Promises of multi-material fiber devices for advanced light delivery systems

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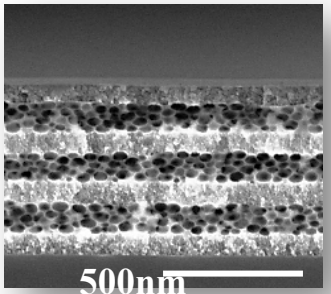
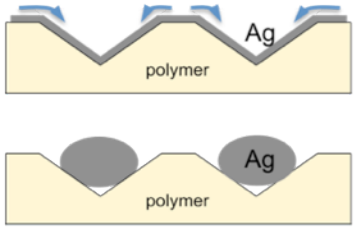
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

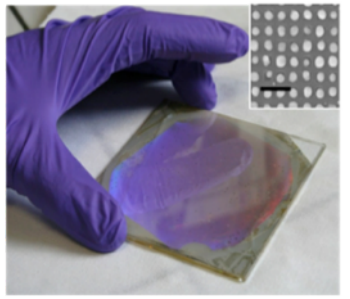
Research at FIMAP

Interplay between the viscous flow and intermolecular forces to integrate complex functionalities within unconventional substrates

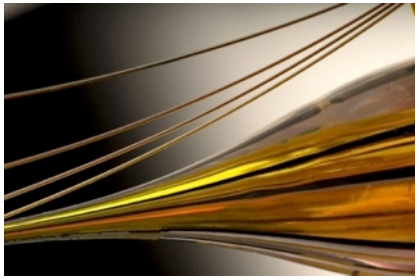
- Multi-material nanostructured 2D and 3D coatings

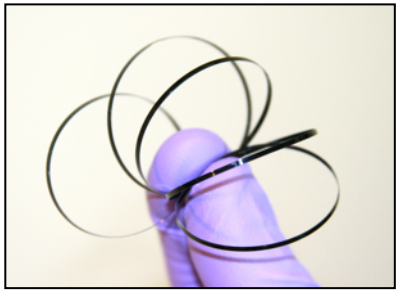


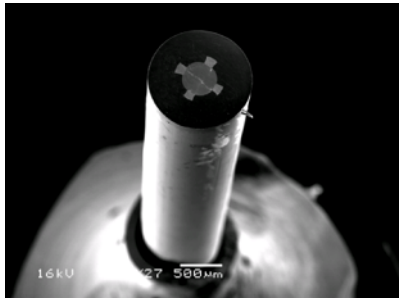




- Multi-material 1D fibre devices



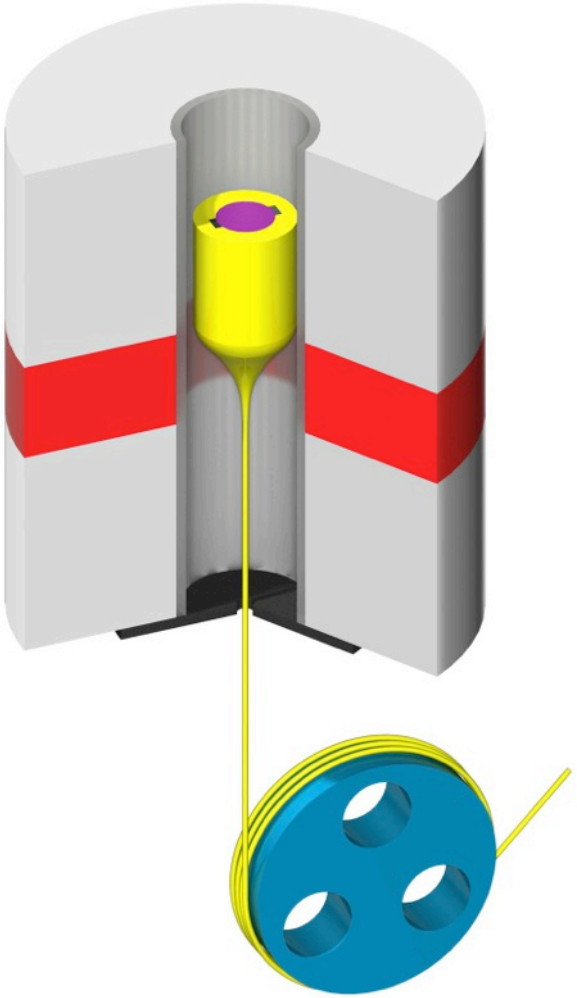




OPTICAL FIBERS

- Professor Kao received the Nobel Prize in Physics in 2009 for the development of optical fibers

Glasses have low optical losses *AND* can be processed efficiently into fibers



Thermal drawing process

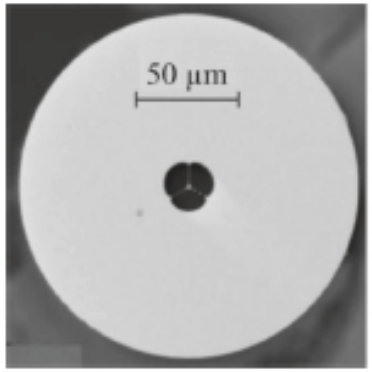
From optical fibres….

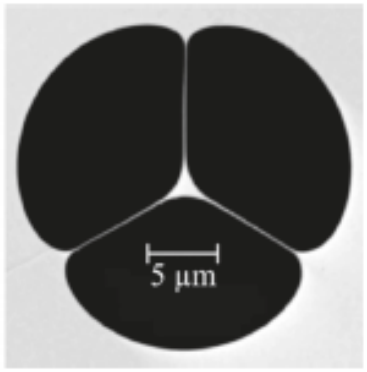
- Optical transport
- Sensing and monitoring

…. to a unique materials processing opportunity

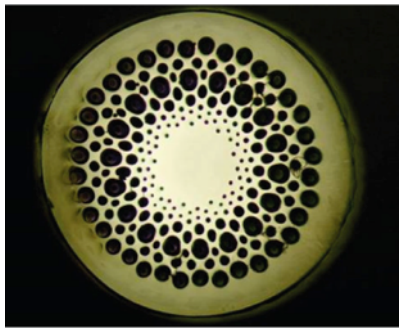
- Simple, scalable, low-cost
- Unique micro-structures
- Distributed functionality
- Flexibility

A Fantastic Materials Processing Technique

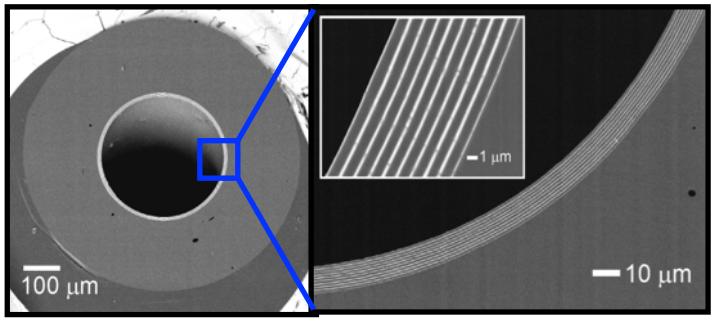




Langmuir 27, 5680 2011



Xue et. al. J. Light Wave 2004



Nature 420, 650 (2002)

Photonic devices require an index contrast

↓

Different materials with different optical and thermo-mechanical properties

↓

Effects of surface tension

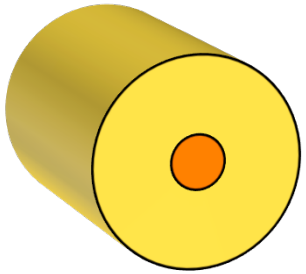
(the process generates surface area)

A rich material process

Extremely fine structures over extended flexible lengths

Engineering novel 1D nanostructured devices

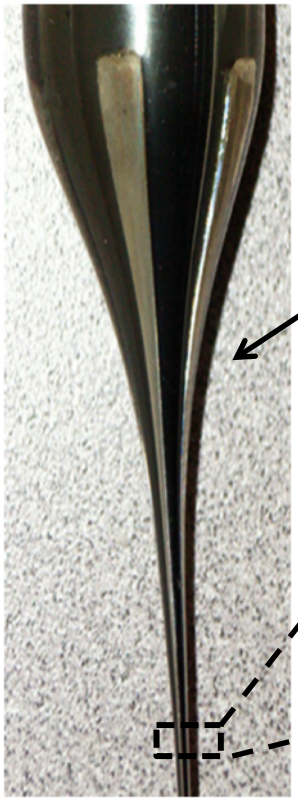
Conventional fibers



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

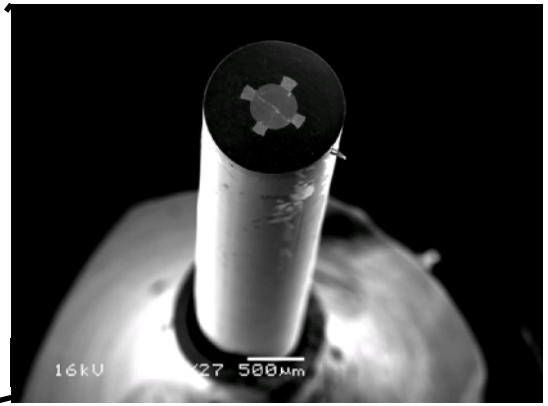
Single material
Simple geometry
Large feature sizes

Materials | **Structure** | **Length scale**



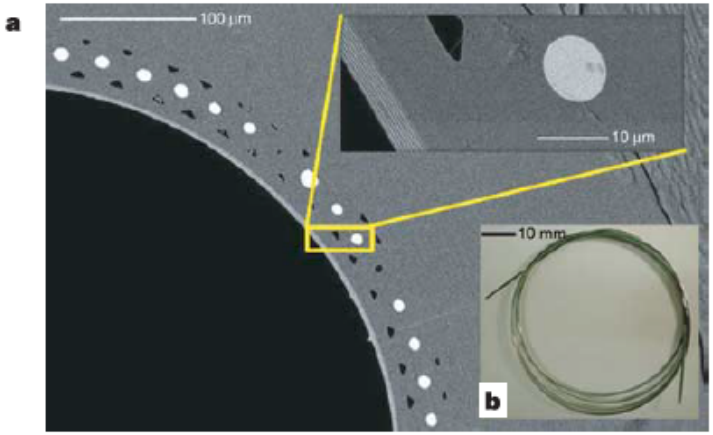
← Manufacturing on the preform level

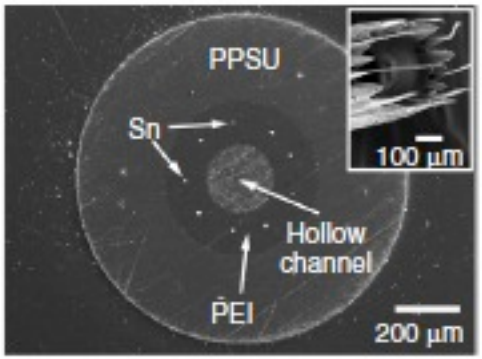
Heat and draw down

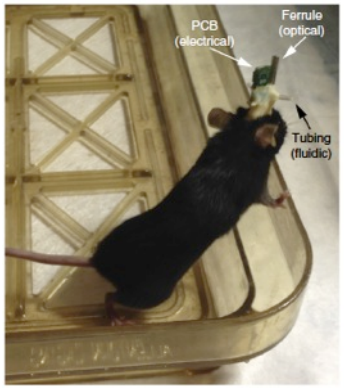


→ Extended length of functional fibers

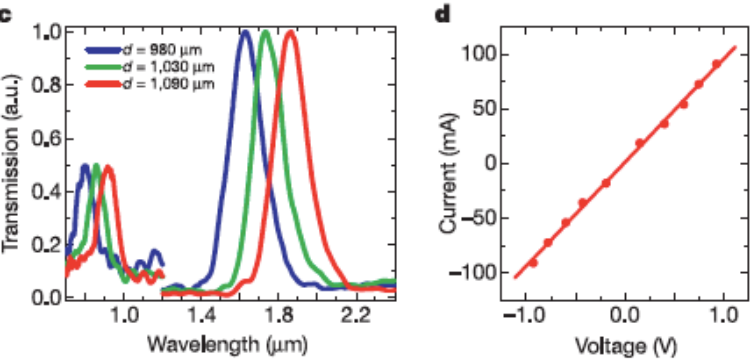
In-fiber metallic systems



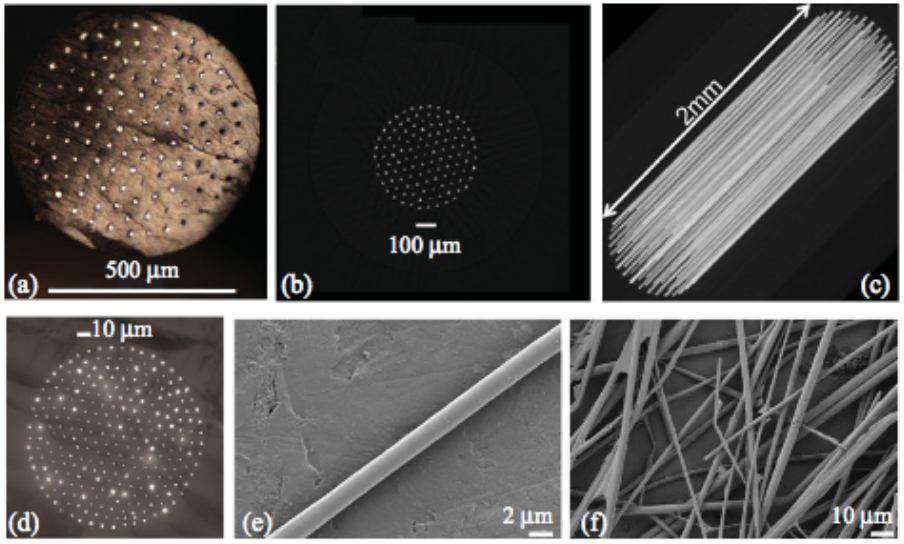




Canales et. al., Nature Biotechnology (2015)



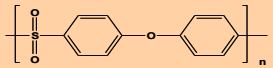
Bayindir, Sorin et. al. Nature 431, 826 (2004)



Adv. Optical Materials 1, 971 (2013)

MATERIALS SELECTION

HIGH-Tg 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

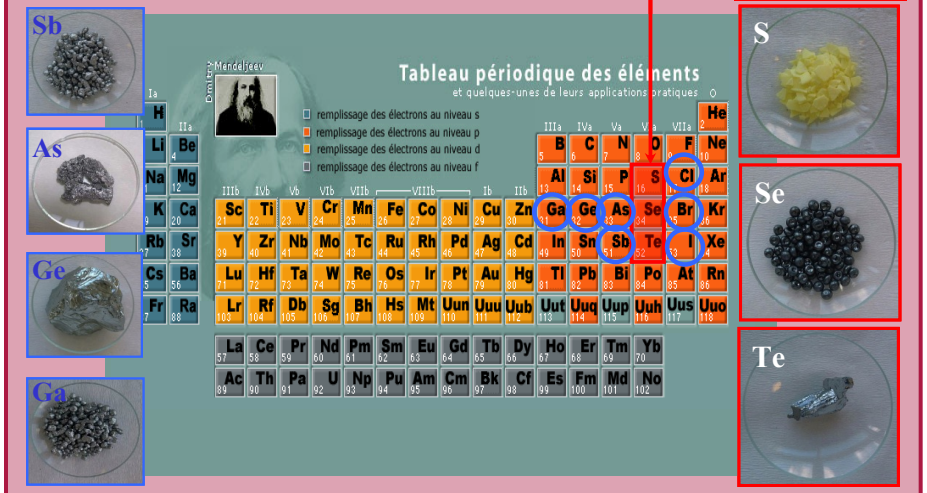
In, Sn, Bi(43%)-Sn(57%)

- 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

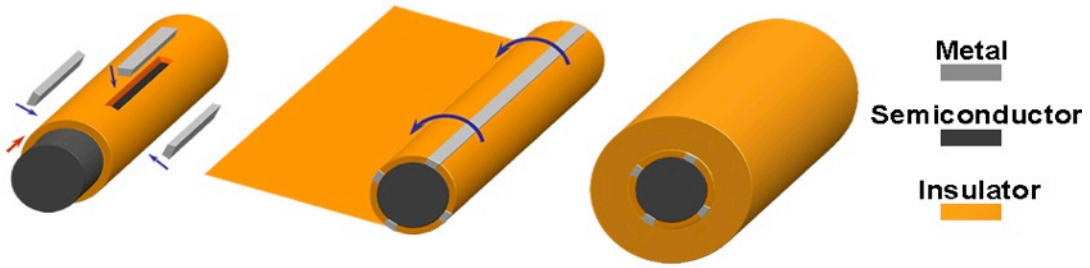
AMORPHOUS SEMICONDUCTORS

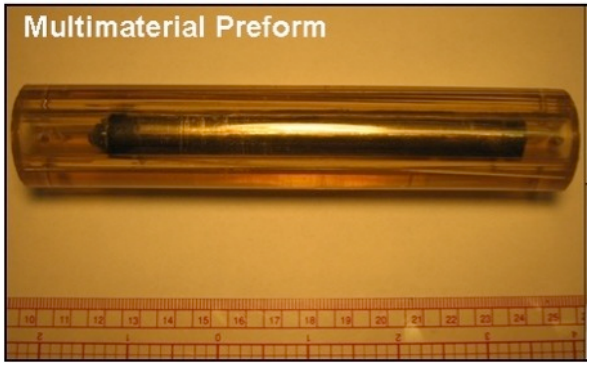
As, Se, S, Ge, Te, Si, Sn

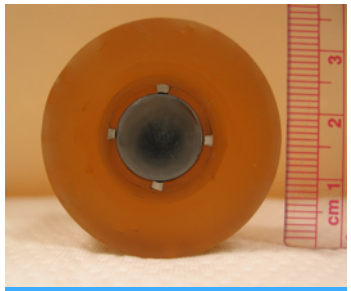
- Amorphous semiconductors (p-type)
- Glass transition temperature: 160-210 °C
- Refractive index @1.5 microns: 2.4-3.4
- High electrical conductivity
- CTE for As2Se3: 25*10^-6/C
- Photoconductivity



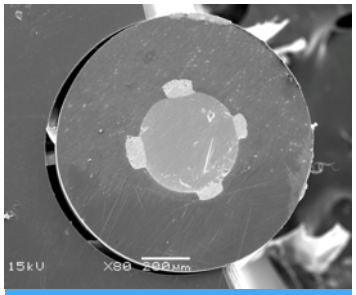
Metal-Insulator-Semiconductor fiber





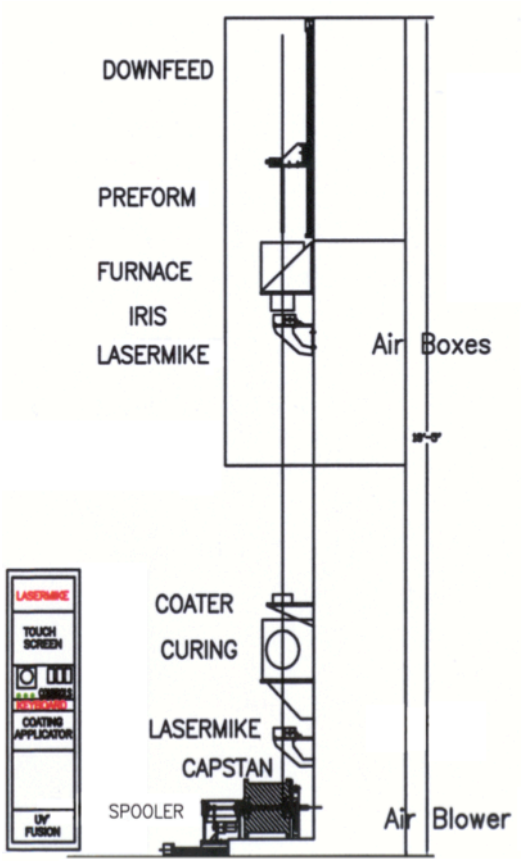


Preform cross section



Fiber cross section

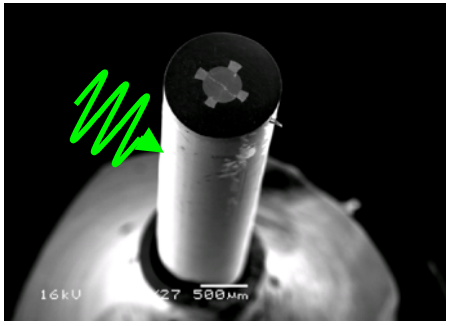
Draw-tower

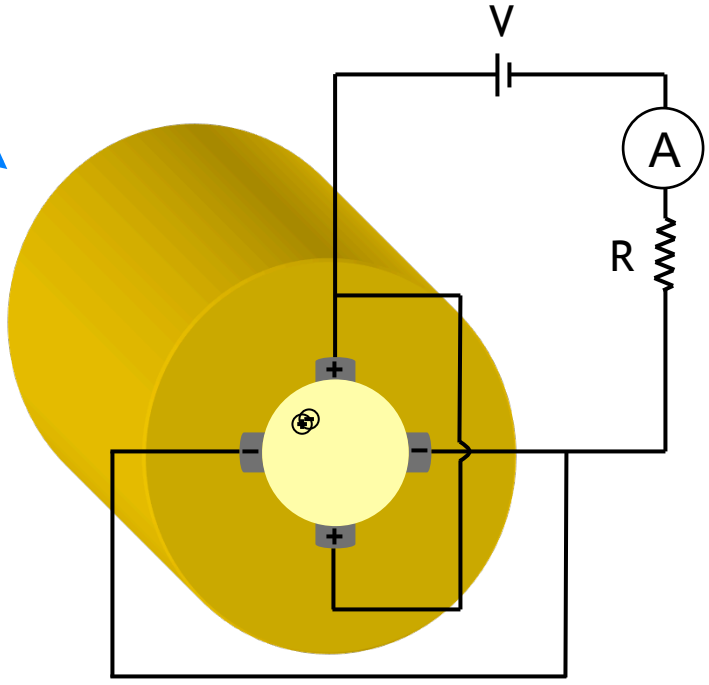


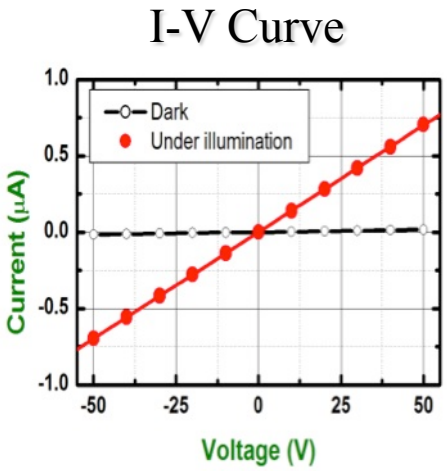
The thermal drawing process inherently generates surface area !

M. Bayindir, F. Sorin, et al *Nature* 431, 826 (2004)

We have already made a photoconductor







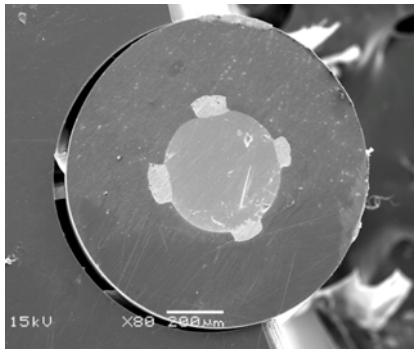
Extremely large area flexible optoelectronic devices

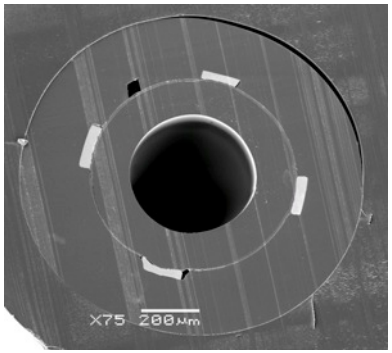
Can we integrate increasingly complex and innovative device structures ?

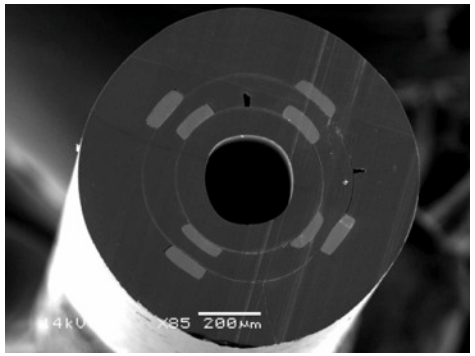
M. Bayindir, F. Sorin, et al *Nature* 431, 826 (2004)

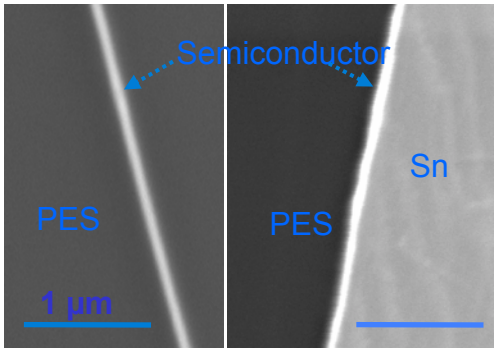
THIN-FILM FIBER DEVICES

A change of architecture can lead to significant improvement in performance

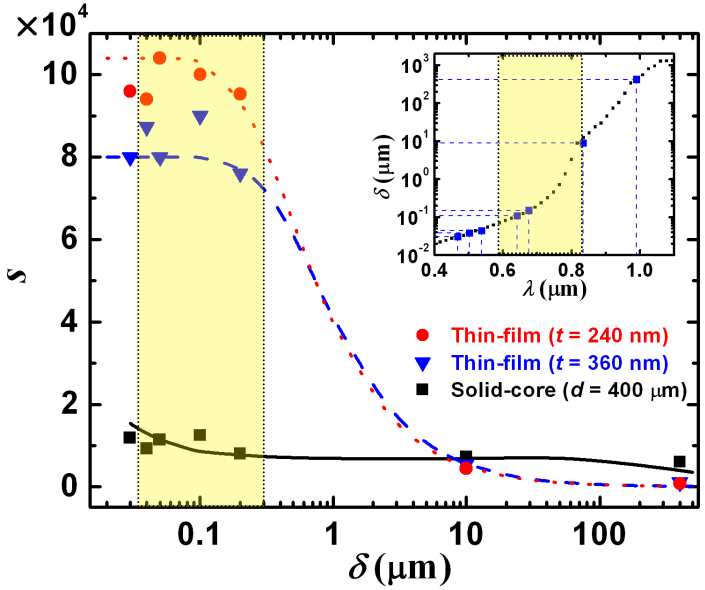




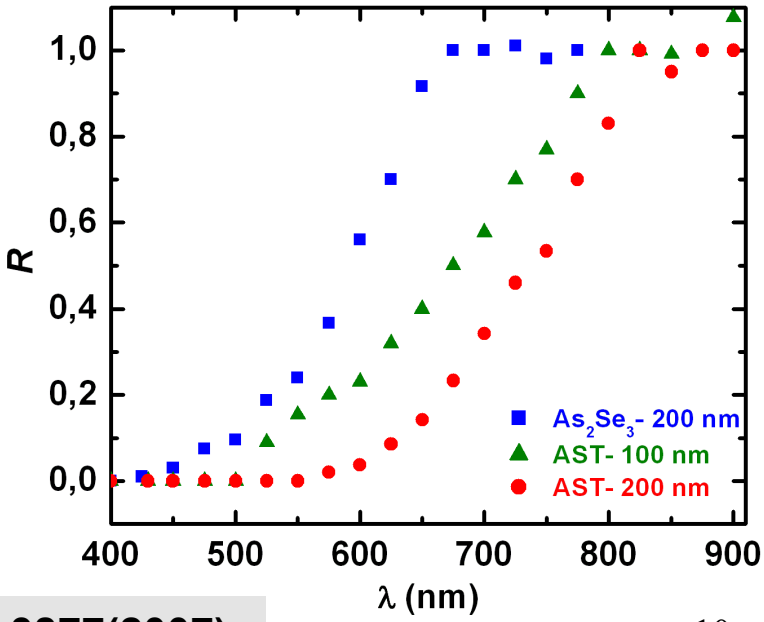




SENSITIVITY vs PENETRATION DEPTH



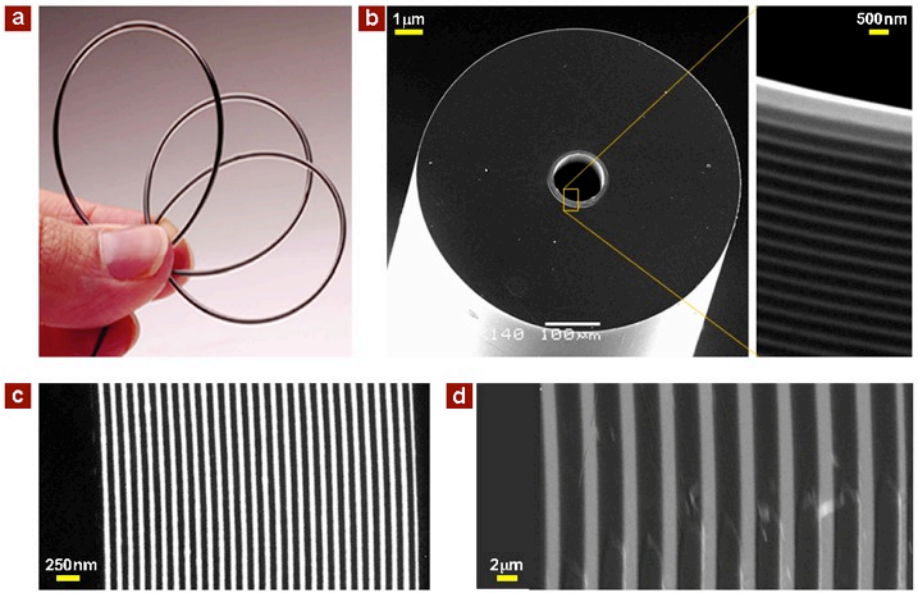
PHOTOCURRENT RATIO vs WAVELENGTH



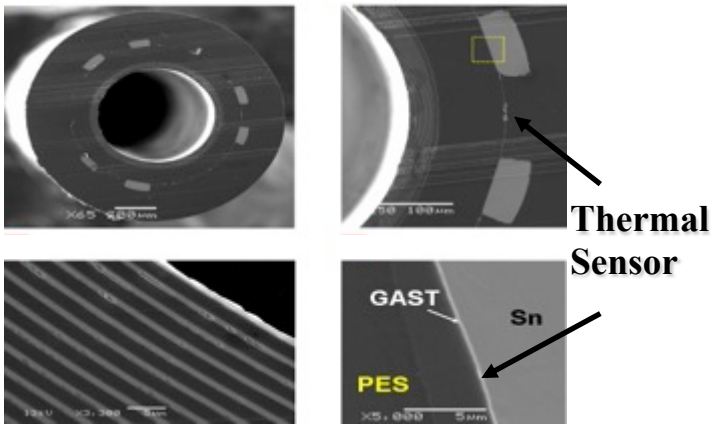
F. Sorin et al, Advanced Materials, 19(22) pp. 3872-3877(2007)

F. Sorin et al, NanoLetters 9 (7), pp.2631-2635 (2009).

Distributed heat sensing for safety monitoring



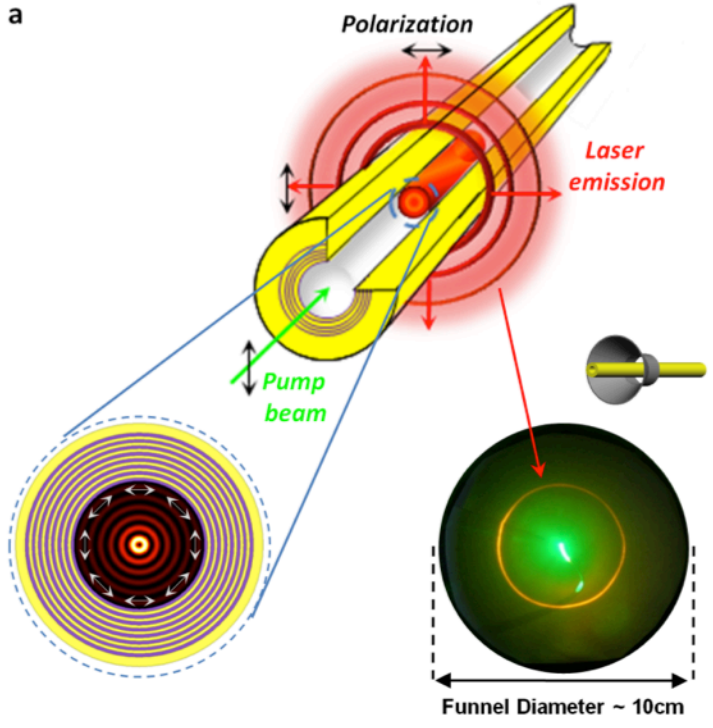
OmniGuide CO_2 Laser Beam Delivery System for non-invasive surgery

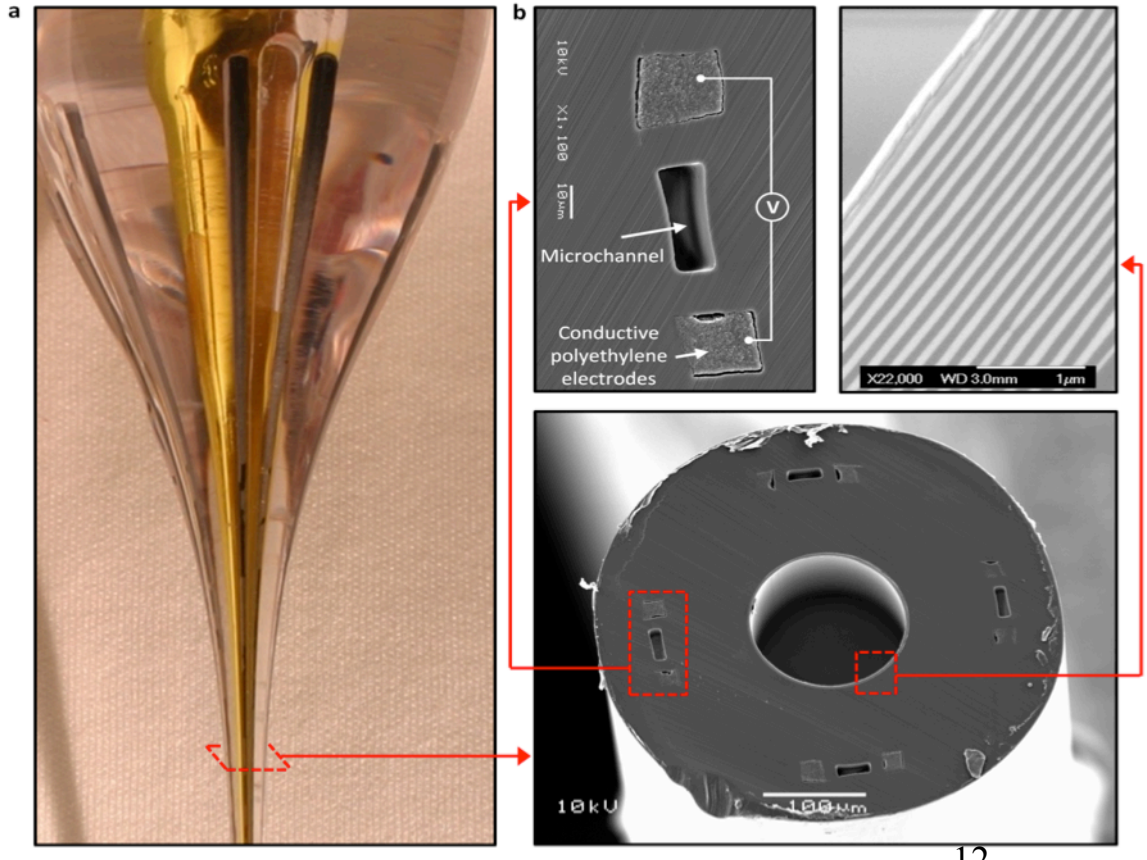


(Patent licensed by Omniguide Inc)

Microfluidic transverse fiber lasers

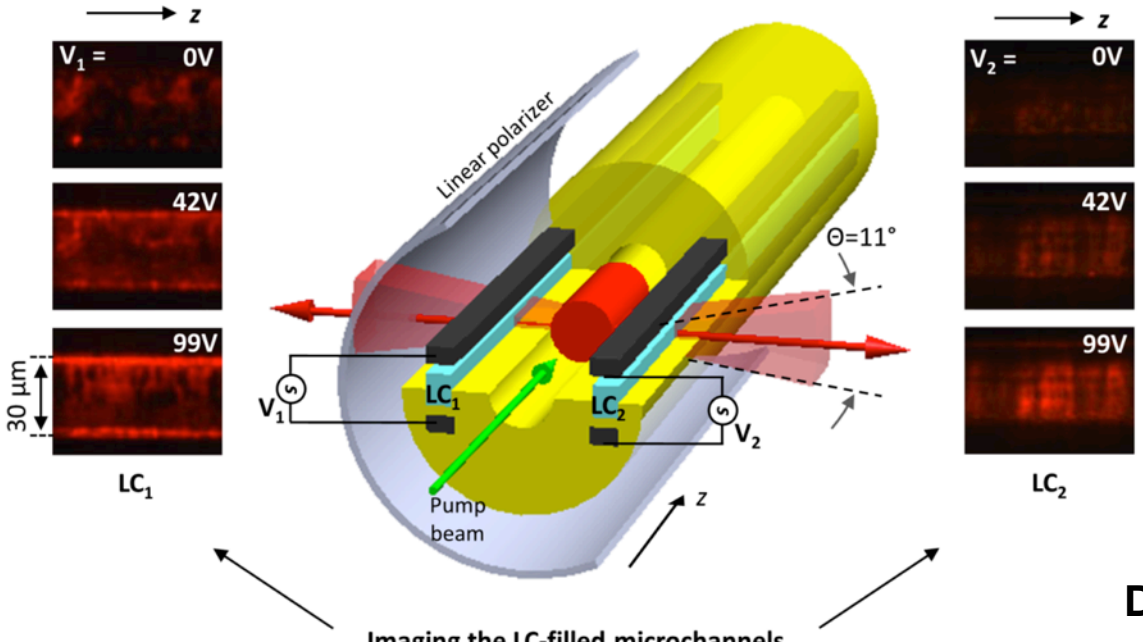
- We demonstrated surface emitting fiber lasers
- Using our multimaterial fiber platform, we could add liquid crystal filled channels
- Another example of integration of complex and different functionalities.



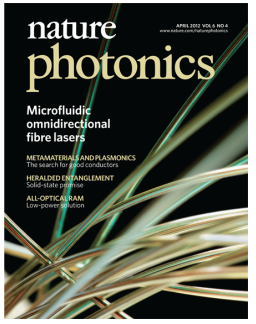


A. Stolyarov, et al, Nature Photonics, 6 229 (2012)

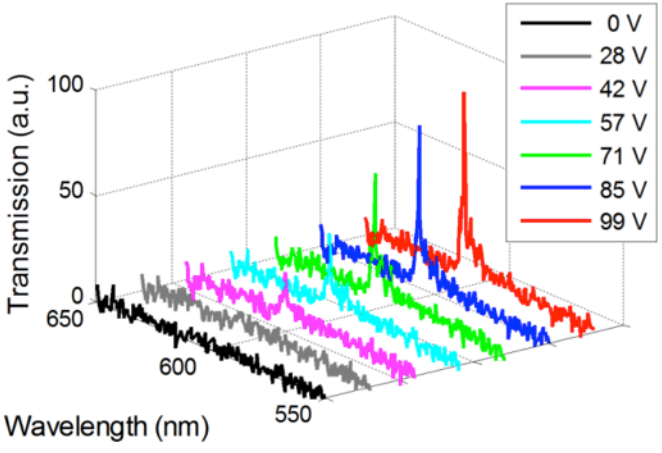
Microfluidic transverse fiber lasers

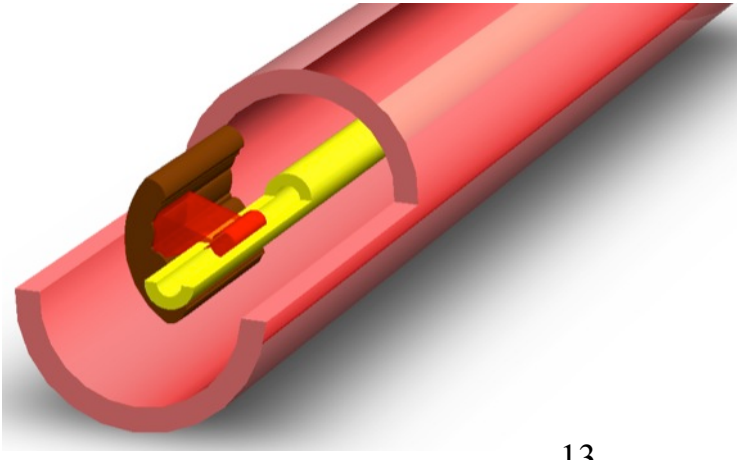


Imaging the LC-filled microchannels



Directional light based activation of photosensitive compounds.





A. Stolyarov, et al, Nature Photonics, 6 229 (2012)

Fiber-integrated Nanowire based detectors

PMMA

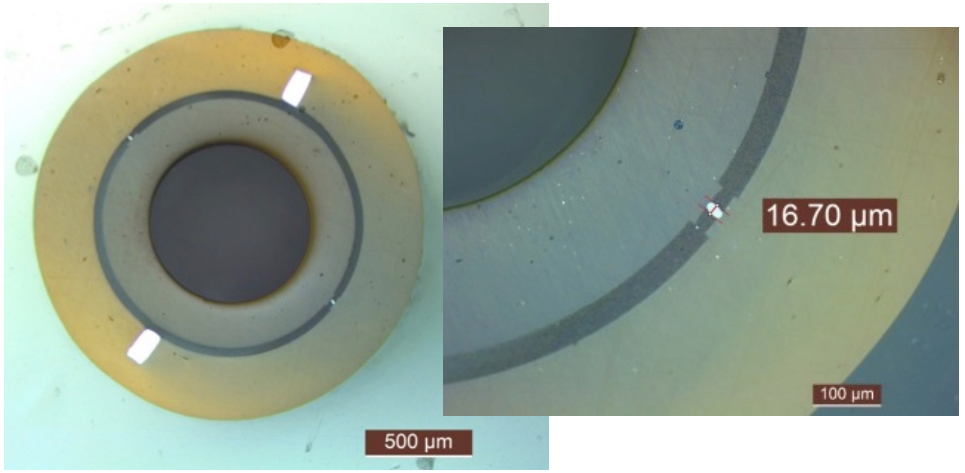
Polycarbonate

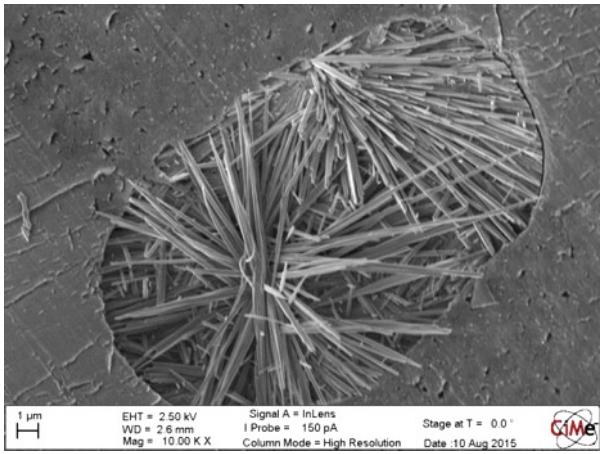
SnZn metal

Polysulfone

Semiconductor

Conducting nanocomposite





RESEARCH AT FIMAP

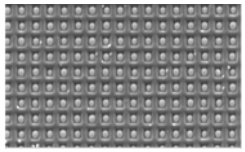
Advanced multi-material optical and optoelectronic fibers

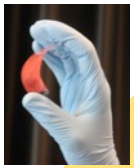
Microstructured and micro-textured fibers and fabrics

Template dewetting of novel materials for Photonic devices

Novel materials for innovative biocompatible, degradable and stretchable fibers

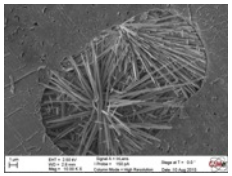
Research areas

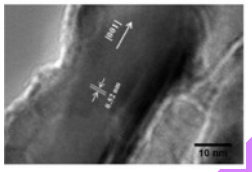




Novel planar and fiber devices

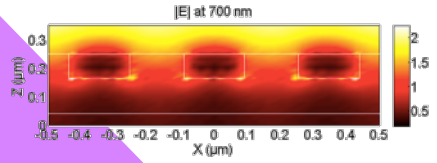
fiber assemblies



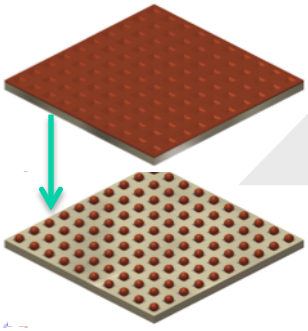


Planar and fiber systems characterization

Process and Photonic properties modeling

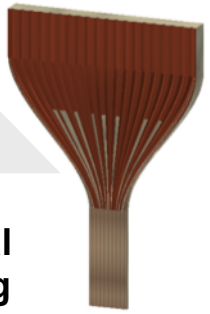


Dynamic flow of viscous liquids and thin films / Surface and interface science and engineering / Innovative device architectures



Template dewetting

Thermal drawing



Group and sponsors

FIMAP today:

Wei Yann PhD student	**Tapajyoti Das Gupta** Postdoc	**Anne Roy** Amdinistration
DangTung Nguyen PhD student	**Yunpeng Qu** Postdoc	
Alexis Page PhD student	**Marco Volpi** PhD student	

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