EPIC Online Technology Meeting on Specialty Optical Fibers

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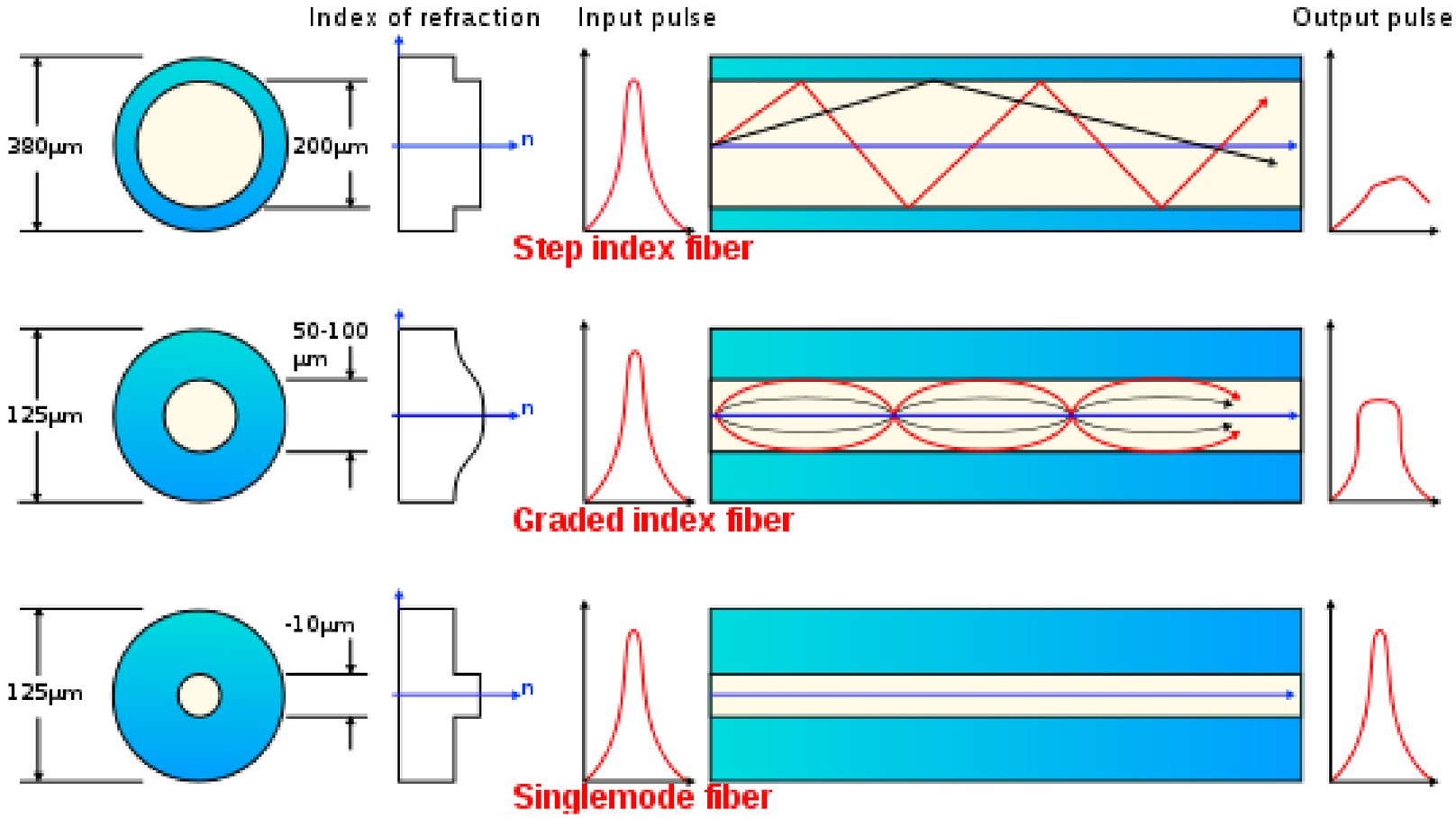
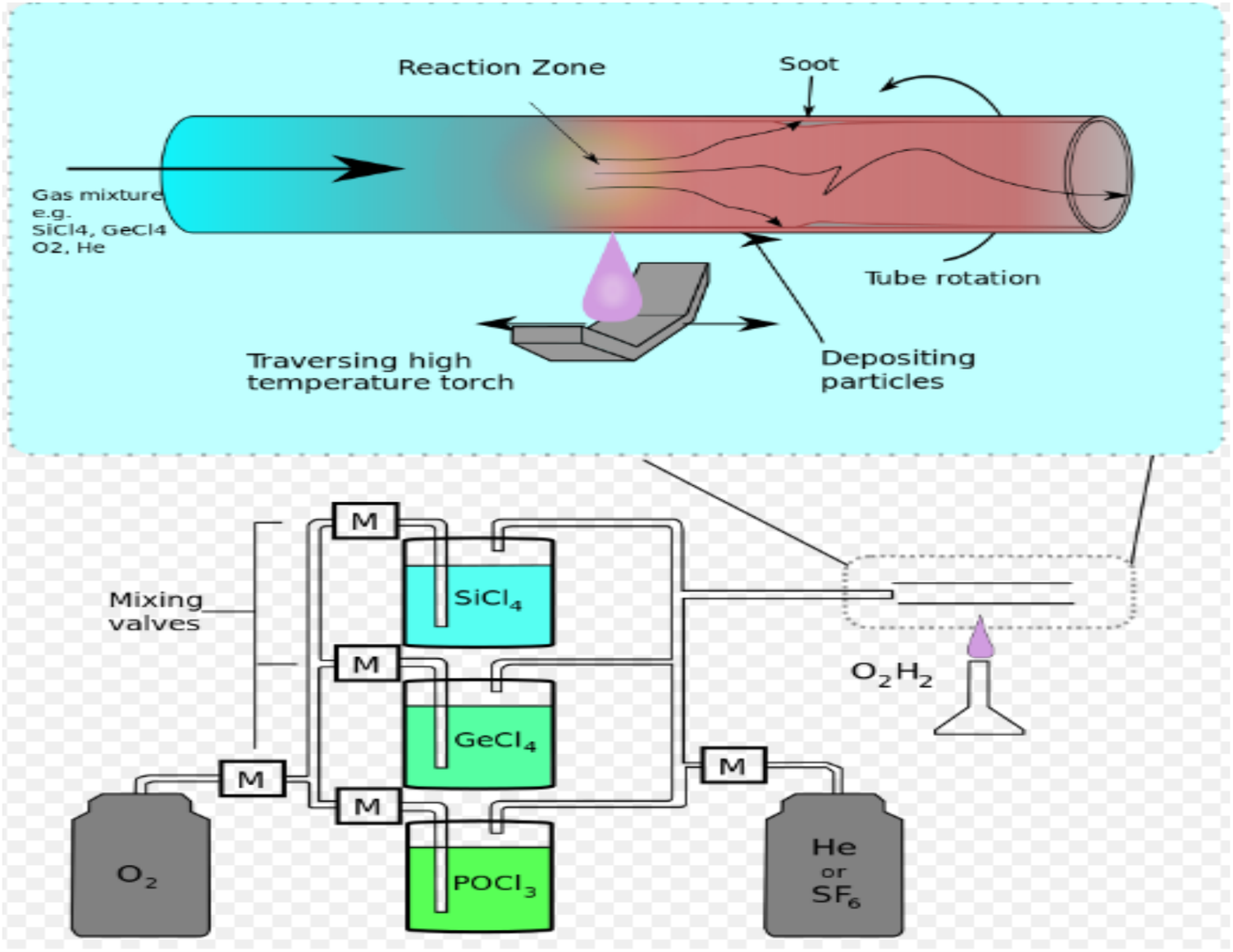
Outline

- Optical fibers for non-telecom applications
- A few examples of non-telecom applications
- Packaging (coatings, buffers, jackets)
- Future and challenges

Types of Fiber Waveguides



Preform Fabrication



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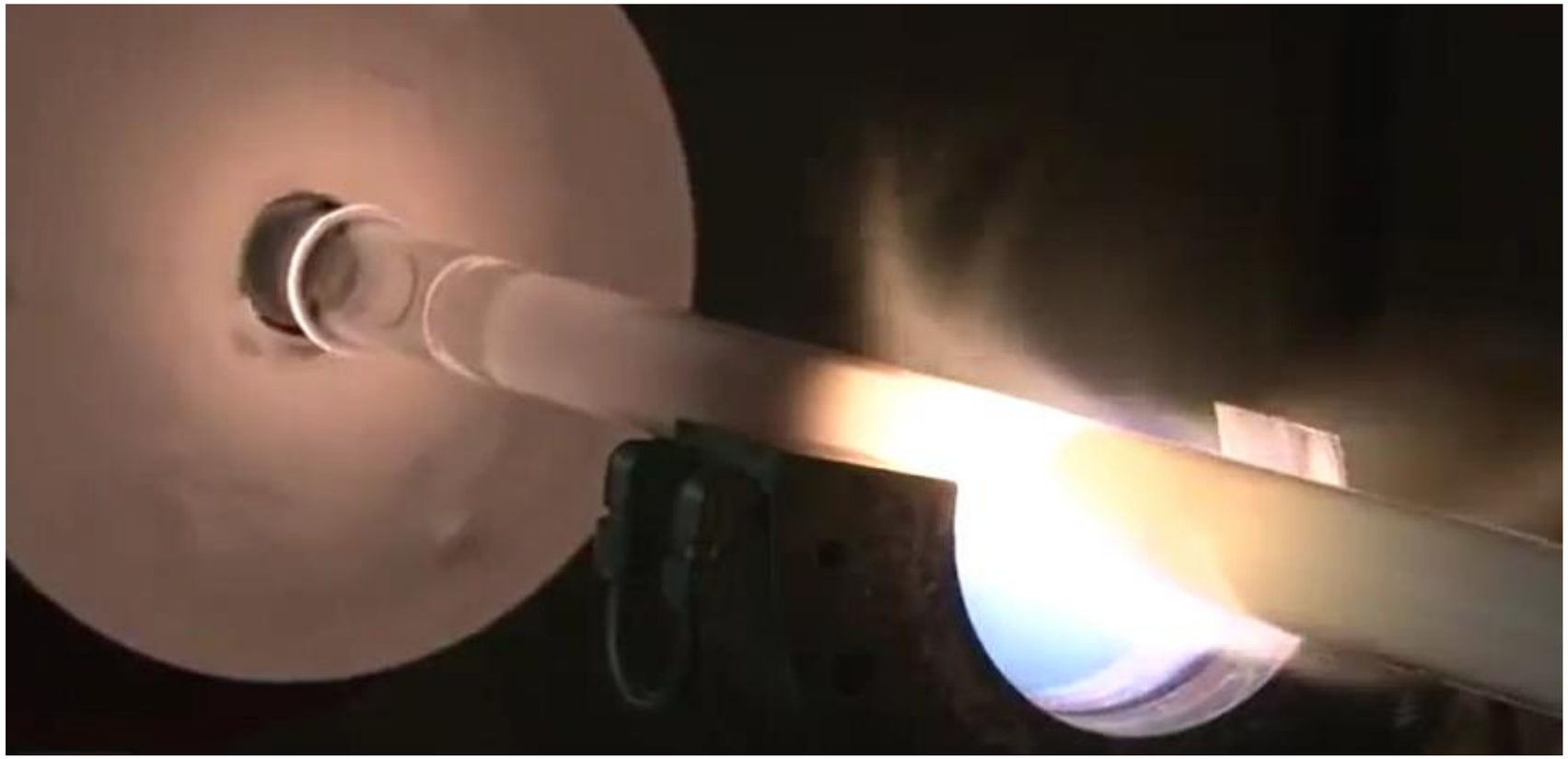


MCVD Process

Optical Fibers for Telecommunications

- Fiber optics for telecommunications – widely recognized as the backbone for global data and voice communication
  - Standardized
  - Produced in staggering volumes
  - Optical Fibers/Fiber Optic Cables
  - Incredibly long distances
  - Vast data rates
  - Extremely low attenuation

- Most know that you can transmit enormous amounts of data over very long distances.

Optical Fibers for Non-telecom Applications

- Fiber optics for "Specialty" applications
  - Much lesser known
  - Often custom in design
  - Used to harness and manage light to solve difficult problems in:
    - Medicine, Aerospace, Communications, Space, Oil and Gas, Security, Sensing

- ...but did you know that specialty optical fiber technologies can also:
  - Carry optical power
  - Amplify optical power signals
  - Detect temperature, strain, vibrations, sound, pressure
    - Amazingly – they accomplish this in "distributed" fashion
      - The fiber is the sensor
      - Virtually every meter along many tens of kilometers becomes a sensing point
      - Imagine a 60 km string of thermometers, microphones or strain gauges

Examples of Specialty Optical Fibers for Non-Telecom Apps.

- Hard clad silica optical fiber – industrial Ethernet
- Polarization Maintaining Fiber – Managing a signal
- Polyimide coated fibers - oil and gas sensing and medical devices
- Carbon coated fibers - hydrogen and fatigue resistance
- Hard Clad Silica medical fibers - high power laser in tight bends
- Pure silica core fibers - geophysical sensing in hydrogen containing environments
- Dual core fiber – dual end distributed temperature sensing (DTS)
- Fiber with enhanced Rayleigh scattering - distributed acoustic sensing (DAS)
- Multicore fibers - shape sensing
- Hollow core fiber - low latency transmission
- Fiber with dual Brillouin peaks - temperature and strain sensing

Markets

Aerospace & Defense

Inflight Communications, Sensing, Navigation, LIDAR, Directed Energy

Specialty Communication

Optical Amplification, Dispersion Management, Components, Modules and Sub-systems

Sensing

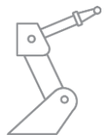
Acoustic, Temperature, Strain

Medical

Minimally-invasive procedures, high-power laser delivery

Fiber Laser

Free Space Communications, LIDAR and Directed Energy, Material Processing



Industrial Networks

Internet of Things, Utilities, Factory Automation

Some Special Applications of Fiber Optics

Aerospace and Defense

- In-Flight Entertainment
- Structural Health Monitoring (SHM) for airplanes
- Network in mobile platforms, planes, ships, trains, and cars
- Gyroscope
- Sensors and arrays

Medicine

- Benign Prostatic Hyperplasia (BPH)
- Laser lithotripsy for kidney stones
- Photodynamic Therapy (PDT)
- Repair of detached retina
- Optical Coherence Tomography (OCT) for cardiology
- Laser Tattoo removal
- Varicose vein treatment
- Signal link used in MRI
- Endoscopy

Light transmission

- Hybrid lighting
- Laser power delivery
- RF-over-fiber for microwave photonics
- Remote power over fiber
- Lidar and Autonomous cars
- Illumination
- Home entertainment systems

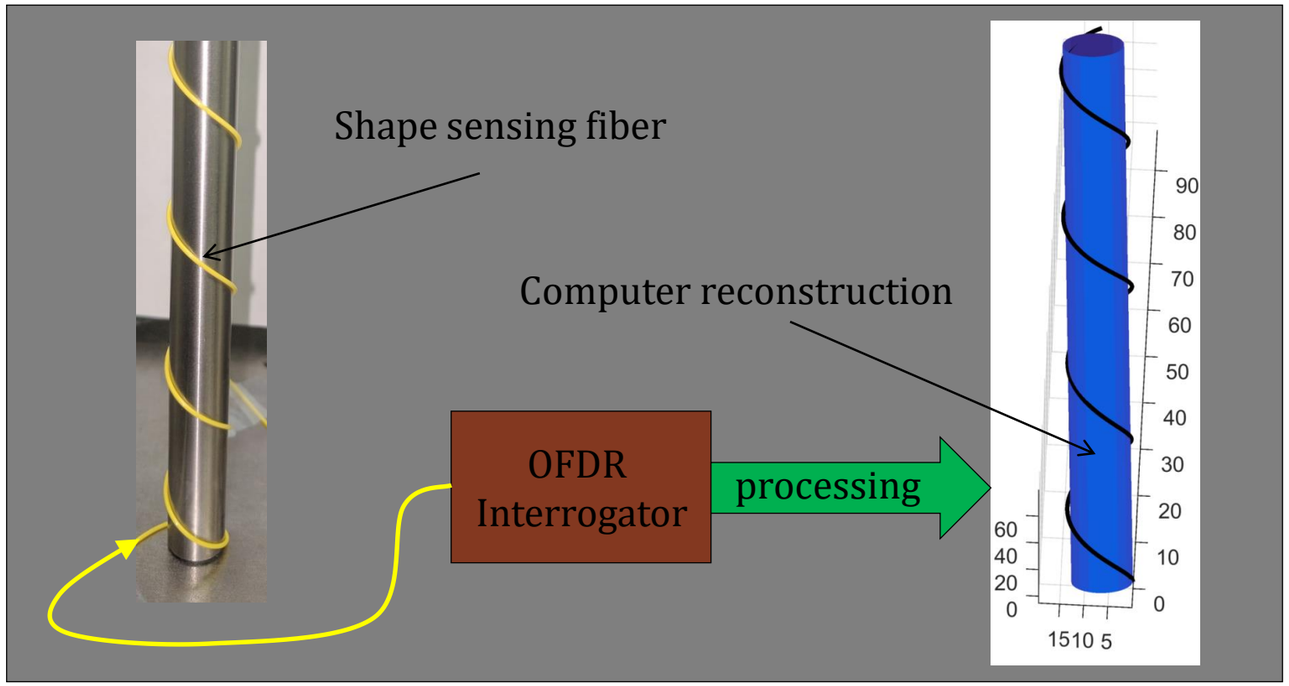
Sensing

- Industrial link-controls system
- Oil and gas sensing
- Pipeline monitoring
- Perimeter sensing
- Railroad sensing
- Highways and bridges
- SHM for Buildings

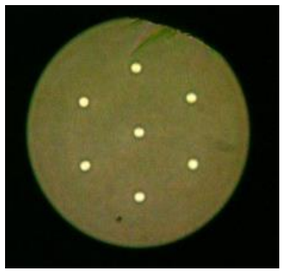
Industrial

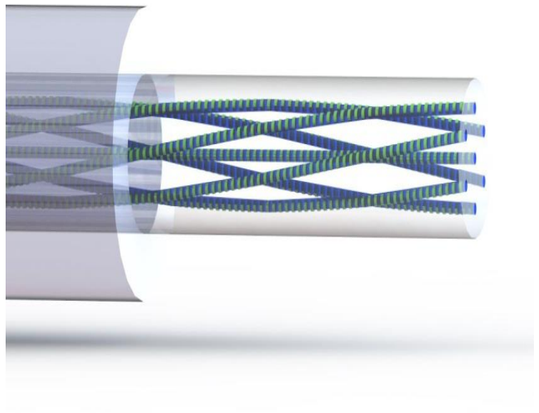
- Power grid
- Inspection and quality control
- Light triggered thyristors
- Current sensing
- Industrial Ethernet
- Silicon Photonics
- Low latency link
- Chemical sensing
- Environmental sensing
- Poultry management system

Optical fiber shape sensing



- *Bend* differential strain among outer FBGs
- *Twist* Common strain in all outer cores
- *Temperature* (or axial strain) equally affects inner and outer FBGs
- Center core: Insensitive to bend and twist. Continuous Bragg gratings make signal much larger.



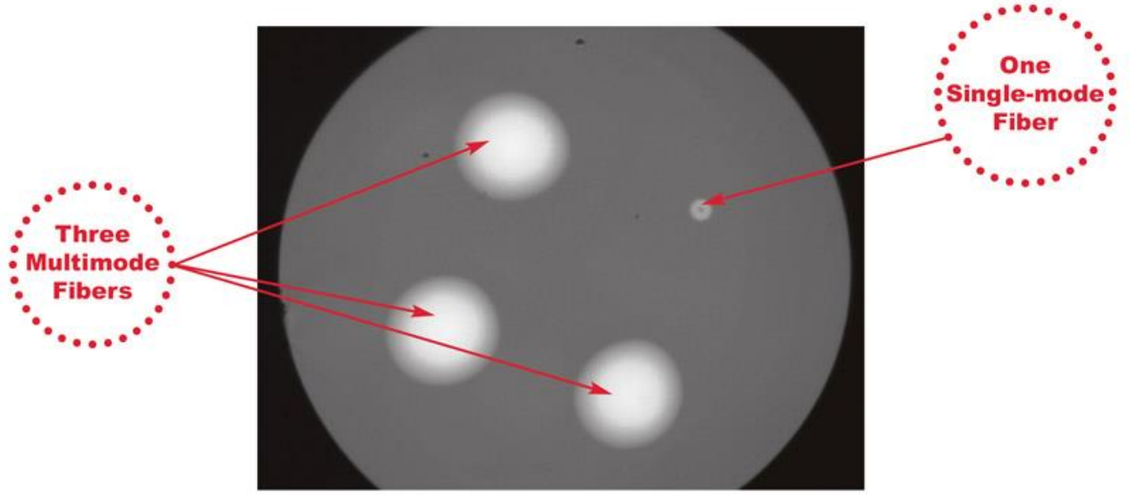


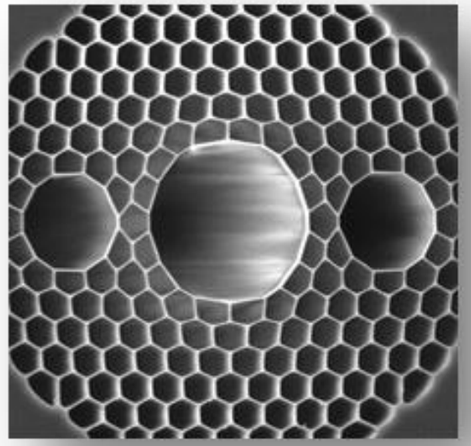
- Reconstruct the shape of an optical fiber using only reflected signals
- Compact, lightweight, robust, electrical immunity, all passive, no moving parts, cost effective

Westbrook et al, JTL (2017)

Multicore and Hollow Core Fibers

- **MCF**
  - Sensing and data links that require identical environments for all fiber cores.
  - Compact format
  - Simplified deployment process
- **HCF**
  - Radical new waveguide concept:
    - Guide light by bandgap
  - Propagation in air offers several advantages:
    - Low nonlinearity (by 10-3)
    - Low latency (30% faster)
    - Low temperature sensitivity
  - Sensing and data link





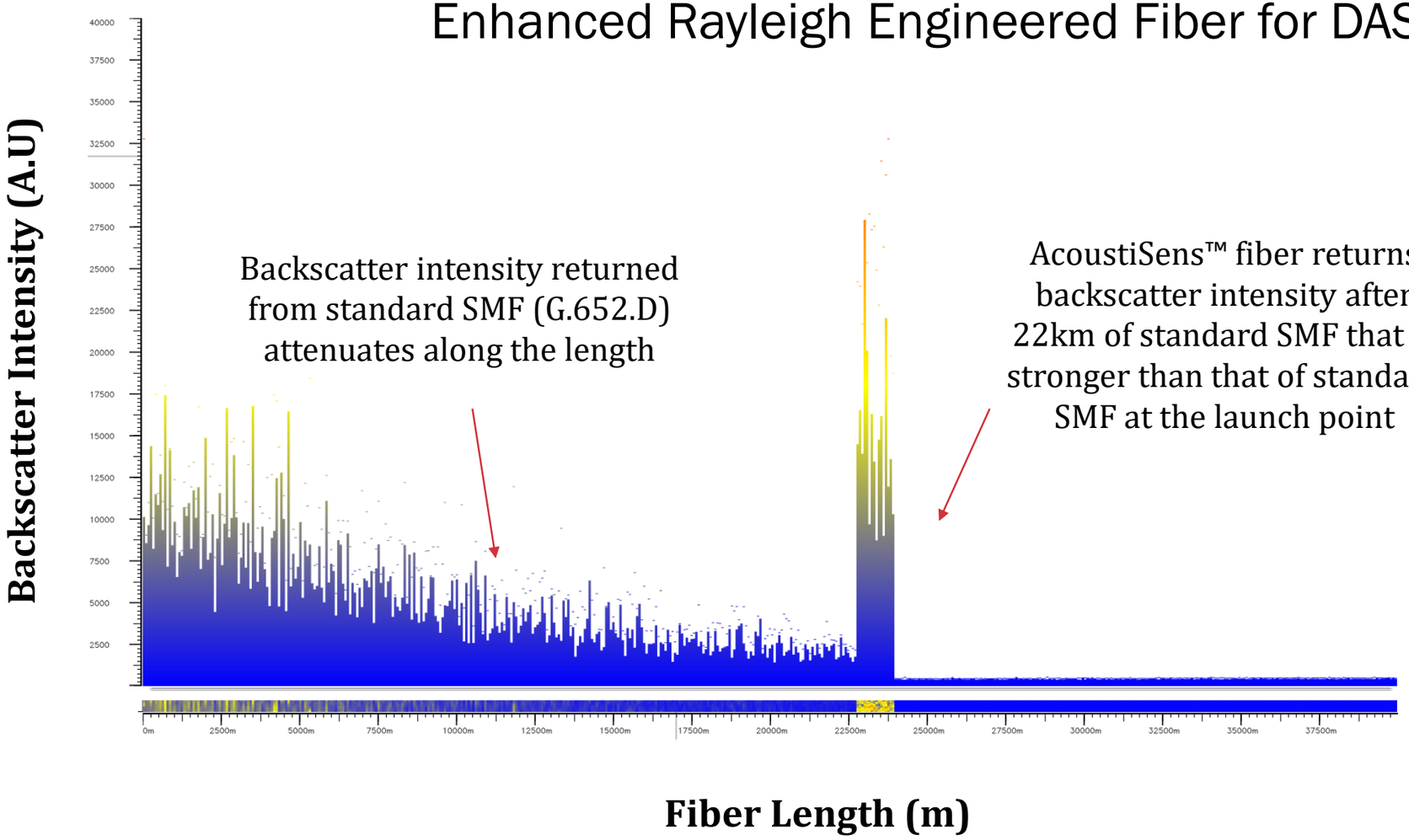
DFOS Markets and Applications

	Pipeline Condition (midstream)	Pipeline Heat Trace Monitoring	Intrusion/ Security	Geo-Technics	Transportation	Oil & Gas In-Well (upstream)	Industrial Processes	Structural Health	Power	Smart Cities/ Highways
DAS	Leak Intrusion/Security Pig Tracking Hot Tap/Valve Detection		Perimeter Security Activity Detection Tunneling Detection Monitoring of Cable Plant Physical Layer	Seismic Rock Fall Land Slide	Train Tracking Traffic Flow Track/Rolling Stock Condition Rock Fall	Seismic Fracking Flow Profiling	Conveyor Belt		Fault Finding TPI (Anchoring) Cable Conditions	Traffic monitoring, speed monitoring, vehicle identification, accident avoidance
DTS	Leak Soil Erosion Trace Heating Power Monitoring	Pipeline Heat Tracing		Geothermal Dams (Leak) Environmental Research	Fire Detection	Temperature Fracking SAGD Flow	Safety (Temp) Plant-Maintenance Process-Optimization Conveyor Belt	Dam/Dyke (Leak)	Load Management Fault Finding Cable Conditions Transformer/ Switching Gears	Locational road condition monitoring
DSS	Landslide Pipeline Deformation Subsidence		Tunneling Detection	Landslide Dam/Dyke	Train Tracking Track Condition Landslide	Casing Strain Bore Holes Deformation Ground Deformation	Hoop Strain Pipe Deformation	Deformation Dam/Dyke Building/ Bridges/Piles /Walls	Curvature/ Elongation (Cable Laying and Operation)	Bridge and highway degradation monitoring

Significant Backscatter Signal Improvement

DAS

Enhanced Rayleigh Engineered Fiber for DAS



- Increases Rayleigh backscatter (signal) while maintaining low attenuation (noise source)
- 10 to 15 dB improvement in Optical SNR (OSNR) compared to naturally occurring Rayleigh backscatter in G.652.D fibers

COATING, FIBER, CABLE CAPABILITIES

Customized Solutions for Harsh Environments

Considerations: Temp Range, Resistance to Chemicals, Abrasion, Radiation, UV and Flame

In-House Technical Experts

COATINGS

- Acrylate
- High Temp Acrylate
- Fluoroacrylate
- Silicone
- Low Temp Silicone
- Silicone/Acrylate
- Carbon
- Polyimide

BUFFERS

- PFA
- FEP
- ETFE
- PVDF
- PEEK
- Thermoplastic Elastomer
- PVC
- Nylon

CABLE JACKET MATERIAL

- PFA
- FEP
- ETFE
- PVDF
- PVC
- PU
- PE
- TPO
- LSZH

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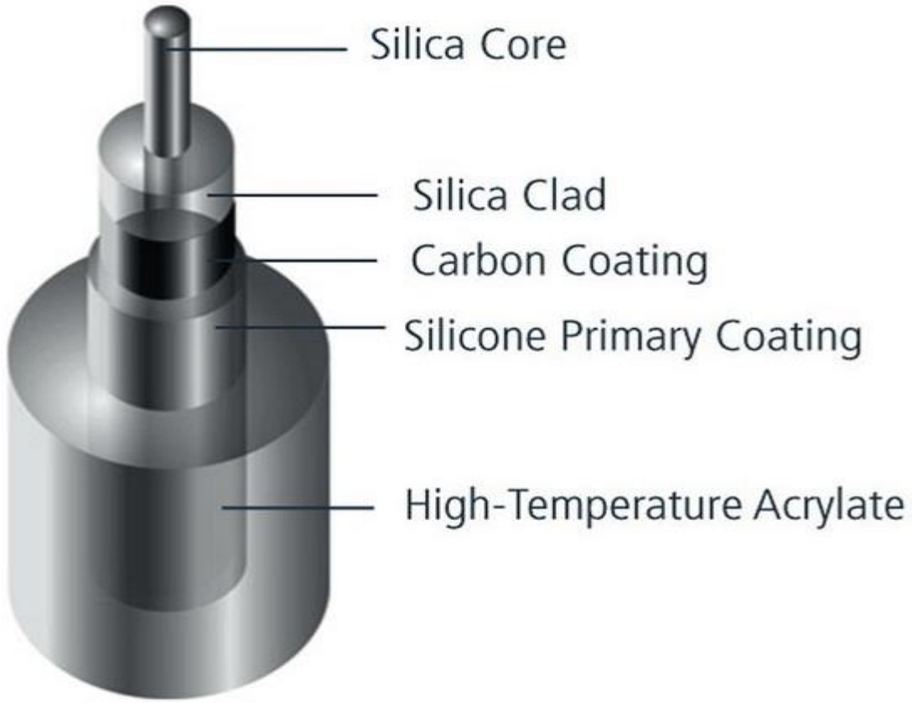
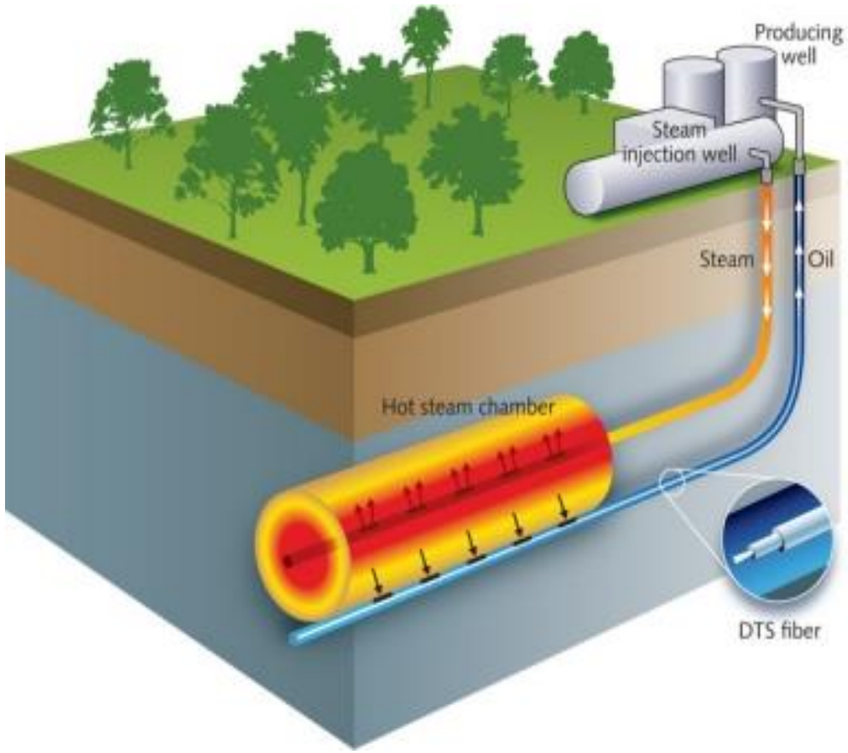
A Furukawa Company

Different coatings for different applications



Optical Fiber for Harsh Conditions

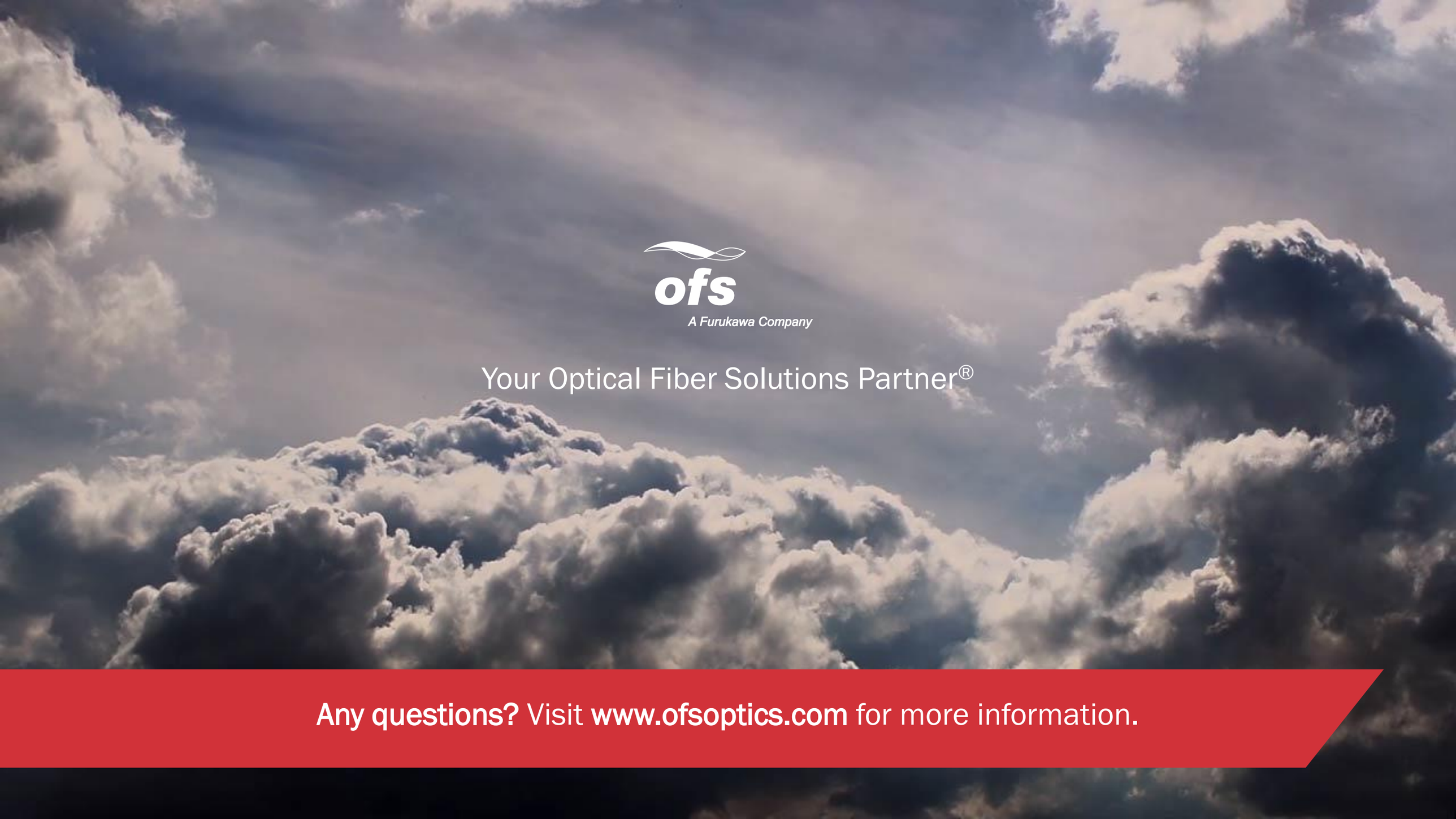


www.laserfocusworld.com

- Harsh Conditions
  - High temperature
  - High pressure
  - High humidity / steam
  - Aggressive chemicals
  - Mechanical interactions
  - Hydrogen
  - SAGD (Steam Assisted Gravity Drainage)
- Requirements for Fiber
  - Minimum added attenuation
  - No breaks
  - Long lifetime

Future and Challenges

- IOT, Smart cities, 5G
  - Merge of IT network, industrial network, and sensing network required by IOT and smart cities
- Emergence of optical fiber enabled devices and connections/links for commercial uses
  - Sensors
  - Medical devices
  - Optical computing devices
- More stringent requirements on performance and reliability
- Interdisciplinary collaboration
- Engineering solutions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