A Fiber-Based Optical Transducer for Wash-Free Analysis of Biomarkers

Team members: Yalun Tang, Quan Wang, Jiameng Li, and Qinming Zhang

Advisor: Prof Meng Lu

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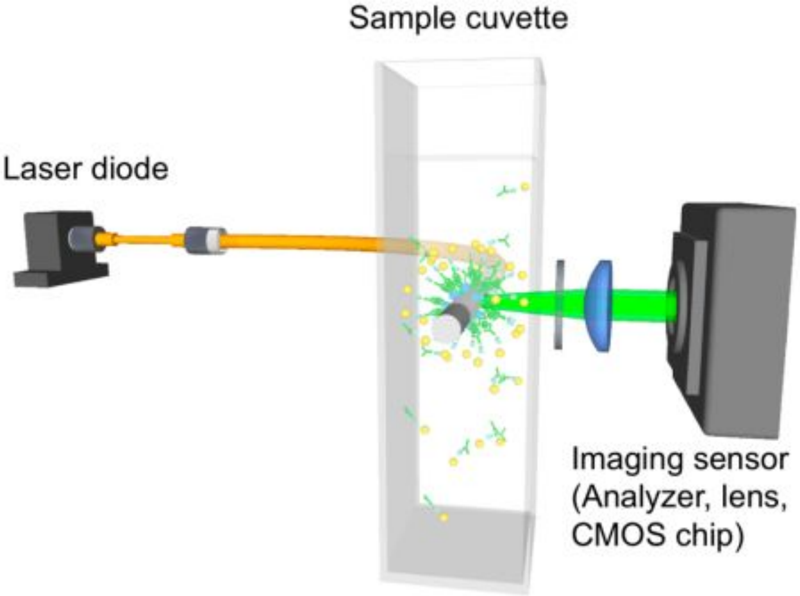
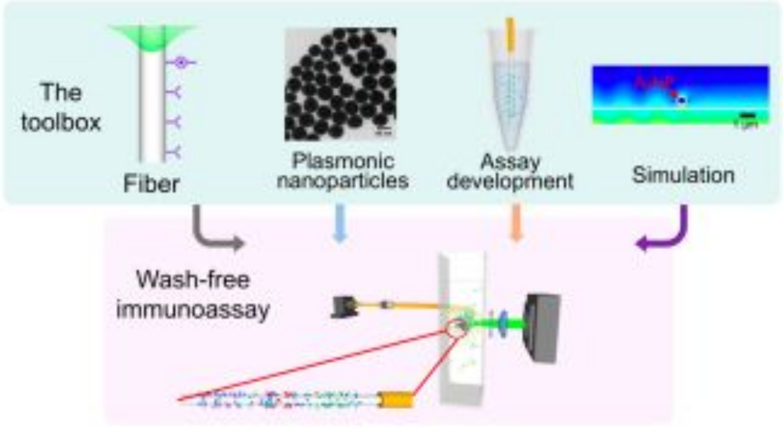
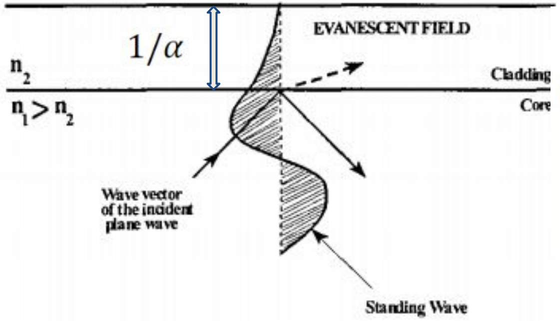
Introduction

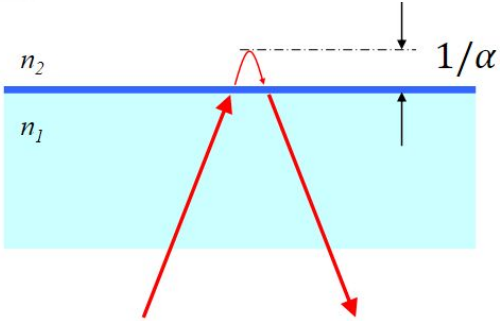
In this project, we aim to collect preliminary results by designing and fabricating a fiber-based optical wash-free transducer that can be used to detect biomarkers.





Working Principle





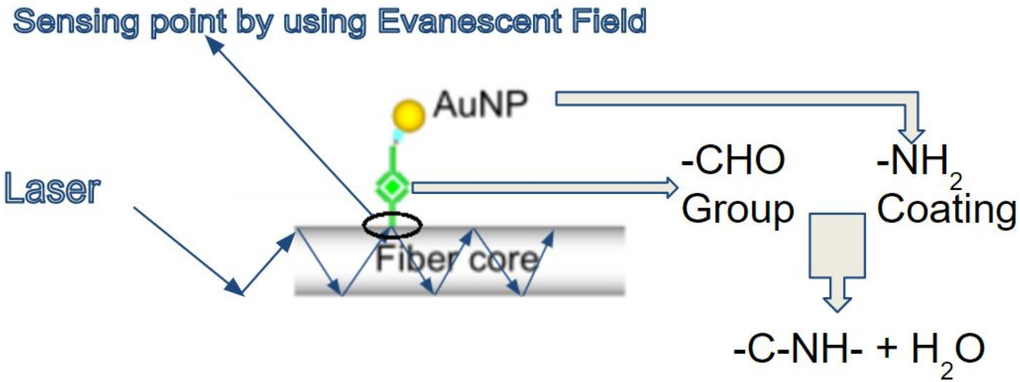
$n_{core} = 1.462 \quad n_{cladd} = 1.453$

$\theta_c = \sin^{-1}\left(\frac{1.453}{1.462}\right) = 83.64°$ Assume $\theta = 85°$

$$d_p = \frac{1}{\alpha} = \frac{\lambda}{2\pi n_{core}\left[\sin^2\theta - \left(n_{cladd}/n_{core}\right)^2\right]^{1/2}}$$

$$= \frac{528 \times 10^{-9}}{2\pi \cdot 1.462\left[\sin 85° - \left(\frac{1.453}{1.462}\right)^2\right]^{1/2}} = 840.39\,nm$$

Integration of Fiber Optics and Nanoplasmonics:

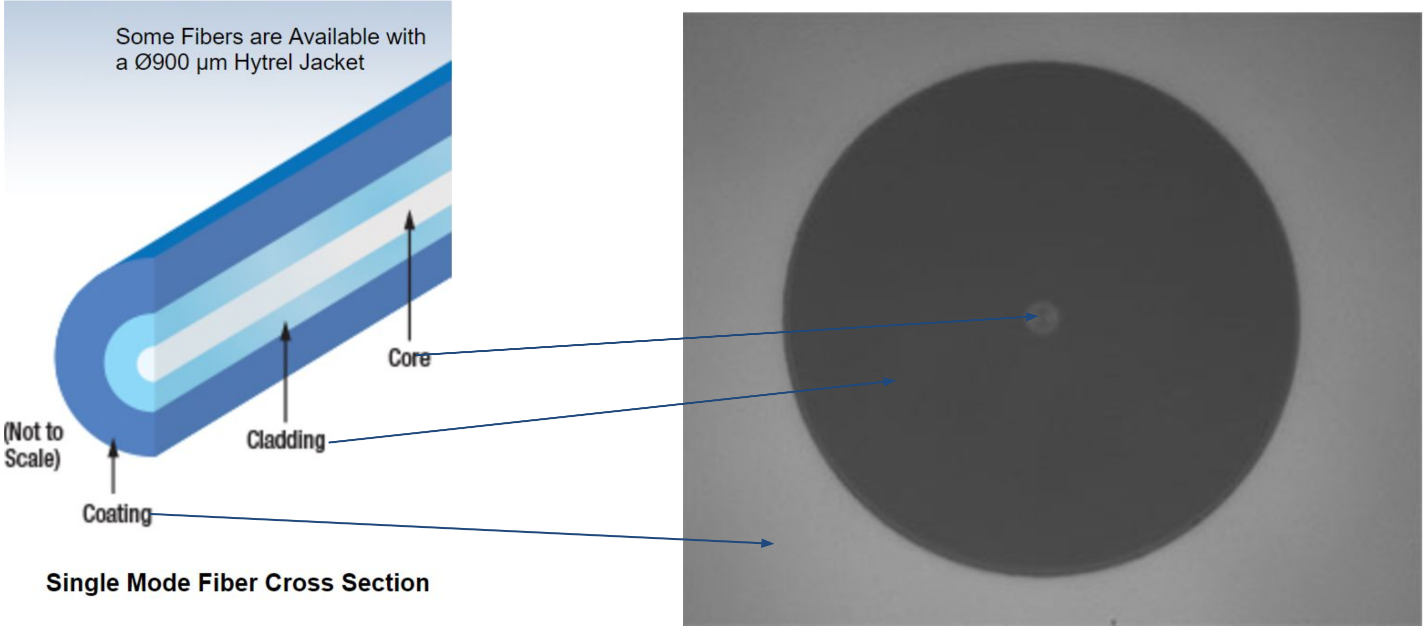


Optical Fiber

Single mode optical fiber produced by Thorlabs is used in this project:

- Diameter of coating: ~ 245 micrometers
- Diameter of cladding: ~ 125 micrometers
- Diameter of core: ~ 10 micrometers

Cross-sectional View



Single Mode Fiber Cross Section

Images are from Thorlabs' website

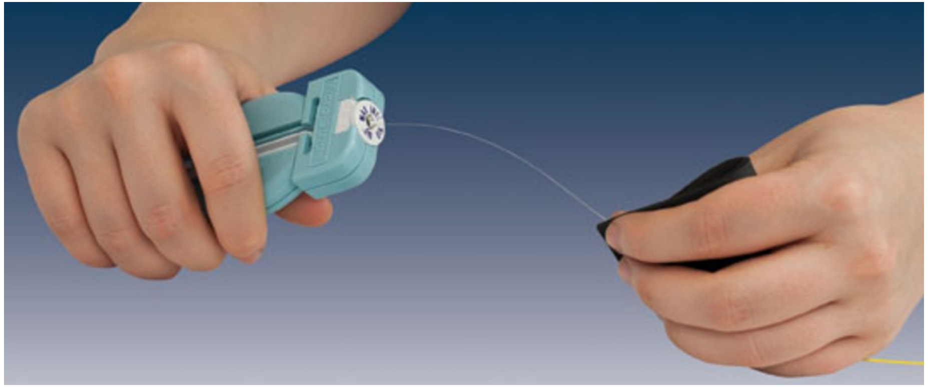
Optical Fiber

Description:

- Coating: *Dual Acrylate*
- Cladding: *Fluorine-doped silica*
- Core: Pure, *undoped silica*

Challenge:

- Difficult to remove the cladding by using physical methods.
- But chemical etching is a good approach.



Fiber Stripping Tool for Removing Coating

HF Wet Etching

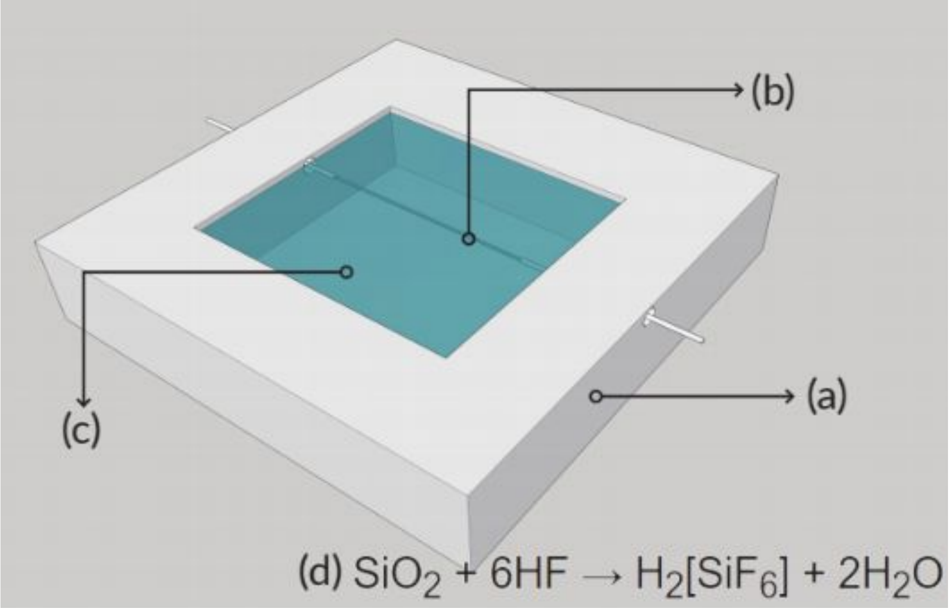
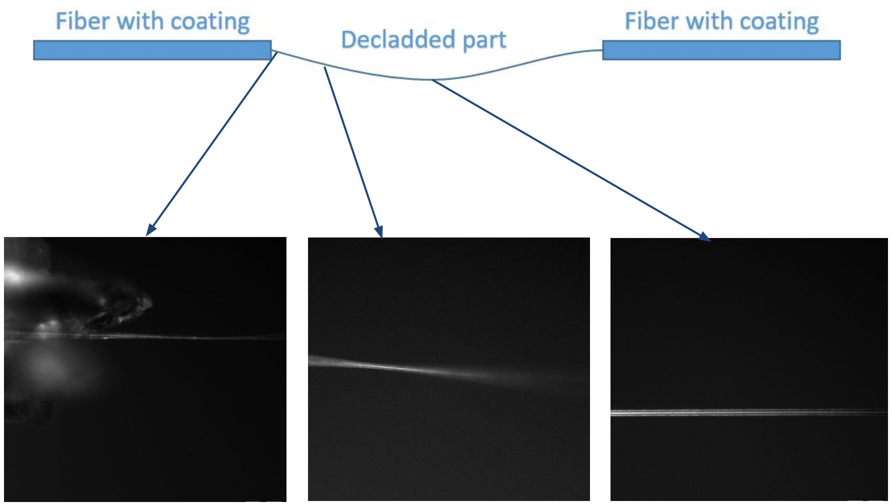


Illustration of the holder used for fiber etching process and microscope observation. (a) The etching platform made by high density plastics; (b) The fiber component without coating; (c) 49% hydrofluoric acid (HF) + 1% acetic acid; (d) Chemical reaction formula for the etching process.

After 50 mins



1 um   6 um   10 um

EM Simulation (Lumerical)

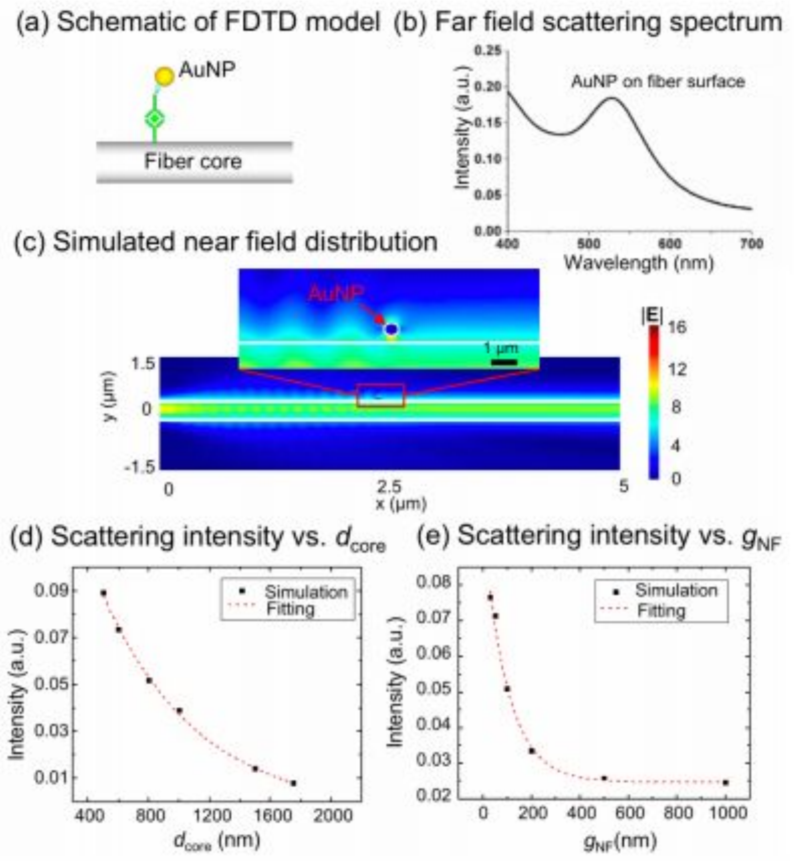
Pilot study on two-dimensional (2D) waveguide with AuNPs:

Finite-difference time-domain (FDTD, Lumerical Solutions) simulation

calculating light propagation in optical fiber → Identifying LSPR modes of AuNPs → predicting the LSPR-enhanced scattering of a waveguide mode

EM Simulation (Lumerical)

Results:



SolidWorks

Design the research components

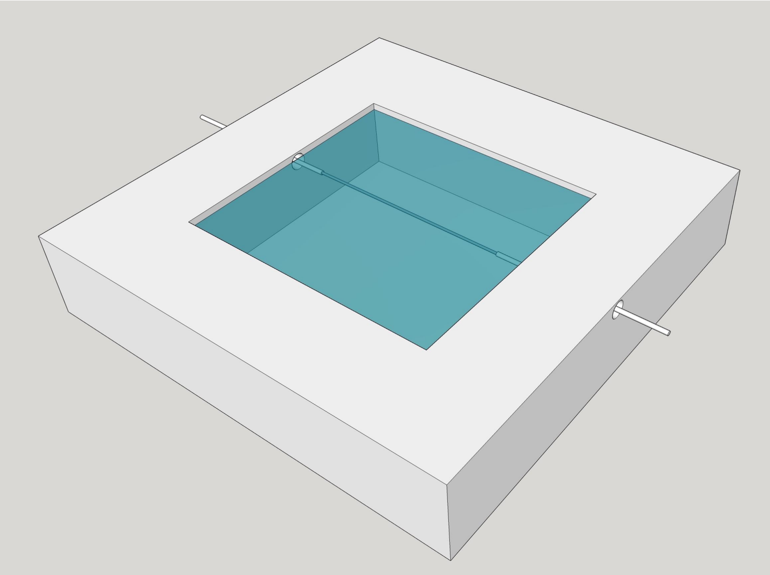
- Fiber holder
  Same size as the microscope slide
  Made of a magnetic stainless steel

We use the Solidworks to design fiber holder for observing purposes under the microscope.

We are able to design the shape of the fiber in precise measurement by using Solidworks,

Then we ask ETG to make the real holder.

The fiber holder will be used as a tool to stabilize the optical fiber under the microscope.



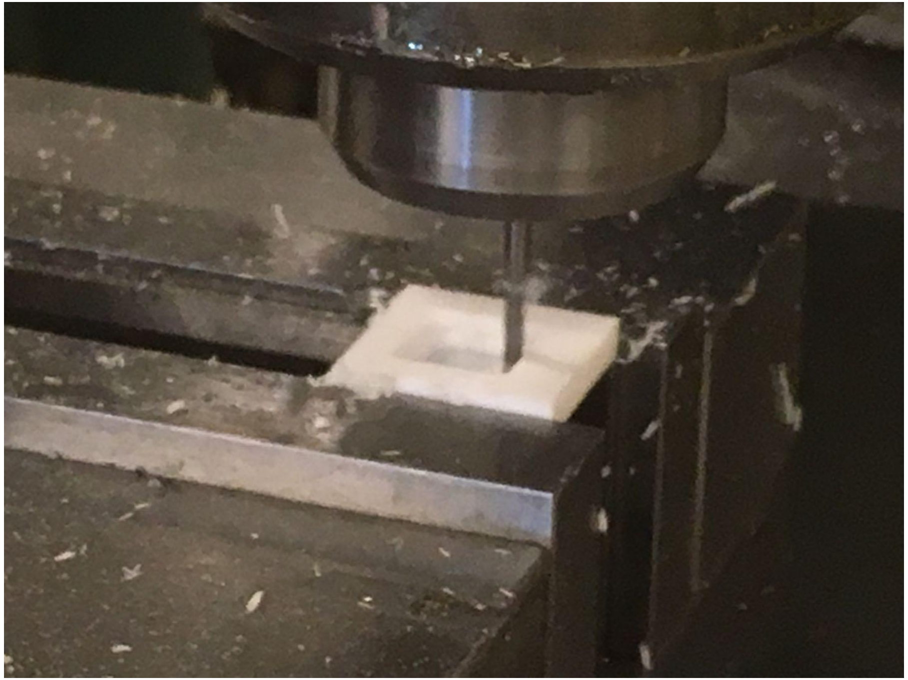
SolidWorks

Design of researching components

- **Etching platform**

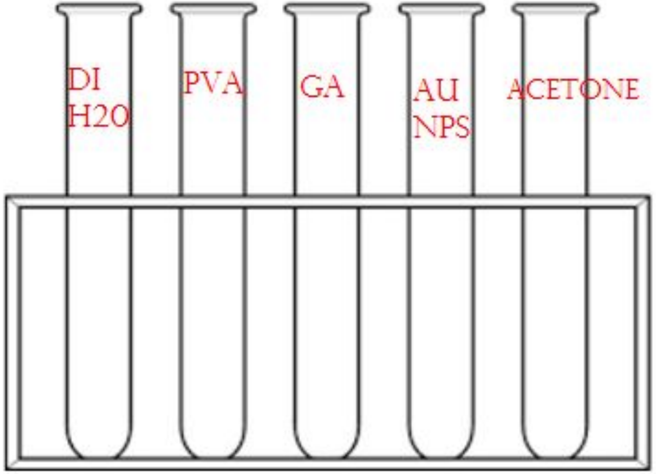
High-density plastic material

It will not be corroded by the 49% HF solution



Surface Chemistry

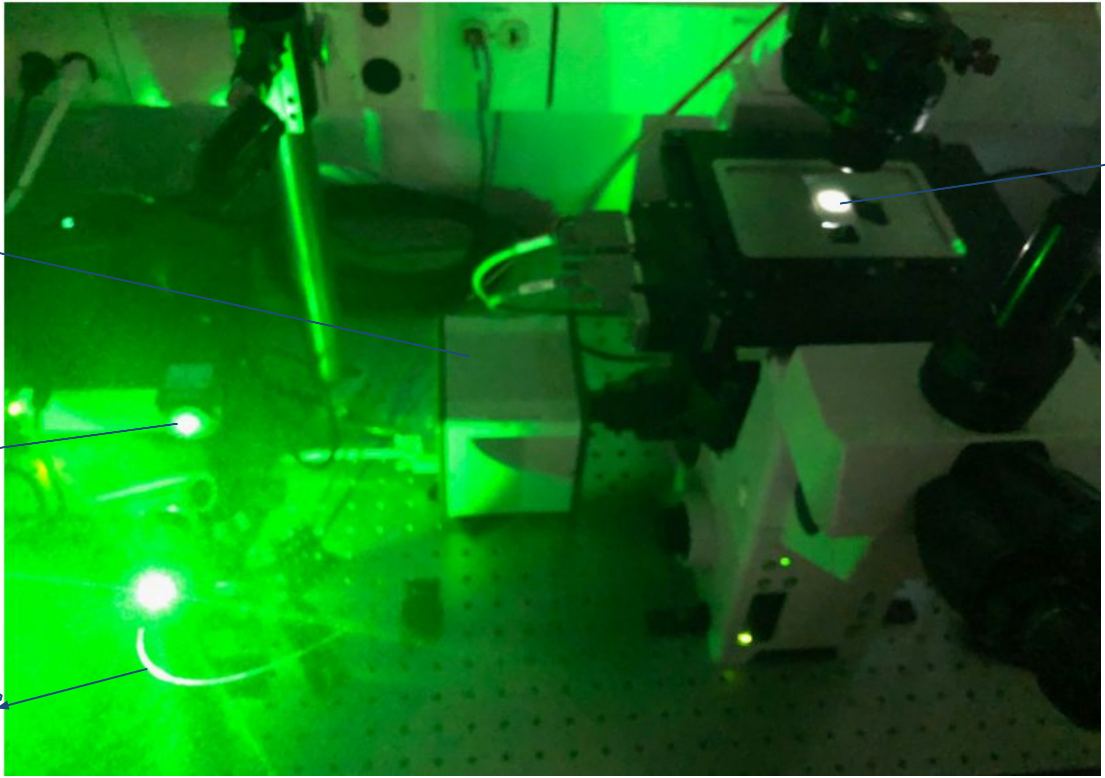
- Establish protocol for the functionalization of the fiber surface
- Prepare the optical fiber for the attachment of gold nanoparticles
- Coating of the gold nanoparticles to inspect the fiber for level of light leakage out of fiber core



Functional Requirement

- Complete Removal of cladding layer and Coating layer
- Gold nanoparticles attached evenly onto the optical fiber
- Stable etching platform
- High efficiency of green laser coupling

Operating environment



Digital camera

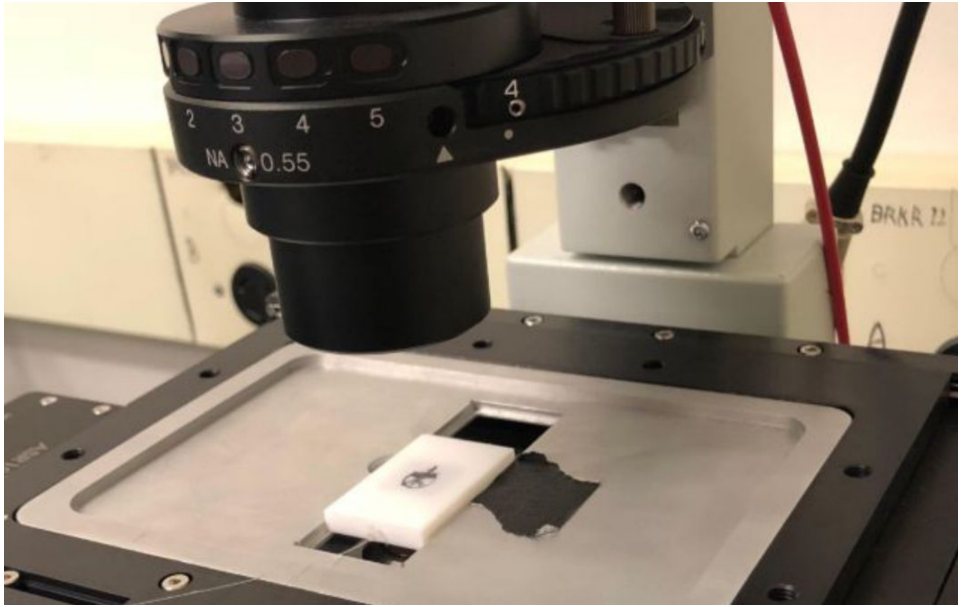
Optical transducer

528 nm Laser

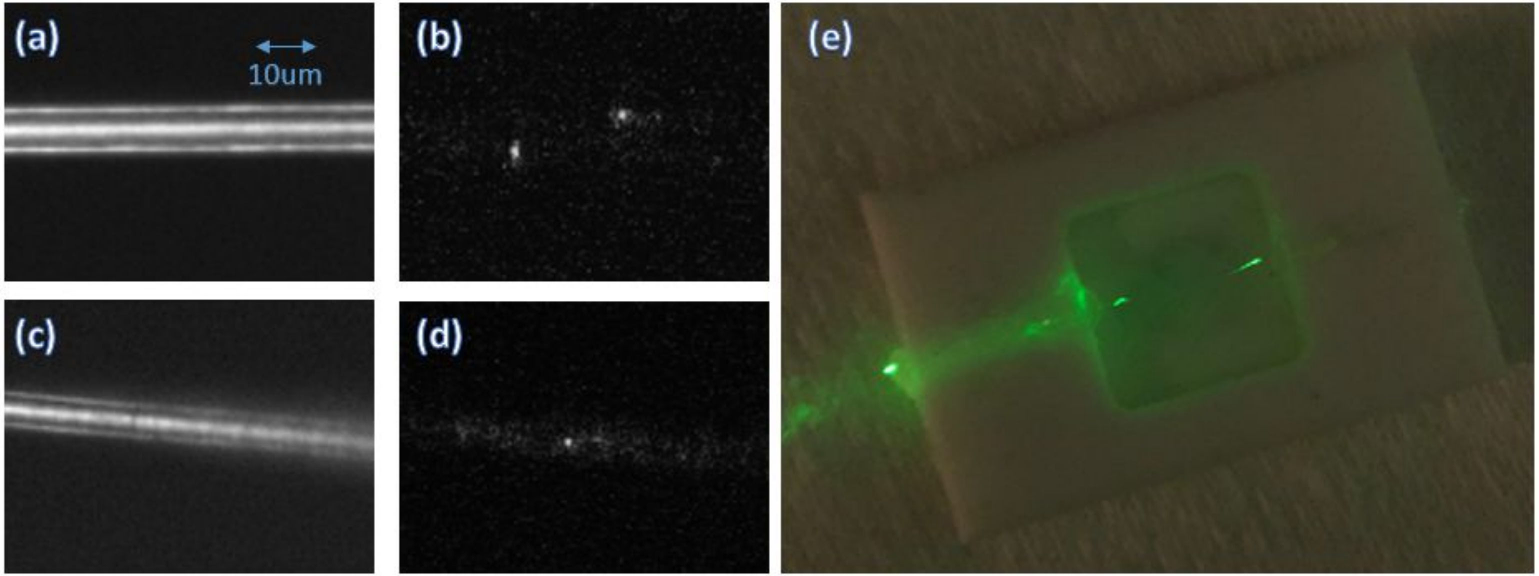
Single mode optical fiber

Testing

- Coupling with the laser
- Adjust the focus under 20X objective lenses
- Turn off the light source from microscope
- Observe scattering of light from fiber core
- Measure intensity of light



Experimental Results



Experimental results of the near-field coupling between the optical fiber core and gold nanoparticles by using the AuNP solution with the concentration of less than 0.25 ug/ml. For (a) to (d), the objective used is 20x. (b) and (d) have the gain of 200 and exposure of 5 ms. (a) The image of the fiber core with about 10 um diameter from the center part. (b) The image of (a) without the light source. The intensity of the light scattering by AuNP is 3010. (c) The image of the fiber core with about 6 um diameter away from the center. (d) The image of (c) without the light source. The intensity of the light scattering by AuNP is 5526. (e) The coupling between a laser with wavelength of 532 nm and our optical transducer.

Strengths and Constraints

Strengths:

- Robust and strong signal
- Inexpensive and miniaturized sensor system
- Analysis is easily multiplexed

Constraints:

- Etching rate is difficult to control
- Surface tension affects the shape of fiber

QUESTION?