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Increased Functionality of Optical Fibers for Life-Science Applications

Aziza Sudirman

Doctoral Thesis Defence, May 21, 2014 in FD5, Albanova KTH

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Motivation and Aim

Question:

- ➢ Why use optical fibers?
- ➢ How can life-science applications benefit from optical fibers?

Answer:

- ☺ Excellent waveguides.
- ☺ Micrometer-size cross section.
- ☺ Thin, flexible and can be made very long.
- ☹ However, cannot offer same complexity as lab-on-a-chip.

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Motivation and Aim

But, optical fibers offer advantages such as...

- ☺ Allow for real-time measurements.
- ☺ Can be inserted into the body.
- ☺ Core-size allows for light delivery to single biological species.

The aim is to work towards optical analysis of biological species at a single-cell level for in-vivo studies.

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Outline

- ➢ Four different areas (proof-of-principle studies):
  1. **Combining** laser light delivery with reflectometry and fluid collection in an optical fiber.
  2. **Developing** all-fiber optofluidic components.
  3. **Reducing** background luminescence in fiber-based fluorescence sensing.
  4. **Detecting** & **collecting** micrometer-size particles using a microstructured fiber.
- ➢ Summary and final remarks.

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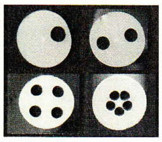
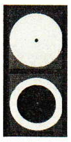
Introduction



Microstructured fiber:
- 125 μm outer-diameter.
- 8 μm core.
- Longitudinal holes.



Capillary:
- 125 μm outer-diameter.
- Various inner-diameter.

Carbon-coated fiber:
- 125 μm outer-diameter.
- Standard telecom fiber.
- ~ 20 nm thick layer of carbon.

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Four different areas

Combining

Laser ablation, reflectometry and microfluidics

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What do we want to solve?

1) Method for positioning of fiber-tip.
Solution: Reflectometry.

2) Removal of sample that is "in the way".
Solution: Delivery of high-power laser light for ablation using optical fiber.

3) Perform biopsy - collecting fluid sample.
Solution: Exploit the holes of microstructured fiber.

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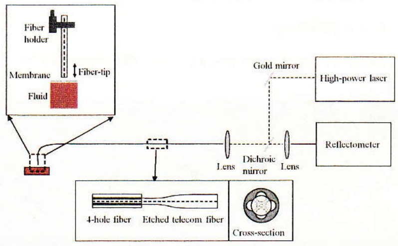
Laser ablation, reflectometry and microfluidics



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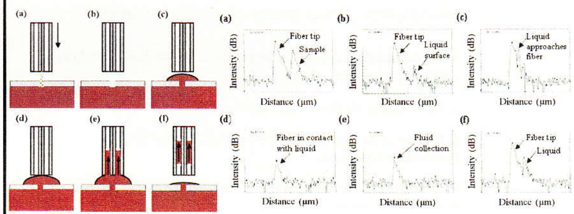
Laser ablation, reflectometry and microfluidics



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Four different areas

Developing
Optofluidic components

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What do we want to solve?

When dealing with coupling light and fluid in a fiber...

1) How to handle fluid in a controlled way without disturbing light guidance.
2) Eliminate issues with liquid evaporation/dripping.
3) Prevent forming of liquid meniscus.

Solution: All-in-fiber components that are user-friendly.

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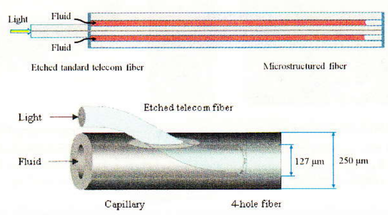
Optofluidic components: "Billys"



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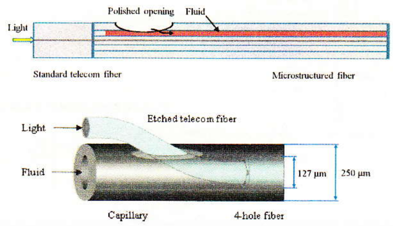
Optofluidic components: "Billys"



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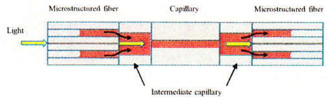
Optofluidic components

Allows for interaction of light and fluid...



Small inner-diameter capillary allows for:

☺ Stronger coupling between light and fluid.

☺ Low-loss light coupling to core of microstructured fiber.

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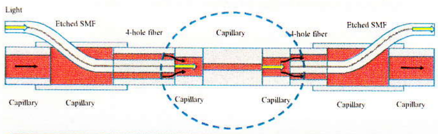
Optofluidic components

All-fiber component:

☺ Fluid-filled or continuous flow of fluid.

☺ Reflected or transmitted signal for measurements.

☺ Entirely sealed, with no risks for fluid contamination.



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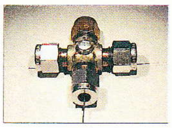
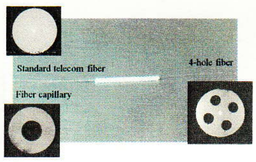
Optofluidic components

Replace... with...

Traditional microfluidic component



Fiber-based component



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Four different areas

Reducing
Fiber luminescence

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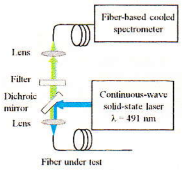
What do we want to solve?

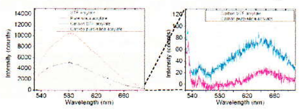
When dealing with low-level signal sensing.

1) Luminescence from fiber is a source for noise.
Solution: Fiber with carbon-coating.

Reducing fiber luminescence



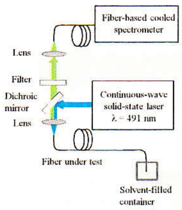
Characterizing luminescence from four different fiber types

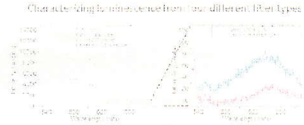


Compared four fiber types:

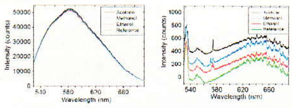
- Standard telecom fiber with Ge-doped core
- Pure silica fiber
- Carbon-coated standard telecom fiber with Ge-doped core
- Carbon-coated pure silica fiber

Reducing fiber luminescence





Detecting Raman signal from organic solvents



Standard telecom fiber

Carbon-coated fiber

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Four different areas

Detecting & collecting

Fluorescent particles

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What do we want to solve?

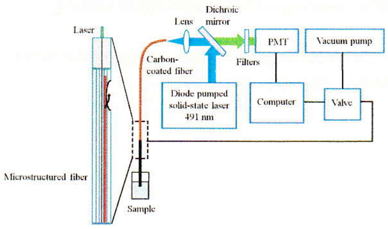
1) Detect single-particles of interest.

Solution: Laser-induced fluorescence sensing.

2) Isolate detected particles.

Solution: Exploit holes of microstructured fiber.

Detecting and collecting fluorescent particles



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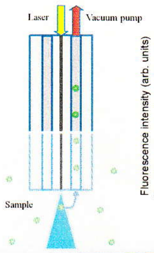
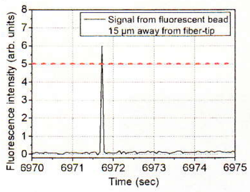
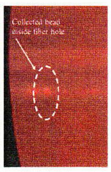
Detecting and collecting fluorescent particles







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Summary

- Laser light delivery for ablation combined with positioning of fiber-tip based on reflectometry.
- Collection of fluid and particles into the hole(s) of microstructured fiber.
- All-fiber components for combining light and fluid.
- Carbon-coated fiber for reducing luminescence from polymer coating of fiber.
- Reflected signal for detecting of Raman and fluorescence.

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Final remarks

Thank you for your attention!

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