

# *Introduction to Biomedical Applications of Optical Fibers & Fiber Sensors*



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**Monday, 11 April 2022, 15:00 - 17:00 CEST**

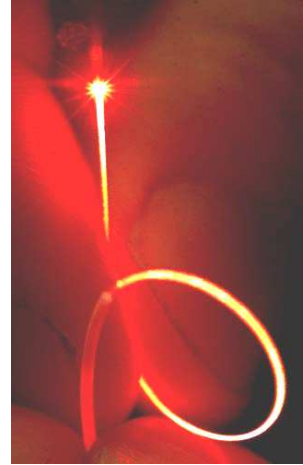
**EPIC Online Technology Meeting on Medical  
Fiber Sensing**

# Contents

- **Why Fiber Optics in Medicine?**
- **Healthcare Industry Trends**
- **Biomedical Sensing – Vast Applications**
- **Market Opportunities & Outlook**
- **Conclusions**

# *Why Fiber Optics In Medicine?*

# The Impact of Light in Medicine



Light is **energy**. Depending on its intensity and wavelength, light can interact with tissues and patients in different ways and be used in medicine for diverse applications.

- *Can be used as a probing signal → Imaging, Analytics & Sensing*
- *Or used as a power source → Treatment, Therapeutics*

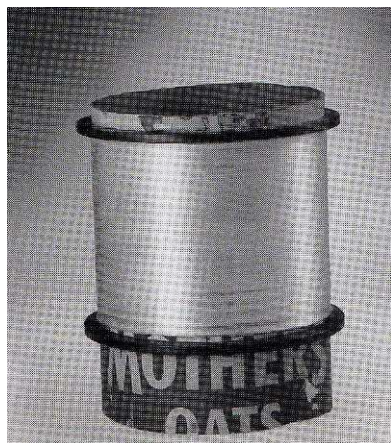
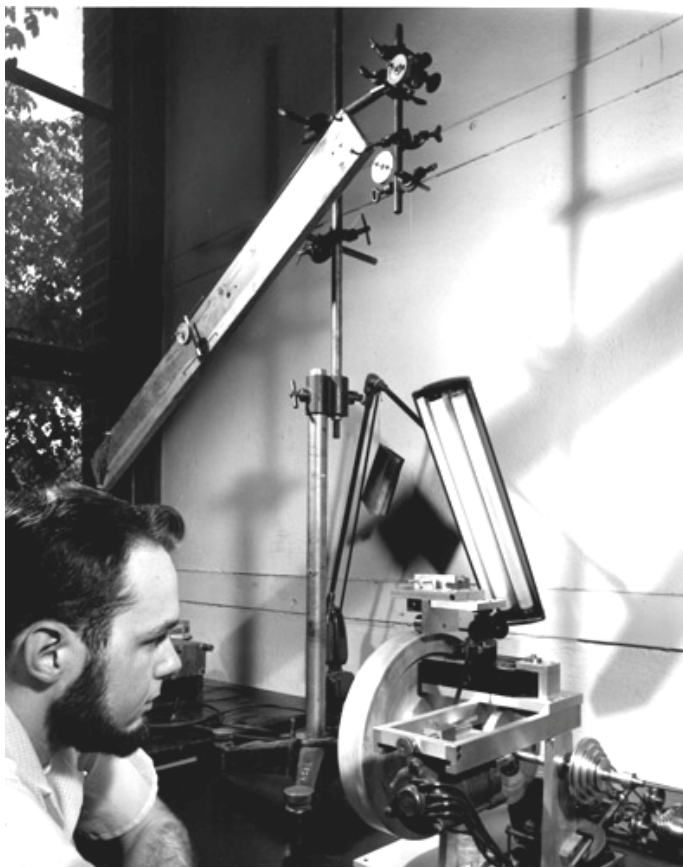
# Why Fiber Optic Sensors for Medical Applications?



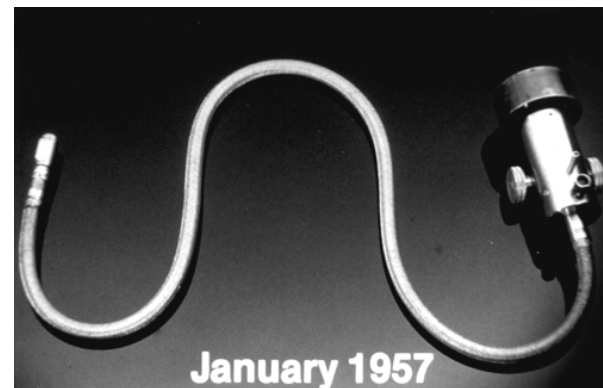
- **Perfect for use in high-EM/RF environments**
  - Immune to electromagnetic interference
  - Very low emission
  - No interaction with microwave/RF diathermy fields.
- **No electrical connection to patient**
- **Minimally invasive**
  - Small size
  - Can be fitted easily into catheters and needle probes
- **Can monitor many parameters**

# The Actual First Drawn Clad Fiber: University of Michigan c. 1956

On December 8, 1956 Larry Curtis, a graduate student at the University of Michigan working for Prof. Basil Hirschowitz, draws the first optical clad fiber by the rod-in-tube method for use in medical endoscope applications



Pulled fiber wrapped  
on an oats container!



The intended use of the fibers was to develop a novel flexible fiberoptic endoscope. Hirschowitz tested the prototype by swallowing it himself in 1957.

# *Healthcare Industry Trends*

# Healthcare Trends:

## Global Population Issues



- Growing global population.
  - Ageing population in some developed nations (US, Japan, Europe, etc.).
  - More prevalence of heart disease, diabetes, infectious diseases, etc.
- More people need medical care. Thus, ***overall growth and expansion of Health Care Industry on a global level.***



# Healthcare Trends:

## Technical Trends



Image: Finisar

**Greater reliance on advanced biomedical instrumentation & sensors for:**

- *Diagnosis*
- *Monitoring*
- *Treatment*
- *Care*

# Healthcare Trends:

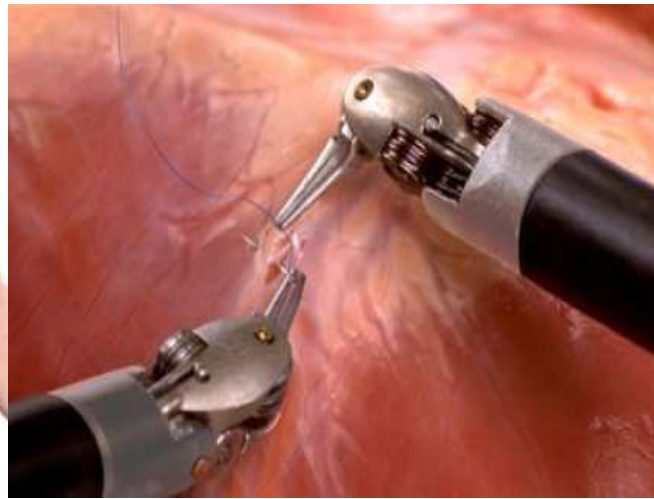
## Technical Innovations

- **Drive towards minimally invasive surgery (MIS)** → *Need for disposable probes & catheters.*
- **Miniaturization, Automation & Robotics** → *Need for instrumented catheters.*
- **Sensors compatible with MRI, CT, PET equipment as well as thermal ablative treatments involving RF or microwave radiation** → *Need for Fiber Sensors.*
- **Increased user of Lasers** → *Need for fiber delivery devices*
- **Increased use of optical imaging and scanning techniques** → *Need for fiber OCT probes.*



# Minimally Invasive Robotic Surgery (MIRS): The Need for Sensors

- One of the shortcomings of MIRS is the lack of **haptic** (force and tactile) sensitivity and feedback to surgeon's hands.
- A key component to the effectiveness and success of MIS and MIRS systems, is the development of tactile **force, position and shape sensors**, that enhance the fingertip perception of surgeons and facilitate the accurate positioning of robotic surgical arms and devices.



# Healthcare Trends:

## Need for faster Biochemical Analysis

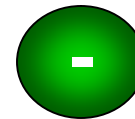
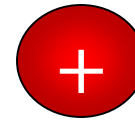
**TODAY**



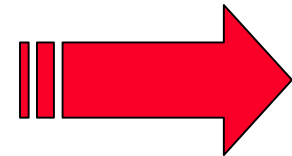
SAMPLE



LAB ANALYSIS



RESULT



FURTHER ACTION

●—————→ **1 HOUR to 7 DAYS** ←—————●

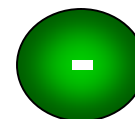
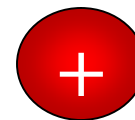
**FUTURE**



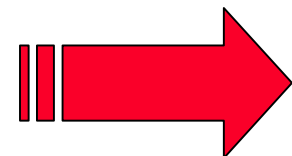
SAMPLE



BIOSENSOR



RESULT



FURTHER ACTION

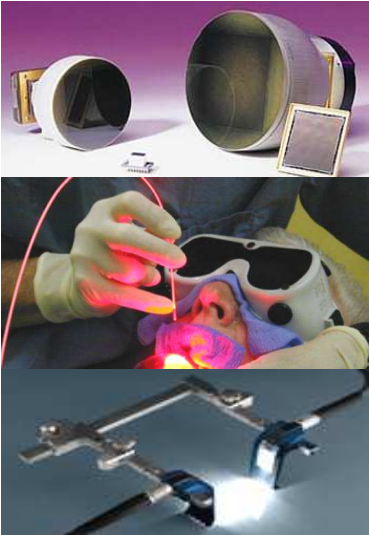
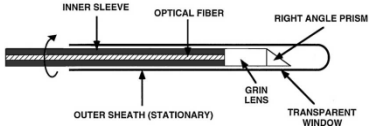
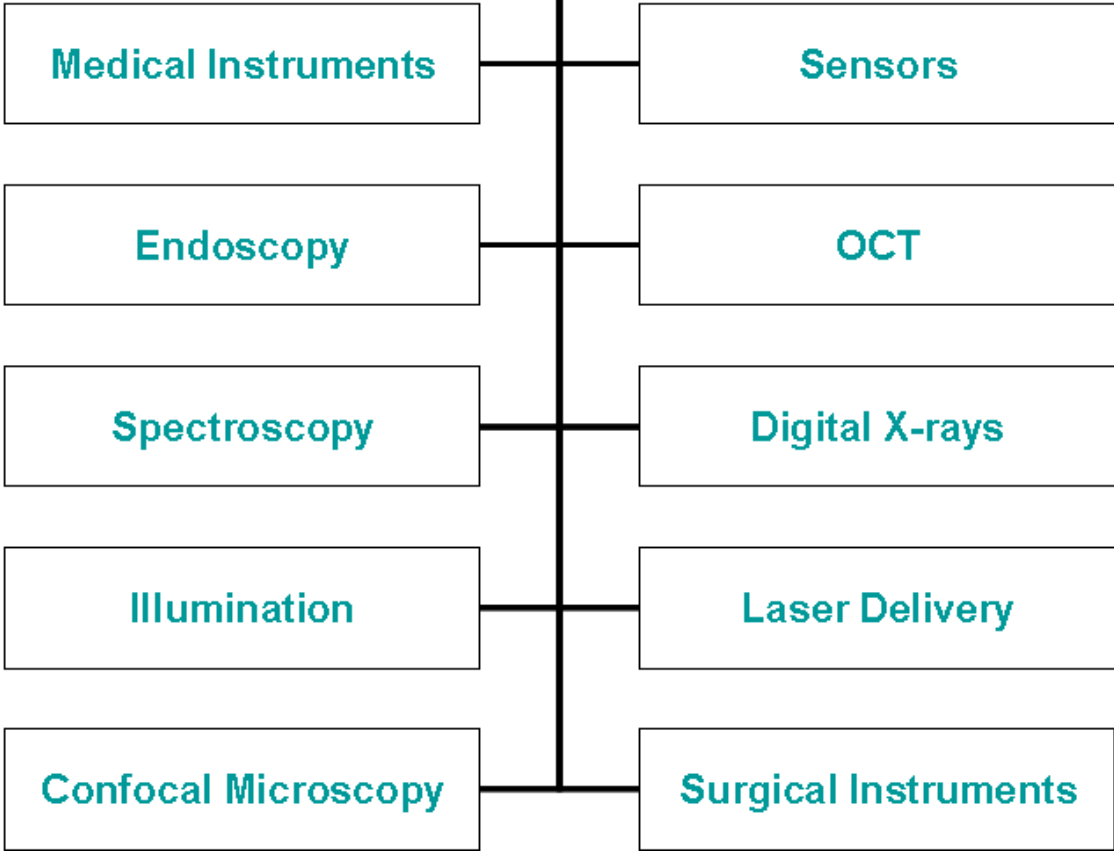
●—————→ **> 1 MINUTE !** ←—————●

# *Vast Applications...*

# Biomedical Applications of Optical Fibers



## Optical Fibers



# Fiber Optic Devices & Sensors:

## Medical Application Areas

*Optical fiber sensors have a widespread applicability and fit in almost every discipline within the medical arena*



Arthroscopy



Otorhinolaryngology



Dentistry



Phlebology



Ophthalmology



Dermatology



Urology



Gynecology



Gastroenterology



Bronchology



Photodynamic therapy



Angioplasty



Aesthetic surgery



Orthopedics



Pneumology

# Biomedical FO Sensors:

## Measurable Parameters & Applications



Physical	Chemical	Biological	Imaging
<i>Body Temperature</i>	<i>pH</i>	<i>Antigens</i>	<i>Endoscopy</i>
<i>In-vivo Pressure</i>	<i>pO<sub>2</sub></i>	<i>Antibodies</i>	<i>Optical Coherence Tomography (OCT)</i>
<i>Blood Flow</i>	<i>PCO<sub>2</sub></i>	<i>Electrolytes</i>	<i>Optical Acoustic Tomography (OAT)</i>
<i>Heart Rate</i>	<i>Oxymetry (SaO<sub>2</sub>, SvO<sub>2</sub>)</i>	<i>Enzymes</i>	<i>Photo Dynamic Therapy (PDT)</i>
<i>Force</i>	<i>Glucose</i>	<i>Inhibitors</i>	
<i>Position</i>	<i>Bile</i>	<i>Metabolites</i>	
<i>Respiration</i>	<i>Lipids</i>	<i>Proteins</i>	
<i>Shape Sensing</i>			



# Biomedical FO Sensors:

## Classification by Type

- **In-Vivo**

(on a whole, living organism)

- *Non-Invasive*
- *Minimally Invasive (indwelling, through natural body orifice)*
- *Invasive*
- *Implantable*



- **In-Vitro**

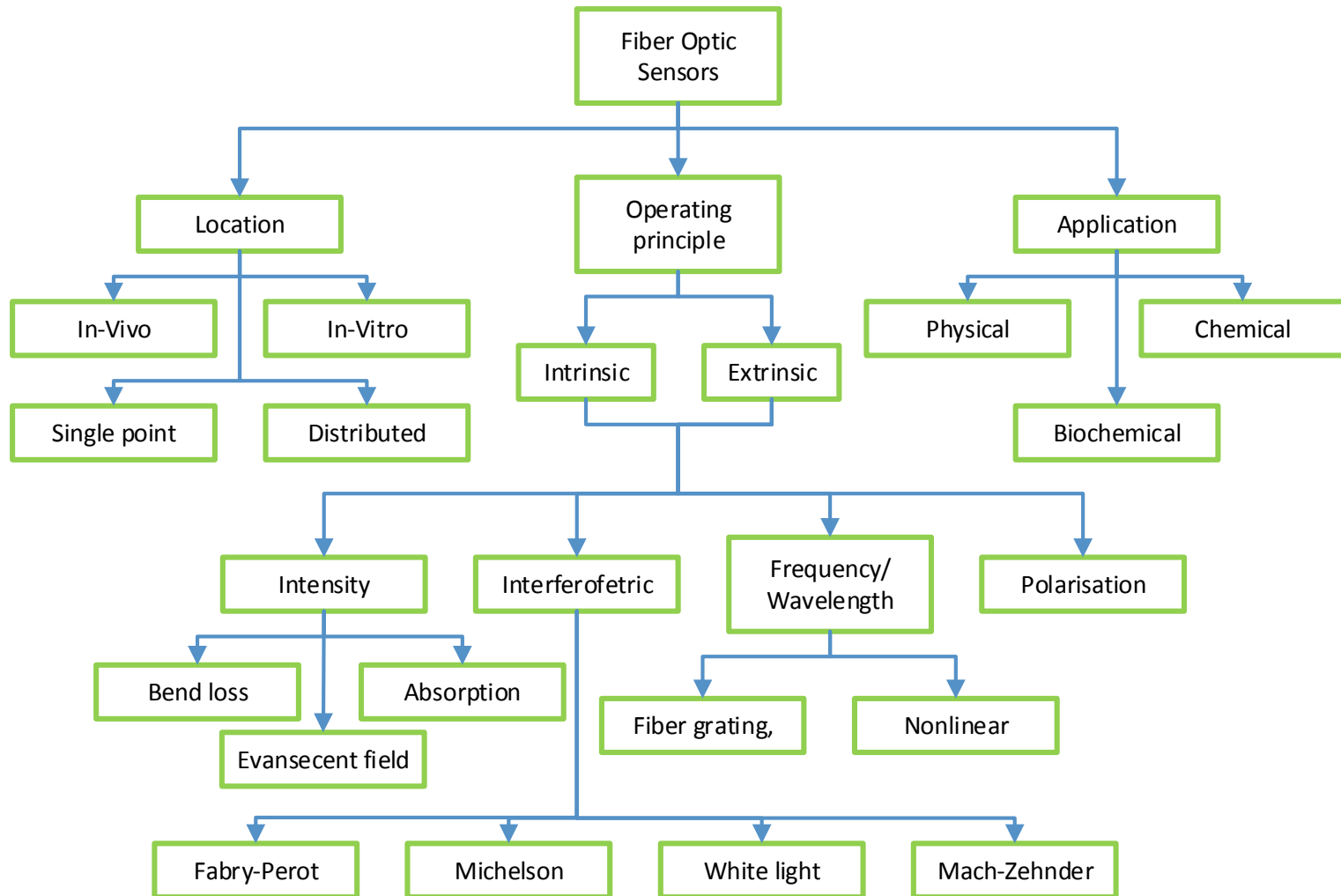
(on a test tube or petri dish)



**Reusable vs. Disposable**

# Fiber Optic Sensors:

## Classification by Type, Principle & Application



# *Market Opportunities & Future Outlook*

# Biomedical Sensing:

## Application Areas

- **Medical**

- Clinical
- Pre-Clinical
- Diagnostics
- Therapeutic
- Surgery

- **Healthcare**

- Point-of-care
- Home care

- **Research**

- Academic
- Life sciences
- Animal research

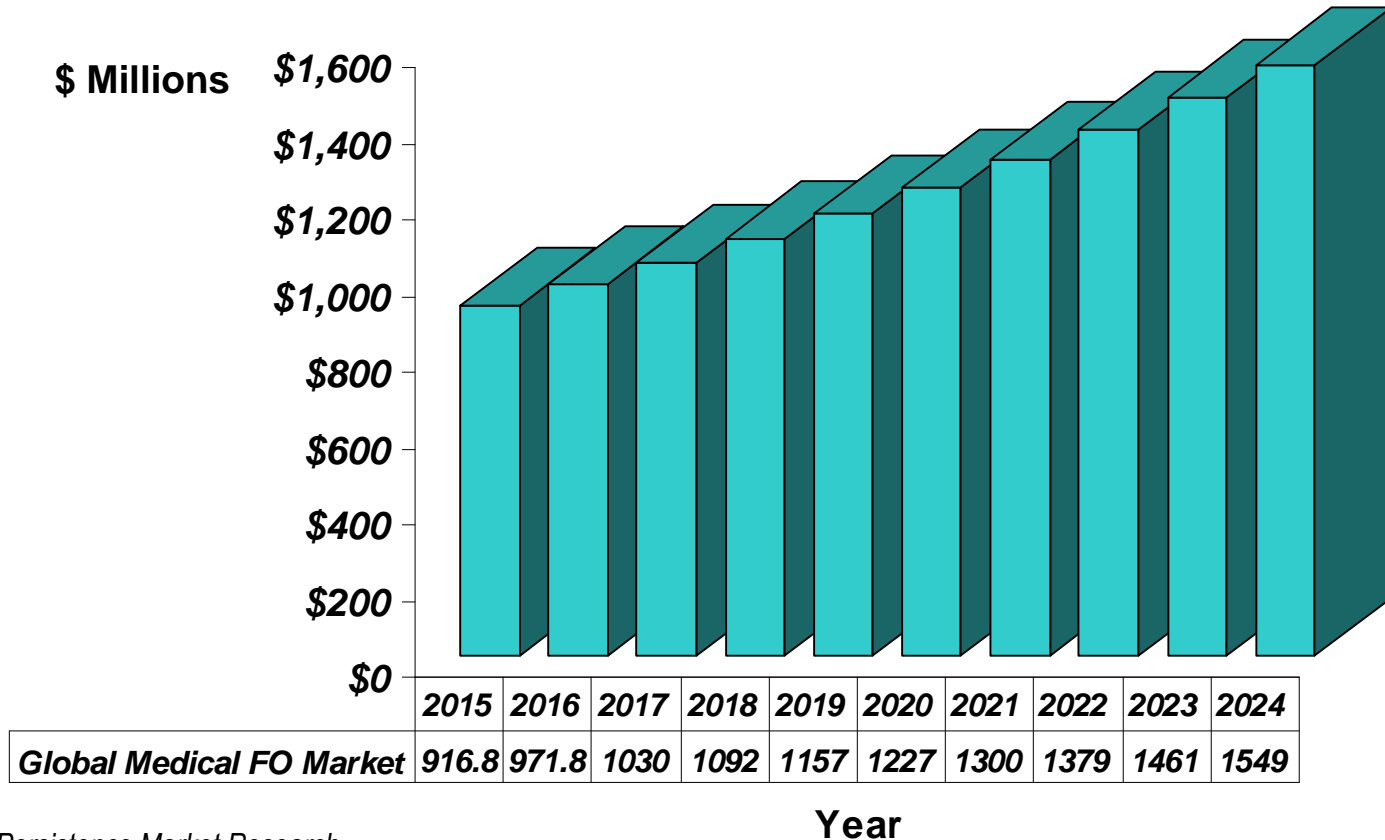
- **Veterinary Medicine**



# Fiber Optic Biomedical Market Product Categories

- *Specialty Fibers* (large core, high-power, metal-coated, etc.)
- *Fiber Bundles* (incoherent & Coherent)
- *Fiber Cables*
- *Lensed Fibers*
- *Fiber Assemblies*
- *Probes* (Sensing & Imaging)
- *Fused Tapers & Faceplates* (Digital X-Rays)

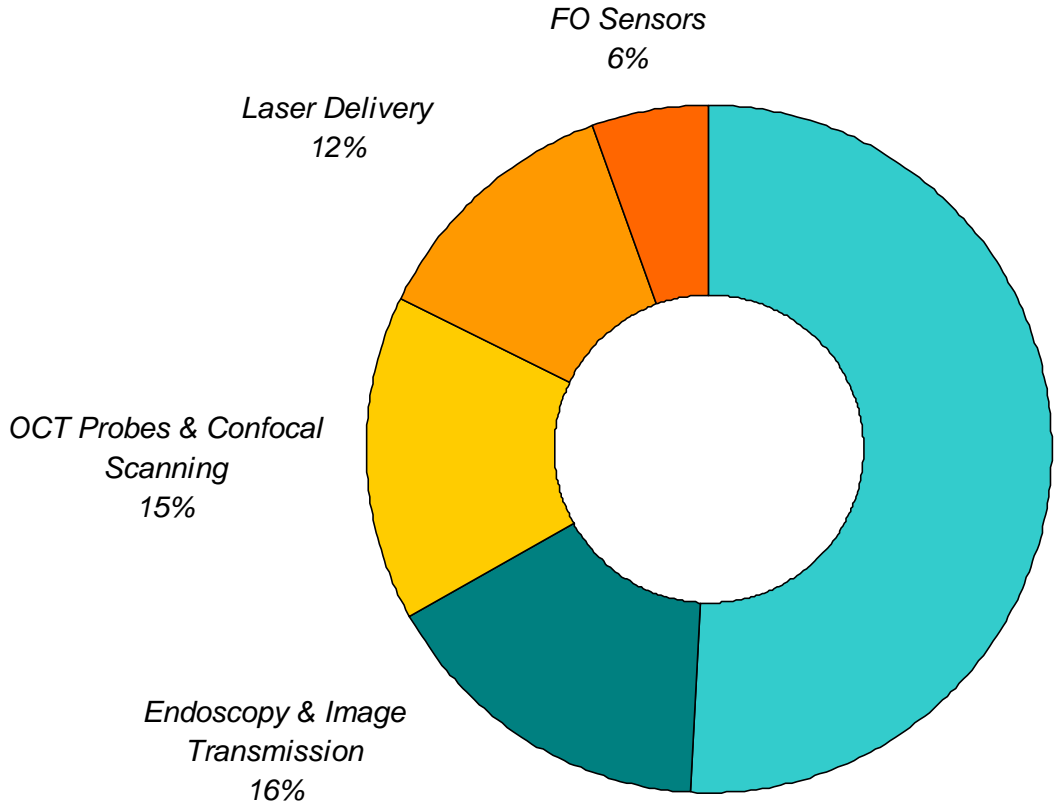
# Global Fiber Optic Biomedical Market Forecast



Source: Persistence Market Research

Amounts are inclusive of specialty fibers, systems and components

# Global Fiber Optic Biomedical Market: Segmentation by Application (2015)

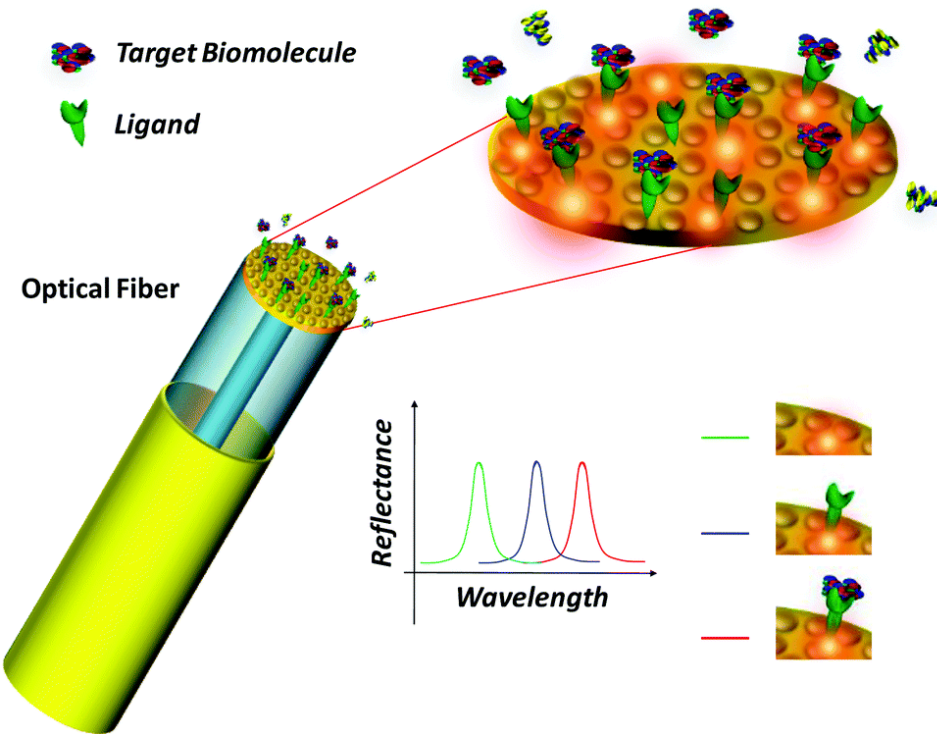


*Lighting & Illumination*  
51%

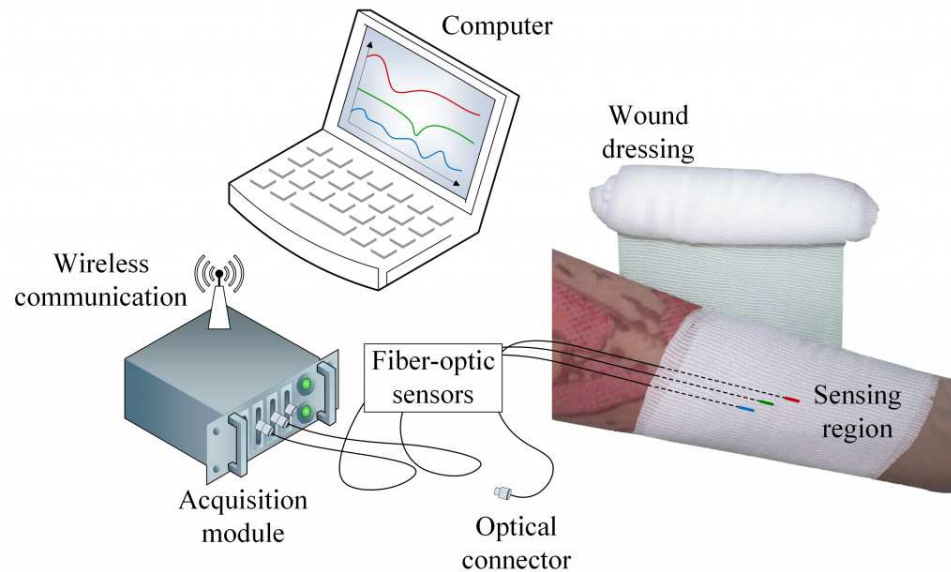
*(2015 market segments values in \$Millions)*

Lighting & Illumination	\$465
Endoscopy & Image Transmission	\$150
OCT Probes & Confocal Scanning	\$138
Laser Delivery	\$112
FO Sensors	\$52

# Future Opportunities/Trends: Lab-on-a-Fiber



## Remote care monitoring of wounds using Lab on-a-fiber devices



*This emerging technology envisages the integration of functionalized materials on micro- and nano-scales (i.e. the labs) with optical fibers to realize miniaturized and advanced all-in-fiber probes, especially useful for (but not limited to) label-free chemical and biological applications.*

THERAN OPTICS

Source: Prof. A. Cusano



# Conclusions

- Since the development of the first fiberoptic endoscope in 1957, optical fibers and fiber-based sensors have seen an increased utilization for diverse biomedical applications.
- Optical fibers are used for illumination, imaging, digital radiography, laser beam delivery, sensing and optical coherence tomography.
- Fiber Optic sensors offer the possibility to perform on-line and real-time Chemical, Biological & Physiological measurements.
- Many new unique applications in:
  - *Medicine*
  - *Food Industry*
  - *Environmental Monitoring*
  - *Homeland Defense*
- Cover broad range of disciplines – need to do proper cross-over between Photonics & Medicine.

A word cloud featuring the phrase "Thank You" in multiple languages, centered around the largest text "THANK YOU" in red. Other prominent words include "dziękuję", "dank u", "gracias", "merci", "danke", "takk", "d'akujem", "grazie", "obrigado", "köszönöm", "kiitos", "paldies", "multumesc", "nandri", "tack", "gracias", "dank u", "paldies", "akciu", "asante", "ngiyabonga", "tack", "obrigado", "d'akujem", "grazie", "köszönöm", "kiitos", "dekuji", "multumesc", "nandri", "tack", "paldies", "gracias", "takk", "takk", "gracie", "salamat", "d'akujem", "ngiyabonga", "misaotra", "terima kasih", "dekuji", "obrigado", "takk", "thank you", "d'akujem", "ngiyabonga", "köszönöm", "takk", "thank you", "d'akujem", "terima kasih", "dekuji", "misaotra", "terima kasih", "aciü", "ngiyabonga", "merci", "ngiyabonga", "gracias", "dekuji", "misaotra", "terima kasih", "aciü", "salamat", "hvala", "danke", "asante", "merci", "hvala", "dank u", "dekuji", "dank u", "misaotra", "terima kasih", "nandri", "hvala", "danke", "asante", "merci", "hvala", "salamat", "dank u", "dekuji", "dank u", "misaotra", "terima kasih", "nandri".