In commercial and research arenas, SPR is a popular transduction mechanism for both benchtop and portable sensing systems that is both highly sensitive and readily functionalized to sense a wide variety of chemical and biological agents.
A collaboration between Prof. Karl Booksh at Arizona State University and Prof. Denise Wilson at the University of Washington seeks to develop an accurate, but Very Small SPR-based sensing system.
Reduction in the “footprint” of any single component of the SPR system, in and of itself, compromises performance for portability.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Level of Integration</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>None</td>
<td>High</td>
</tr>
<tr>
<td>Portable</td>
<td>Partial</td>
<td>Moderate</td>
</tr>
<tr>
<td>Portable</td>
<td>Full</td>
<td>Low</td>
</tr>
</tbody>
</table>
Comparable performance can be targeted by considering the redesign of all components at once, as a system whose quality exceeds the sum of performance of individual components.

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</table>
Reduction in peripheral components without loss of performance in SPR-based systems can be done by:

(a) Choosing a system configuration amenable to miniaturization.

(b) Converting the optical path from discrete components to integrated fiber optic components;

(c) Compressing the signal processing to a single integrated circuit (chip).
Surface Plasmon Resonance
System Configuration: How it Works

When the wave vector closely matches that of the surface plasmon at the metal-sample interface, reflected light is significantly attenuated.

\[ k_{spw} = k_0 \sqrt{\varepsilon_s \varepsilon_m \varepsilon_s + \varepsilon_m} \]

\[ k_x = k_0 n_{sub} \sin(\theta_{inc}) \]

\[ k_o = 2\pi/\lambda \]
Surface Plasmon Resonance
System Configuration: Portable Probe Design

By placing a mirror at the end of the probe, output light is reflected back in the same direction as the input. Thus, the probe can be inserted into a sensing overhead (no sampling required) rather than requiring the sensing solution to be “passed by” the SPR sensor (considerable sampling overhead).
The point at which SPR occurs can be detected at a:
- Particular angle (constant wavelength interrogation)
- Particular wavelength (constant angle interrogation)

**Constant Angle is chosen here because it enables an inexpensive light source (LED), easy and stable optical alignment, and simpler, more compact configuration.**
In the traditional approach, many, many photodetector signals are scanned off of the sensing plane and then transferred to a PC for signal processing.

**Approach #1 (Traditional)**

- High Resolution Photodetection
- Communication/ADC Overhead
- Measurement to Reference Ratio
- High Resolution Regression
- Multivariate Calibration

**Surface Plasmon Resonance**

Signal Processing:

(Cumbersome) Traditional Approach
Surface Plasmon Resonance
Signal Processing:
(Partial) Integrated Approach

In the partially integrated approach, a much smaller number of custom photodetector signals are integrated in a “smart” way and then transferred to a PC for signal processing.

**Approach #2 (Voltage-Mode, Partially Integrated)**

- Low Resolution Photodetection
- Integration Time Programming
- “Flatlining” Reference Ratio
- Multivariate Calibration
- Software
- Low Resolution Regression
In the traditional approach, many, many photodetector signals are scanned off of the sensing plane and then transferred to a PC for signal processing.

**Approach #1 (Traditional)**
In the first fully integrated approach, all signals are processed on the sensing (photodetection) plane using both current-mode and pulse-mode arithmetic operations.

**Approach #3 (Pulse-Mode, Fully Integrated)**

- Low Resolution Photodetection
- “Flatlining” Current Scaling
- Conversion to Pulse Mode
- Low Resolution Regression
- Multivariate Calibration
- Software
Surface Plasmon Resonance
Signal Processing: (Fully) Integrated Approach

In the second fully integrated approach, all signals are processed on the sensing (photodetection) plane using current-mode arithmetic operations which significantly reduces circuit size and complexity.

**Approach #4 (Current-Mode, Fully Integrated)**

- Low Resolution Photodetection
- Dark Current Compensation
- “Flatlining” Current Scaling
- Low Resolution Regression
- Multivariate Calibration
- Software
Surface Plasmon Resonance
Portable Systems: Do they work?

All (CMOS) Integrated approaches are operational, as individual circuits, but how do they perform in the system?

Approach #2

Approach #4

Approach #3
Reduction in peripheral components without loss of performance in SPR-based systems can indeed be done by:

(a) Choosing a system configuration amenable to miniaturization.

(b) Converting the optical path from discrete components to integrated fiber optic components;

(c) Compressing the signal processing to a single integrated circuit (chip).
**Surface Plasmon Resonance**

Output Generated by Portable Approach

Clearly Indicates point of Resonance

---

Raw Data *(background overwhelms resonance)*

Referenced Data *(Resonance is evident)*
Surface Plasmon Resonance
Comparable Performance is Achieved!

<table>
<thead>
<tr>
<th>Approach</th>
<th>Level of Integration</th>
<th>Size (λ X λ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>None</td>
<td>Big</td>
</tr>
<tr>
<td>Voltage Mode</td>
<td>Partial</td>
<td>200 X 1800</td>
</tr>
<tr>
<td>Pulse Mode</td>
<td>Full</td>
<td>200 X 1200</td>
</tr>
<tr>
<td>Current Mode</td>
<td>Full</td>
<td>200 X 1000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Approach</th>
<th>Prediction Error</th>
<th>RI Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>6.07%</td>
<td>5 X 10^{-4}</td>
</tr>
<tr>
<td>Voltage Mode</td>
<td>3.53%</td>
<td>2 X 10^{-4}</td>
</tr>
<tr>
<td>Pulse Mode</td>
<td>2.72%</td>
<td>6.9 X 10^{-4}</td>
</tr>
<tr>
<td>Current Mode</td>
<td>2.54%</td>
<td>6.8 X 10^{-4}</td>
</tr>
</tbody>
</table>
Surface Plasmon Resonance
The Story of Portable Systems
National Science Foundation # ECS0300537

Pixel
Analog Sampling
Digital Control
Phototransistor

2mm

The End