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Awesome Photons: The Current State of Fiber Optics

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FIBER OPTICS? GREAT STUFF - AND SO USEFUL!
OVER-BUILT INFRA-STRUCTURE
Mike Keefe 2001

GIBBLEGUTS.COM By Dan Gibson

Before the days of tiny fiber optics cameras, having an anoscopy was a scarey and often painful experience.

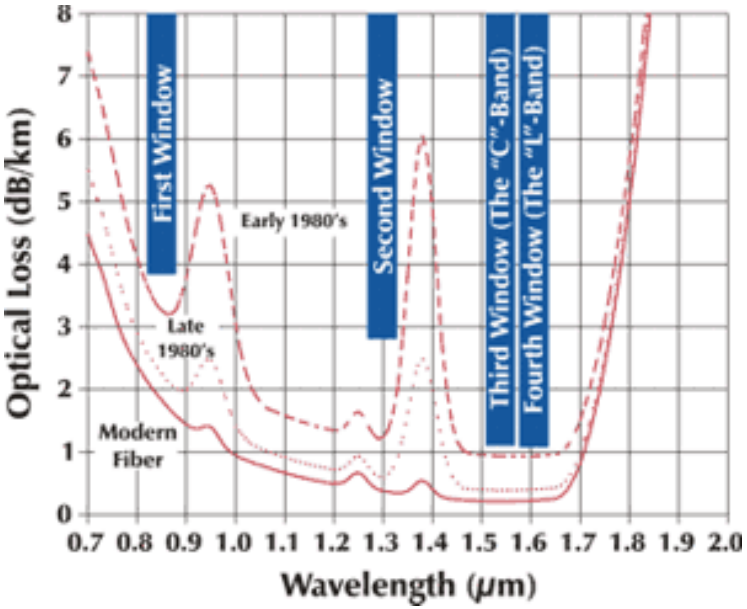
Outline

1. Fiber Basics. Why Fiber Optics?
2. Telecommunications Trends
3. Military and Aerospace Trends
4. Industrial Trends
5. Transportation Trends
6. Medical Trends
7. Q & A

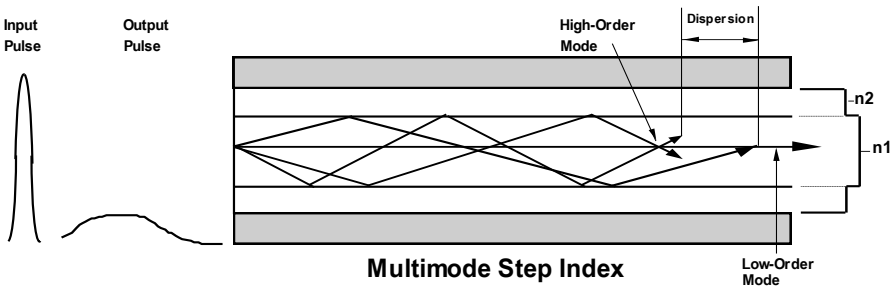
Some Common Acronyms

- MMF = Multimode Fiber (Typical operation at 850 or 1300nm)
- BW = Bandwidth, measured in MHz-km
- POF = Polymer Optical Fiber (Large Core MMF, up to 1000 µm)
- HCS = Hard Clad Silica Multimode Fiber (Typically 200/230 MMF)
- OM1 = Standard BW 62.5/125 MMF (200/500 MHz-km)
- OM2 = Standard BW 50/125 MMF (500/500 MHz-km)
- OM3 = Laser Optimized Medium-BW 62.5/125 MMF (Effective BW=2000 MHz-km)
- OM4 = Laser Optimized High-BW 50/125 MMF (Effective BW=4700 MHz-km)
- GbE = Gigabit Ethernet (1 Gb/s)

- SMF = Single-Mode Fiber (1300, 1550 and 1625nm)
- OS1 = Standard 9/125 SMF
- OS2 = Low Water Peak 9/125 SMF
- WDM = Wavelength Division Multiplexing
- CWDM = Coarse Wavelength Division Multiplexing
- DWDM = Dense Wavelength Division Multiplexing



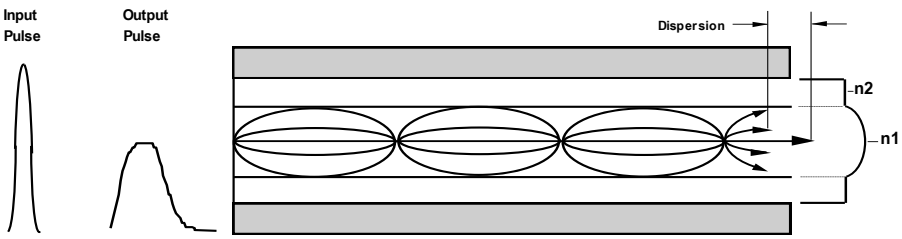
1. Fiber Basics



Multimode Step Index

Multimode Step Index Fiber

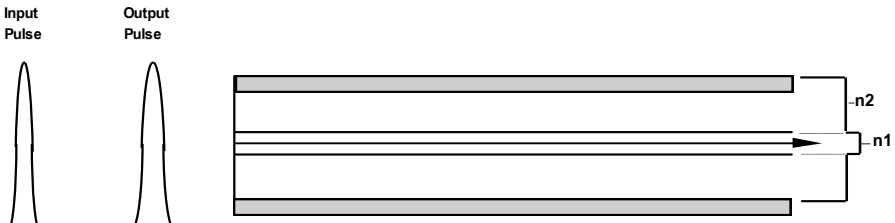
- Short distance links, <100 m
- 10-100 Mb/s, Single λ
- POF (1mm) or HCS (200/230)



Multimode Graded Index

Multimode Graded Index Fiber

- Short-Medium distance links, 10m - 2000m
- 100 Mbs - 10Gb/s, Single λ
- 50/125 (OM2/OM4) or 62.5/125 (OM1/OM3)



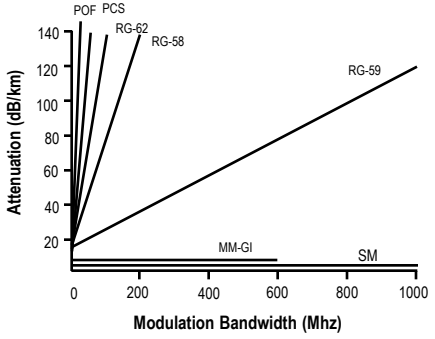
Single-Mode Step Index

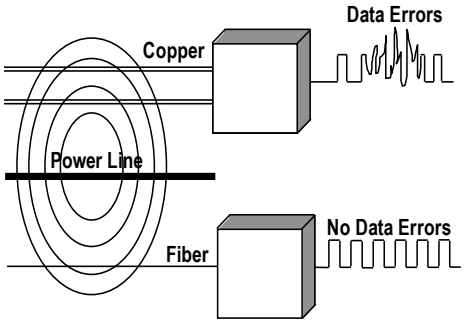
Single Mode Fiber

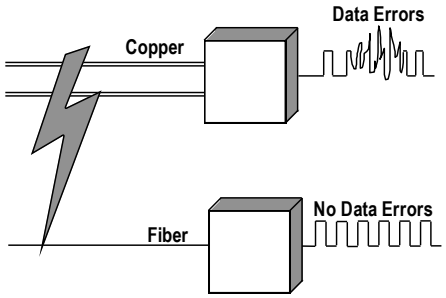
- Long distance links, 1000m -100km
- 2.5/10/40/100 Gb/s, Single λ or WDM
- 9/125

Advantages of Fiber Optics

- Small Size and Light Weight
- Highest Bandwidth-Density Product
- Ground Isolation
- Noise Immunity
- Intrinsic Safety
- Lightning and EMP Protection
- Intrusion Resistant
- Wide Temperature Range
- Non-Obsolescence
- Material Availability







Disadvantages of Fiber Optics

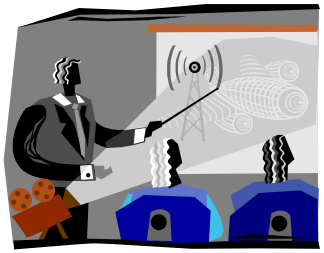
- **More expensive**

  Fiber optic components, connectors and cable assemblies are generally more expensive than copper-based components.

$$

- **Requires More Training**

  Fiber optic installers need more training than copper cable installers.



- **Requires More Care**

  Fiber optics is susceptible to mishandling and dirt. Workers dealing with fiber optics have to use care not to damage or degrade performance of the fiber optic system.

How is Fiber Optics Used?

Communications/Signal Transport

- Wired and Wireless
- Digital Links, Data Bus, Network
- RF Photonics

Sensors

- Intrinsic – Temperature Sensors, Bragg Gratings, Smart Structures, Fiber Optic Gyro
- Extrinsic – Rotary Encoder, Proximity

Light and Image Transmission

- Illumination – spot lighting, medical
- Imaging Optics – borescopes, surgery
- Laser Cutting & Marking – surgery, industrial fabrication

2. Telecommunications Trends

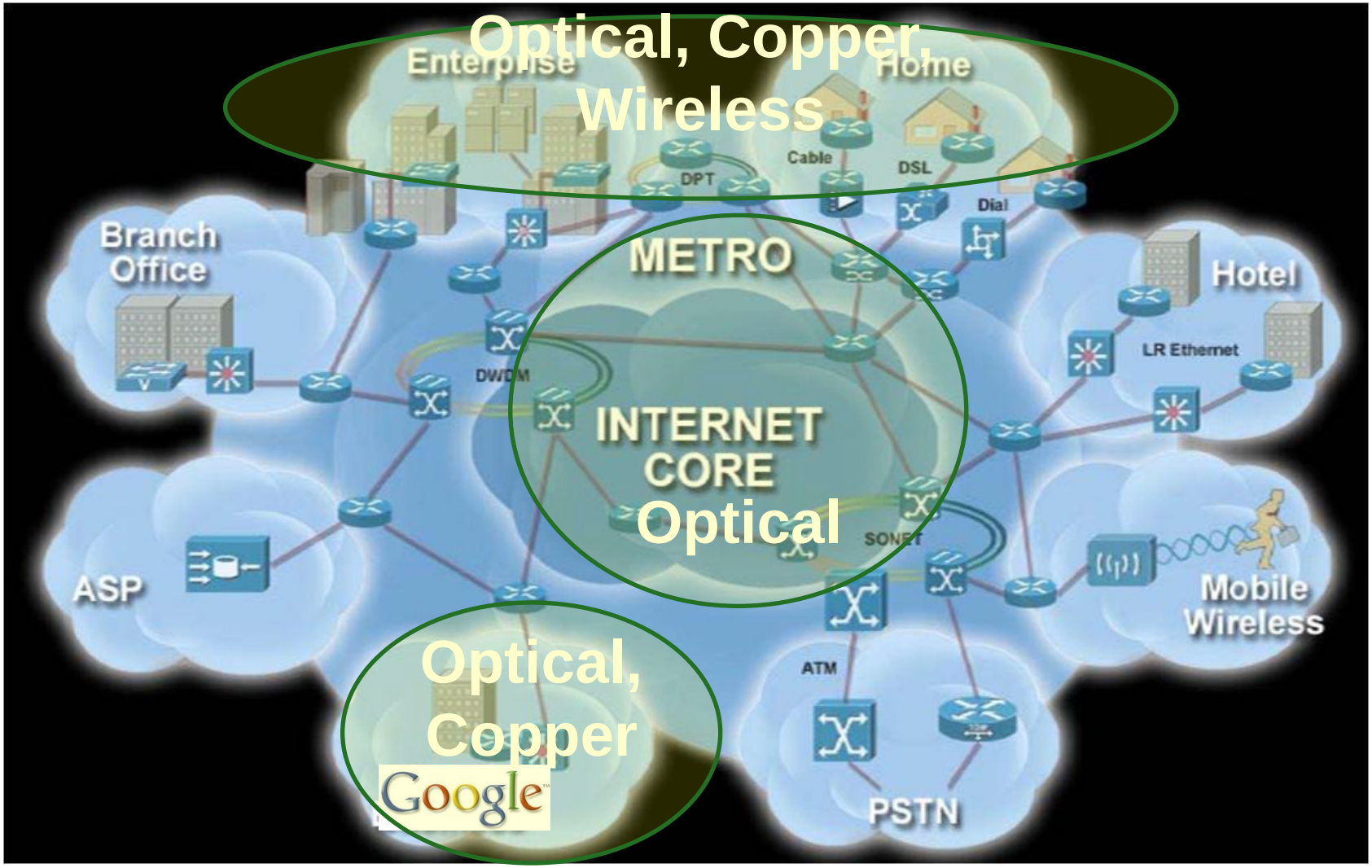
What is most important fiber attribute in telecom?

- Fiber offers the lowest TCO for long haul transmission
- Highest bandwidth over long distances
- Upgradable for increasing data rates
- TCO of Fiber and Copper equipment is near-parity but the high cost of Fiber To The Premises (FTTP) construction favors new housing over existing housing.

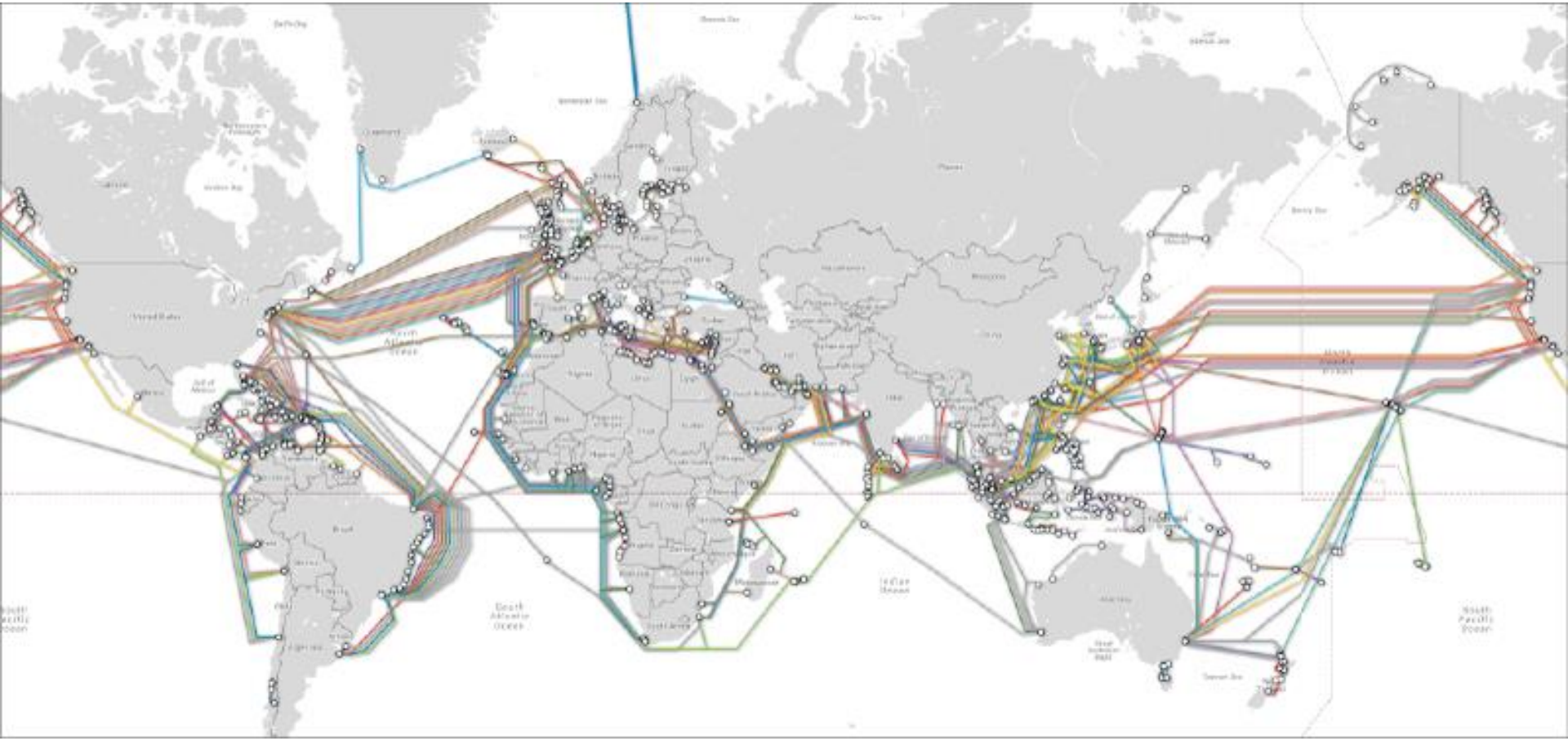
What is driving fiber construction?

- Expansion of cellular network for mobile broadband – especially smartphones, tablets and laptops
- Enterprise expansion and new FTTX installations

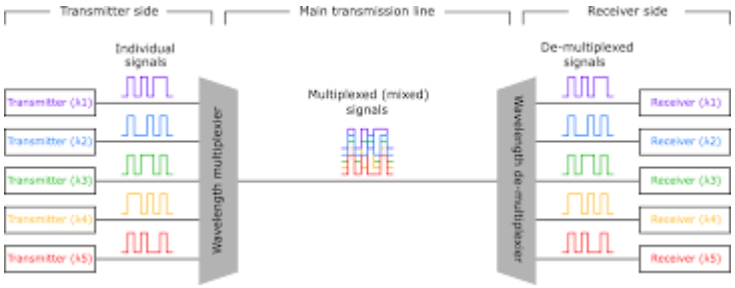
Global Network



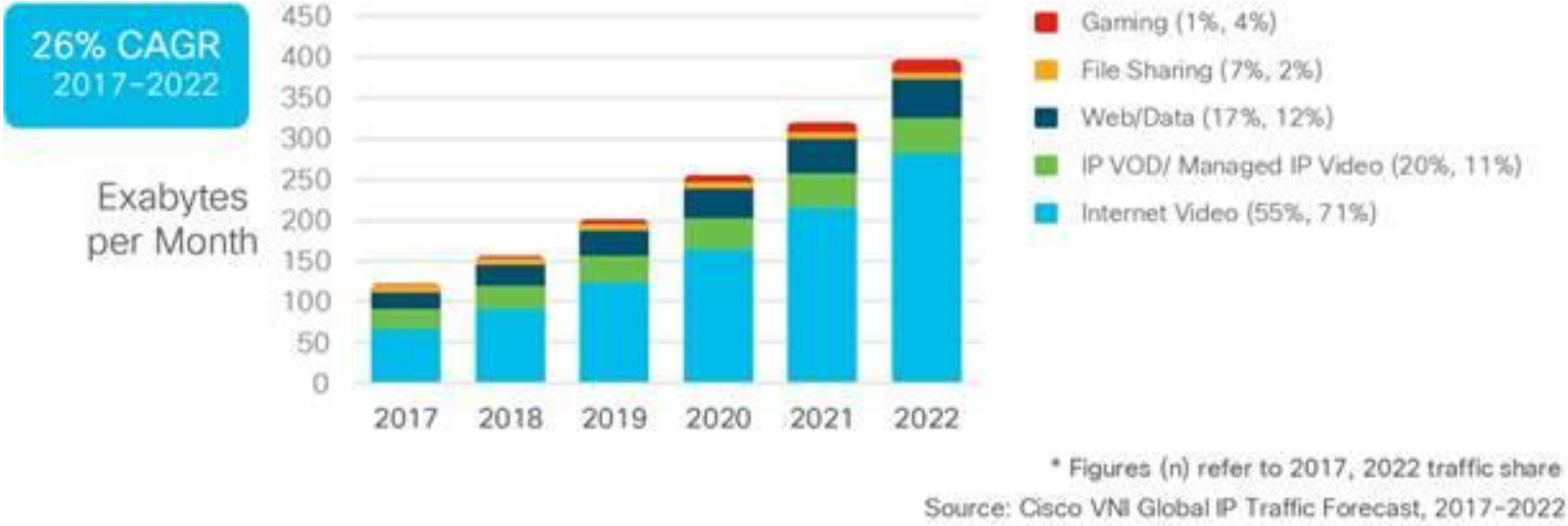
Worldwide Submarine Cable Networks



Enabling Technology:
Dense Wavelength
Division Multiplexing (DWDM)

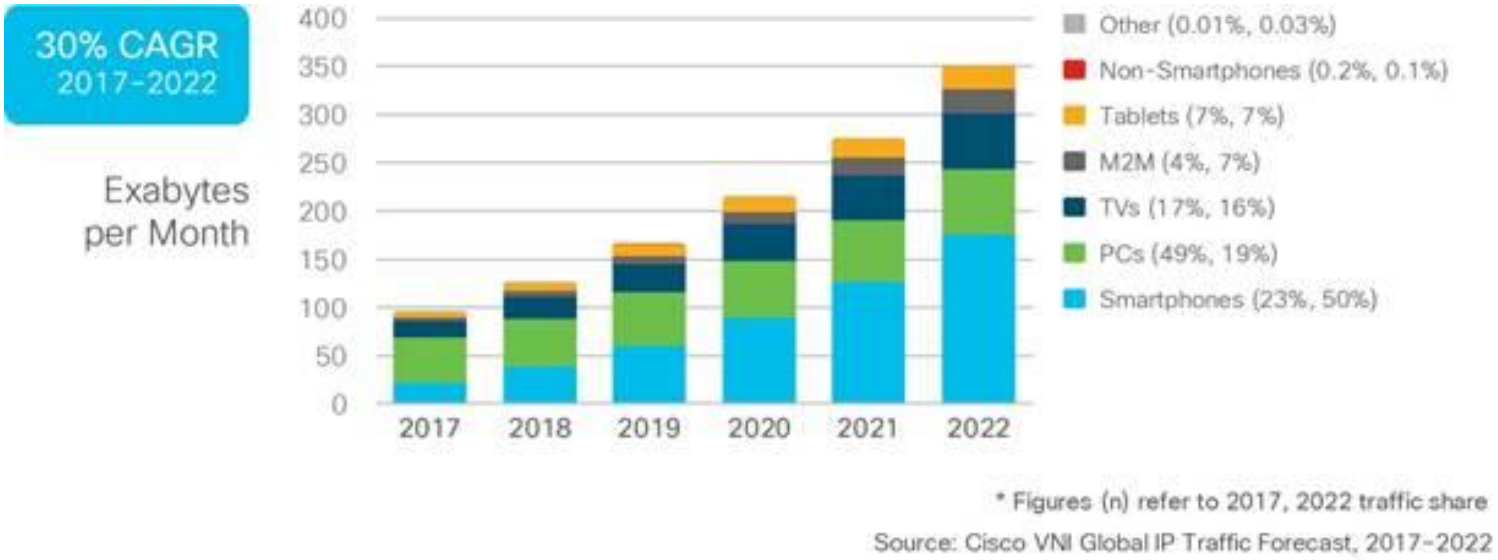


What Are We Using The Internet For?



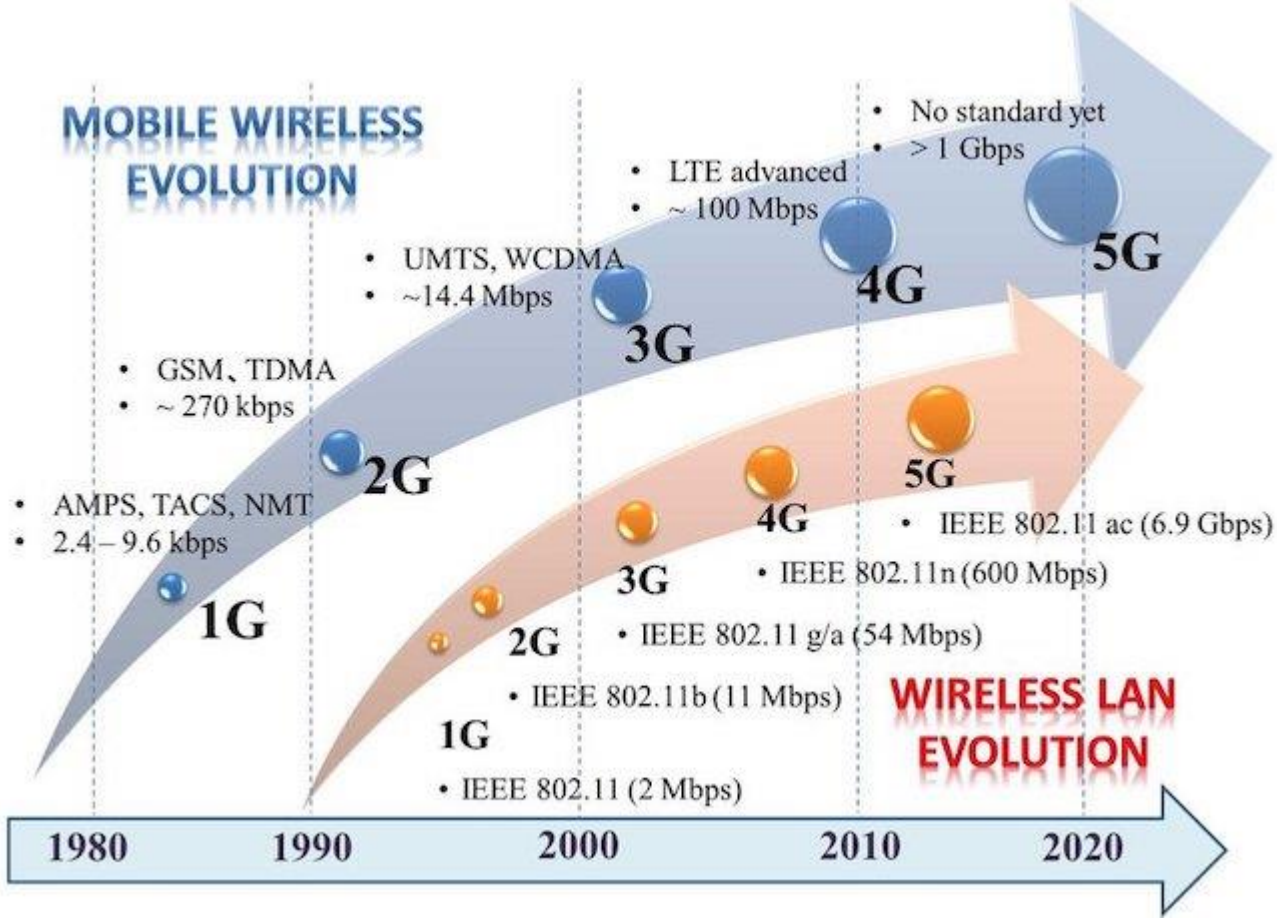
The network is under constant pressure to upgrade!

How Do We Access The Internet?



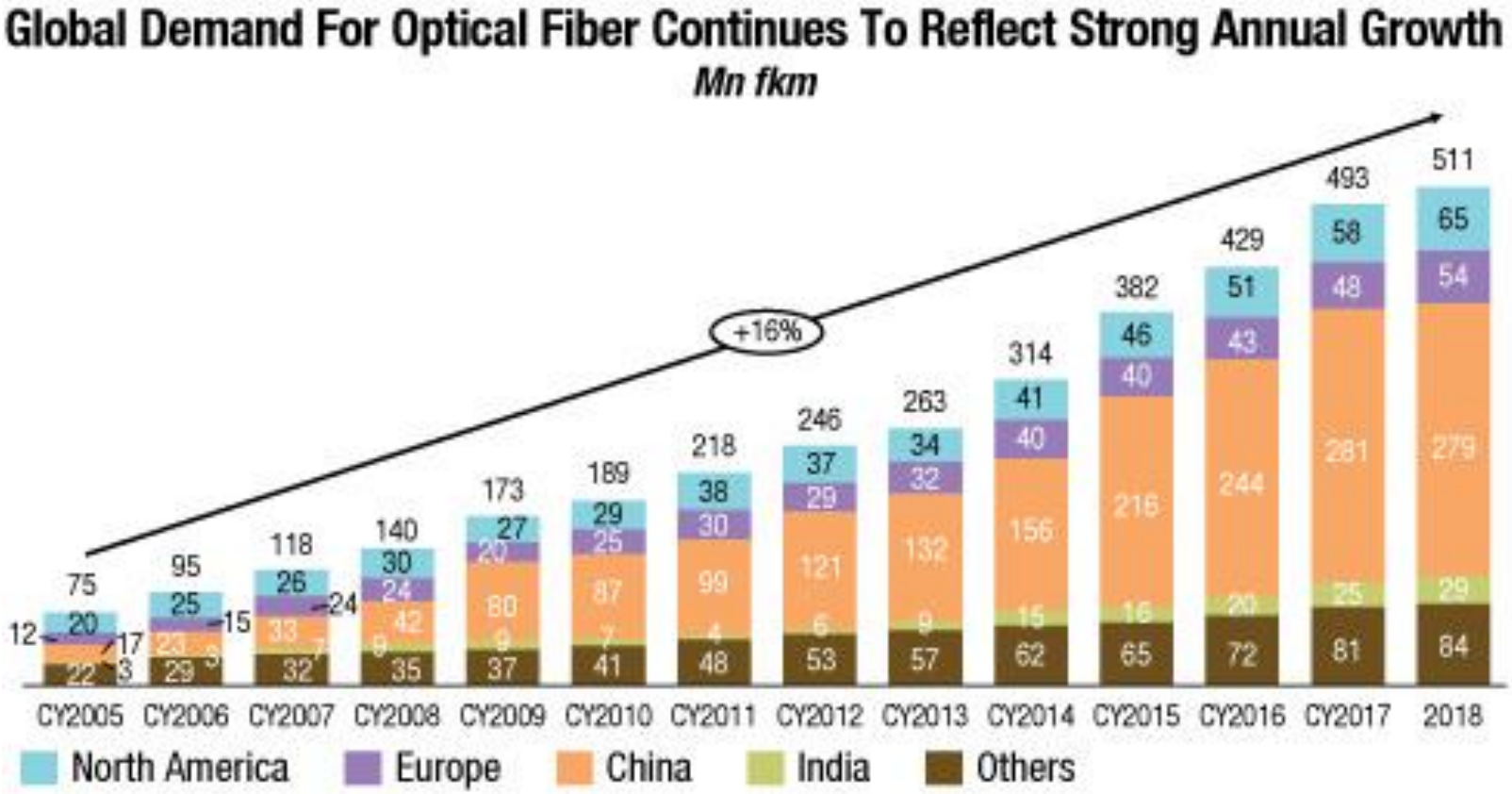
The network is under constant pressure to upgrade!

Mobile Wireless Evolution



…Enabled by the underlying optical fiber network technology which connects cell towers and base stations to the worldwide network

Optical Fiber Demand



More Bandwidth = Requires More Fibers
More Bandwidth = Smaller & Denser Interconnects
More Bandwidth = Shift from MMF to SMF

Interconnect Trends

More Bandwidth = Requires More Fibers
More Bandwidth = Smaller & Denser Interconnects
More Bandwidth = Shift from MMF to SMF

Duplex LC

MTP

12-fiber MTP/MPO

12 Fibers

Hybrid Solution: Active Optical Cables

- **Longer Distance over Multimode Fiber**
- **Optical Transmitters and Receivers built in**
- **No need for optical connectors or related expertise**

3. Military & Aerospace Trends

The Future is Light

The delivery of the first Boeing 787 Dreamliner represented more than just the aircraft's revolutionary composite materials, fuel-efficient engines and health monitoring and reporting systems … **fiber optics played a critical role in the avionics systems, saving weight and protecting against electromagnetic interference.**

First 787 Delivery to ANA

When developing the 787 aircraft, Boeing was able to cut at least 60 miles off the length of wiring due to fiber optics.

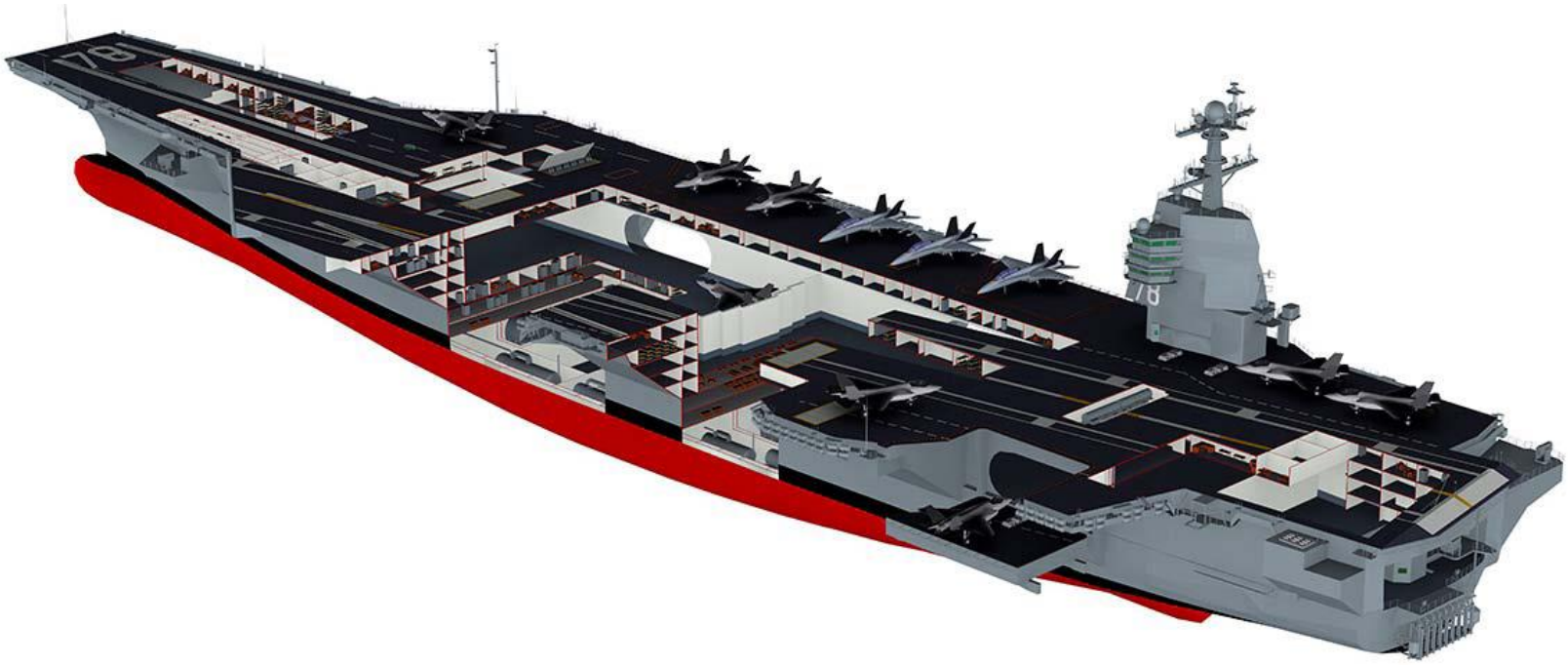
787 Cockpit

The 777 was the first commercial aircraft launched with a glass fiber-based optical fiber network. First delivered in 1995.

The 777-X will be first aircraft to use POF Graded Index Fiber. First delivery 2021-2022.

New Gerald R. Ford-class Aircraft Carrier CVN-78, Expected Delivery 2032

- The ship's design enables the Navy to operate the ship with 20% less manpower and operate 25% more sorties (flight missions) than previous Nimitz-class carriers
- Ten million feet of electrical cable is installed on *Ford*, enough cable to span the distance from Washington, DC to Albuquerque, NM.
- Four million feet of fiber optic cable is installed on Ford, the length of more than 7,200 Washington Monuments stacked on top of each other.



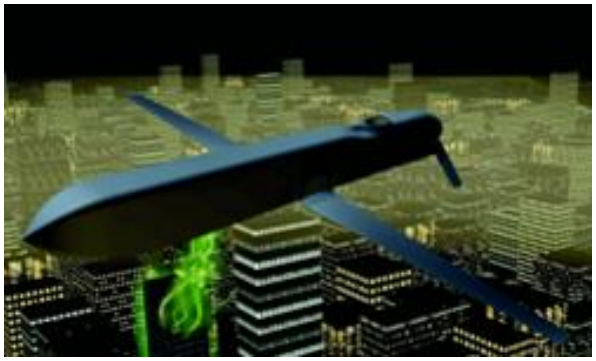
China Building Electromagnetic Pulse (EMP) Weapons

A declassified intelligence reports China's military is developing EMP weapons that Beijing plans to use against U.S. aircraft carriers in any future conflict over Taiwan.

EMP weapons mimic the gamma-ray pulse caused by a nuclear blast that knocks out all electronics, including computers and automobiles, over wide areas. The phenomenon was discovered in 1962 after an aboveground nuclear test in the Pacific disabled electronics in Hawaii.

Electronic Warfare Missile

The U.S. has built, flown, pointed and triggered a missile designed specifically to carry a directed energy weapon (DEW). The payload, expected to be operational soon, will be able to disrupt, shut down, spoof or damage electrical systems. Boeing has been working with AFRL on the Counter-Electronics High-power microwave Advanced Missile Project (CHAMP).



4. Industrial Trends

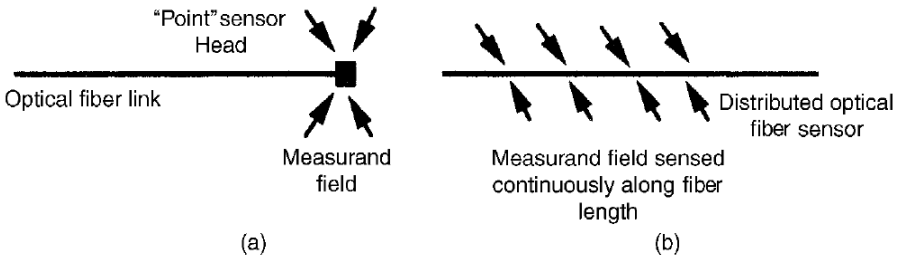
Where does fiber optics fit in?

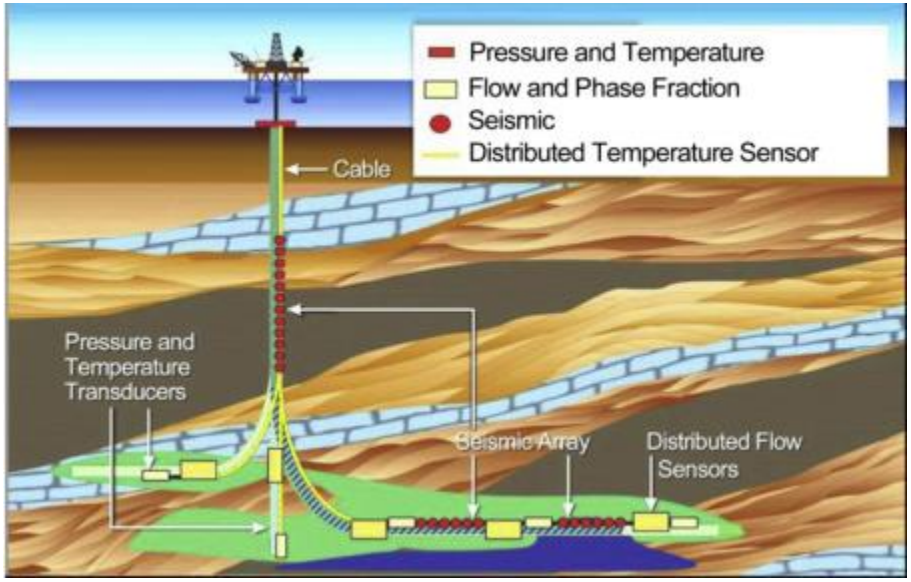
- Deploying fiber optic cabling and networks around the factory eliminate EMI problems caused by RF/wireless interference & large electrical equipment
- Fiber optic sensors solve EMI issues introduced with replacing old energy-hungry motor drives with new VFD systems.
- Passive fiber optic sensors can be easier to install and cheaper to deploy in hazardous locations, i.e. fuel tanks, etc.

What are the challenges to using fiber optics?

- Industrial market can be very “old school” and prefer copper solutions
- Unlike the well-trained and procedure-oriented Telecom and Mil/Aero sectors, the industrial world is mean, dirty and hazardous.
- Optical products must be **Plug & Play… and FORGET**.

Fiber Optic Sensors Improve Downhole Monitoring





The problem is that the average oil well is not a particularly hospitable environment for sensing devices. Components are subject to pressures of 10,000 psi and temperatures of 300°C or more. The crude oil is a soup of hydrocarbons that can attack all forms of materials.

Enter the distributed optical sensor solution. Using passive devices, systems are now able to remotely monitor temperature, pressure, flow and other metrics. They can even take seismic readings along sections of the well, which can help engineers located oil deposits.

The clever aspect of this approach is that all of the sensitive electronics stay up on the surface.

5. Transportation Trends

Fiber Optics Take A Drive In Automobiles

- **Lighting**
- **Communications**
- **Sensing**

MOST Automotive Network

Fiber transmits 'cold' light, making it a safe alternative to traditional sealed beam or halogen lighting. Fiber also allows for light source and output location separation, creating high performance lighting options for difficult and restricted access locations.

Communications and sensing in automobiles is of utmost importance with the continual increase in onboard safety devices and systems.. On-board sensor and entertainment systems require more and more bandwidth.

MOST (Media Oriented Systems Transport) network standard has been in use on automobiles for 10+ years.

LED and Fiber Optic Taillights

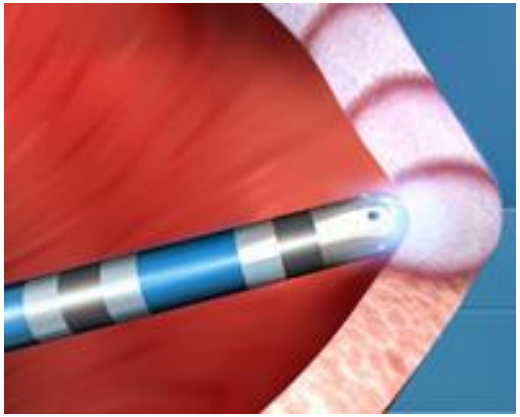
Optical Sensors Improve Railway Safety

A string of fiber-optic sensors running along a 36-km stretch of high-speed commuter railroad lines connecting Hong Kong to mainland China has taken more than 10 million measurements over the past few years in a demonstration that the system can help safeguard commuter trains and freight cars against accidents.

Attuned to the contact between trains and tracks, the sensors can detect potential problems like excessive vibrations, mechanical defects or speed and temperature anomalies.

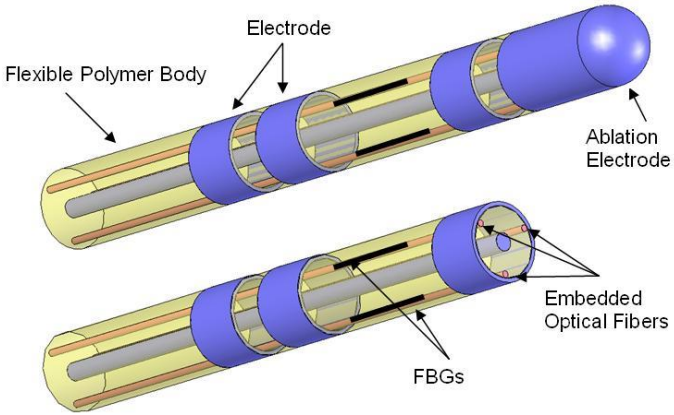
6. Medical Trends

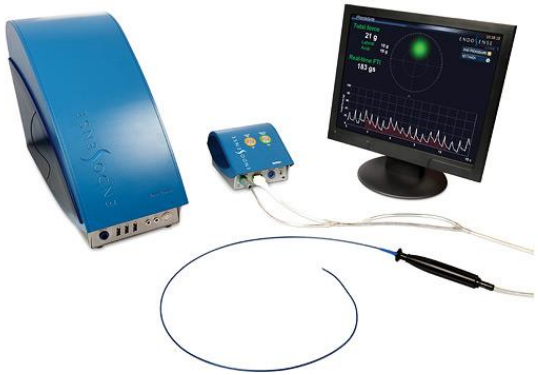
Force Sensing Ablation Catheter Calculates Pressure Applied With Embedded FBG Sensor



The next generation TactiCath force-sensing ablation catheter was recently granted CE mark and unveiled at German Cardiac Society meeting in Mannheim, Germany. The product gives physicians a real-time, objective measure of contact force during the treatment of cardiac arrhythmias. It includes a smaller fiber optic sensor at the tip, a force-time integral display and automatically generated summary reports of the procedure.

Contact force is derived by three optical fibers which measure micro deformation of the catheter tip using Fiber Bragg Grating technology.

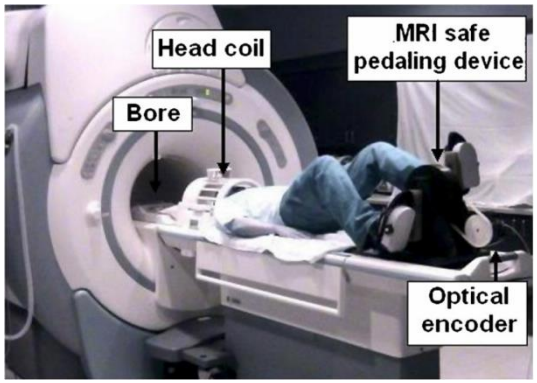


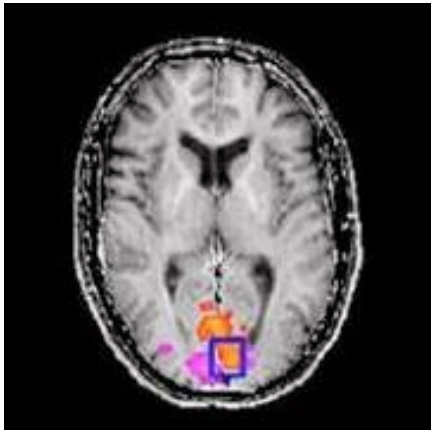


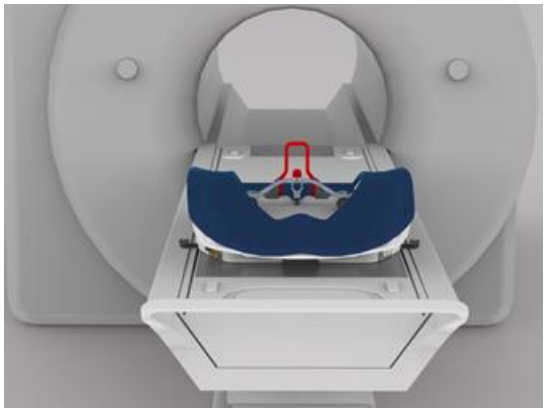
fMRI Research and MRI Guided Robotic Systems require Passive, Non-Metallic, Fiber Optic-based Sensor Solutions

- Micronor MR328 MRI Safe Incremental Encoder
- Micronor MR338 MRI Safe Absolute Encoder
- Micronor MR430 MRI Safe POF Abs Encoder
- Micronor MR386 MRI Safe Microswitch
- Optocon MRI Safe Temperature Probes

MRI-based research is ever expanding but the extremely high electromagnetic fields (measured in Teslas!) precludes using electronics or other metallic components. Whether monitoring physical-stress inducing pedaling or pneumatic-driven treadmill, these motion control applications require position and speed feedback. Passive fiber optic-coupled sensors are the solution – and sensors of all types are required. The plastic construction is also ideal for radar and EMC test applications where RF “transparency” is required.







7. Questions?

Thank you for your attention and interest!

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