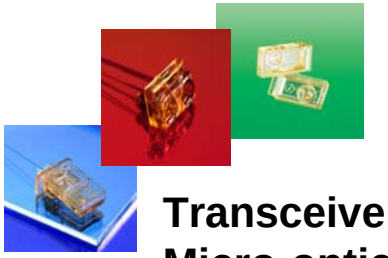
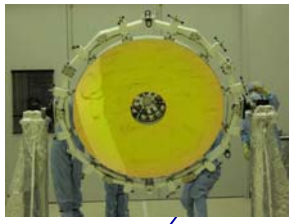
OCLI Products Division (OPD)

POLYMER OPTICS



Transceiver optics
Micro-optic Assys.

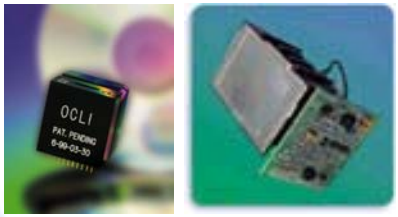
MILITARY/AEROSPACE



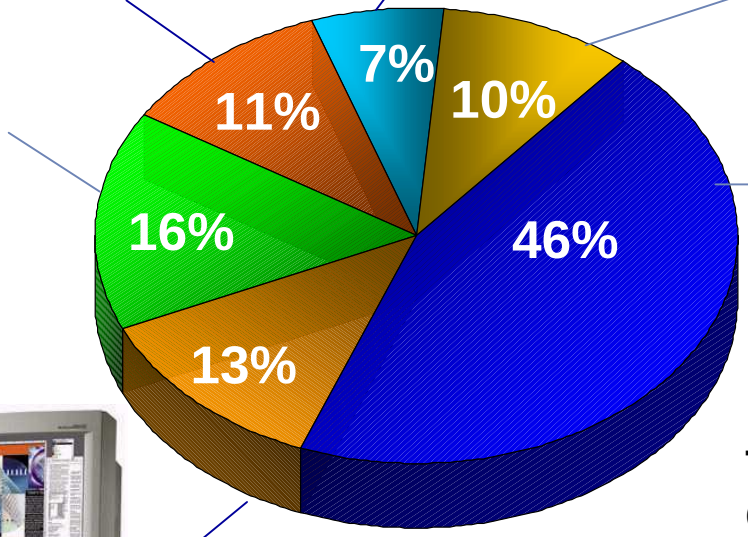
DWDM FILTERS

DWDM Filters

INSTRUMENTATION



Industrial and Medical



PROJECTION DISPLAY

Top Hat
Color Wheel
Dichroics
Front Surface Mirror
Prisms

DIRECT DISPLAY

Plasma
AR on Glass
AR on LP & OLEDs

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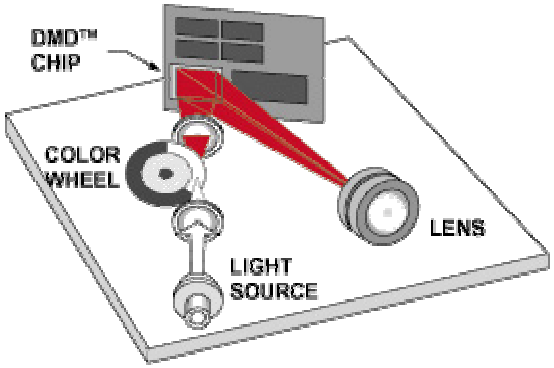
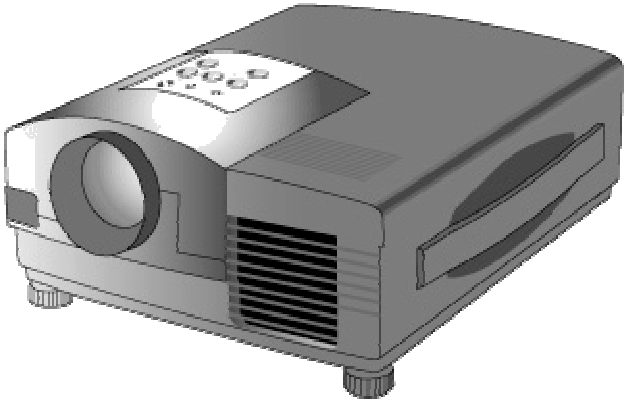
OPD Projection Display Products

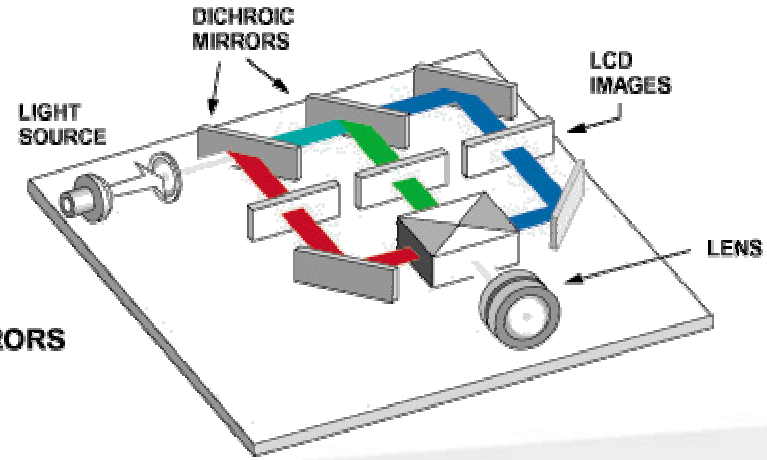
FRONT PROJECTION DISPLAY





DIGITAL MICROMIRROR DEVICE
WITH COLOR WHEEL

LCD IMAGERS
WITH DICHROIC MIRRORS



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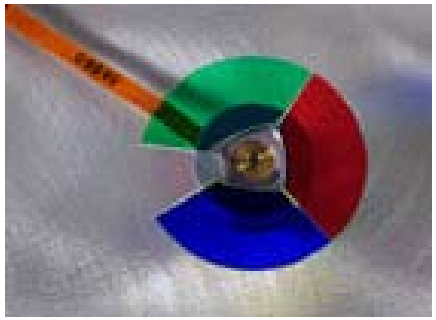
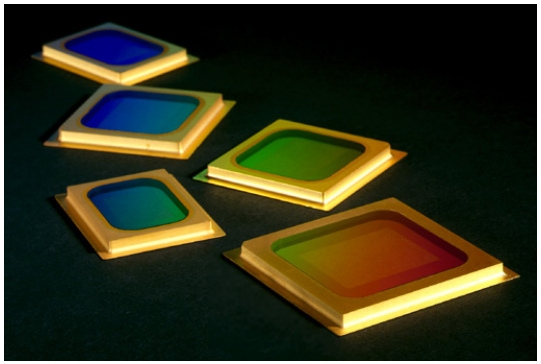
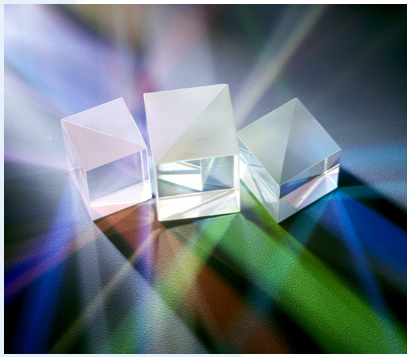
OPD Display Components for Light Engines

Color wheels



Low defect windows





Polarization and wavelength control

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OPD Custom Display Products

- Custom display cover panels
  - Contrast enhancement, ruggedization, EMI shielding, LCD heaters
  - Government, military and instrumentation markets

- Business strategy includes:
  - Competitive high-conductivity coatings (< 2 Ω/sq)
  - Comprehensive offering of custom configurations
  - Glass types, coatings, laminates, bus bars
  - Short-cycle batch processing for rapid delivery

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OPD Strategic Products

- Custom high-technology coated optics
  - Large optics (up to 100” diameter)
  - Space-based x-ray, microwave and laser mirrors
  - Specialty configurations (tubes, novel shapes)
- Defense and aerospace markets
- Business strategy includes:
  - Sustaining technology leadership
  - Management of complex multi-year programs

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Nova Laser Fusion Optic

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ALPHA Laser Beam Compactor

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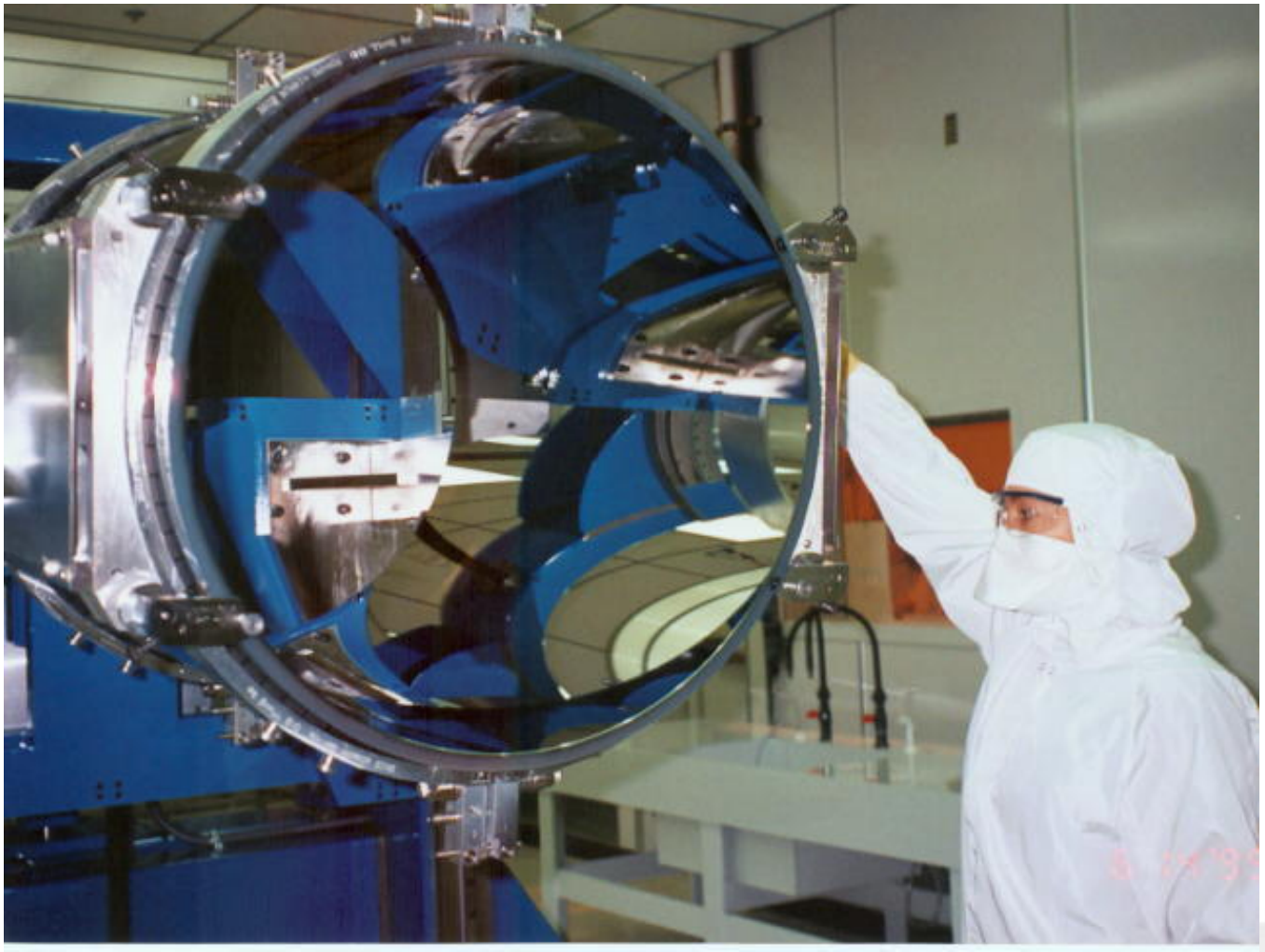
AXAF/Chandra P6 Mirror on Lift Truck



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120 inch Double-Door Coating Machine

Other door opens into class 100 clean room

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OPD Inline coating equipment

- OCLI developed “MAC” in 1970.
- Inline EB evaporator
- AR and FSM
- 32” by 50” substrate

- C-9 inline sputter coating machine
- Put in service 1995
- First-Surface Mirror
- 74” by 130” substrate

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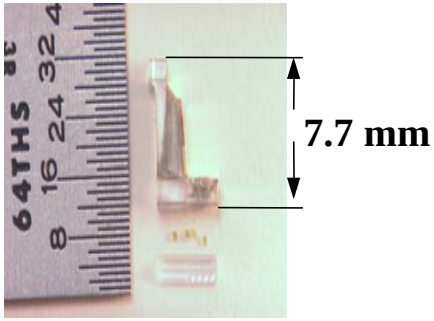
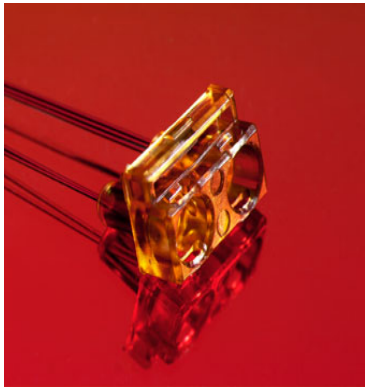
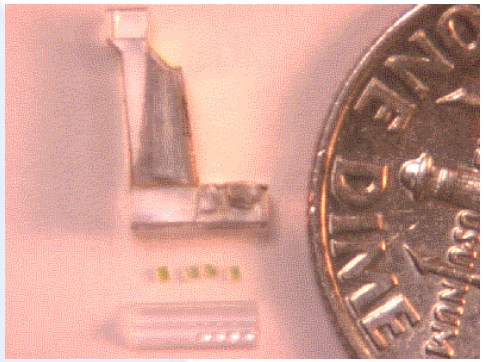
OPD Polymer Optic Capabilities



4 channel demux in polycarbonate





Complexity and quality at the costs of plastic

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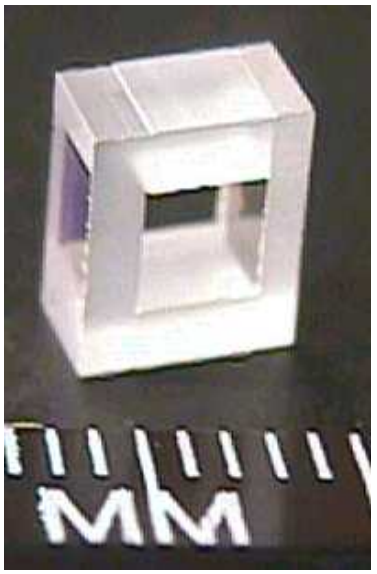
OPD Telecom Products



Thin-film filters and micro-optic assemblies for DWDM
Targeting long-haul and metro fiber-optic markets

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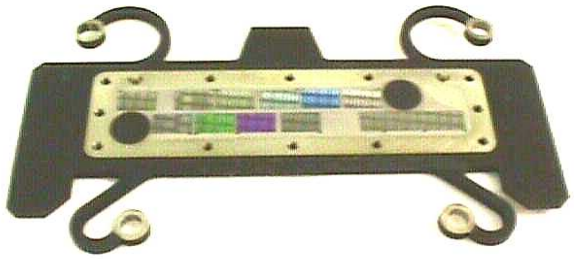
Coating performance

Wavelengths from 0.2 to 40 μm
Part size from mm to meters



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Flex Products Division

- Wholly-owned subsidiary of JDSU
- HQ in Santa Rosa, CA
- Facility in Beijing, China
- >260 people
- Key Capabilities
  - Platform for expansion of TFPG thin film science to other markets
  - High-rate roll coating
  - Multi-layer coatings
  - High Volume Quality Manufacturing
  - Particle Coating
  - Sol-Gel Processing

Flex Product Lines

Optically Variable Pigment (OVI®)

ChromaFlair® ColorShift™ Effects Leader

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Commercial Lasers

Technologies

HeNe Lasers

Argon Lasers

DPSS

Fiber Lasers

1979-HeNe Lasers

1994-Micro Lasers

1984-Argon Lasers

1999-Nano Lasers

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Science & Technology Division

- Coating process development
- Chemistry and materials development
- Lasers and Optics
- Equipment design and construction
- Surface analysis and materials characterization
- Optical and color metrology

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S&T Materials Characterization

- Optical Microscopy
- Micro-Analysis (EDX, SIMS)
- Electron Spectroscopy (XPS)
- Surface Metrology (AFM)
- Optical Properties (VASE)
- Other Capabilities
  - Product Reliability Center

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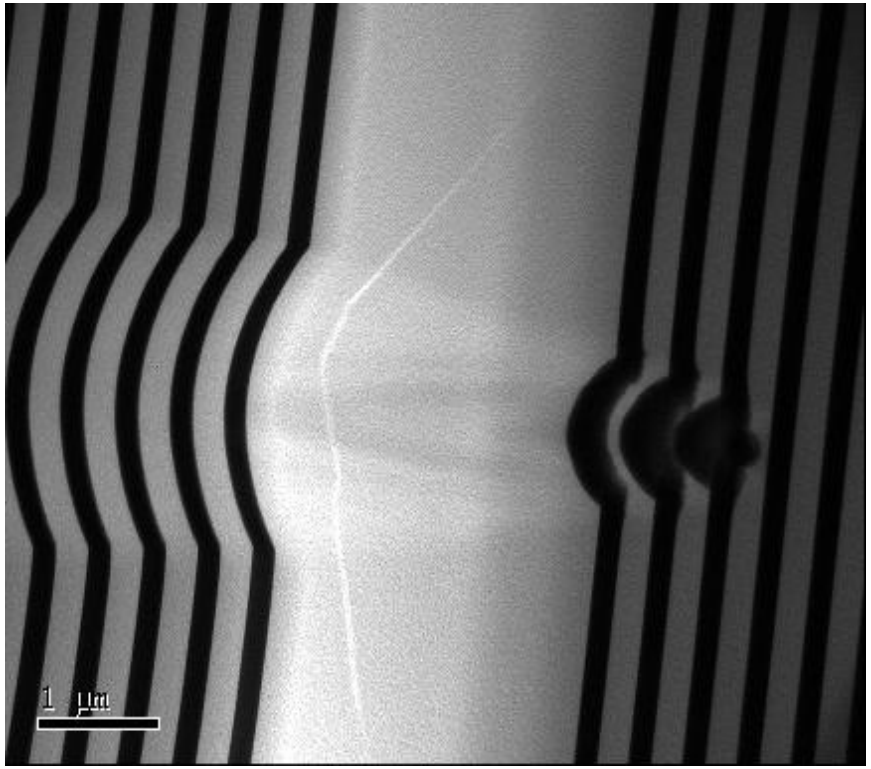
S&T Electron Microscopy



TEM x-sect micrograph of nodular defect growth

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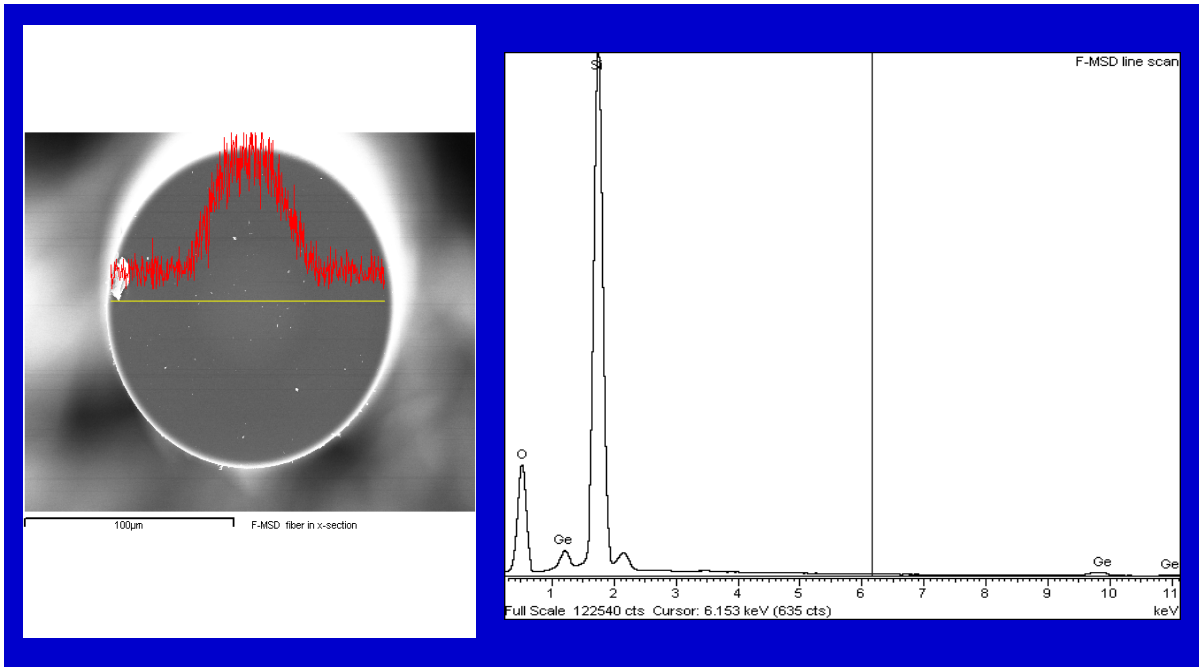
S&T Micro-Analysis (Line Profile)



Elemental Analysis and Ge Line Profile in a Fiber Using EDS

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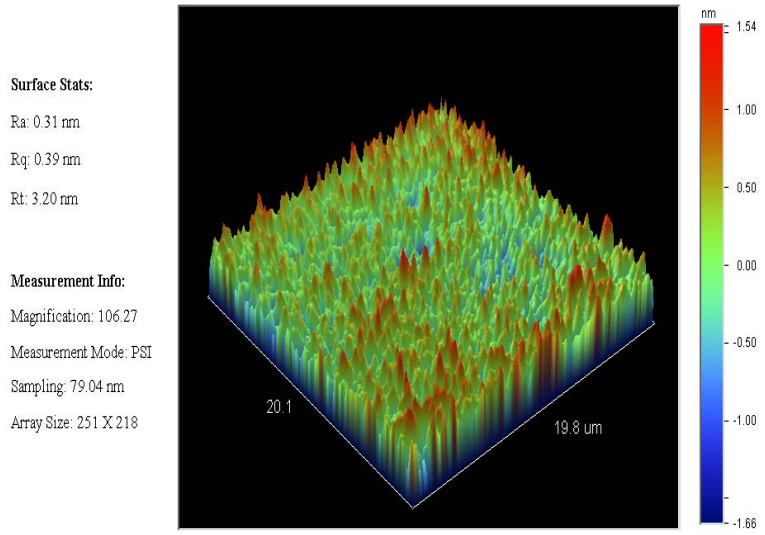
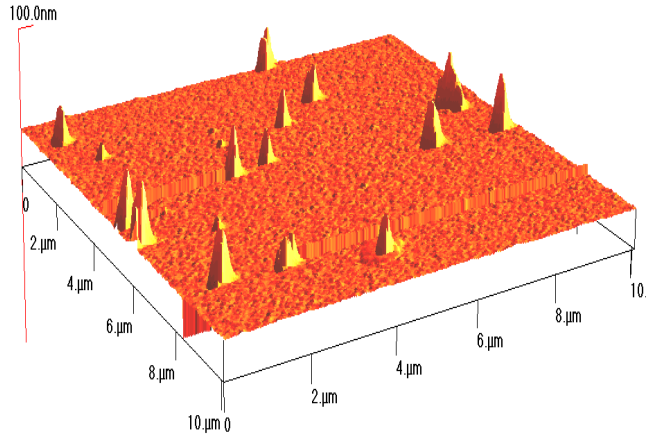
S&T Surface Analysis



Surface Roughness Using WYKO



Surface Roughness using AFM

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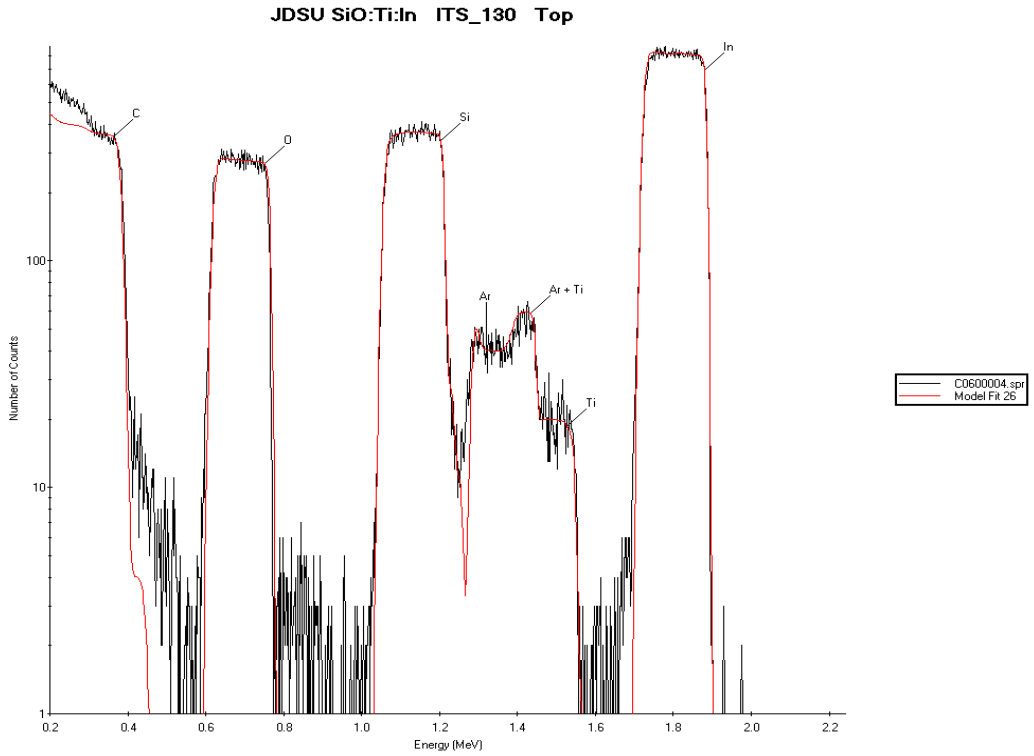
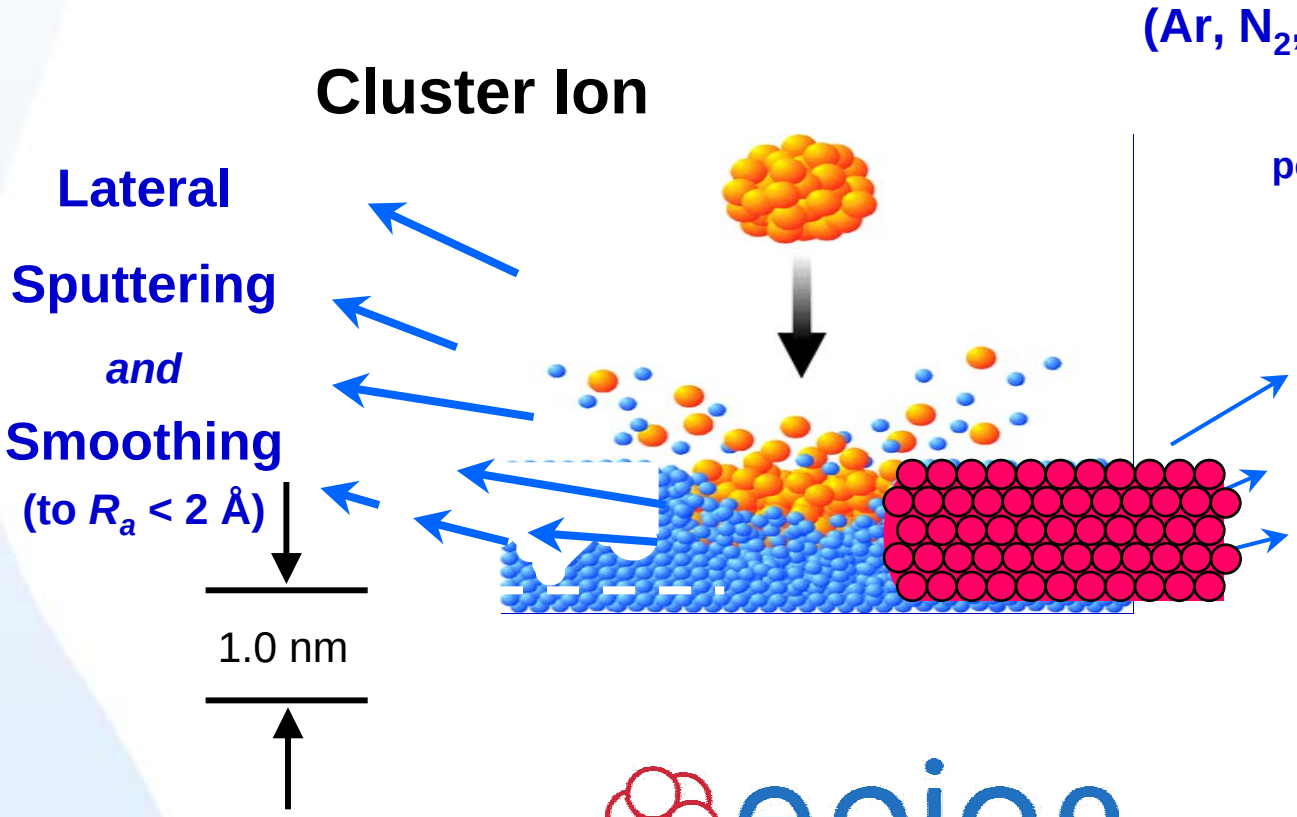
Rutherford Backscatter (RBS)

		Si	O	Ti	In	Ar	(atoms/cm2)
ITS_130	Top	27.4	65.1	0.6	5.1	1.8	2.12E+18



Layer Thickness and Layer Composition of Doped SiO2 Layer using RBS

Nano-Scale Processing of Surfaces (GCIB)



epion

http://www.epion.com

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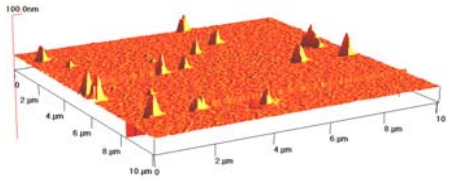
Glass Substrate (Ar-Cluster Process)

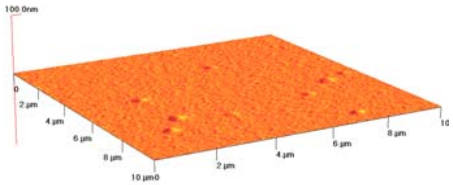
100 nm



Low

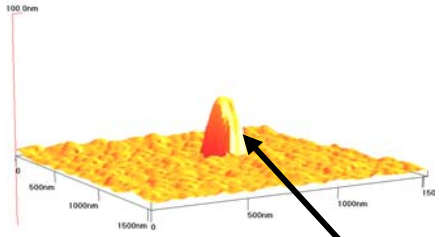
Resolution

10 mm squares



100 nm

Before



Asperity 450 Å high

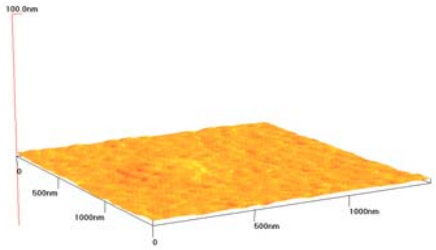
Plateau with R_a ~18 Å

High

Resolution

1.5 mm squares

After



Plateau with R_a ~ 7 Å

Note: Power Spectral Density (PSD) improved 100X (over spatial range ~0.1 to >50 mm^{-1}).

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Fabrication

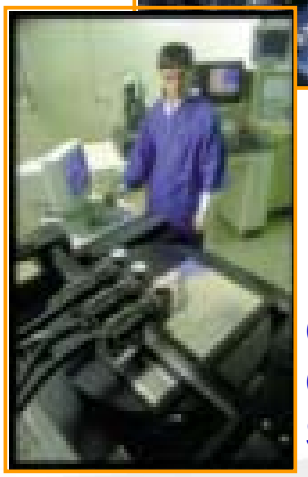
- Global Facility Coverage: Asia
  North America
- From Very Small to Very Large

High Volume, Large Component Fabrication

Precision Substrate Sawing

FOCUS AND DIRECTION:

High volume, precision optical fabrication



Computer Controlled Shape Cutter

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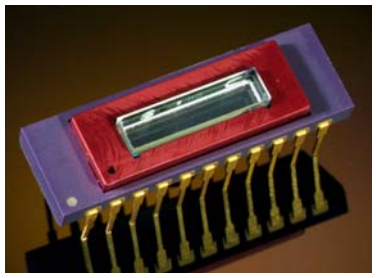
Optical Assembly Capabilities

- Precision optical assemblies
  - Color wheels
  - Spectral sensor
  - Filter-detector pairs
  - Polarizing components
- Micro-assembly
  - CWDM demux



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Program Examples

- Biological Aerosol Warning System (BAWS) 266 nm solid state laser
- Infrared Filters
- Large Optics Coating & Metrology
- Laser Rejection Filters
- Process Development and Scaling
  - CIGS SPM
  - Solid state electrochromics
  - DWDM multilayer filters

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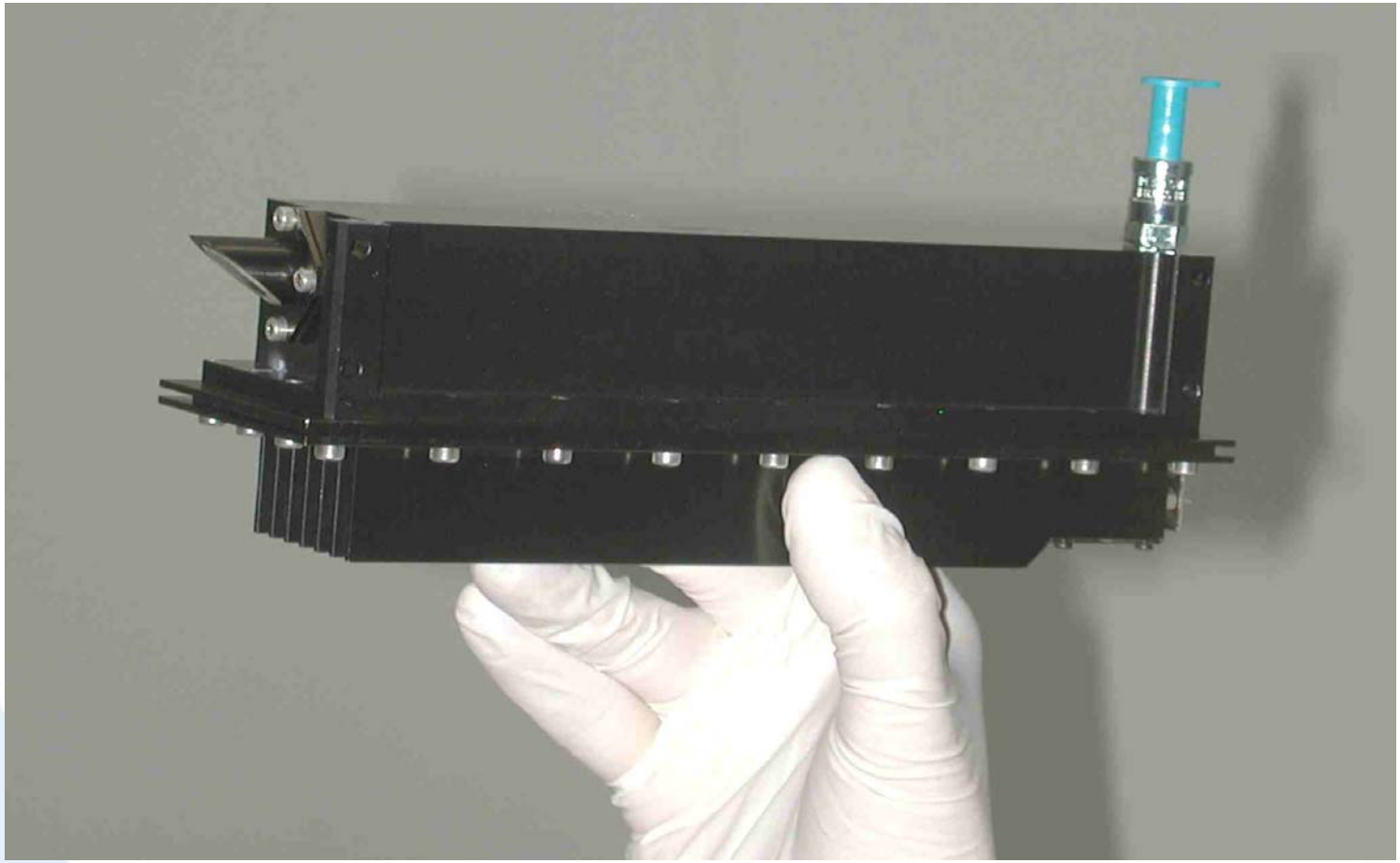
BAWS Prototype Laser



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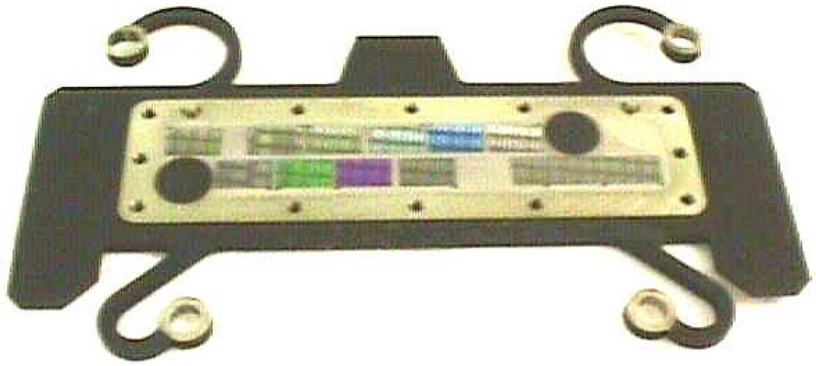
Atmospheric Infrared Sounder (AIRS)

- 18 bandpass filters on Ge substrate
- 3.4mm to 15.4mm wavelength region
- sized after coating



- mounted into molybdenum frame
  - coated with an ultra-broadband dark mirror
- 0.001% absolute out-of-band blocking
- 60K operating temperature

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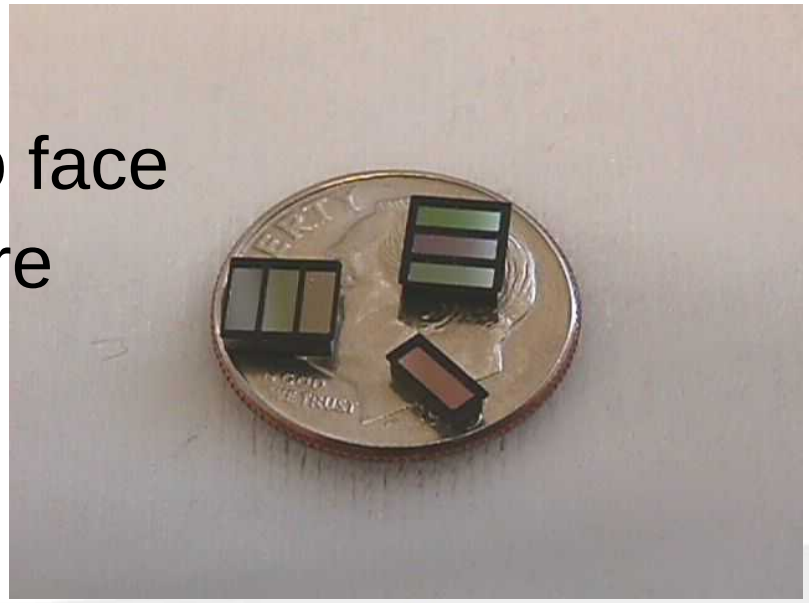
Advanced Earth Observing Satellite – Global Imager

- 7 narrow bandpass filters on sapphire and Ge
- 3.7 to 12.1μm wavelength region
- coated filter thickness tolerance ±0.013mm
- sized after coating to 5mm x 2mm
- bonded into 1- and 3-band assemblies
- edge painted
- opaque mask mounted to face
- 80K operating temperature



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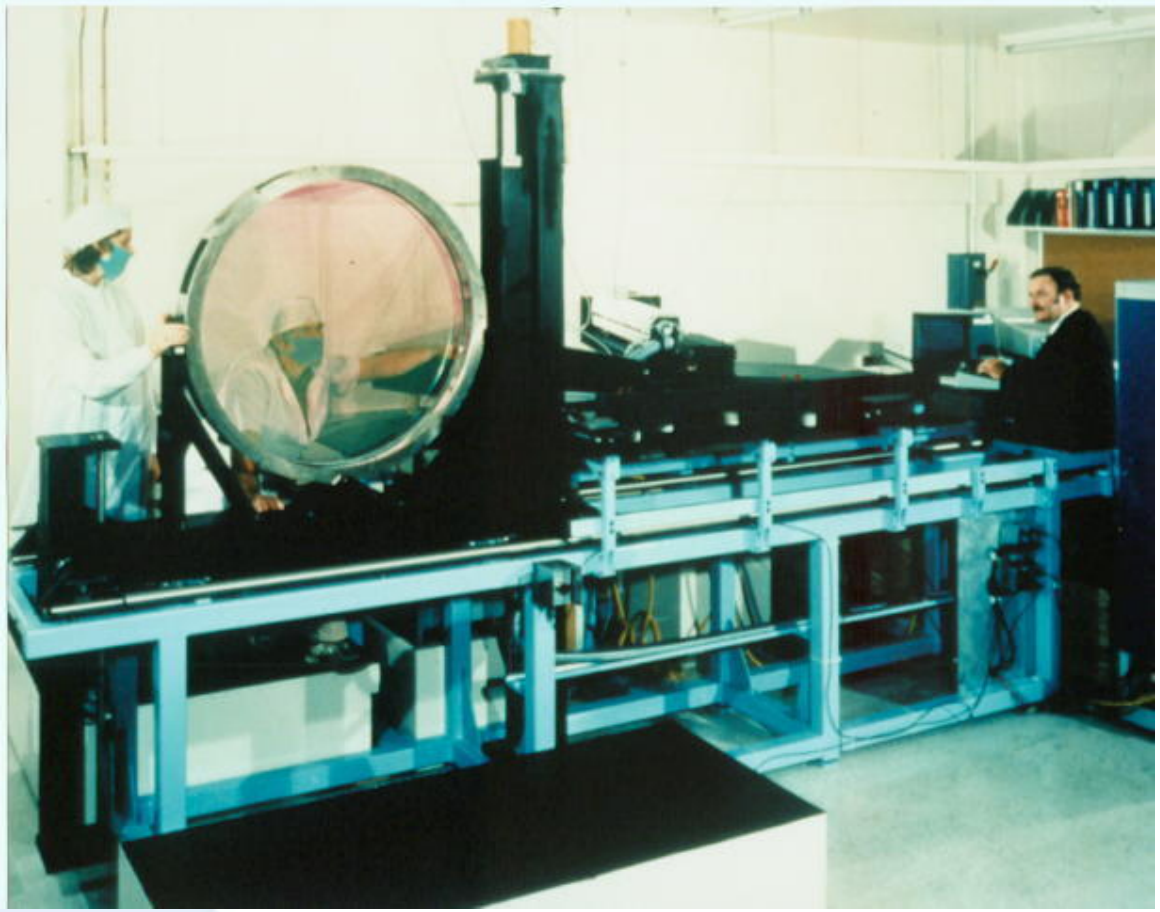
Nova Laser Photometer



- R & T at multiple laser wavelengths
- Rasters optic in laser beam
- Area up to 1 m^2
- Developed at OCLI

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Visual Blocking Filters – Products

- Laser Protection
  - "ANVIS"

- Avionic Night Vision
  - "Leaky Green"

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Process Development and Scaling

- Process Selection
  - Inline: better suited for low layer count
    - High coating rates, large area
  - Batch: better for high layer count
    - Ability to mix deposition processes
    - Minimize non coating (pump and vent) time
  - Deposition method
    - Dependent upon materials and desired properties
- Three Examples
  - CIGS Solar Power Modules
  - Solid State Electrochromic Devices
  - DWDM Filters for Telecom

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Example 1: Solar Power Module

- Multi-layer p-n thin film photovoltaic
  - $CuInGaSe_2$
  - Scaled from NREL lab process
  - Deposition at 600C
  - Mixed low pressure sputtering and thermal evaporation processes
  - 72” diameter batch coater
  - Deposited films had short range crystal structure
  - Prototype modules of 12”x12” demonstrated

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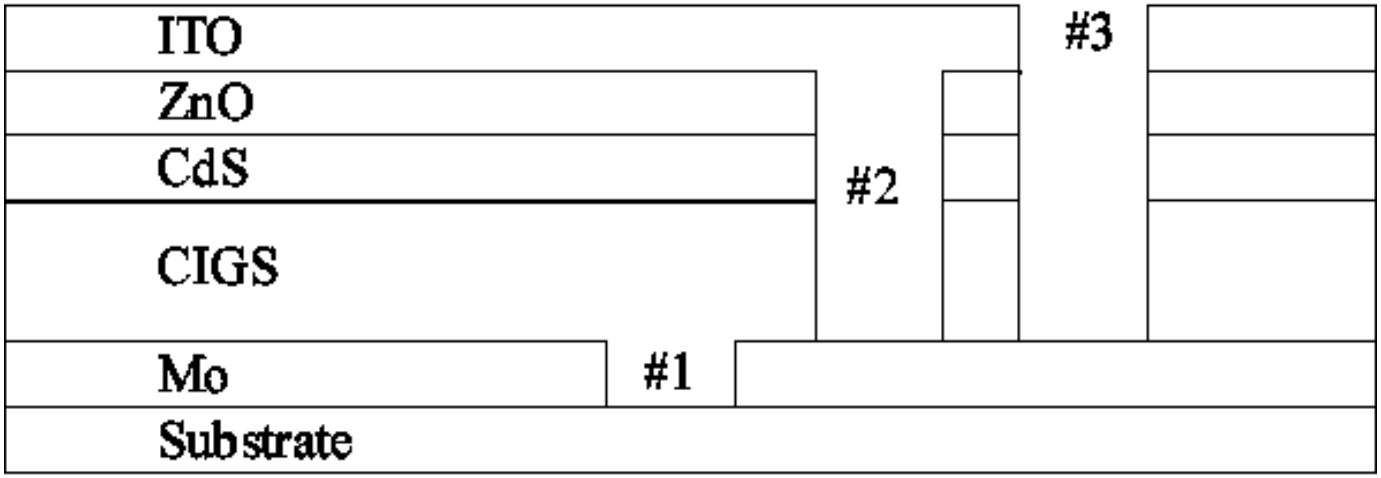
SPM Patterning Cross-Section



Three scribes

- #1 & #3 provide electrical isolation between adjacent cells
- #2 allows connection of ITO and Mo from adjacent cells to connect cells in series

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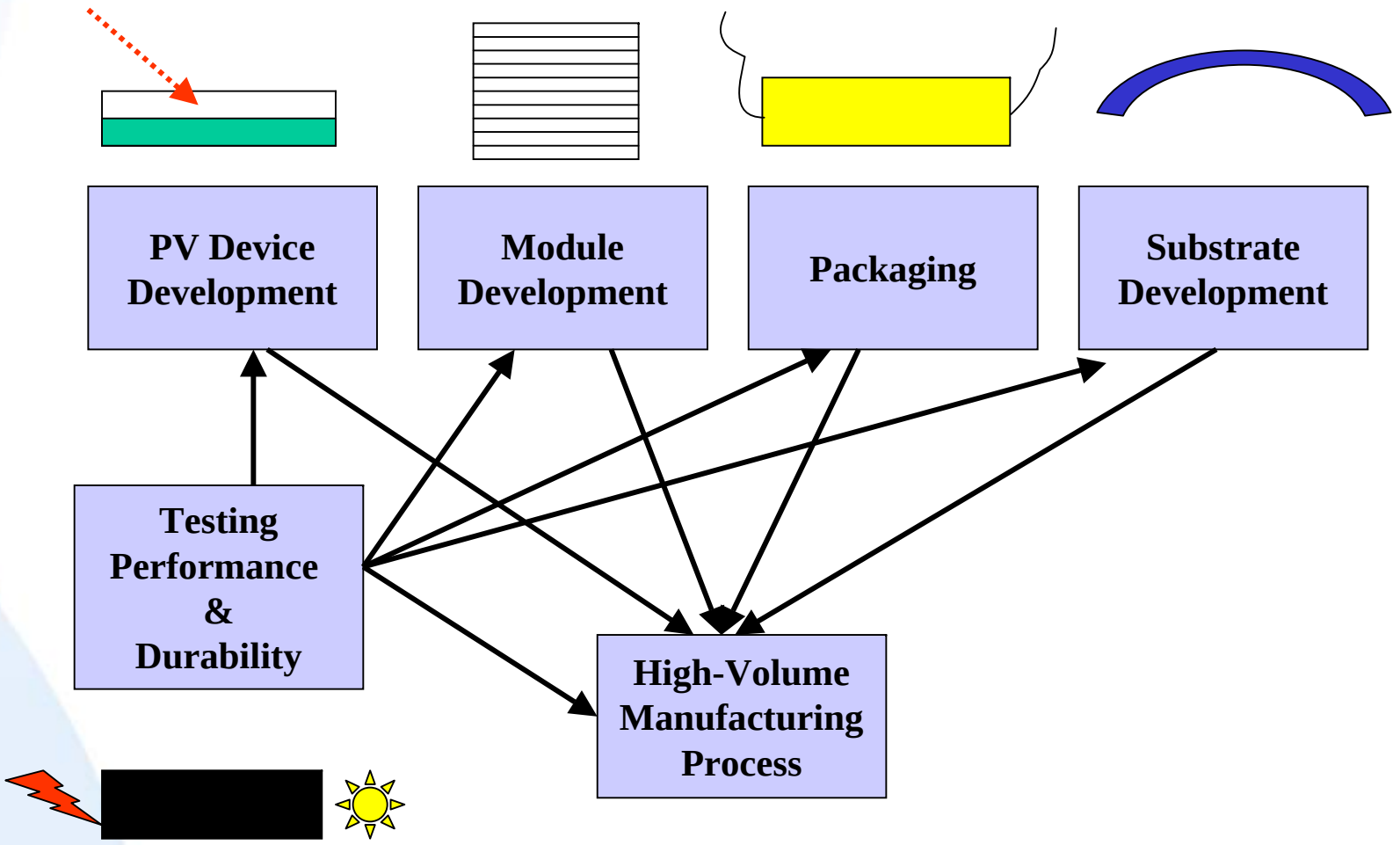
CIGS SPM Development Process



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SPM Development

Milestones	Time
Completion of conversion of batch Machine for CIGS	Day 0
9% cell (AM1.5) OCLI Mo & CIGS, NREL CdS, ZnO, & Al:ZnO	Day 19
All-OCLI CIGS 2 in.x2 in. module (all layers + scribing demonstrated)	Day 46
Established rotary process for uniform coating process (12”x12”)	Day 60
7.96% all OCLI module (AM1.5) 2.42 $in.^2$, 8 cells	Day 81
10.7% cell (AM1.5) on Na-free thin film glass	Day 85
Uniform CIGS on full size thin substrate (12”x10.5”) (<+/-4%)	Day 92
14.7% cell, FF=0.74 (AM1.5) demonstrated	Day 124
8.3% module, FF= 0.59 (AM1.5) 2.75in^2 demonstrated	Day 124

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SPM Scaling to Volume

- Plan for inline production machine planned
  - at this point a full cost study was performed
    - Process flow - from substrate receiving, substrate preparation, coating, post coating treatments, packaging to pack-out and shipping
    - Throughput and yield estimates
    - Factory layout - floor plan, capital and facility costs
    - Resource loading
  - Required for favorable cost/unit area

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Example 2: Solid State Electrochromic

- Electrically induced change in a film's optical properties (n and/or k) by insertion of metal ions (H^+, Li^+, Na^+, K^+) and electrons (e^-)
  - *e.g.*, Tungsten Trioxide (WO_3) reversibly changes from clear to blue with the insertion of protons (H^+) and an equal number of electrons to form tungsten bronze (H_xWO3).

$$WO_3 + xH^+ + xe^- \leftrightarrow H_xWO_3$$

clear blue

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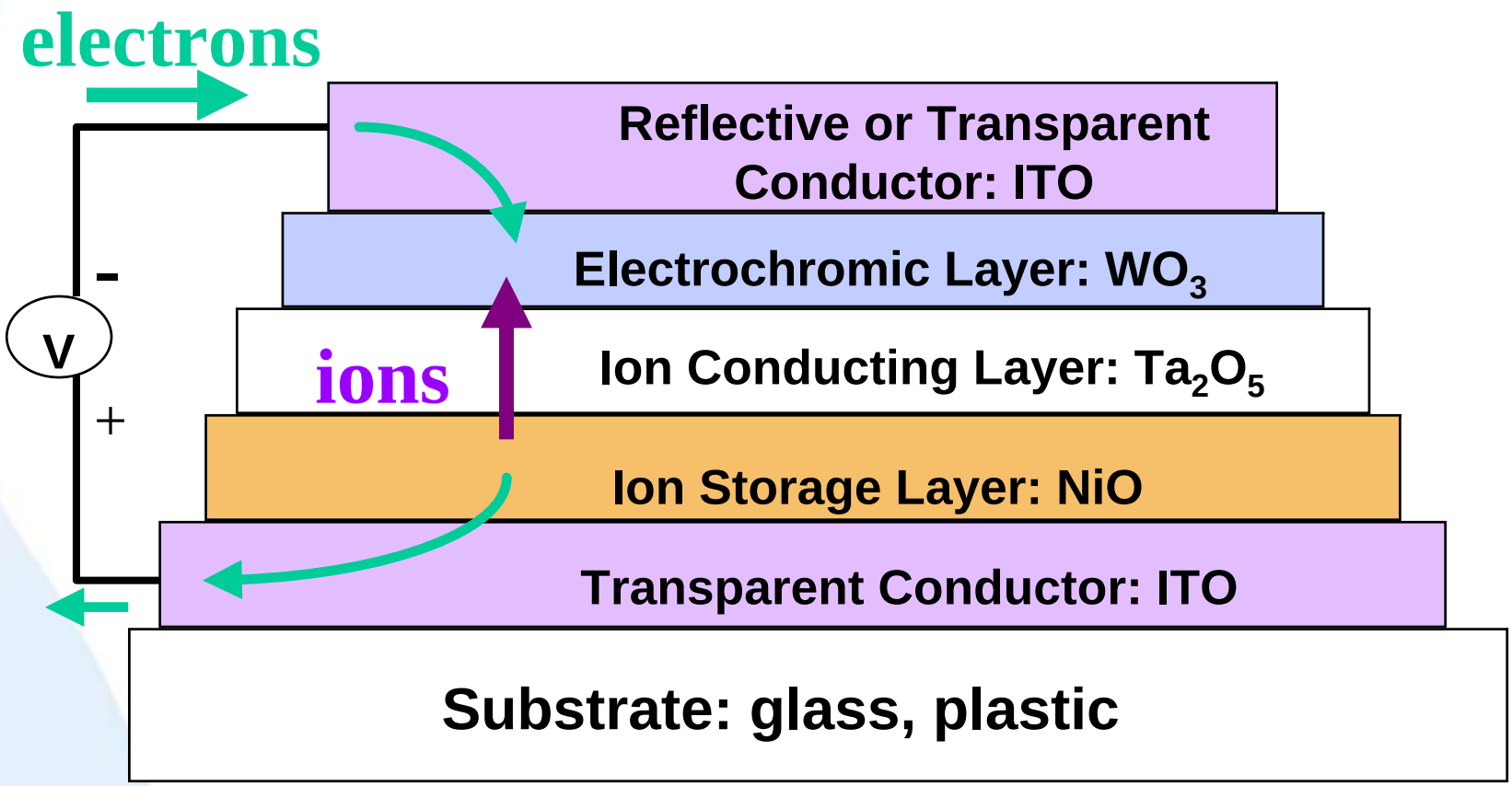
Monolithic solid-state EC device



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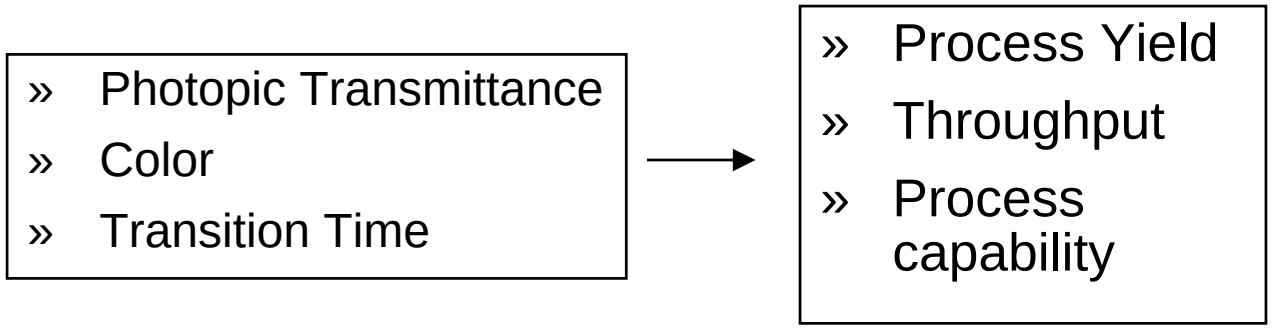
EC Process : Goals

- EC technology conversion from laboratory curiosity to a stable manufacturing process:



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EC Deposition Process Development

- Critical Parameters
  - Stoichiometry
  - Density
  - Morphology
    - Grain Size
    - Surface Roughness
- Critical Process Control
  - Residual Gas Pressure and Composition
  - Deposition Rate
  - Substrate Temperature
  - Substrate Preparation
  - Uniformity (thickness and homogeneity)

- EB evap.: WO_3, Ta_2O_5, Nb_2O_5, NiO, ITO, Al
- Thermal evap.: WO_3, $LiNbO_3$, K_xWO_3
- Sputter: WO_3, Ta_2O_5, Nb_2O_5, NiO, ITO, Al

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Analytical Techniques for EC

- Physical properties
  - Rutherford Backscattering Spectroscopy (RBS)
    - Density, Stoichiometry
  - Scanning Probe Microscope (SPM)
    - Morphology
- Optical Properties
  - Spectrophotometry: %T, %R, chromaticity
  - VASE: n,k,thickness
  - FTIR

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WO_3 process effect on EC performance

Process	Dep Rate Å/sec	% Bulk Density	Coloring Range %T, (633nm)	Coloring time (sec)
Thermal	20	94	85 - 8	3
Thermal	10	89	88 - 10	5
e-beam	0.5- 1.0	71	78 - 10	5.4
MetaMode® Hi P	90	80	82 - 5	5
MetaMode® Lo P	135	89	87-10	12

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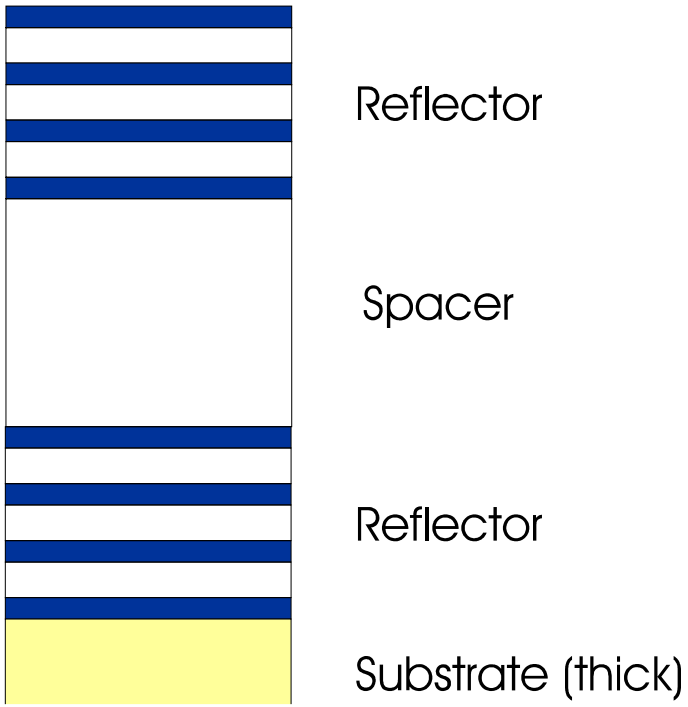
Example 3: Multilayer DWDMs

- DWDMs use high layer count filters
- Fabry-Perot etalons constructed from thin film dielectric materials:Ta_2O_5, SiO_2



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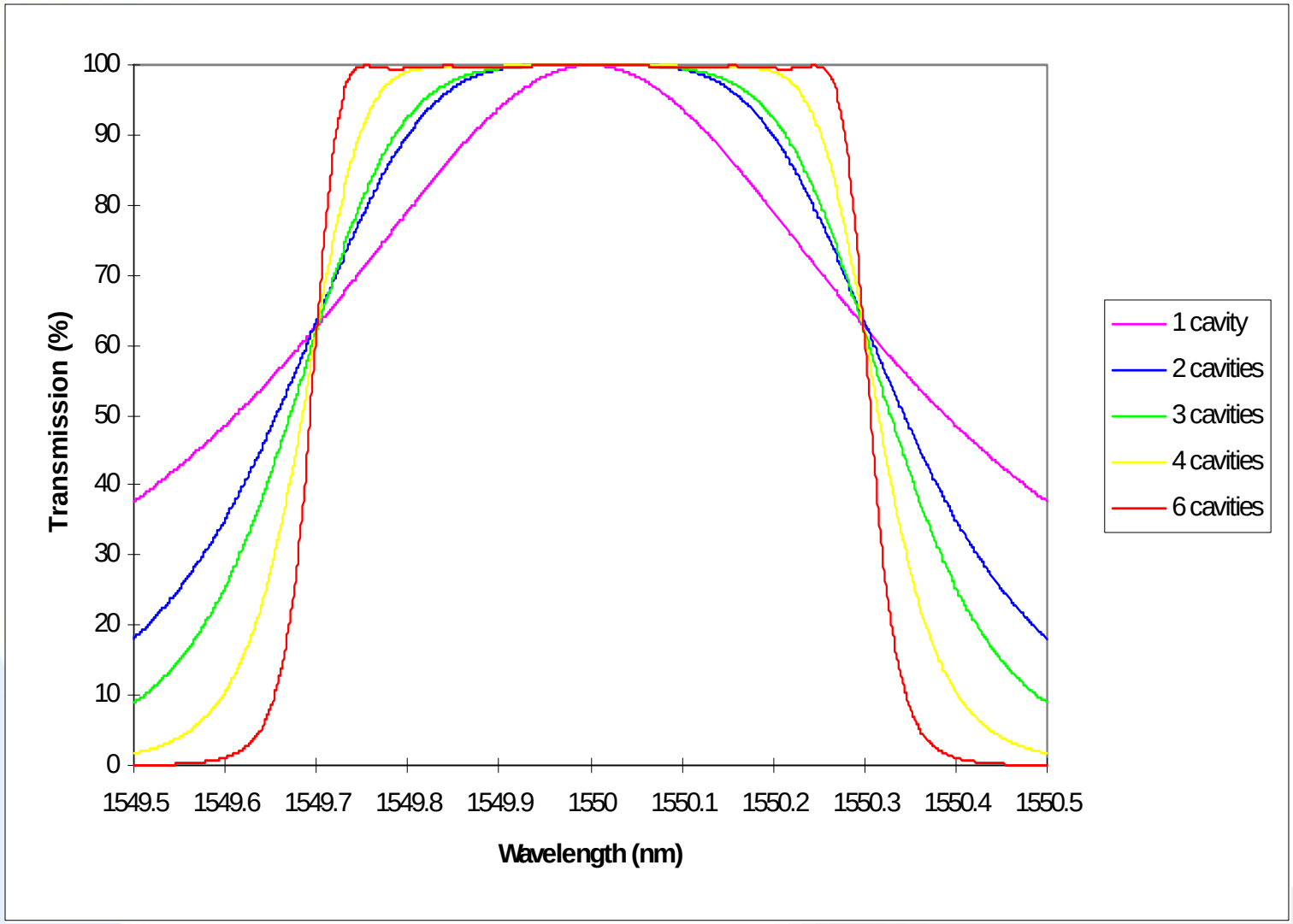
Multiple cavities needed for performance



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Film Properties for DWDM

- Environmental Durability
  - 20 years of field service is required
  - Accelerated aging test: Telcordia Generic Reliability 1221
  - 2000 hrs at 85°C/85% relative humidity
  - dense bulk-like films are needed
- Low loss
  - low scatter
  - low defect level from coating and substrate
  - amorphous microstructure
  - low absorption: $k < 10^{-6}$ @ 1550nm

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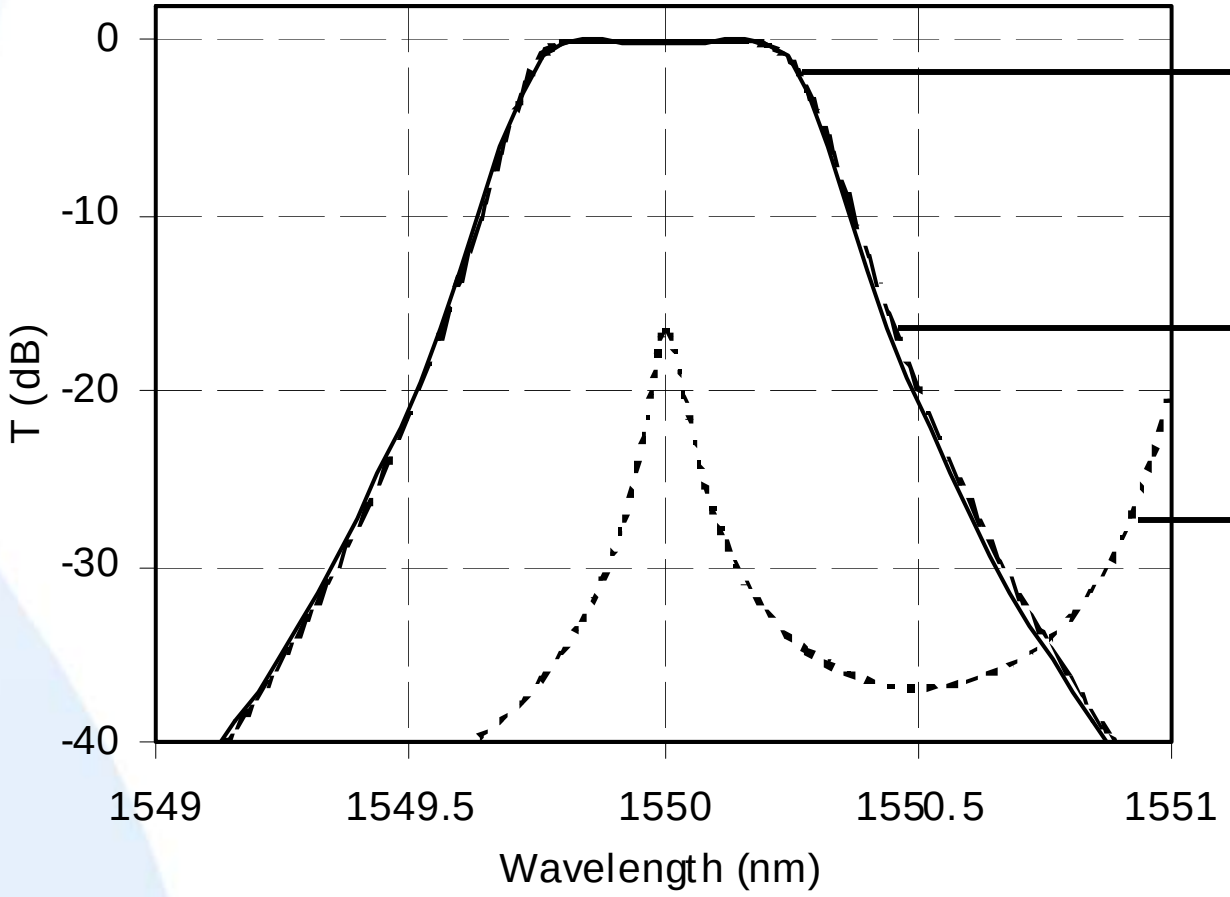
Composite Turning Point Monitoring



Thin film design

1% thickness error on each layer, with turning point monitoring

0.5% random thickness error on each layer

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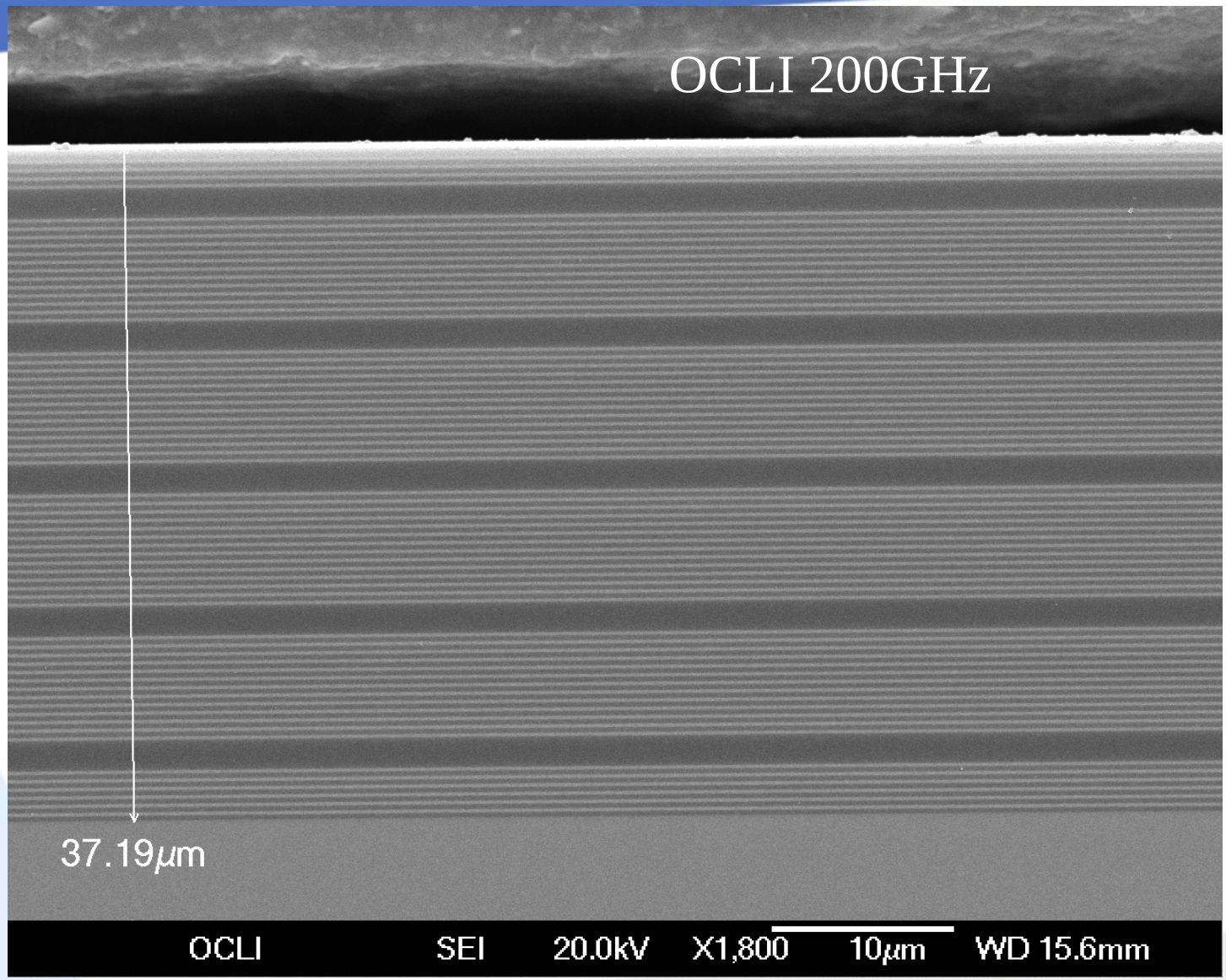
DWDM film structure



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Conclusions

- JDSU TFPG has experience developing a wide variety of thin film processes and devices.
  - Meeting several types of film requirements (optical, electronic, environmental, etc.)
  - Integrating many processes other than just deposition
- JDSU TFPG has experience developing and operating processes over a broad range of economic conditions.
  - Ranging from speculative development to mass production
  - And we can take processes and products continuously through this cycle
- OCLI has access through JDSU to many more technologies than previously.
  - Gas and solid state lasers
  - Active telecommunications devices

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