

Wir schaffen Wissen – heute für morgen

Paul Scherrer Institut

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Nanostructures pour la détection photonique intégrée

- Single molecule detection
- Individual molecule quantification
- Integration of different functionalities
 - Separation of substances
 - On-Chip detection and reading
- Parallel and high throughput of sensing/reading
- Reliability

*Chip & photo by IBM and
University Hospital of Basel
Lab on a Chip, 9 (2009)*

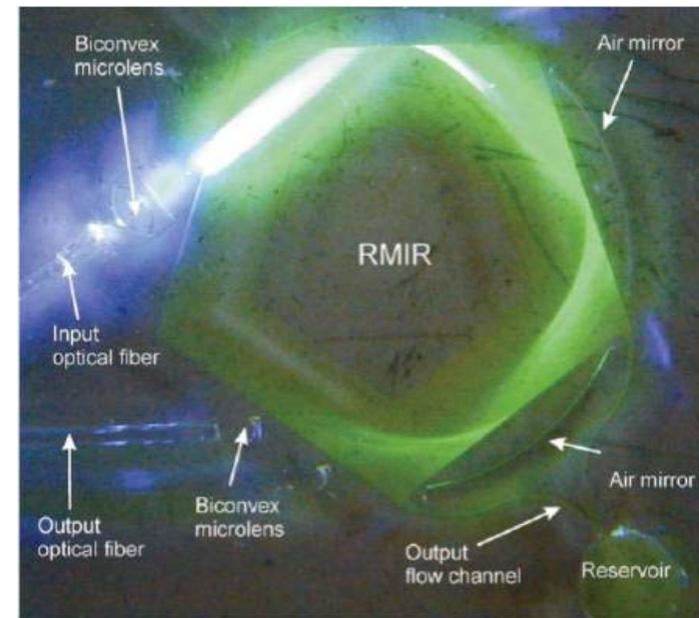
Optical sensing elements:

- High sensitivity
- Small detection volumes
- High robustness
- Contactless
- Real time

Challenges:

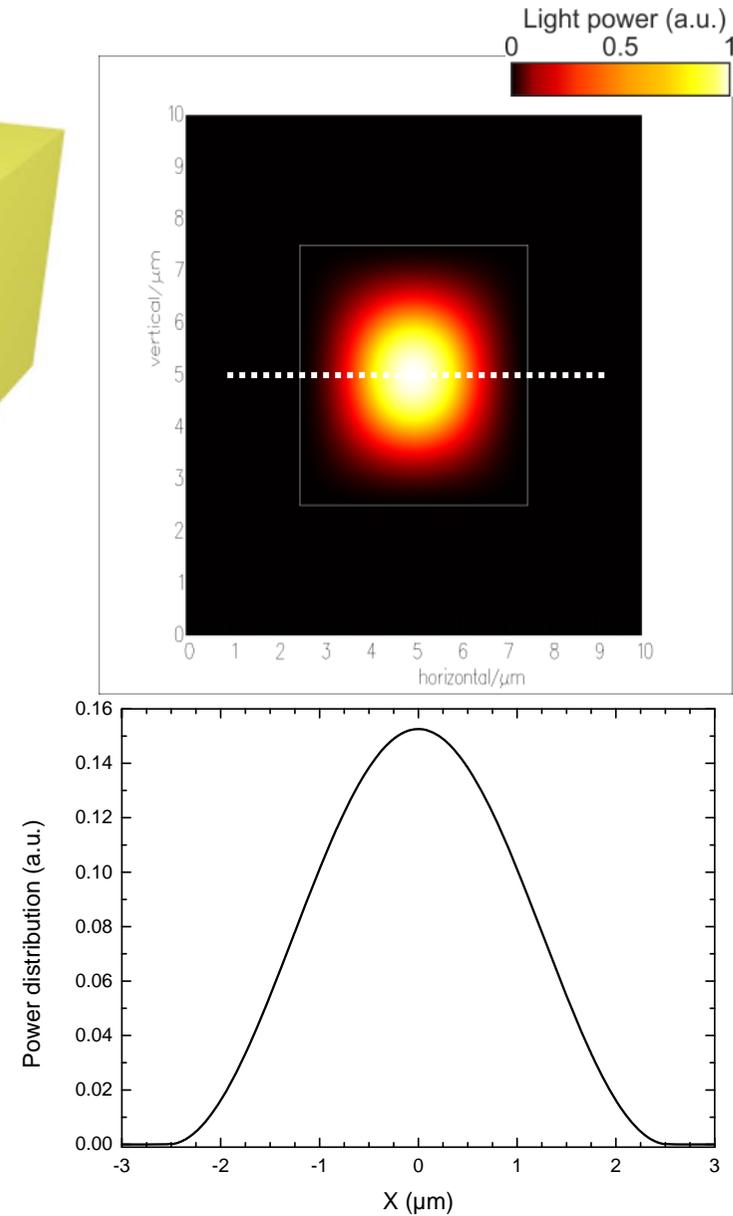
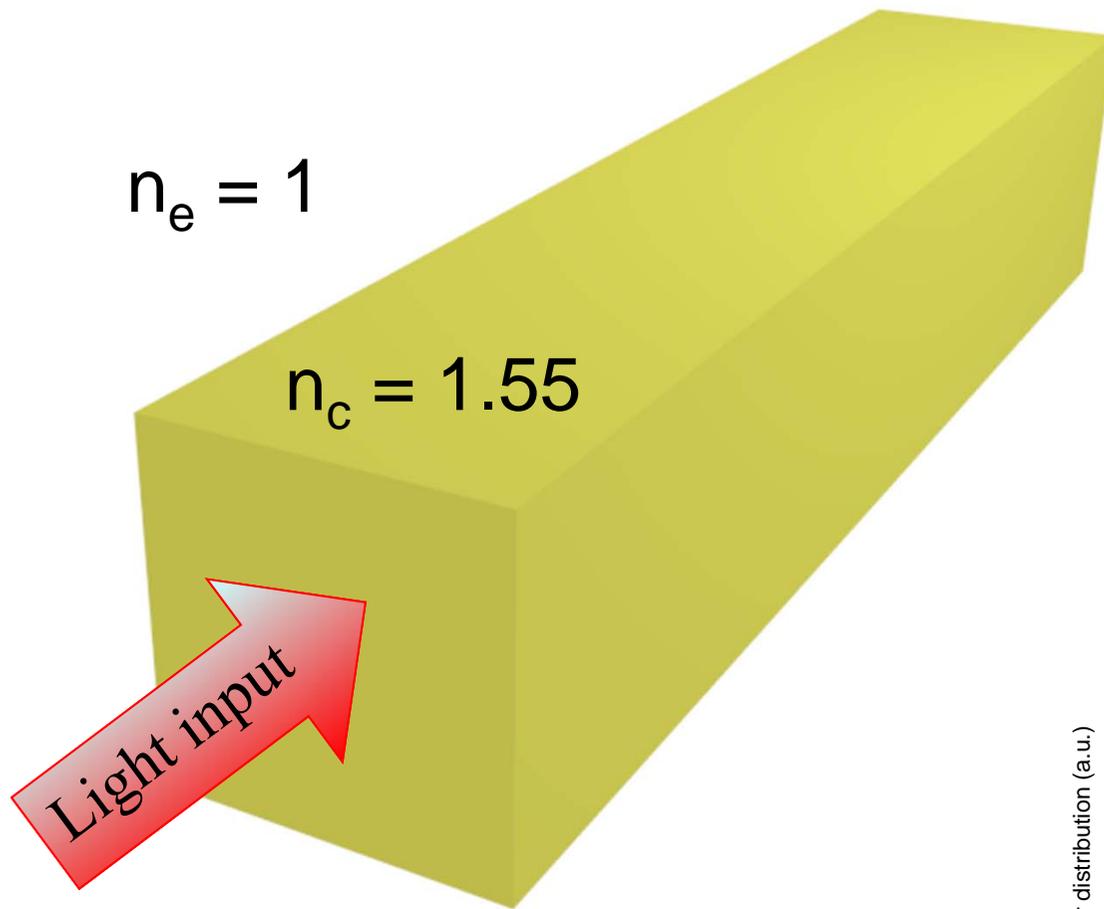
- Portable
- Easy-to-use
- Low cost

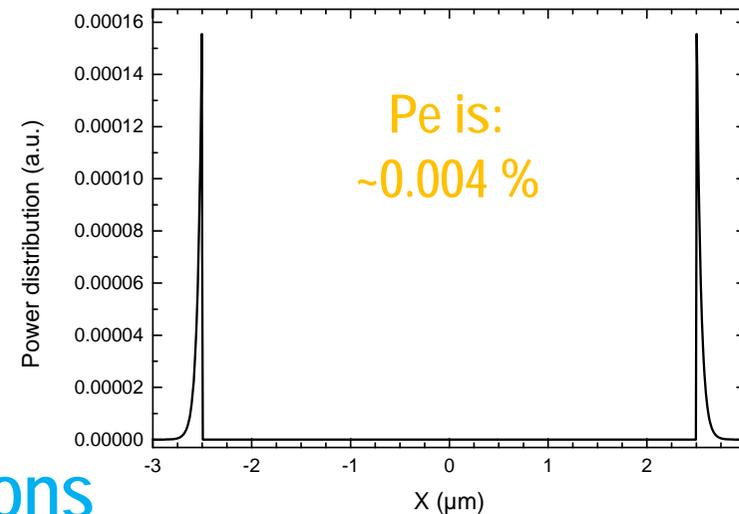
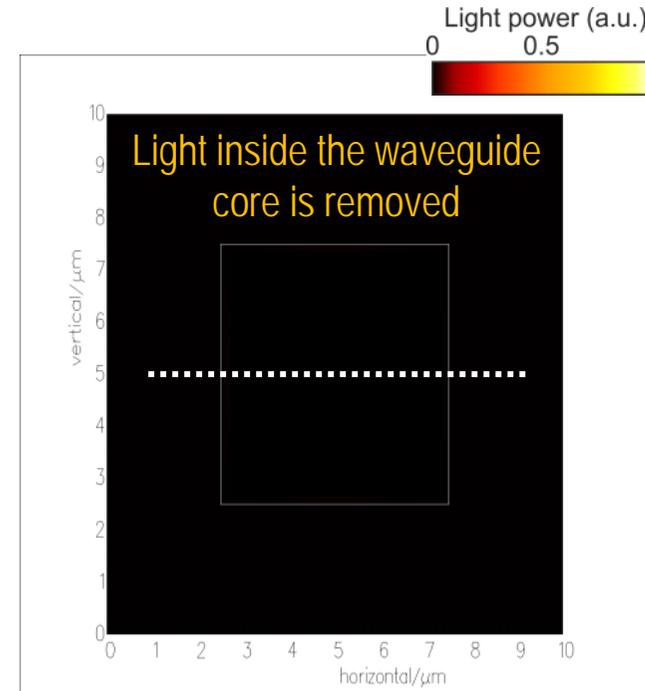
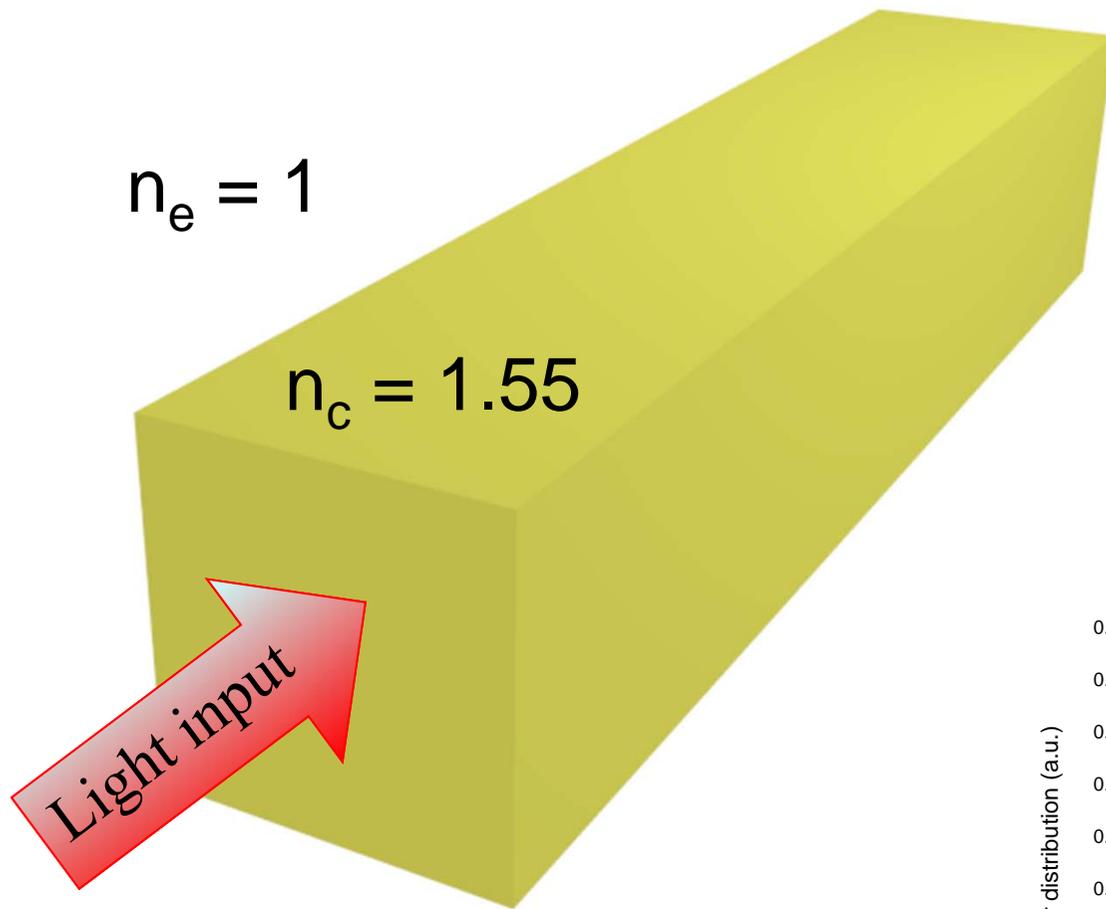
Multiple mirror sensing system



A. Llobera, et al. Lab on a Chip, 2007

Development of complete photonic LoC is in its infancy





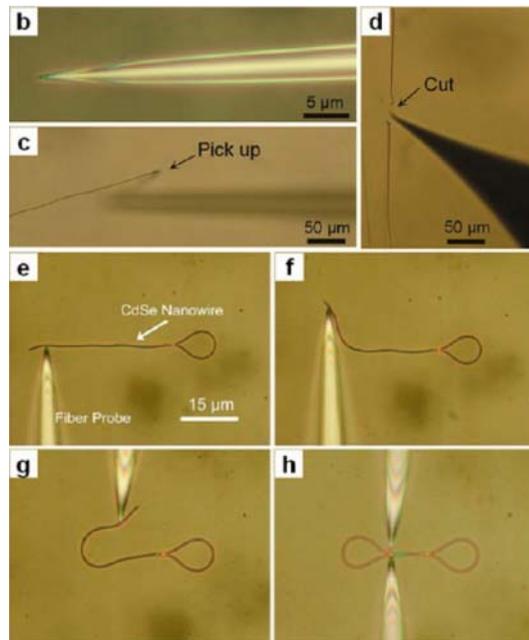
EF is used to interact with the environment in sensing applications

Evanescent field based sensing:

- Low interaction with environment
- Long sensing areas required

Alternatives:

Photonic nanowires

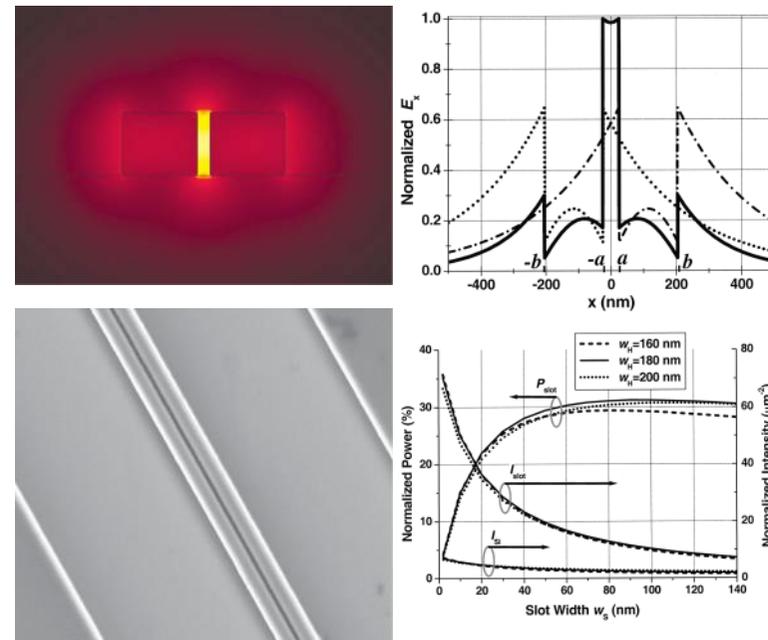


- Subwavelength structures
- High evanescent field
- Single element manipulation required

Tong et al. Nature 2003,
Guo et al. Acc. Chem. Res 2013

**Not valid for
commercial applications!**

Slot waveguides

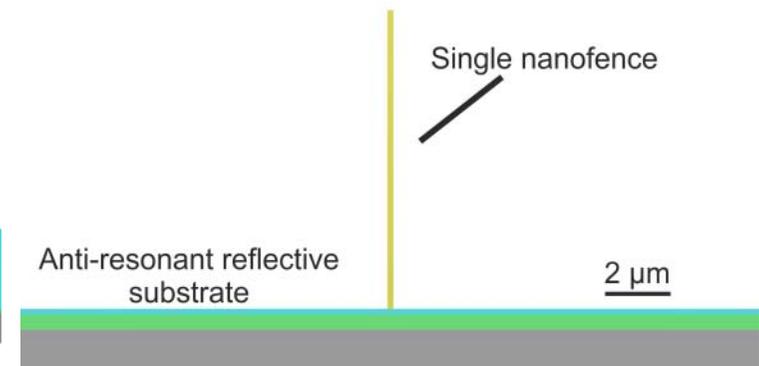
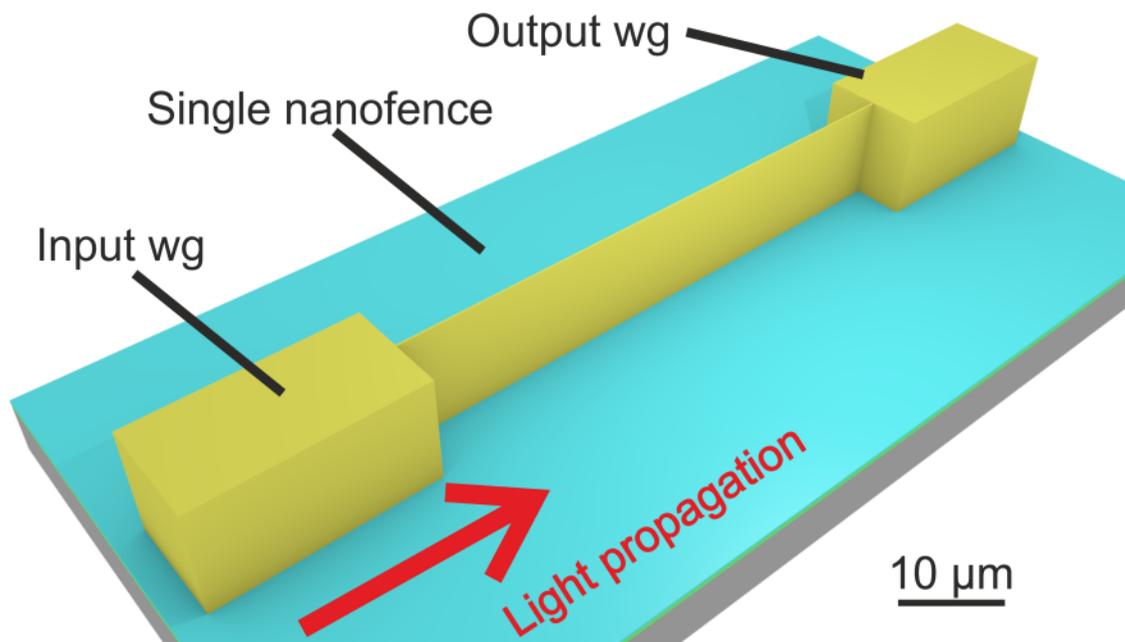


- Subwavelength lit between waveguides
- Electric field hot-spot
- Complex nanofluidics for sensing

Almeida et al. Opts Lett. 2004
Yang et al. Nature 2009

New concept: Photonic Nanofences

- High aspect ratio photonic subwavelength waveguide (between 3:1 and 40:1)
- Integrated structures: no single elements manipulation
- Compatible with classical integrated optics and silicon photonics
- Potential mass manufacturing

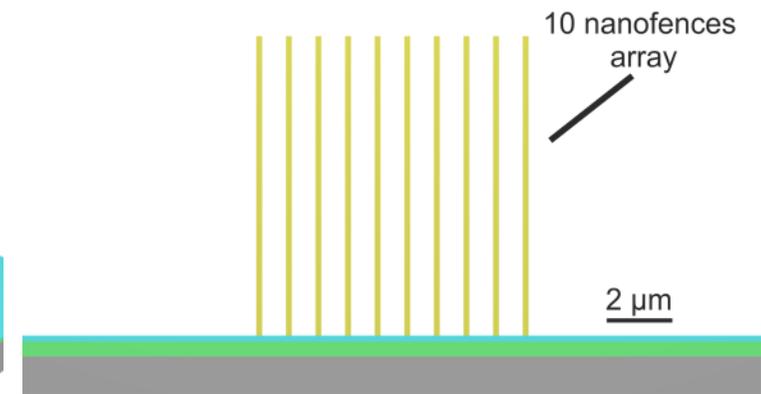
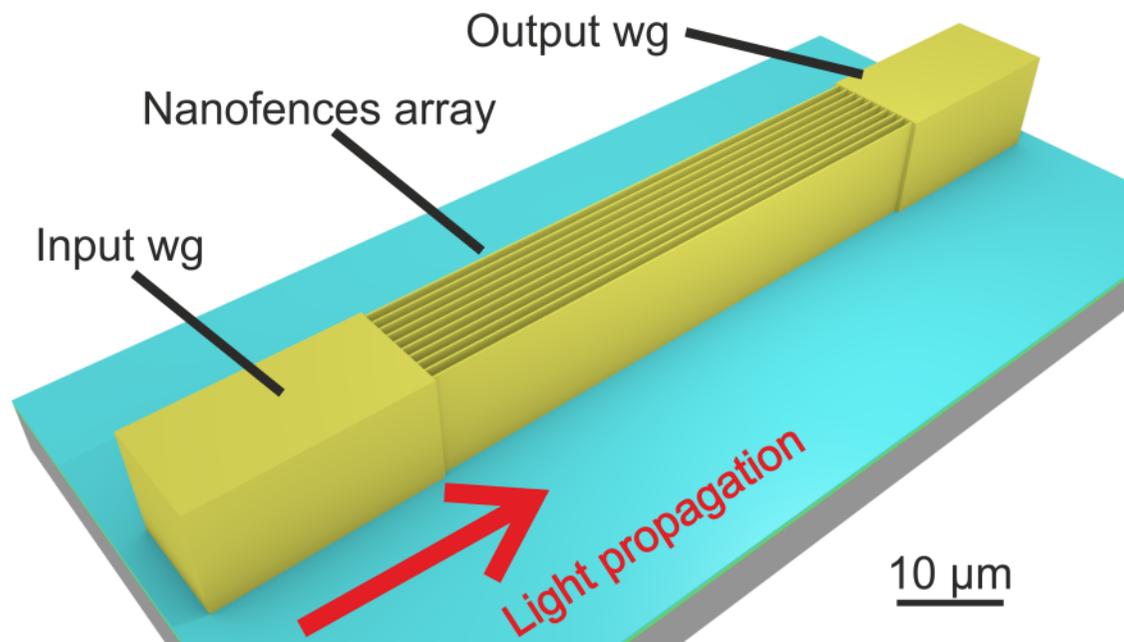


Optical Nanofences properties:
- High evanescent field

New concept: Photonic Nanofences

Patent PTC/EP2015/053883

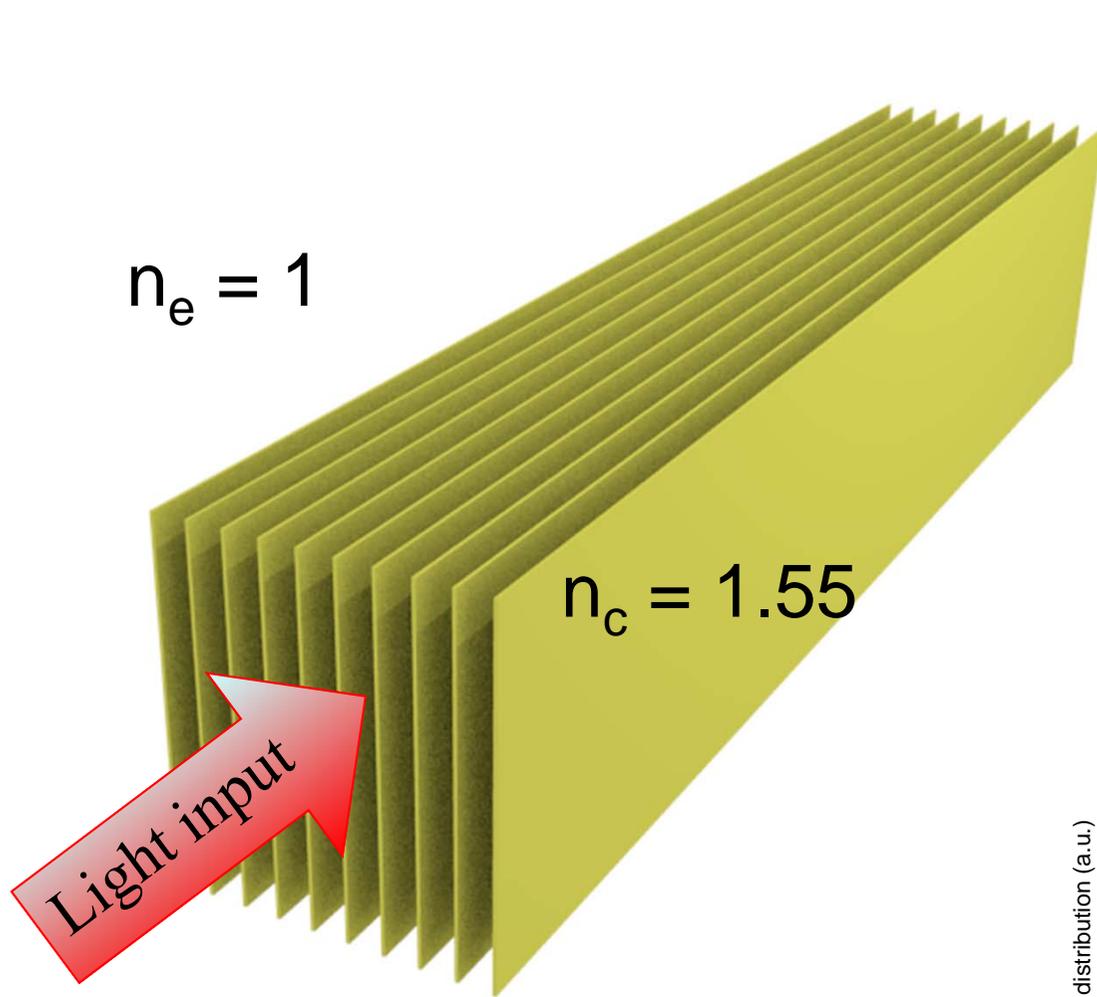
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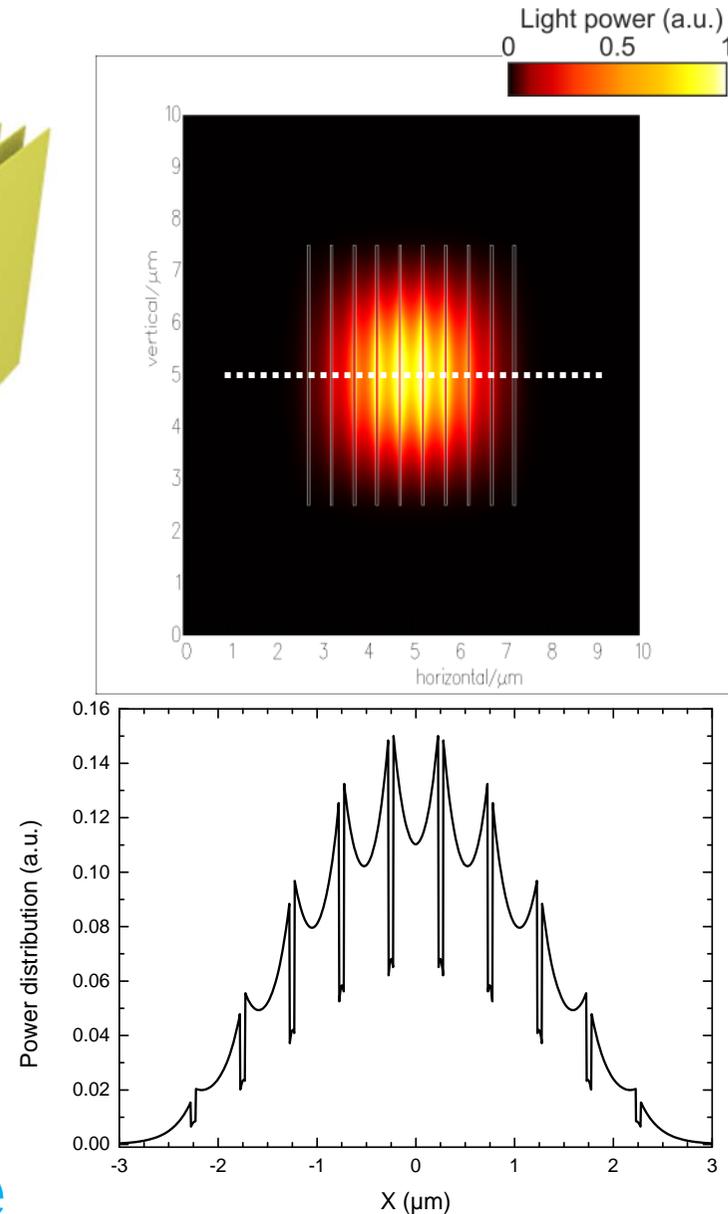
Optical Nanofences properties:

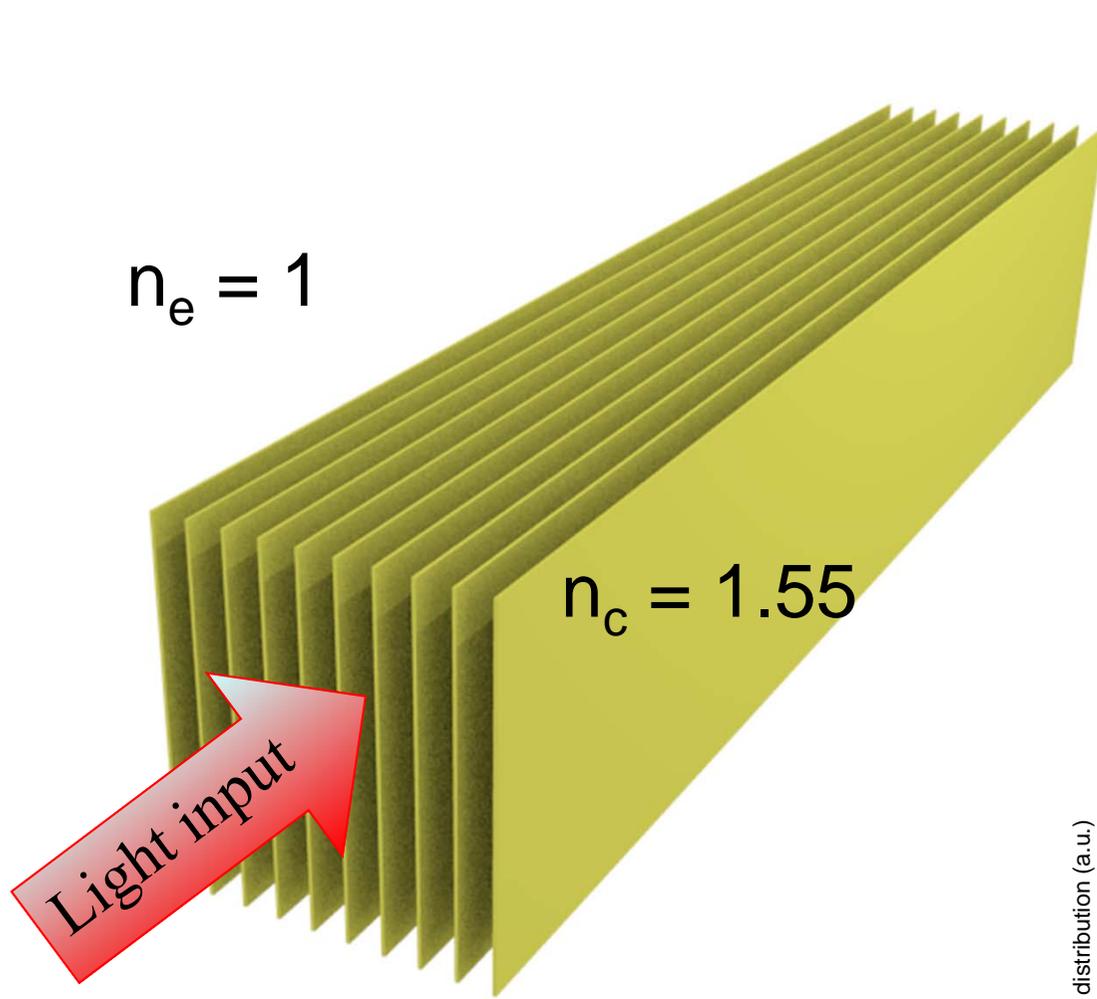
- High evanescent field
- Core segmented in nanostructures
- Low optical losses
- Large sensing area
- High interaction with environment

Ideal candidates for sensing applications

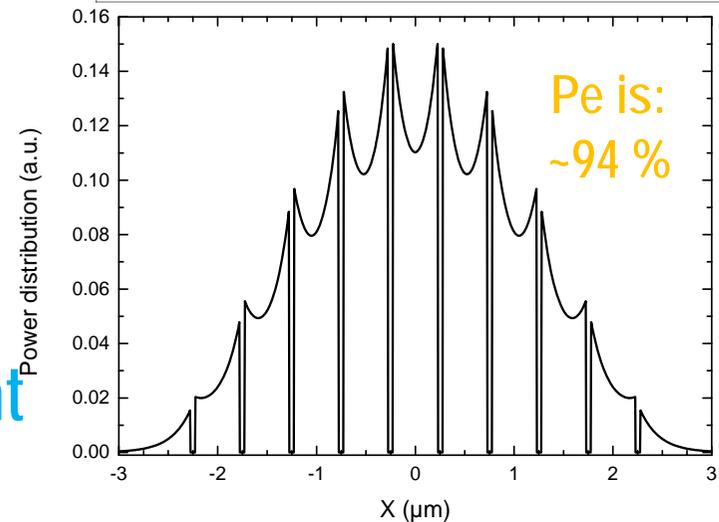
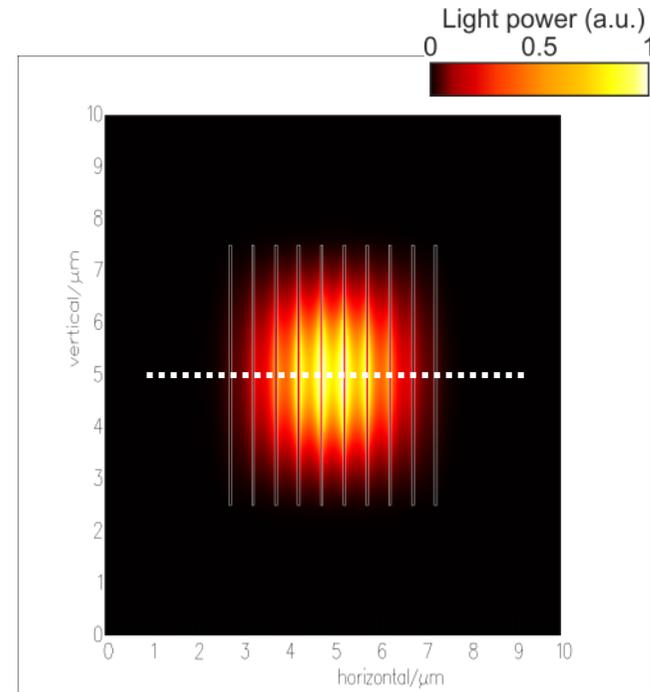


An array of optical nanowires
behave as a classical waveguide

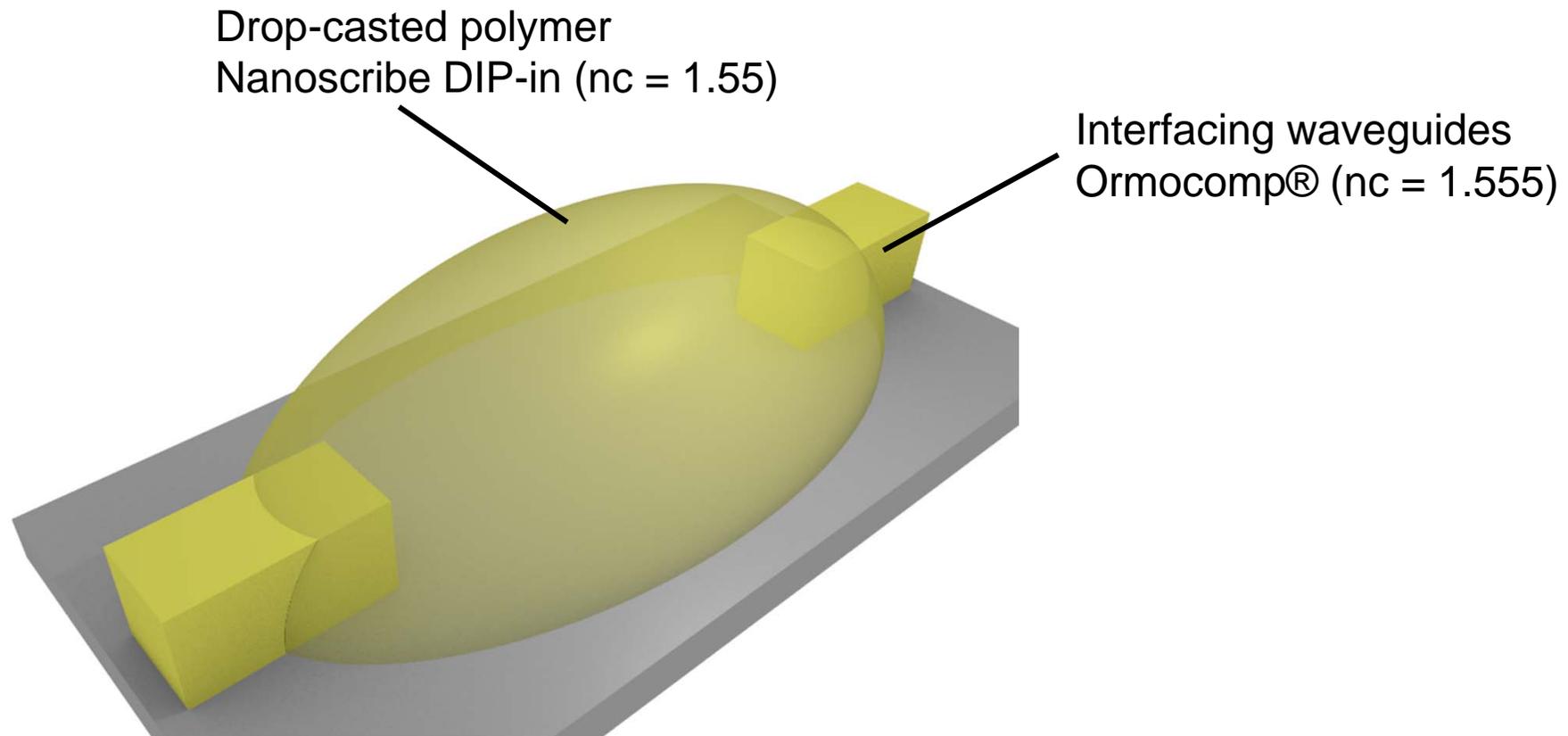




High interaction with environment
> x20000 higher



- a. Microstructures fabrication: UV-lithography
- b. Nanostructures fabrication: Nanoscribe
 - 1.- Nanoscribe polymer drop-casting

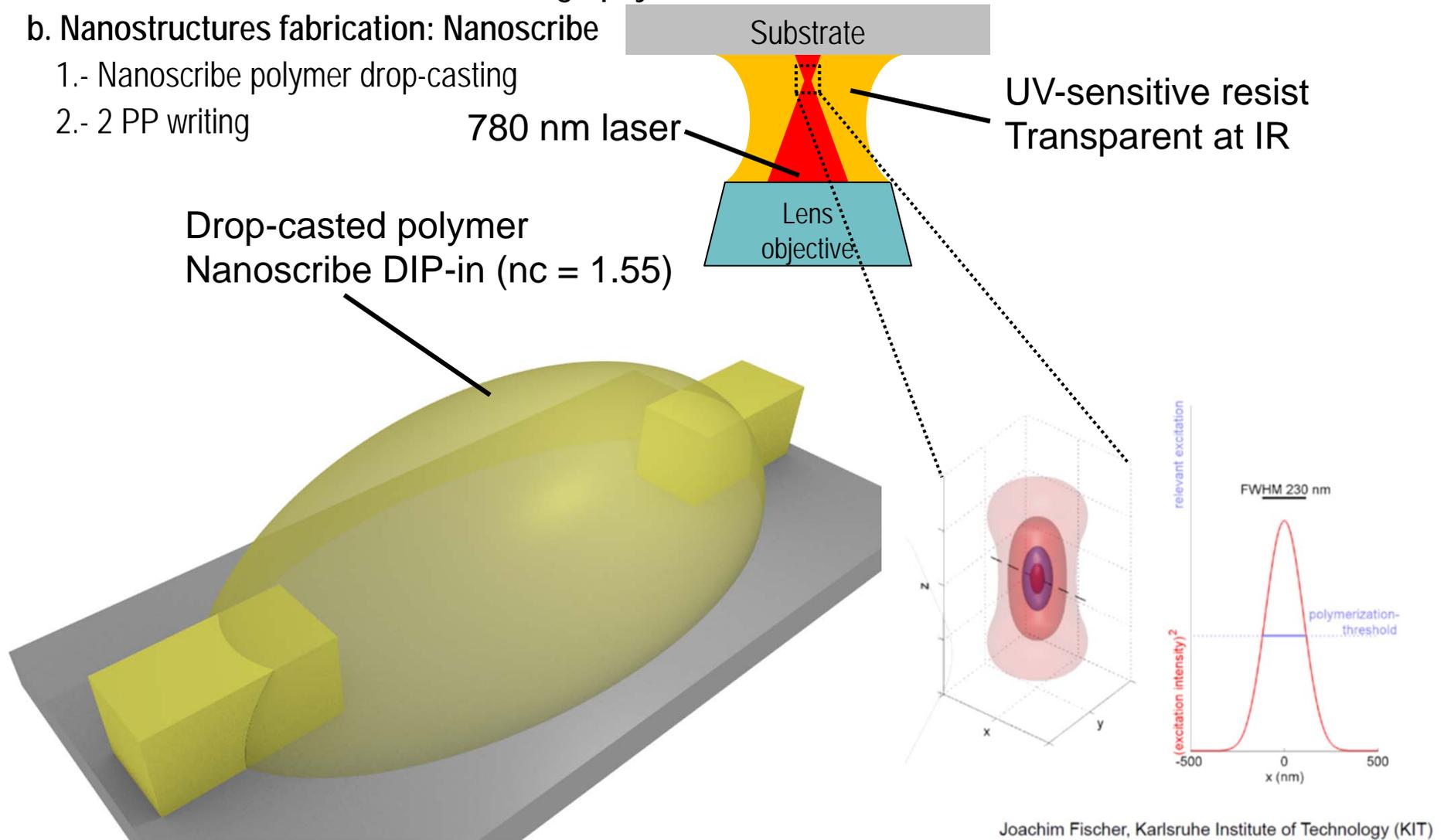


a. Microstructures fabrication: UV-lithography

b. Nanostructures fabrication: Nanoscribe

1.- Nanoscribe polymer drop-casting

2.- 2 PP writing



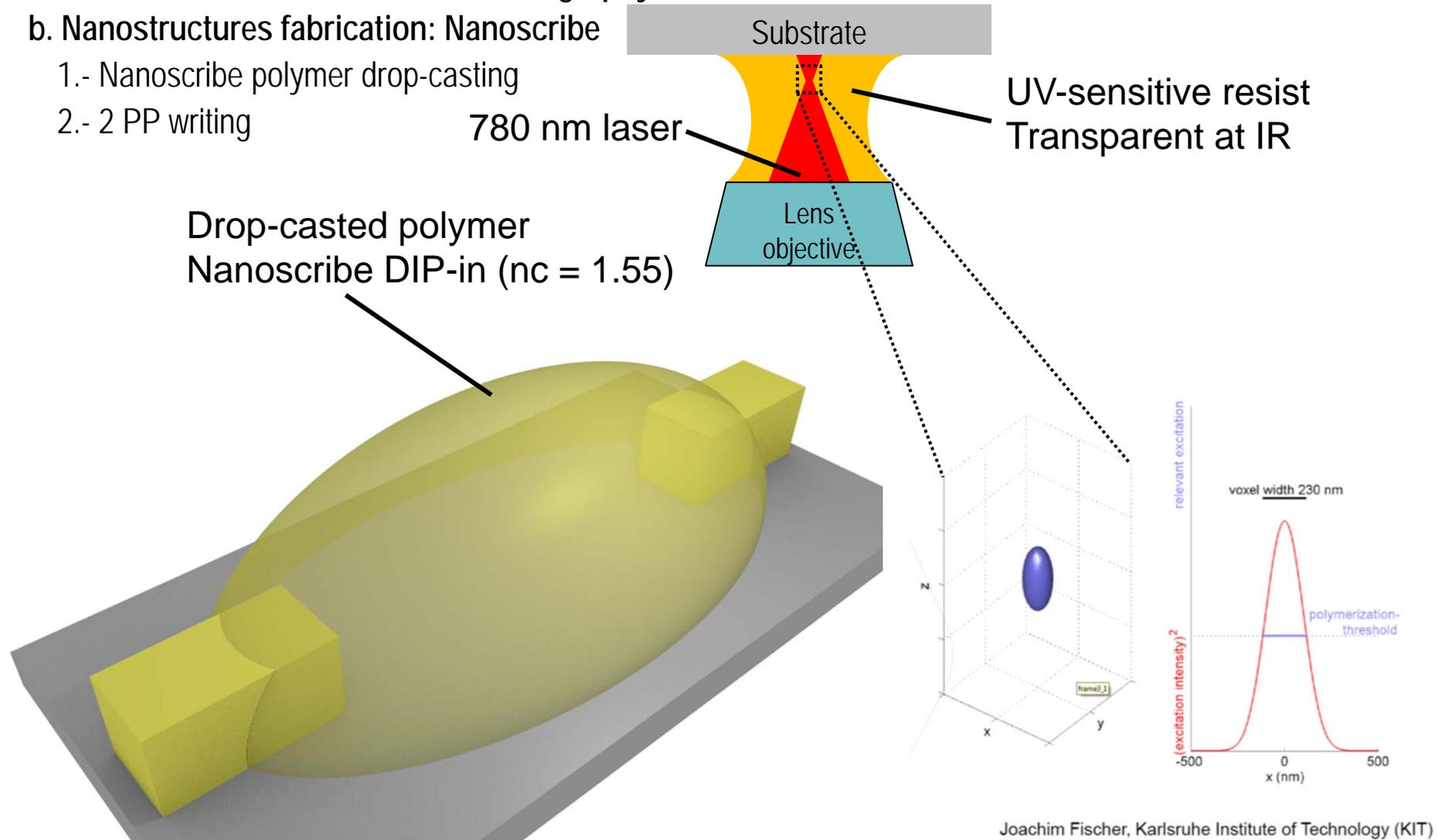
Joachim Fischer, Karlsruhe Institute of Technology (KIT)

a. Microstructures fabrication: UV-lithography

b. Nanostructures fabrication: Nanoscribe

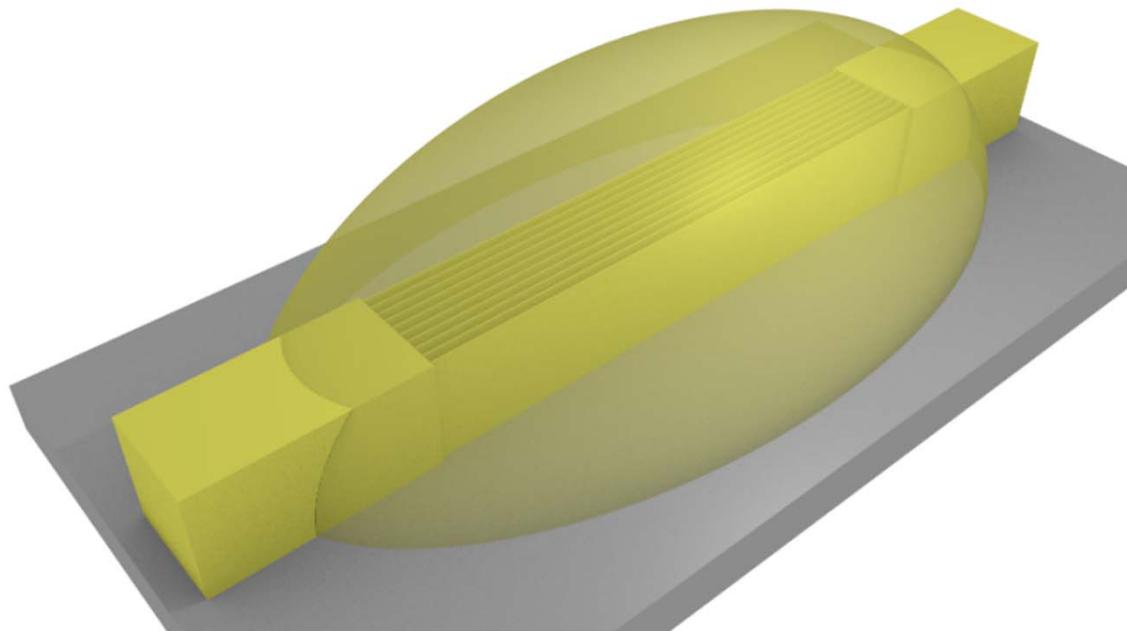
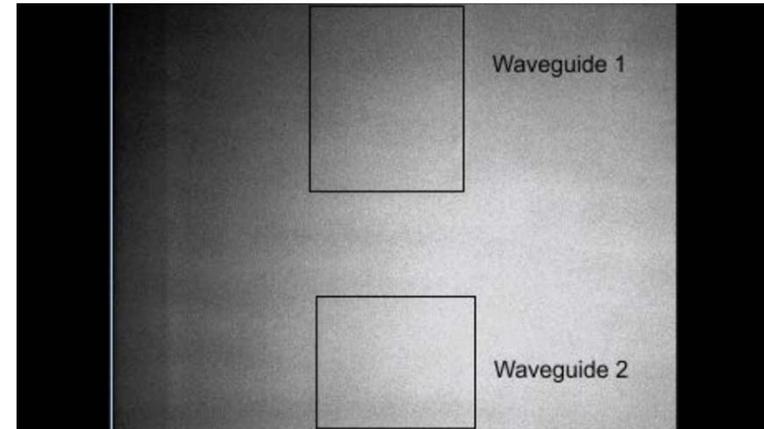
1.- Nanoscribe polymer drop-casting

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Nanostructures fabrication: Nanoscribe

- 1.- Nanoscribe polymer drop-casting
- 2.- 2 PP writing



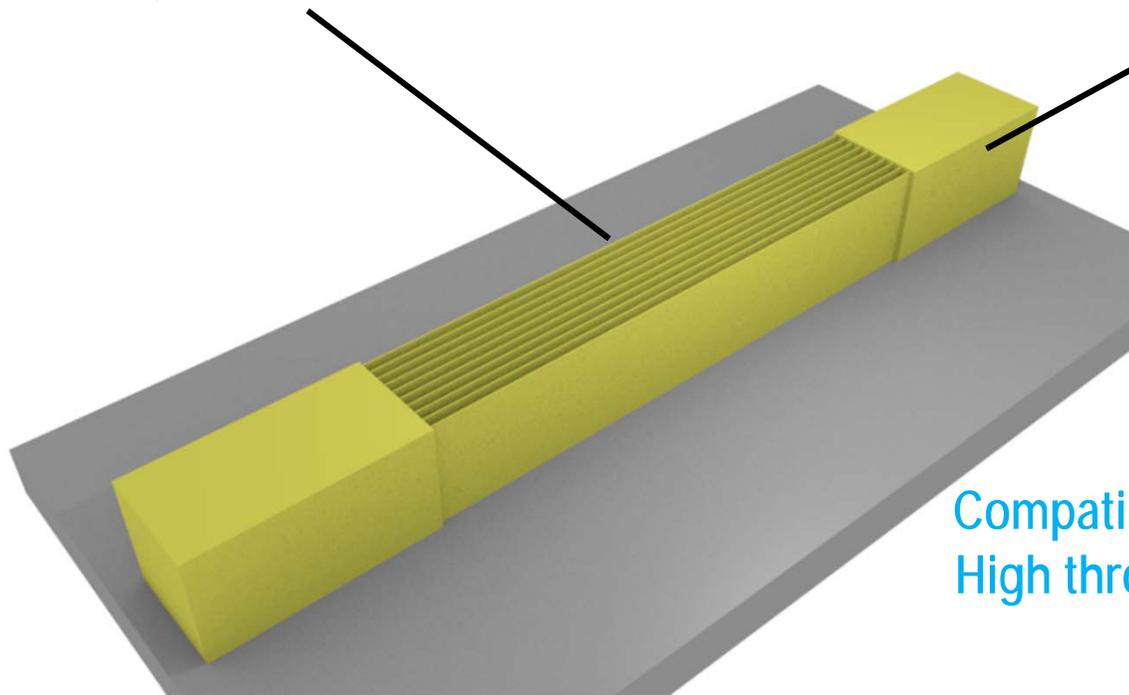
Alignment is possible
Fast prototyping method

Nanostructures fabrication: Nanoscribe

- 1.- Nanoscribe polymer drop-casting
- 2.- 2 PP writing
- 3.- Development
- 4.- Super critical drying

Polymer Nanofences

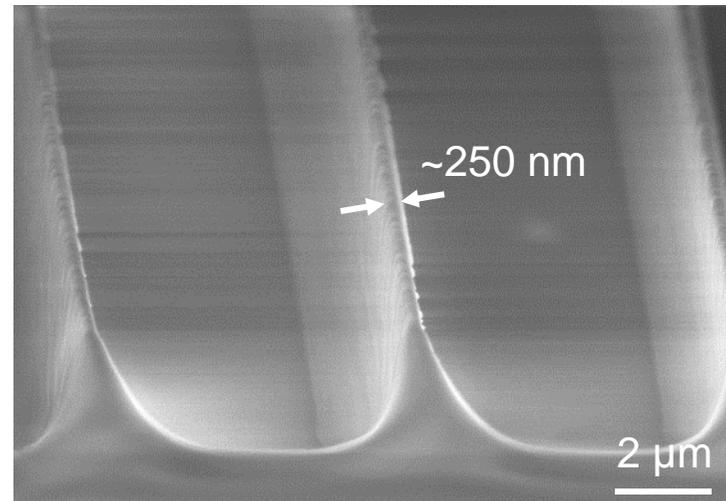
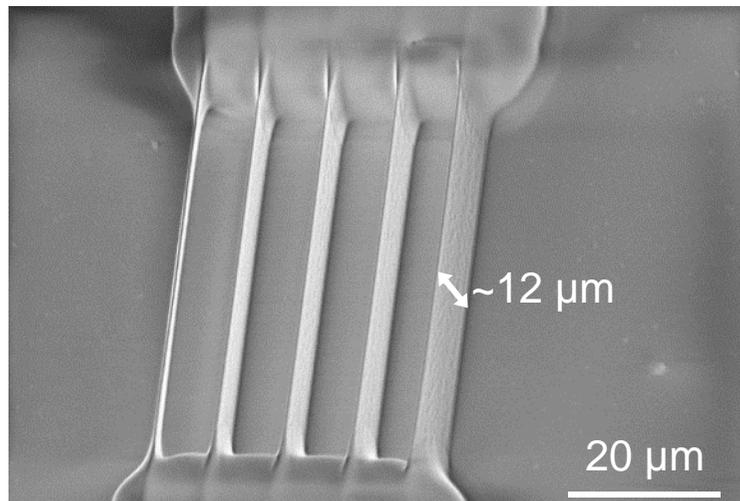
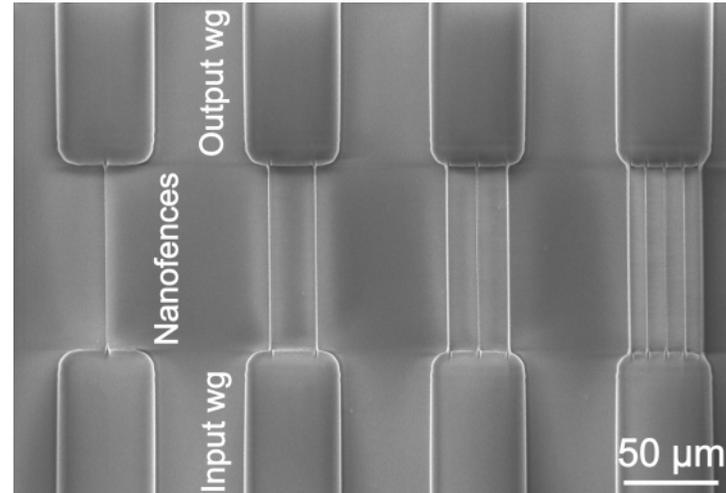
Polymer microstructures
(Interfacing waveguides)



Compatible with replication technologies:
High throughput cost-efficient fabrication
is possible

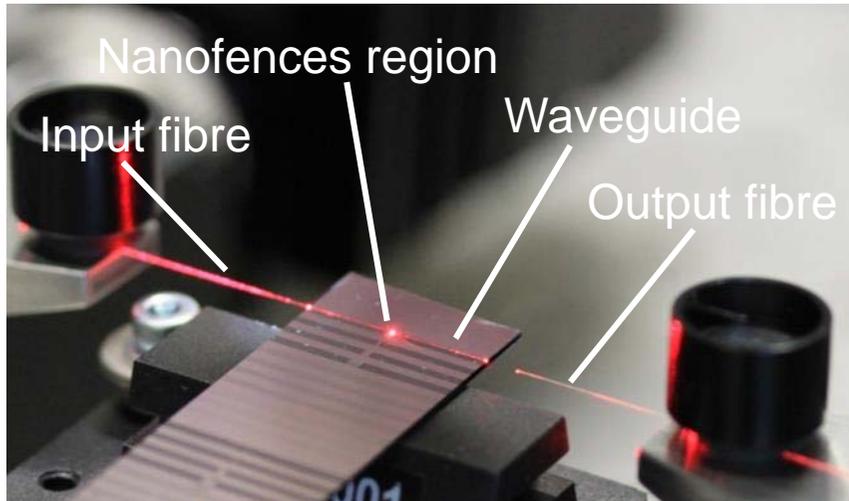
Direct fabrication of structures

- Fast prototyping
- Smallest structures ~250 nm
- High aspect ratios (> 40:1)
- Structures up to millimeters long
- High design flexibility
- Straightforward combination of micro and nanostructures

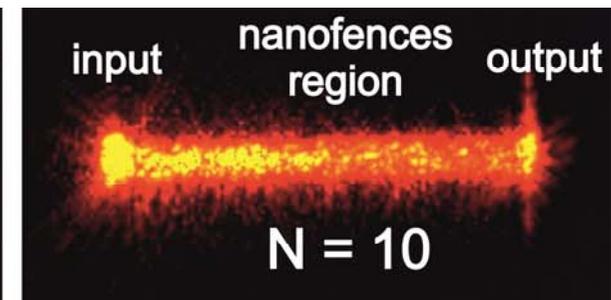
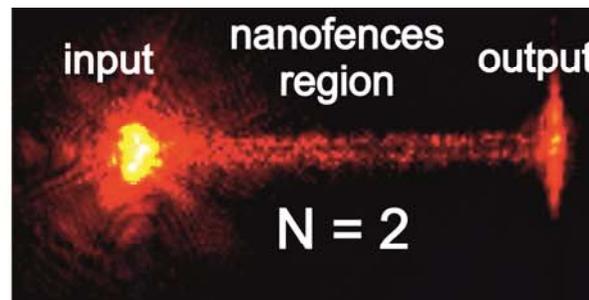
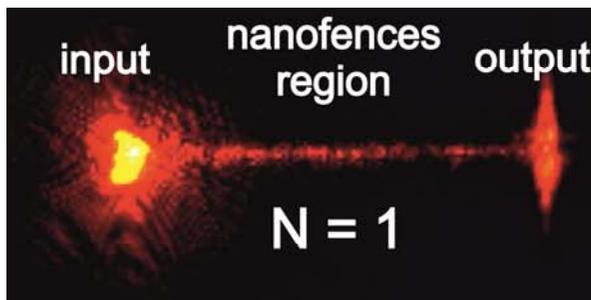
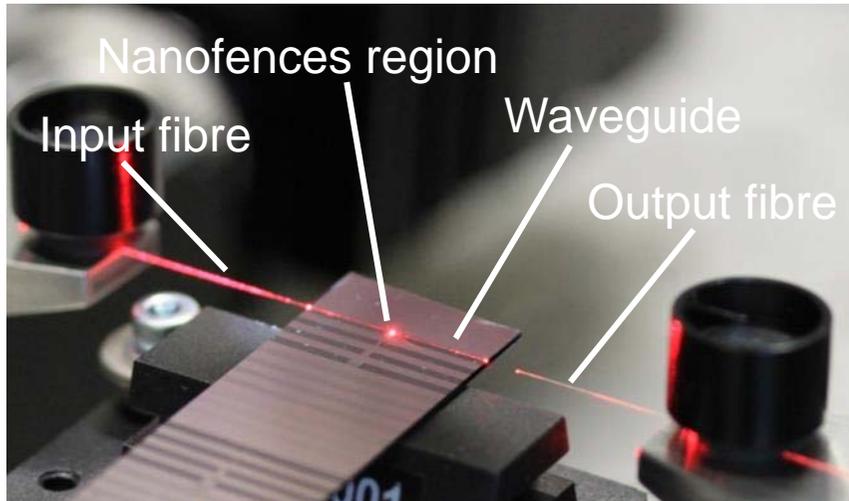


High aspect ratio > 40:1 achieved (5:1 needed)

Direct coupling of light

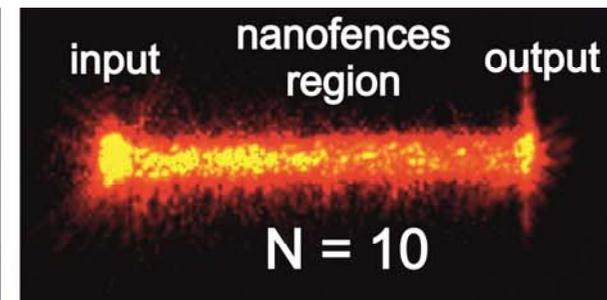
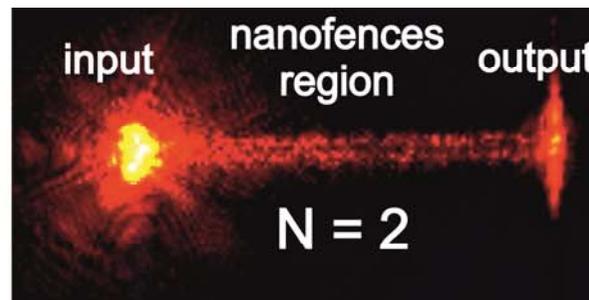
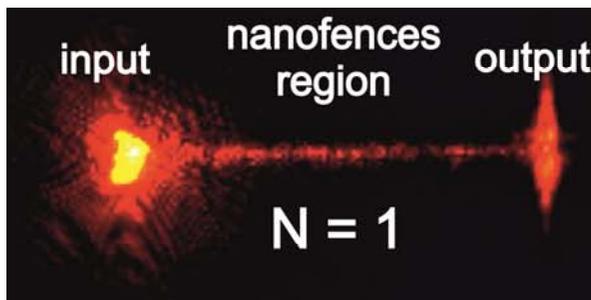
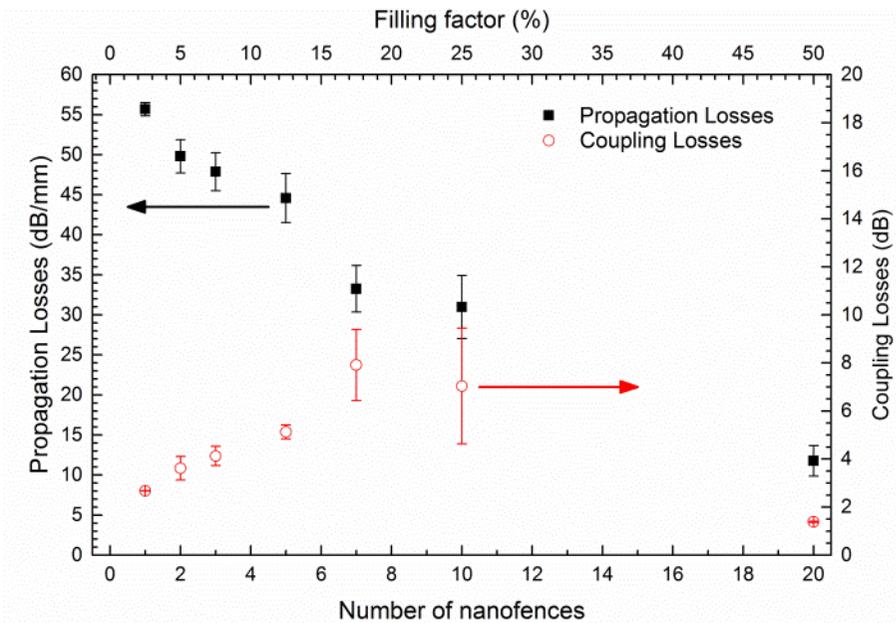
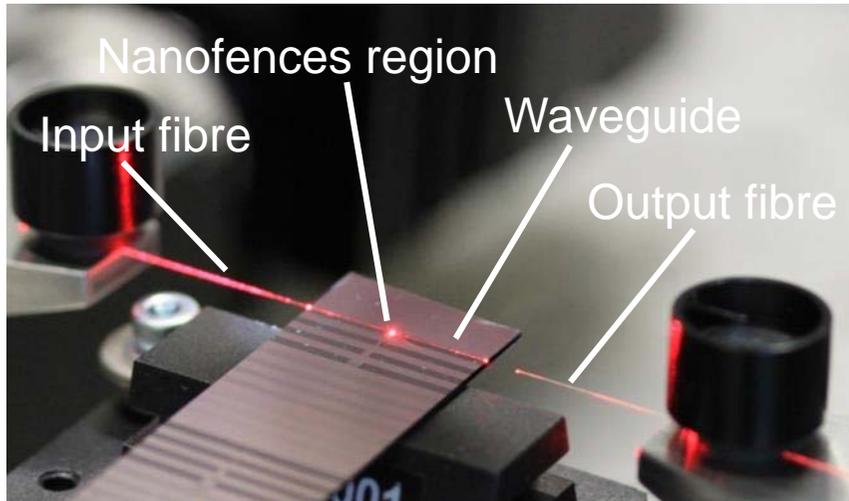


Direct coupling of light



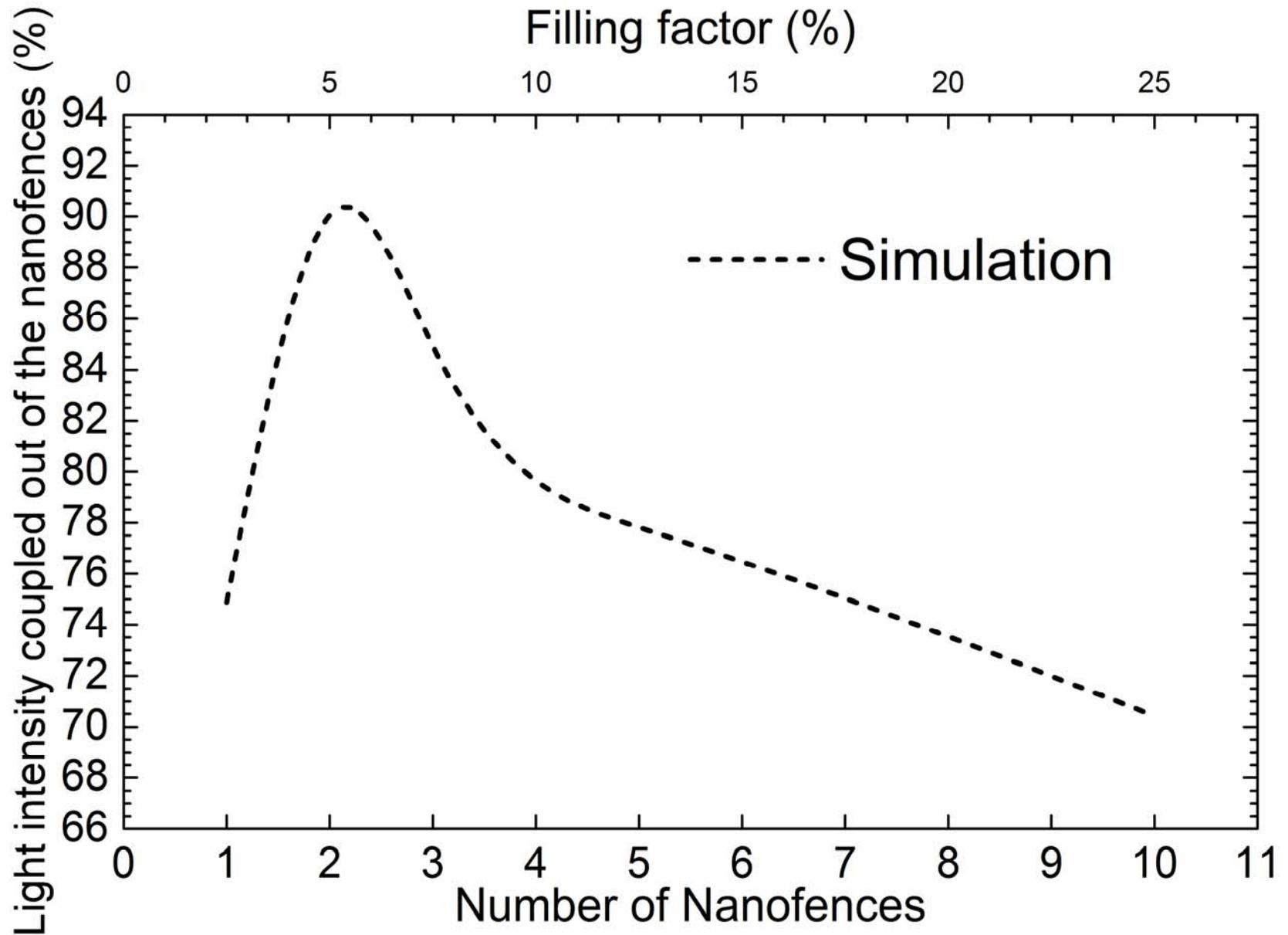
Efficient direct coupling of light from standard waveguides to photonic nanofences

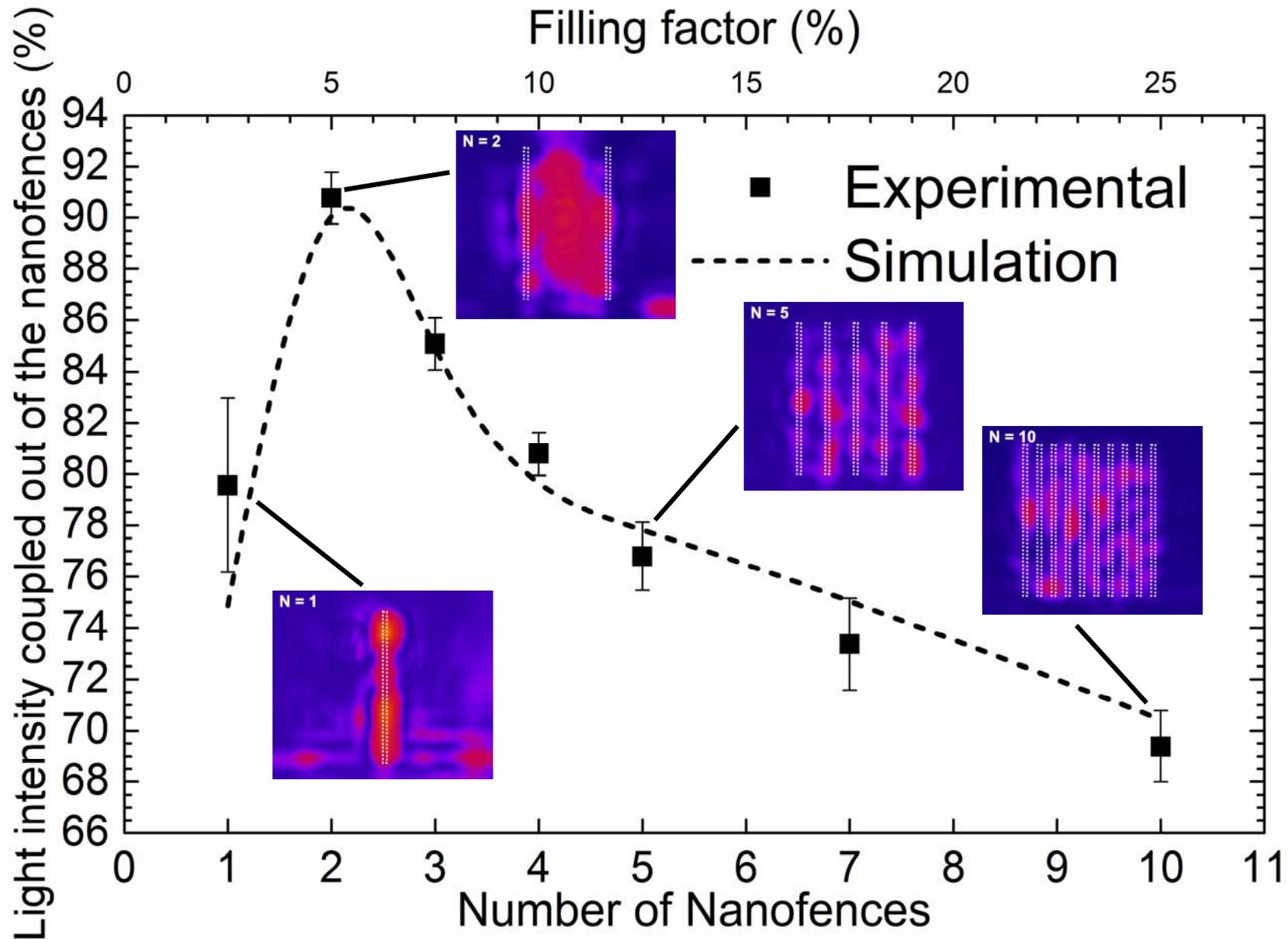
Direct coupling of light



Efficient direct coupling of light from standard waveguides to photonic nanofences
Propagation losses in the range of semiconductor photonic nanowires

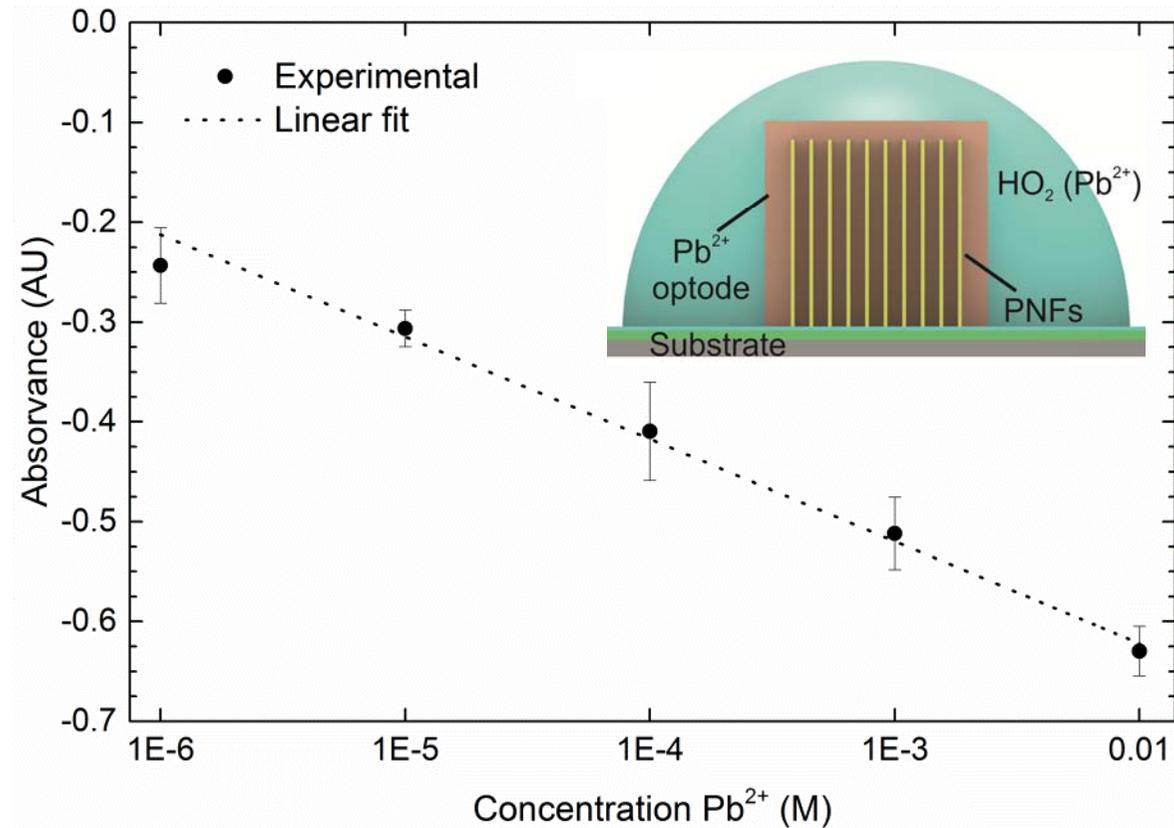
V.J. Cadarso et al. TBP, ACS Nano 2015





Preliminary results in water monitoring

- Integration of an ion-sensitive optode
- Absorption length: 500 μm
- Array with 7 nanofences
- Detection of Pb(II) in water samples
- High sensitivity: > 0.1 AU/decade
- Low limit of detection: 7.3 nM



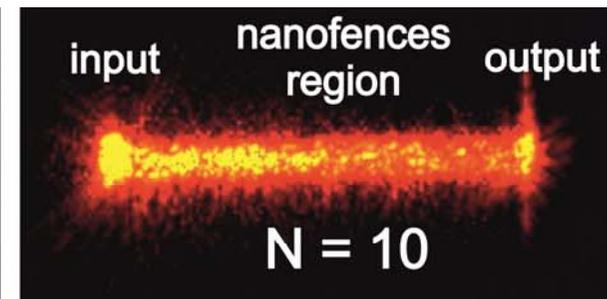
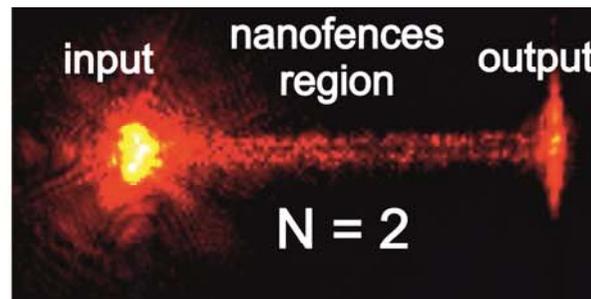
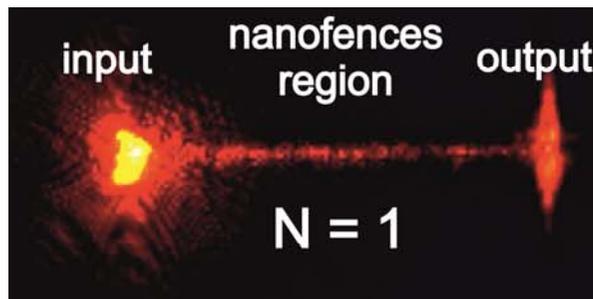
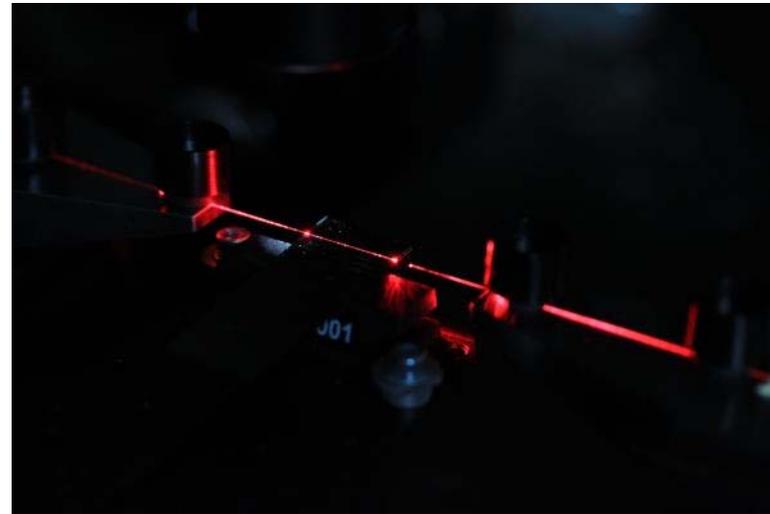
V.J. Cadarso et al. TBP, ACS Nano 2015

Summary:

- Hybrid fabrication of micro- and nanostructures
- High aspect ratio nanostructures achieved >40:1
- Photonic nanofences based waveguides demonstrated
- High interaction with the environment demonstrated
- Sensing capabilities demonstrated

Outlook:

- Combination of photonic nanofences with mature integrated optic components
- Integration with microfluidics towards complete sensors



Acknowledgements

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