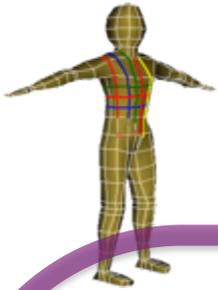


Multi-material Fibers: a new building block for the next generation of textiles ?

Fabien Sorin

Ecole Polytechnique Fédérale de Lausanne (EPFL)
STI-Institute of Materials



centimeter



meter



Tens of meters

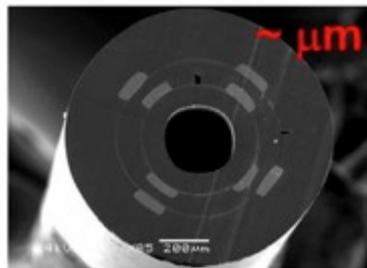


kilometer

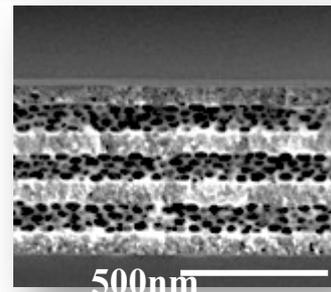
Materials and device architecture Challenge:

Realizing, over unconventional substrates (flexible, stretchable, 1D, macroscopic..) complex functionalities that often rely on rigid, micro and nano-scale devices

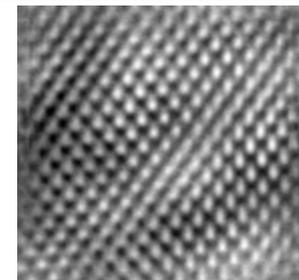
micrometer



nanometer



Angstrom



Innovative materials processing approaches

Guiding objective: Integrating complex functionalities within unconventional, substrates

Novel micro and nanostructured photonic device architectures

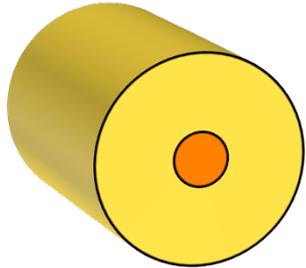
- **Multi-material nanostructured 2D and 3D coatings**
- **Multi-material 1D fibre devices**



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ector Distributed Bragg Reflector Distribu

Engineering novel 1D nanostructured devices

Conventional fibers



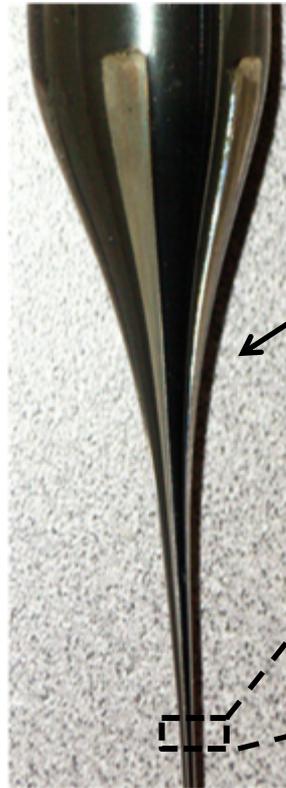
- 1 m long, 300 mm in diameter preform pulled into tens-of-kilometer long fiber
- Such fiber would cover 10 to 100 square meters !!

Single material
Simple geometry
Large feature sizes

Materials

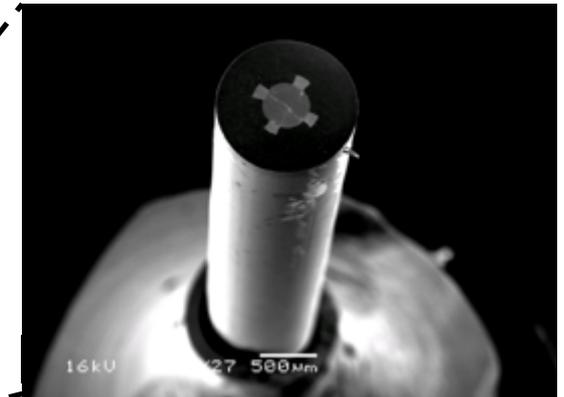
Structure

Length scale



← Manufacturing on the preform level

Heat and draw down



→ Extended length of functional fibers

Materials with different optic and optoelectronic properties also often have different thermo-mechanical properties

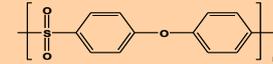
Thermo-mechanical properties

- Glassy materials: Continuous derivative $d\eta/dT$ with respect to temperature
- Upper bound viscosity (η) at a common temperature: less 10^7 Poise ($\Delta T_g < 30C$)
- Resistant to crystallization ($T_x - T_g > 100C$)
- Or materials can flow in a very low viscosity liquid state

Fabrication and Processing

- Careful preform machining
- Finding the right drawing parameters

HIGH-T_g TERMOPLASTICS



- Electrical Insulators
- PES, PEI
- Amorphous thermoplastics
- Glass transition temperature: 150-240 °C
- Refractive index @1.5 microns: 1.6
- Availability: Thin films (8-150 microns)

METALS

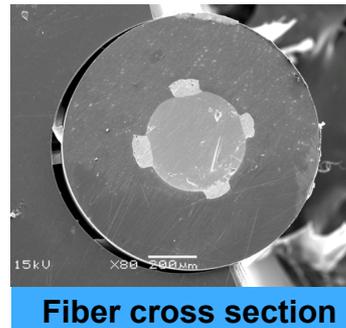
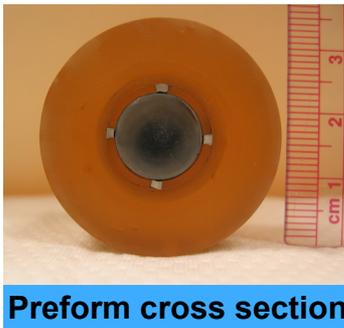
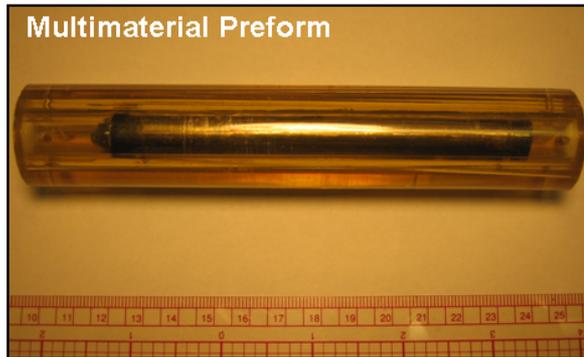
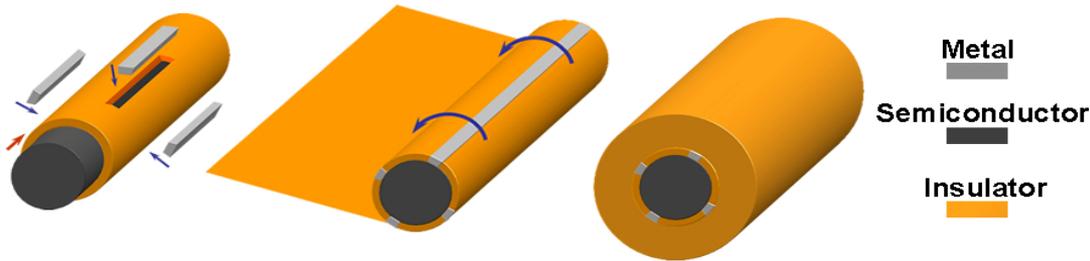
In, Sn, Bi(43%)-Sn(57%)

- Metals
- Crystalline Materials
- Melting Temperature: 140-232 °C
- T_m has to be lower than the drawing temperature
- Good wetting of glass and polymer
- Use of Flux to prevent oxidization
- Low viscosity at drawing Temperature

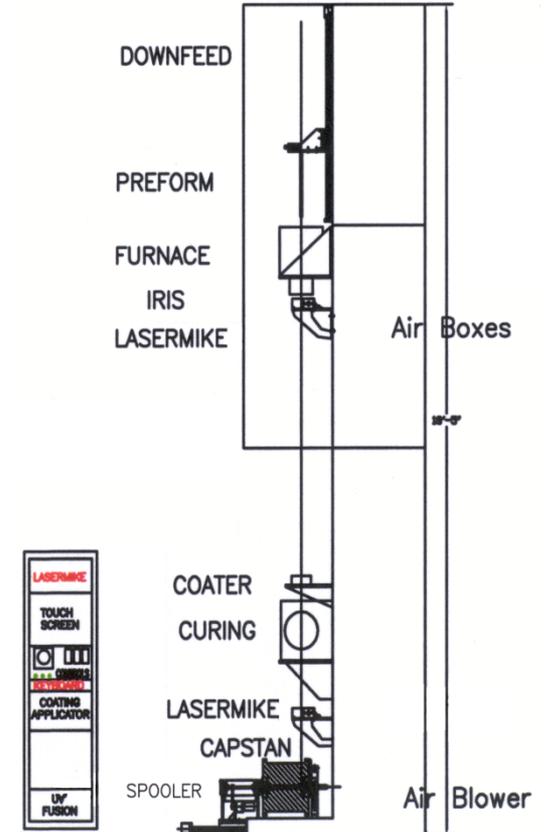
AMORPHOUS SEMICONDUCTORS

As, Se, S, Ge, Te, Si, Sn

- Amorphous semiconductors (p-type)
- Glass transition temperature: 160-210 °C
- Refractive index @1.5 microns: 2.4-3.4
- High electrical conductivity
- CTE for As₂Se₃: $25 \cdot 10^{-6}/C$
- Photoconductivity



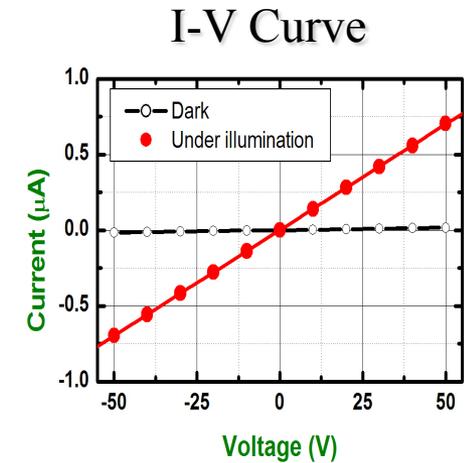
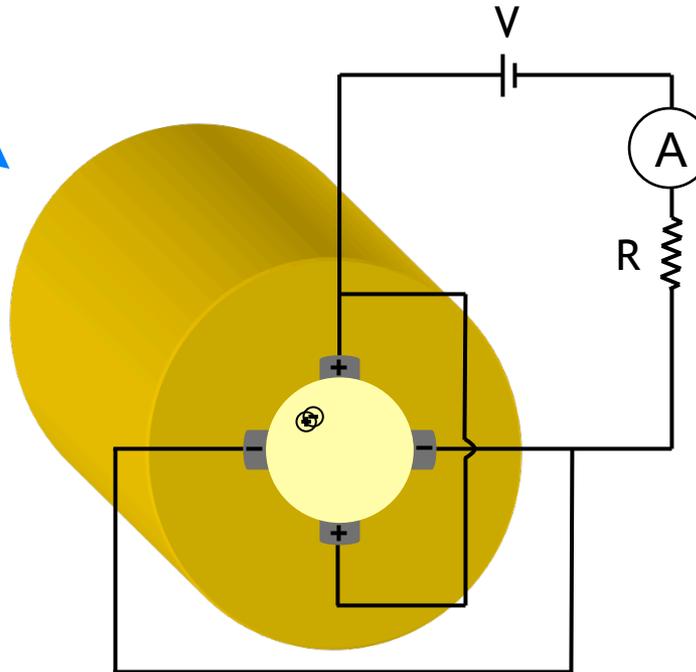
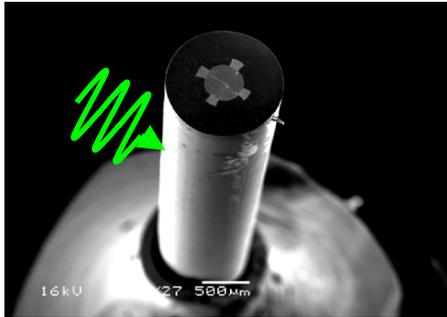
Draw-tower



The thermal drawing process inherently generates surface area !

OPTOELECTRONIC FIBER SENSORS

We have already made a photoconductor



Extremely large area flexible optoelectronic devices

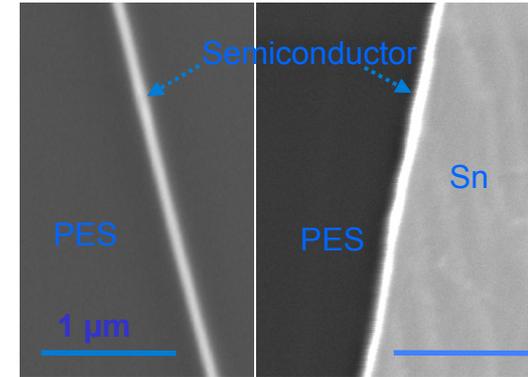
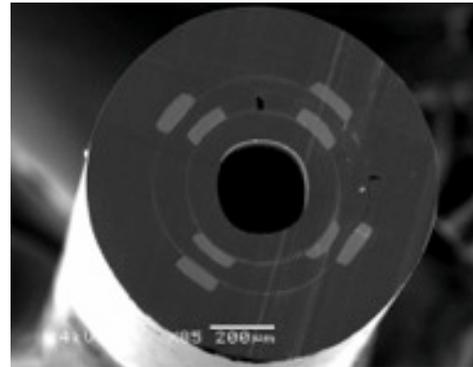
Can we integrate increasingly complex and innovative device structures ?

Novel photonic devices and architectures

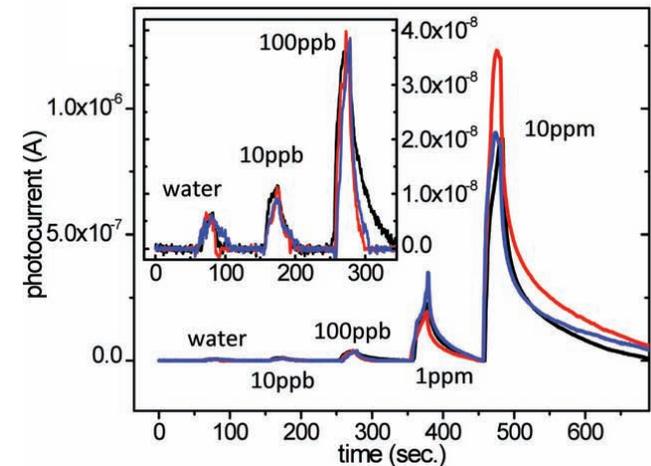
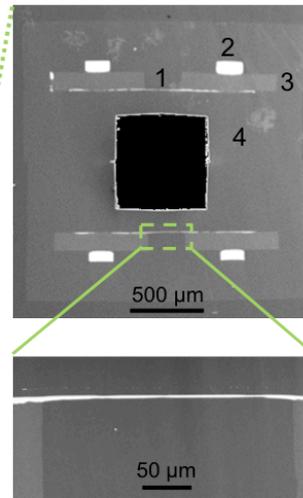
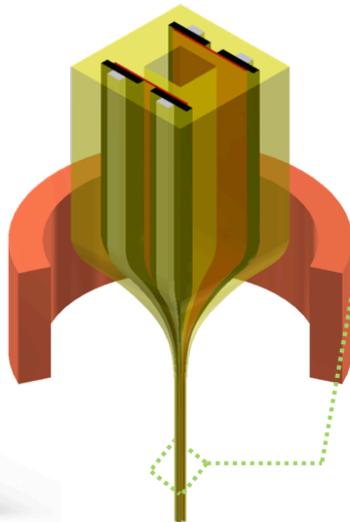
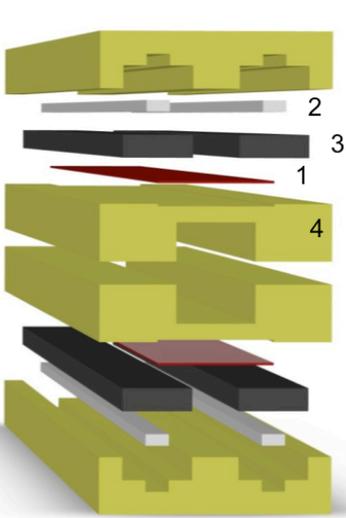
1D devices with 2D complex nanostructured cross-sections

- Fiber integrated Semiconducting thin films

- Screens and imaging systems
- Color sensing

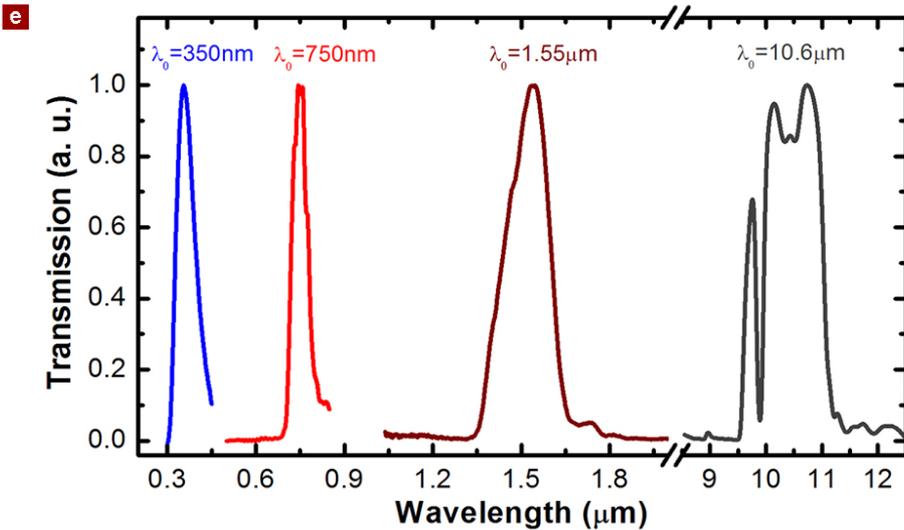
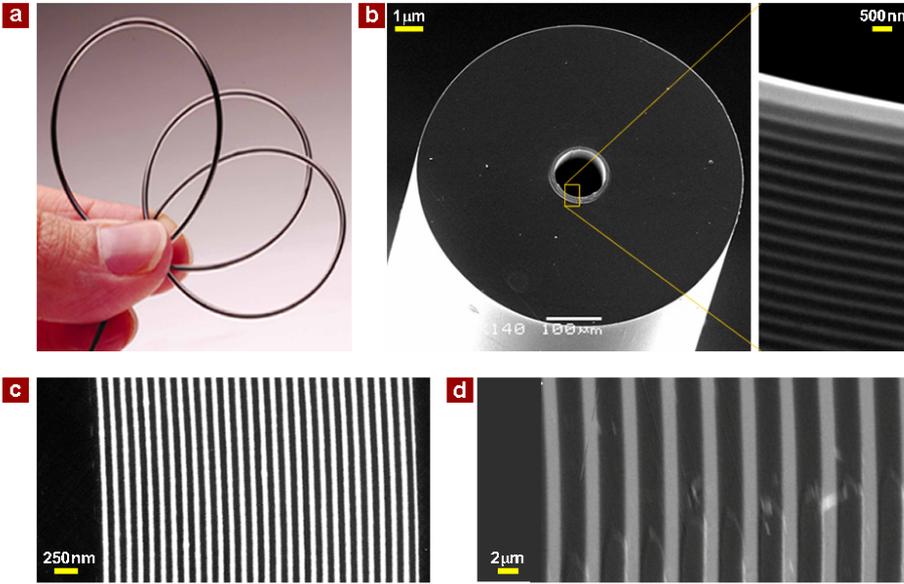


- Distributed heat and chemical sensing: interfacing with the environment

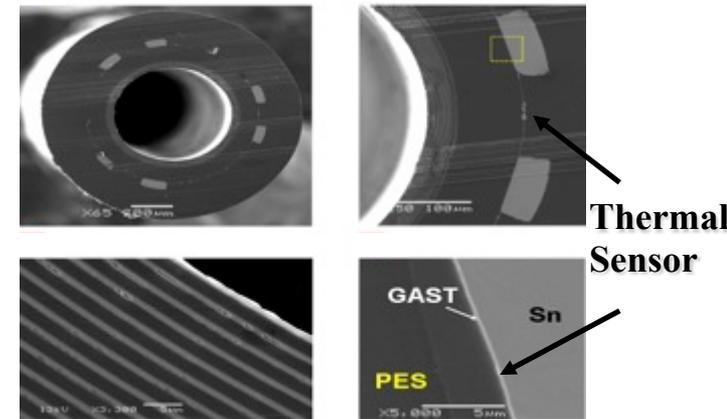


HEALTH CARE APPLICATION

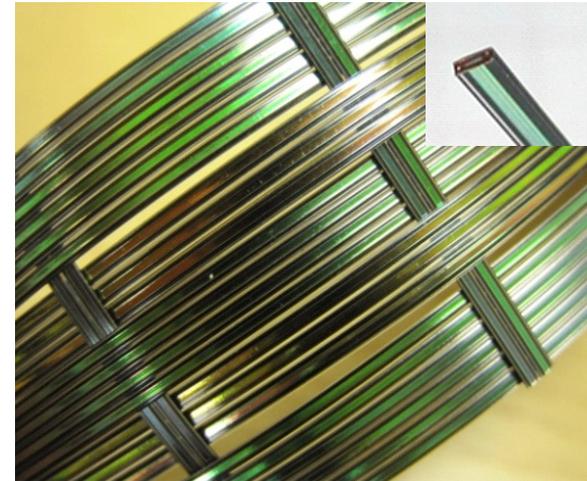
Distributed heat sensing for safety monitorin



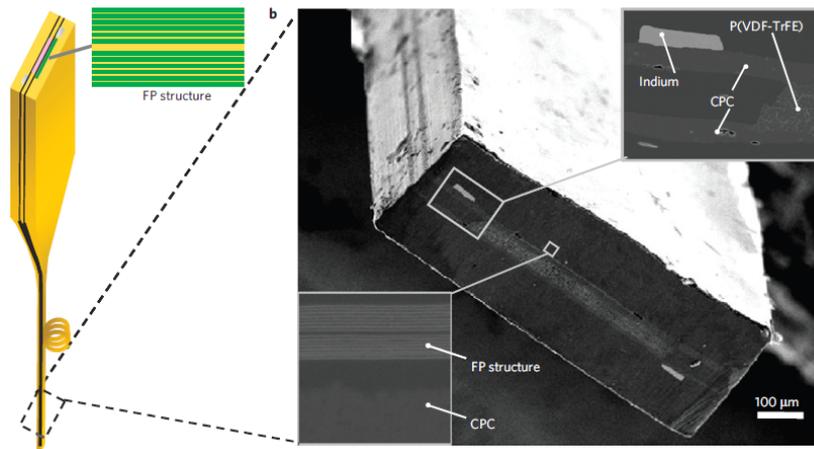
OmniGuide CO₂ Laser Beam Delivery System for non-invasive surgery



- The same effect that guides light in a core, reflects light in controlled color spectrum
- Sourceless distributed Color !



- Can we integrate actively modulated devices?

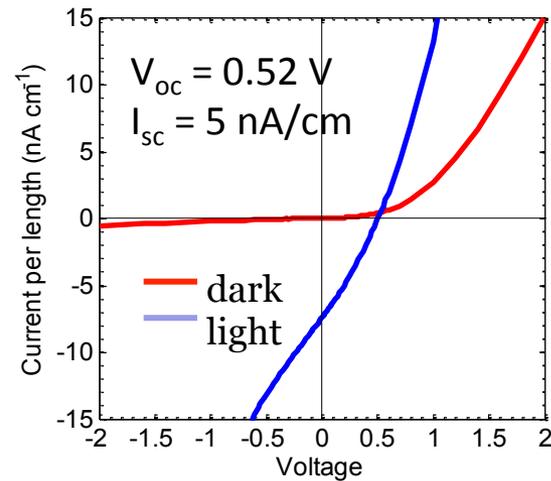
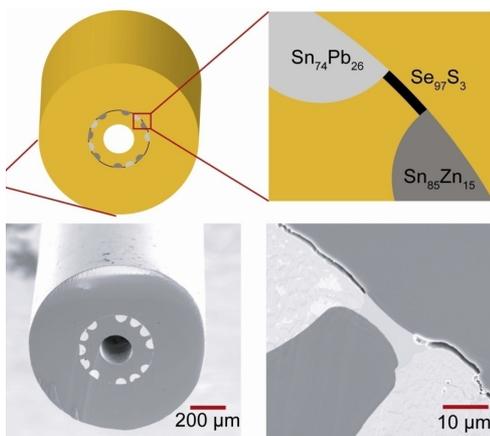


- Piezoelectric Fibers

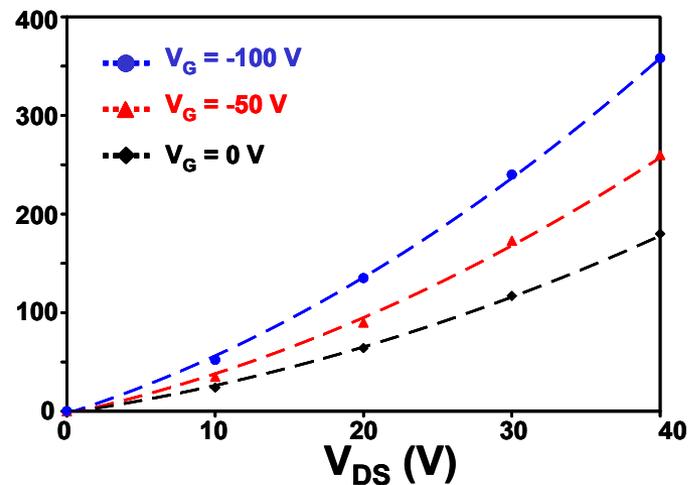
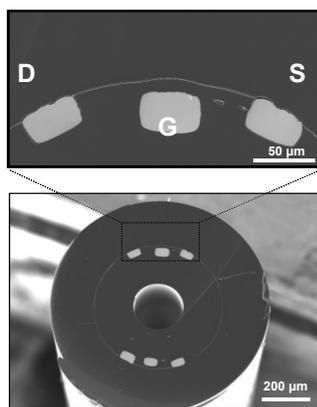
- Opportunities: Ultrasound imaging, Large area vibration sensor,.....

- Can we make fibers that change color under mechanical excitation ?

- Junctions in Fibers

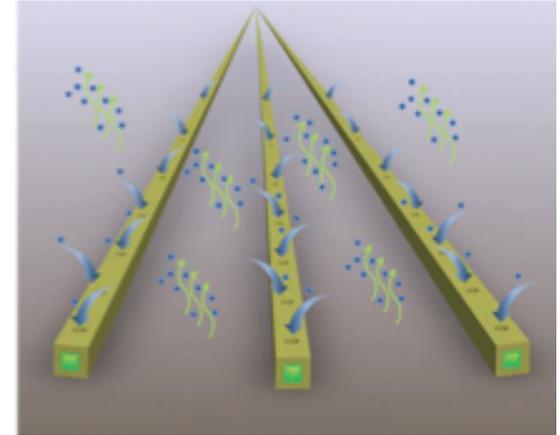


Fibers capable of logic operations ?



Inter fibres integration: screens and fabrics

- **Arrays of fiber devices can be used in large area functional systems**
 - **1D devices for sensing and monitoring**
 - **2D meshes : distributed chemical sensor**
 - **3D constructs**



- **Environment monitoring**
- **Functionalizing large areas and unconventional surfaces**
- **Optical Fibers carry information in their core, ie internet: can they collect or emit it through their side ?**

- **Fibers flexibility enables to deploy them on curved surfaces**

- NIR photosensitive fibre

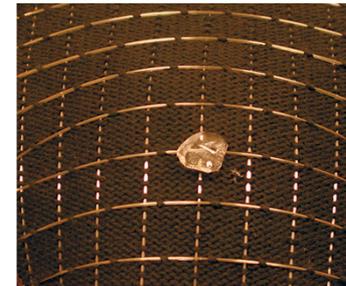
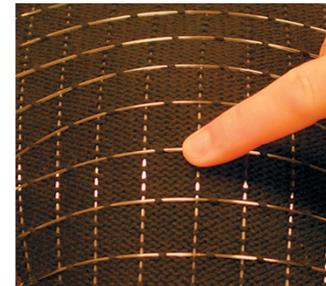


- **Weaving fibers into fabrics :**

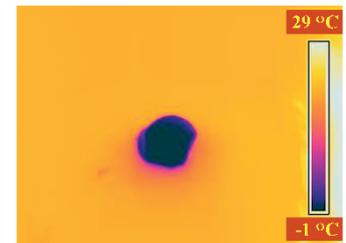
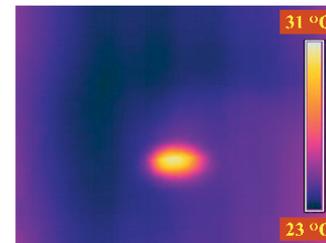
- Several applications in health care, sport and leisure...

- **Fruitful Challenges:**

- What Materials ?
- Feature sizes ?
- Mechanical properties ?
- What new functionalities ?



VISIBLE

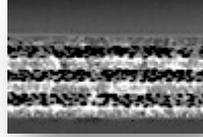


INFRARED

- **The functionality is integrated inside the fiber itself !**
 - Future of textile ?
 - Challenges and opportunities
- **Truly distributed functionality opening new potential applications**
 - Color changing, energy harvesting and storage, distributed sensors, health care etc..
- **Scalability and flexibility in their assembly:**
 - Dense or sparse meshes (1D, 2D or 3D)
 - Fabrics or coatings
- **A new scientific and technological platform: a lot of room for research and innovation**



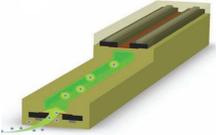
**Energy Harvesting,
storage
and saving**



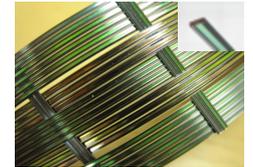
**Innovative Healthcare
systems**



**Sensing
and monitoring**



**Large area nanostructured
Coatings
and Fabrics**



Applications

**Large area and
flexible systems**



**Large area
Flexibility
Simple processing**

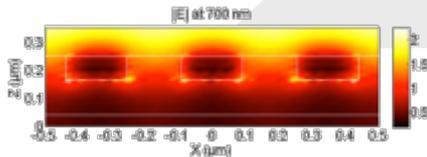
**2D innovative photonic
structures**

Multi-material Fibers



**Photonic systems
Semiconductor devices
Piezoelectricity
Thermoelectricity
...**

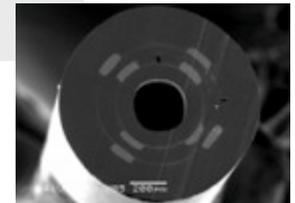
**Materials/Interfaces, Processing,
Geometry and Length Scale**



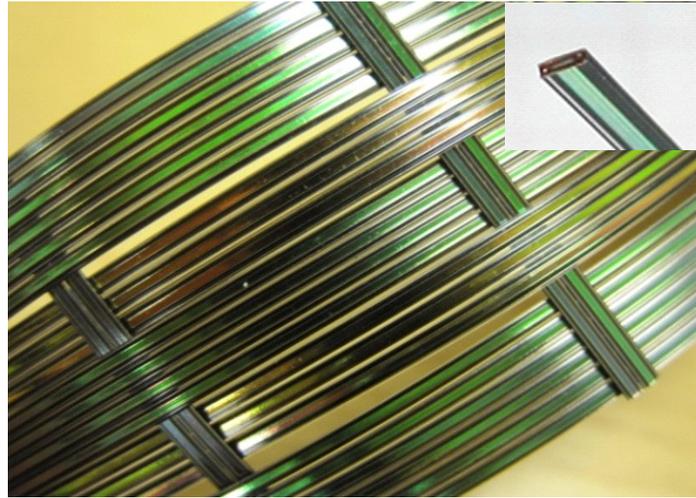
Modeling



**Innovative
processing**



Novel devices architectures



Acknowledgment:

- Prof. Fink and Prof. Joannopoulos
- All the collaborators at MIT: Prof. Abouraddy, Dr. Shapira, Dr. Stolyarov, Dr. Hart etc...

Sponsors

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THANK YOU

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