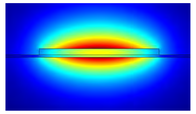
Waveguide-Enhanced Raman Spectroscopy for Field Detection of Threat Materials

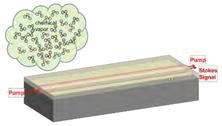
Erik Emmons[1], Phillip Wilcox[1], Kevin Hung[1], Erik Roese[1], Ashish Tripathi[1], Jason Guicheteau[1], Ben Miller[2], Ethan Luta[2], Matthew Yates[2], Nathan Tyndall[3], and Todd Stievater[3]
[1]U.S. Army Combat Capabilities Development Command Chemical Biological Center, Aberdeen Proving Ground, MD, [2]University of Rochester Medical Center, Rochester, NY, [3]Naval Research Laboratory, Washington, DC

Introduction

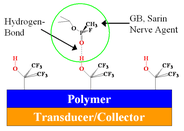
Detection of chemical threats such as chemical warfare agents, explosives, and narcotics is important for protection of soldiers and civilians. With waveguide-enhanced Raman spectroscopy (WERS), waveguides in photonic-integrated circuits are used to tightly confine the excitation light over a long path length, leading to large signal levels from molecules present in the evanescent field just above the waveguide. Sorbent polymers are used to concentrate vapors in the evanescent field to enhance detection.



TM 00 mode



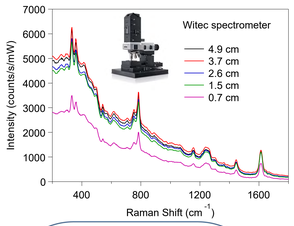
SiN waveguides

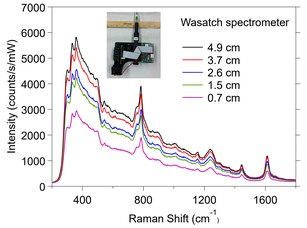


Polymer sorbents

Compact Raman Spectrometers

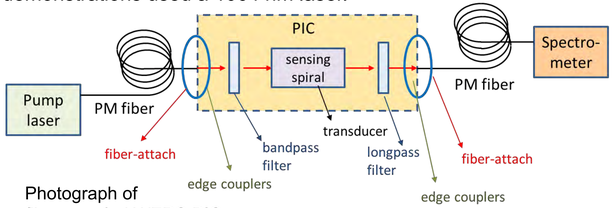
Compact Raman spectrometers enable field detection of chemical vapors. They are compared to a (benchtop) Witec Raman chemical imaging microscope system at 785 nm



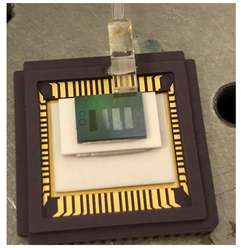


Fiber-coupled PICs

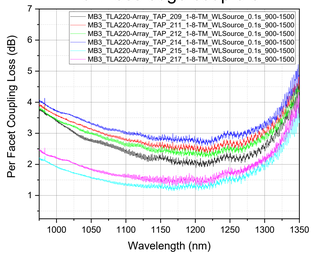
Compact fieldable WERS systems require permanent fiber coupling to PIC facets, low-loss edge couplers for the laser and the Stokes-shifted signal, and filters to separate the laser from the signal. Initial demonstrations used a 1064 nm laser.

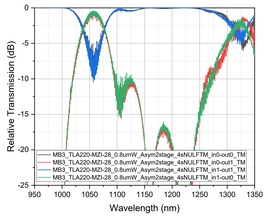


Photograph of fiber-coupled WERS PIC

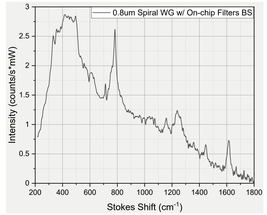


Low-loss edge couplers





Lattice filters for on-chip bandpass and notch filtering



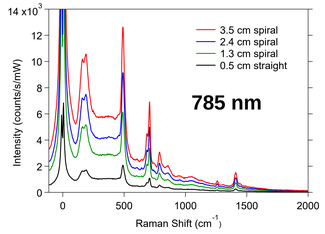
Measured high-quality backscattered WERS spectra

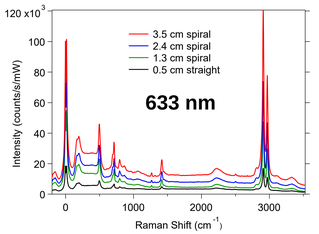
WERS with Visible Excitation

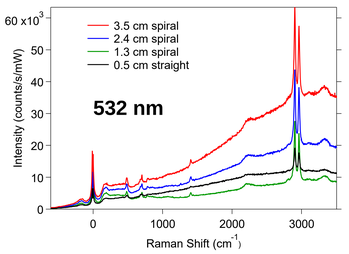
Benchmark measurements were performed with a Witec Raman chemical imaging microscopy system with 532 nm, 633 nm, and 785 nm excitation

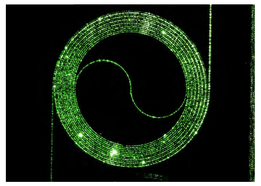
- Raman scattering cross-section (signal) increases with decreasing wavelength
- Waveguide losses increase with decreasing wavelength
- Waveguide fluorescence increases with decreasing wavelength
- 633 nm and 785nm excitation gave the best performance

WERS spectra obtained with different excitation lasers







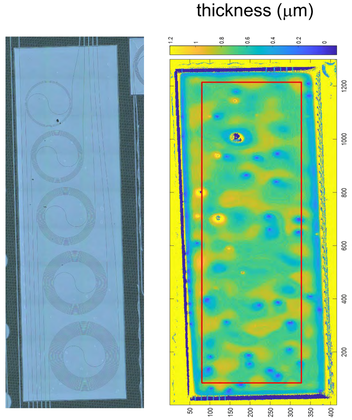


WERS spiral excited with 532 nm laser light

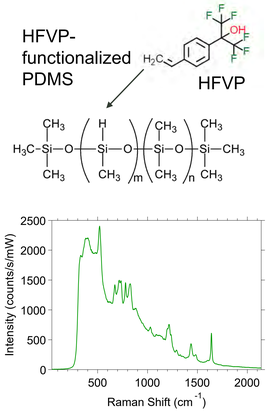
Sorbent Deposition

Piezoelectric droplet dispensers are being used to deposit sub-micron thin films of polymers on PIC sensor chips. This allows for multiplexing of sensors with different polymers as well as deposition on fiber-attached chips.

Microscope images reveal nearly continuous nanoplotter-deposited films with minimal gaps, which are mostly off the waveguides. White light reflectivity was measured using a Witec microscope to determine thickness as a function of position for the deposited films.



average thickness = 709 nm
standard deviation of thickness = 121 nm



High-quality WERS spectra are obtained for nanoplotter deposited polymer sorbents.

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