FACULTY OF ENGINEERING AND ARCHITECTURE

PHOTONICS RESEARCH GROUP

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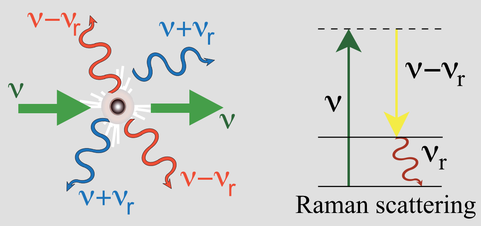
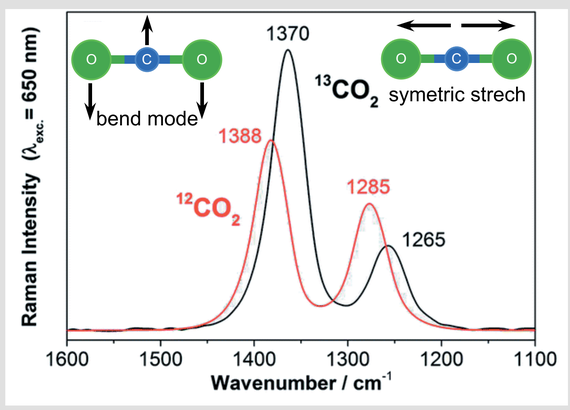
ON-CHIP RAMAN SPECTROSCOPY

Raman spectroscopy at a glance

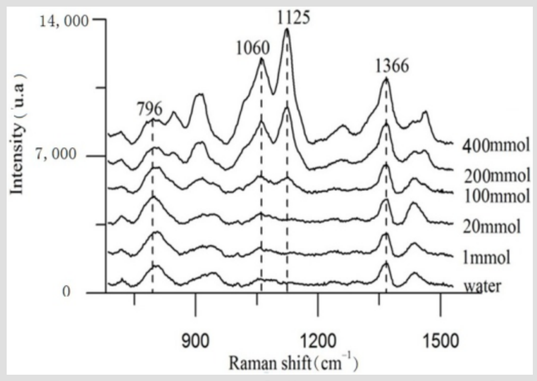
Molecular vibration excited off-resonance
≠ absorption spectroscopy)
= **weak** scattering process
= fingerprint of molecular bonds
= laser excitation at any frequency ν



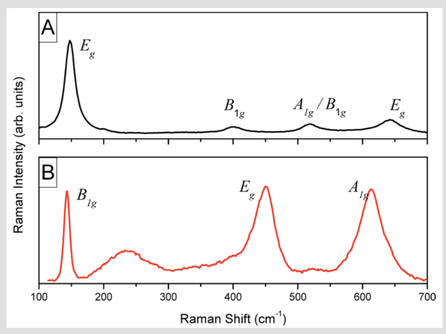


Identification of chemical composition
crystallinity
physical phase
molecular binding

Applications in life sciences
chemistry
material science
pharmaceutics
art preservation
geology



Raman spectra of dilute solutions of glucose [2].

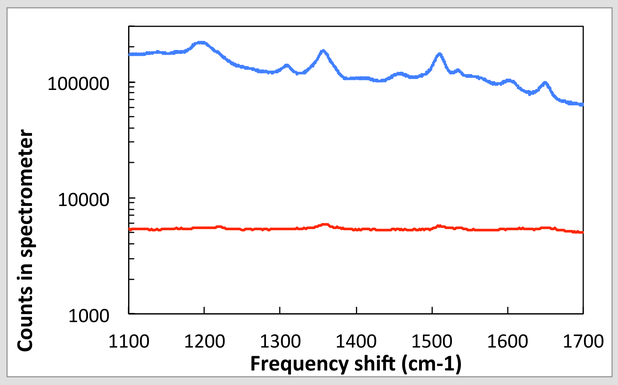


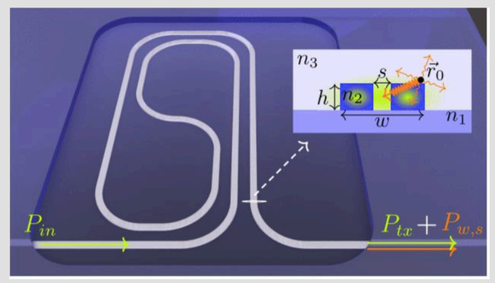
Raman spectra of TiO_2 in anatase (A) and rutile (B) phase [1]

Waveguide sensor

Slot waveguides
- large evanescent field 50-100 nm away from the guiding core
- can be cm-long

→ ideal for probing gas, liquid, solid analyte



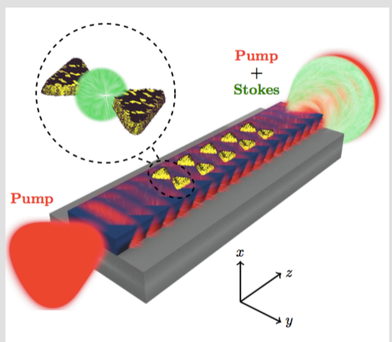


Dramatic improvement of the generated Raman signal.

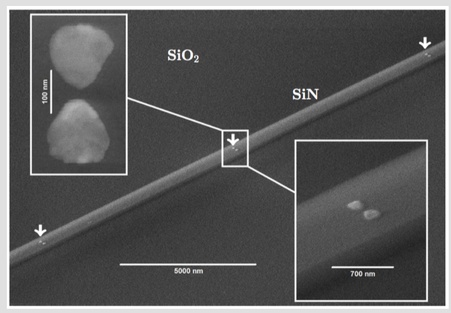
←monolayer of rhodamine using a slot waveguide (blue) and a confocal Raman microscope (red).

On-chip surface-enhanced Raman spectroscopy for increased sensitivity

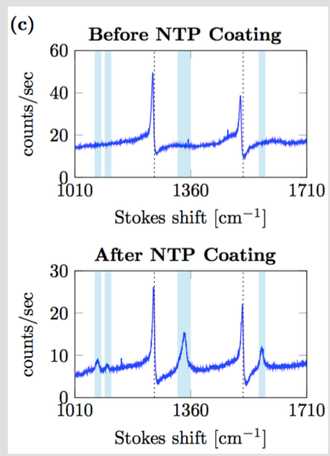
Nanoplasmonic gold antennas
→ huge electromagnetic field close to gold surface.
→ sensitive detection of ultra-small volumes or monolayers



Schematic of plasmonic antenna on a photonic waveguide



Bow-tie antenna and waveguide etched using e-beam lithography



Measurement of Raman spectra from a monolayer of NTP

Collecting Raman scattering

Pump Laser

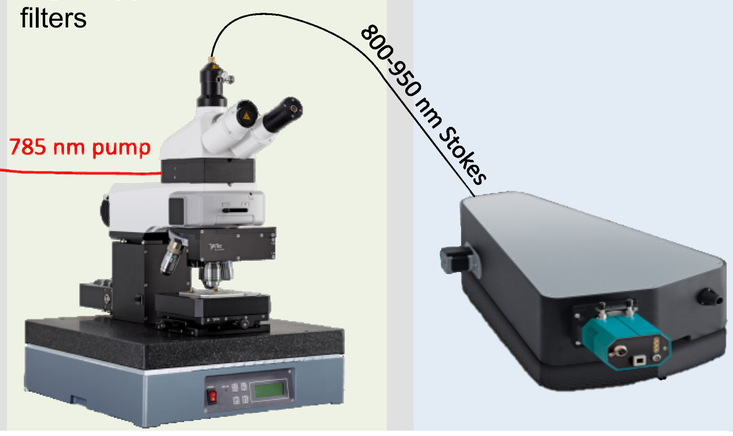
Signal Collection

Spectrometer

PAST: a € 100.000, 1 m^3 microscope

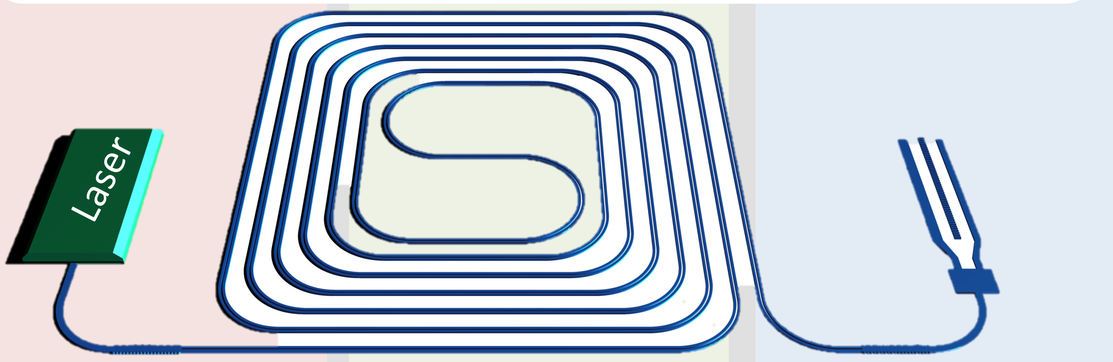
Stable, narrow band
Visible to near-IR wavelength

Microscope
Confocal to remove Raman background
High suppression chromatic filters



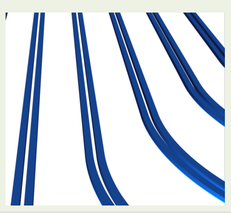
Large for good spectra resolution
> € 30.000 cooled CCD camera for low noise

FUTURE: a € 5, 1mm^2 chip



Integrated laser with on-chip filters

Slot Waveguide
Long interaction length to increase signal



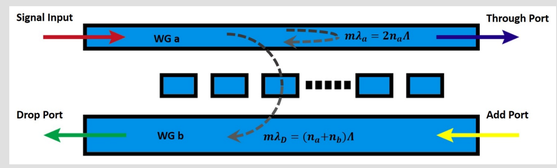
Integrated spectrometer
Increased signal
➔ cheaper detectors

On-chip spectral functions

Incident laser radition must be separated from scattered Raman spectrum

Solution: Bragg grating →

Raman spectra resolve via
- arrayed waveguide grating
- stationary Fourier transform spectrometer
- arrays of ring resonators

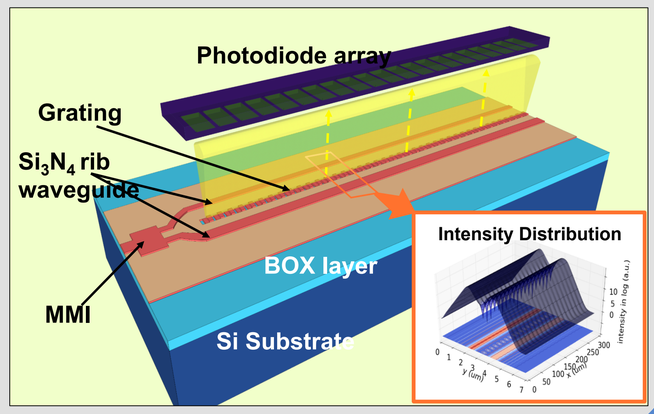


Output signal from Raman sensor can be fed into this filter:

- Raman signal → Through Port → on-chip FTS
- Raman pump → Drop Port → get out of Raman system

→

In this example, the beating between propagation in 2 waveguides of different phase velocities creates a interferogram that can be diffracted up onto a CMOS sensor



More about this work.

A. Dhakal et al., Evanescent excitation and collection of spontaneous Raman spectra using silicon nitride nanophotonic waveguides, Optics Letters, 39(13), p.4025-4028 (2014).
F. Peyskens et al., Surface Enhanced Raman Spectroscopy Using a Single Mode Nanophotonic-Plasmonic Platform, ACS Photonics, 3(1), p.102-108 (2016).
A. Dhakalet al., Nanophotonic waveguide enhanced Raman spectroscopy of biological submonolayers, ACS Photonics, 3(12), p.2141-2149 (2016).
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[1] Pier Carlo Ricci, Carlo Maria Carbonaro, Luigi Stagi, Marcello Salis, Alberto Casu, Stefano Enzo, and Francesco Delogu, Anatase-to-Rutile Phase Transition in TiO2 Nanoparticles Irradiated by Visible Light, The Journal of Physical Chemistry C 117(15):7850–7857 (2013)
[2] Shao J, Lin M, Li Y, Li X, Liu J, Liang J, Yao H , In vivo blood glucose quantification using Raman spectroscopy, PLoS ONE 7.10 (2012): e48127.
[3] Yiping Zhao, Sarat Shanmukh, Yongjun Liu, Les Jones, Richard A. Dluhy, and Ralph A. Tripp,] Silver nanorod arrays can distinguish virus strains, *Phys. Rev. Lett* 78, 1667-1670 (1997).