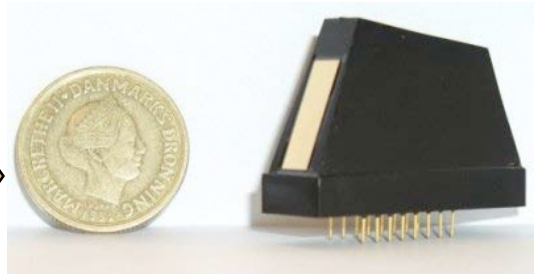
Surface Plasmon Resonance

Portable Biochemical Sensing Systems

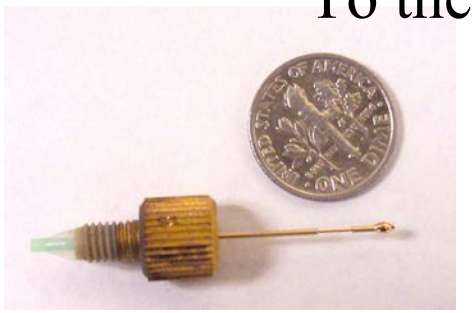
National Science Foundation # ECS0300537

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.

Biacore (the very big)



To the very small?



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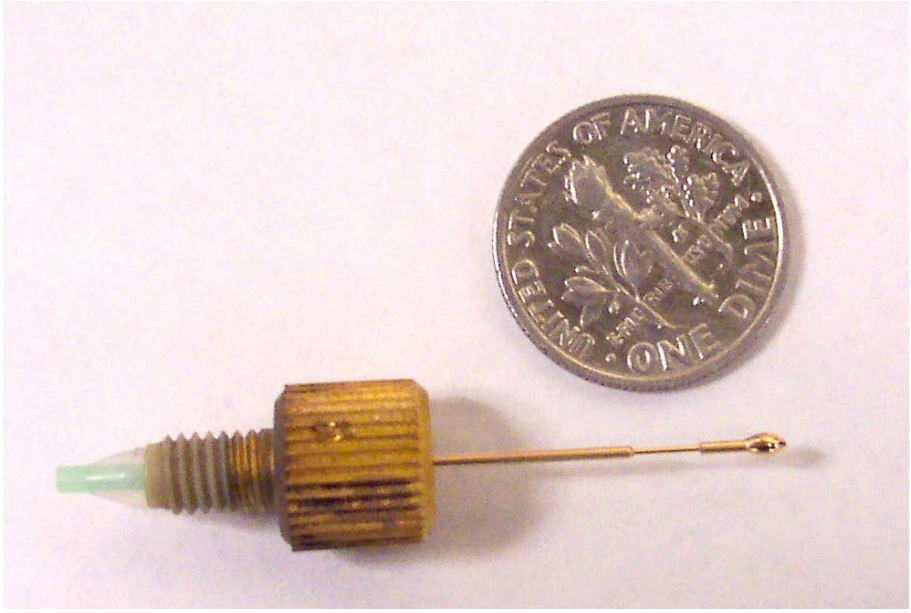
A collaboration between Prof. Karl Booksh at Arizona State University and Prof. Denise Wilson at the University of Washington seeks to develop an accurate, but Very Small SPR-based sensing system.



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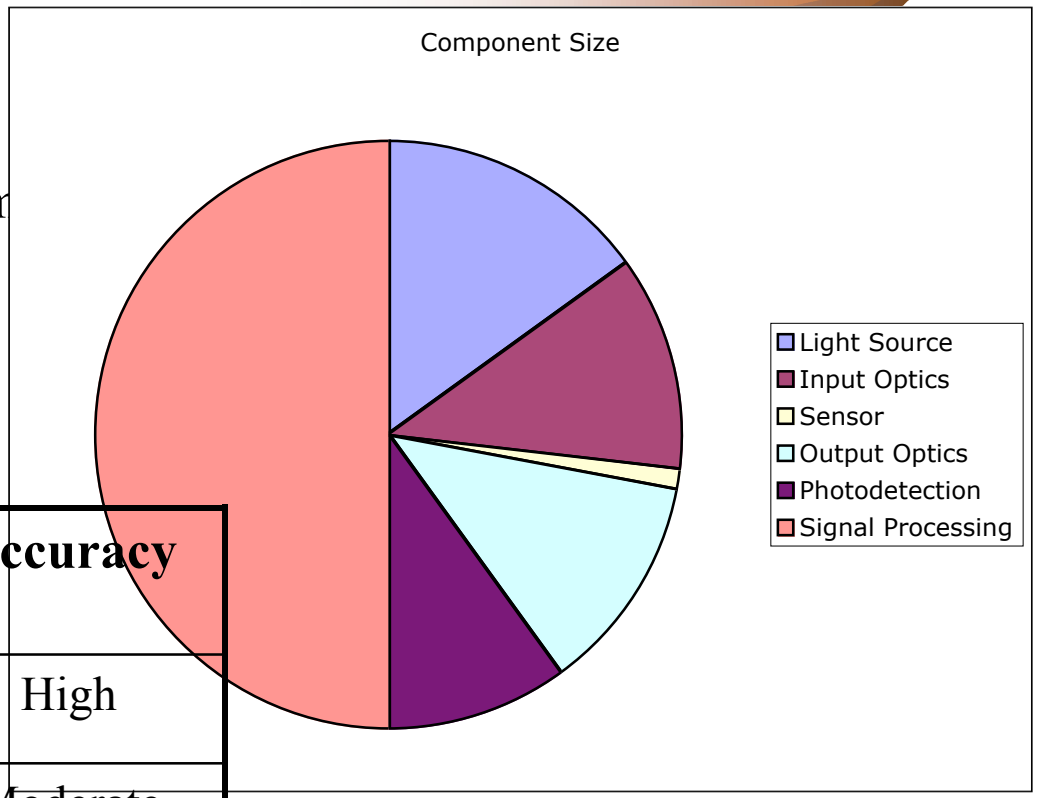
Reduction in the "footprint" of any single component of the SPR system in and of itself, compromises performance for portability.



Approach	Level of Integration	Accuracy
Traditional	None	High
Portable	Partial	Moderate
Portable	Full	Low

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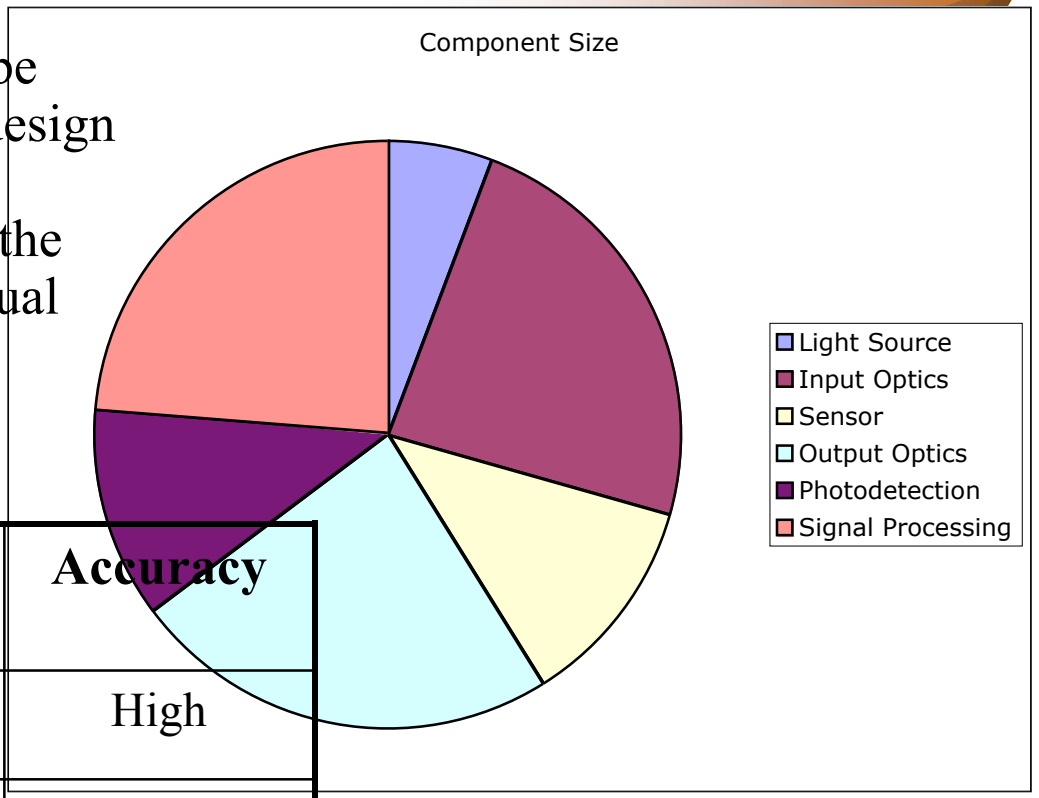
Comparable performance can be targeted by considering the redesign of all components at once, as a system whose quality exceeds the sum of performance of individual components.



Approach	Level of Integration	Accuracy
Traditional	None	High
Portable	Partial	High
Portable	Full	High

Surface Plasmon Resonance

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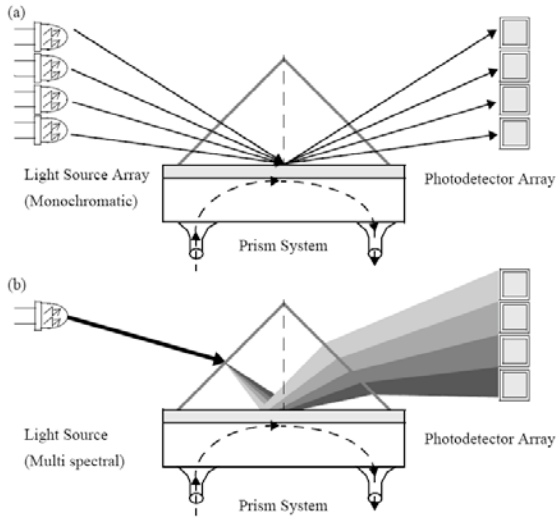
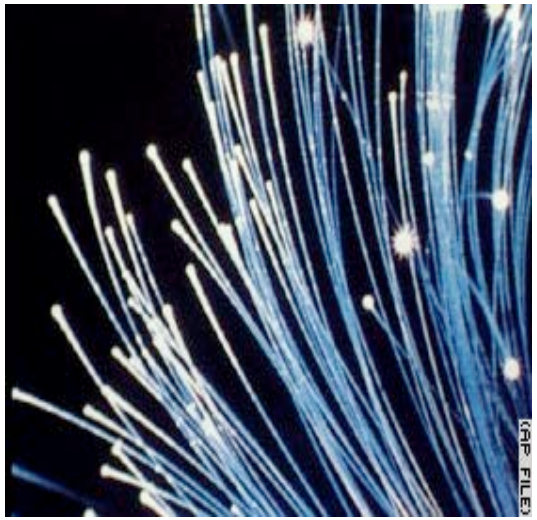
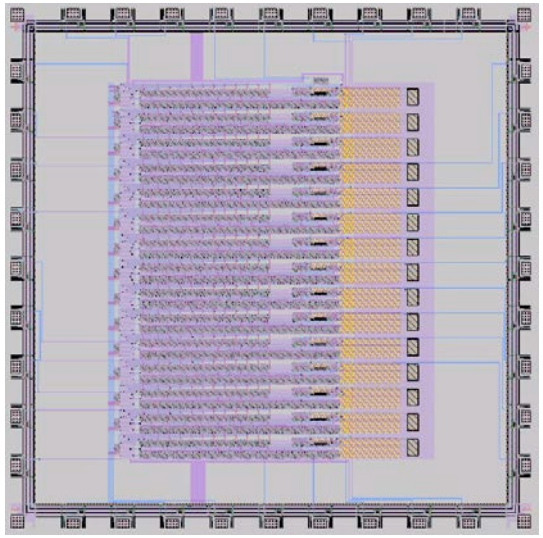
Reduction in peripheral components without loss of performance in SPR-based systems can be done by:



(a) Choosing a system configuration amenable to miniaturization.



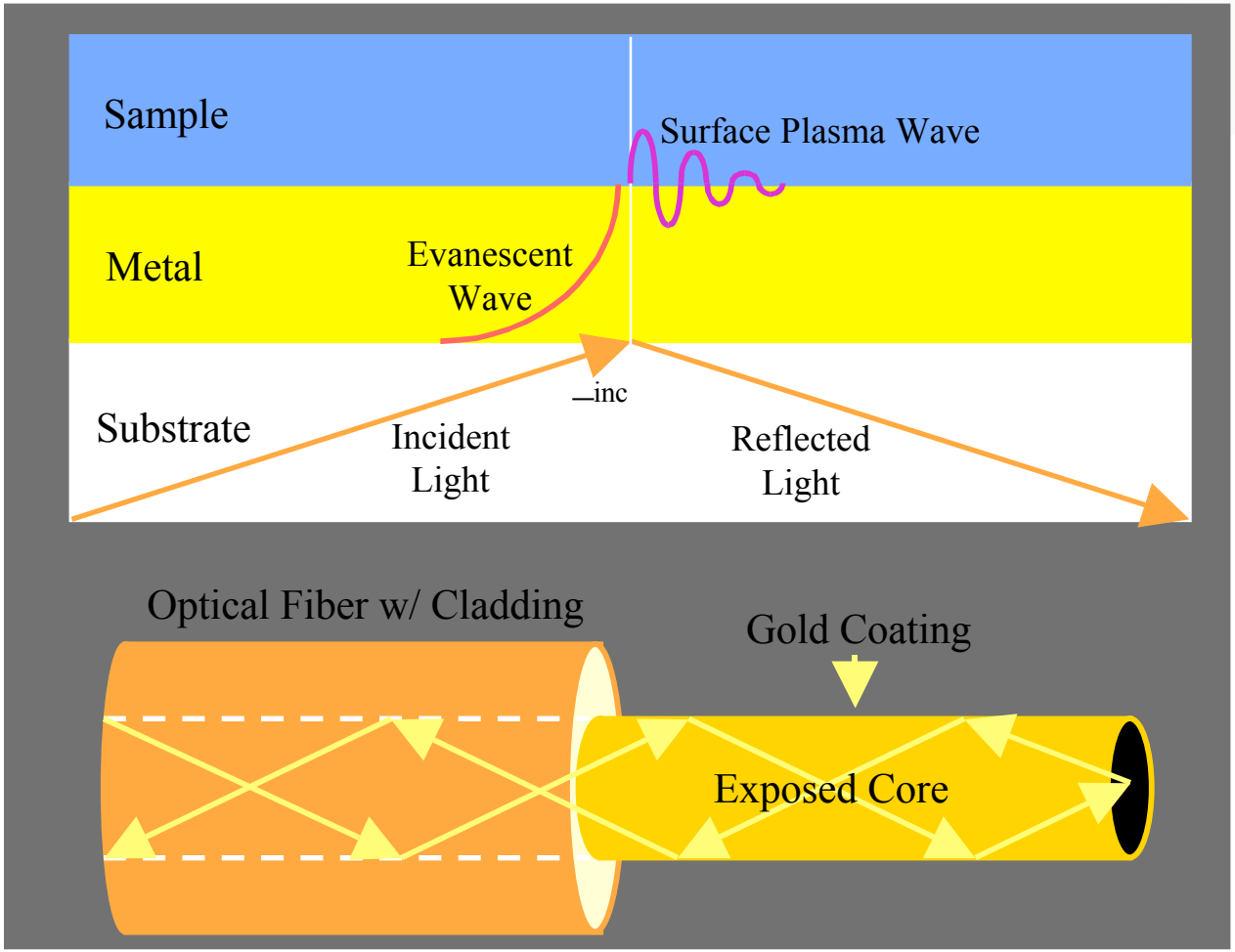
(b) Converting the optical path from discrete components to integrated fiber optic components;



(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

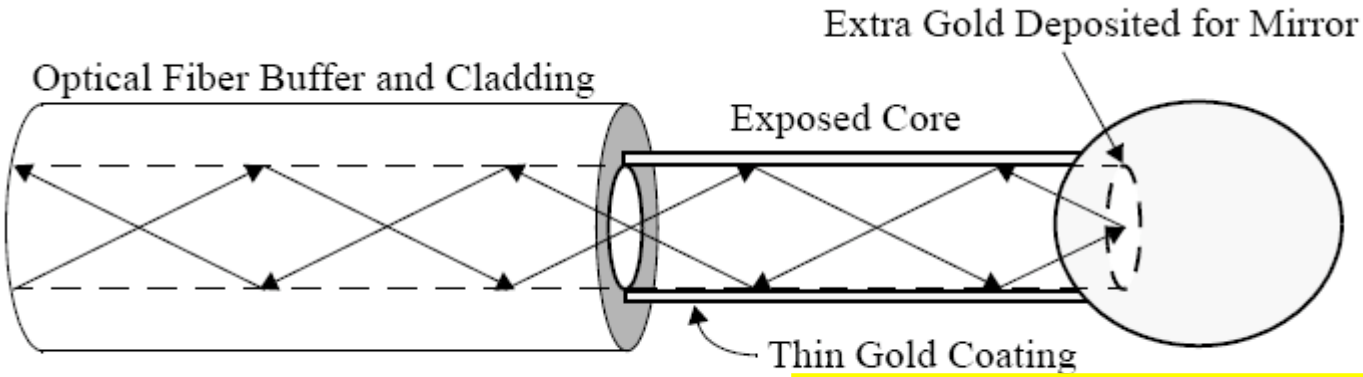
$$k_{spw} = k_0 \sqrt{\frac{\varepsilon_s \varepsilon_m}{\varepsilon_s + \varepsilon_m}}$$

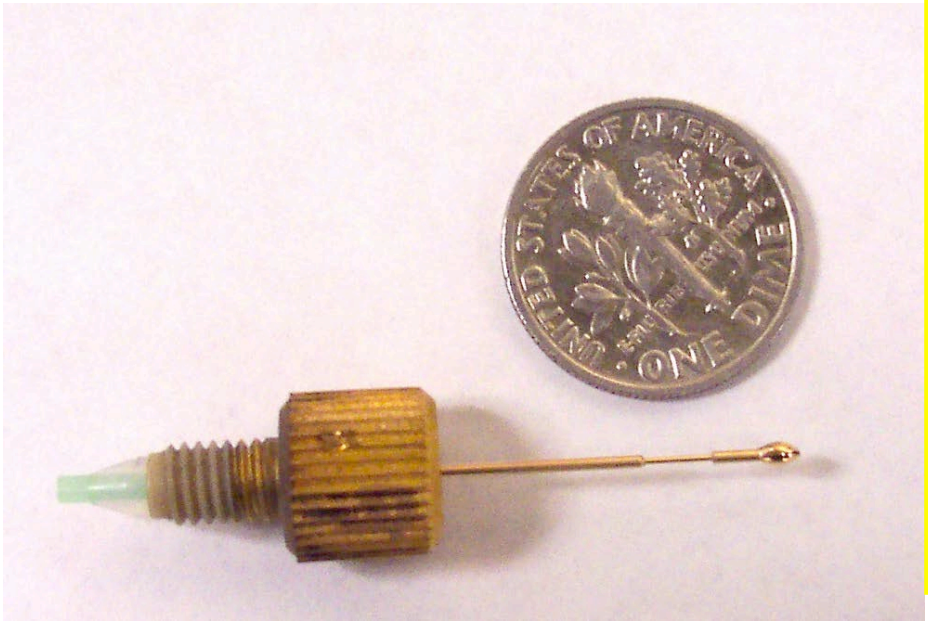
$$k_x = k_0 n_{sub} \sin(\theta_{inc})$$

$$k_o = 2\pi/\lambda$$

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).

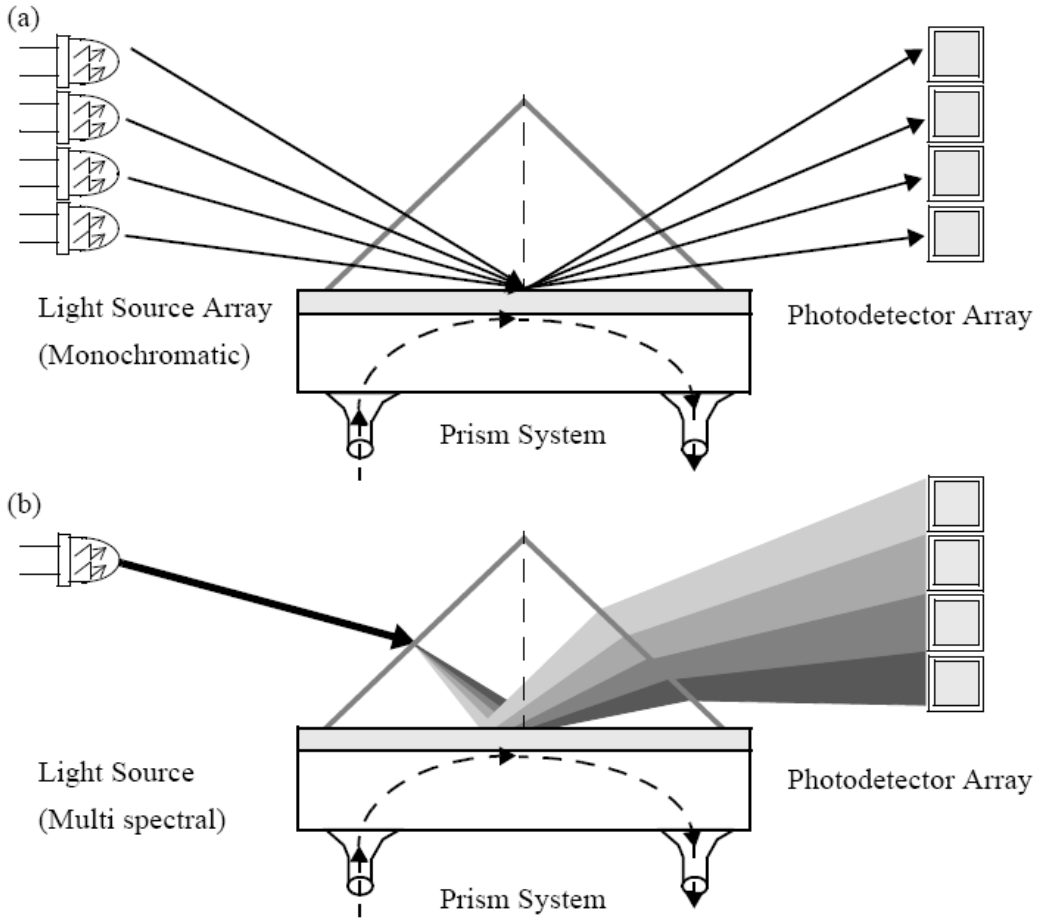
Surface Plasmon Resonance

System Configuration: Portable Optics Path

The point at which SPR occurs can be detected at a:

- Particular angle (constant wavelength interrogation)
- Particular wavelength (constant angle interrogation)

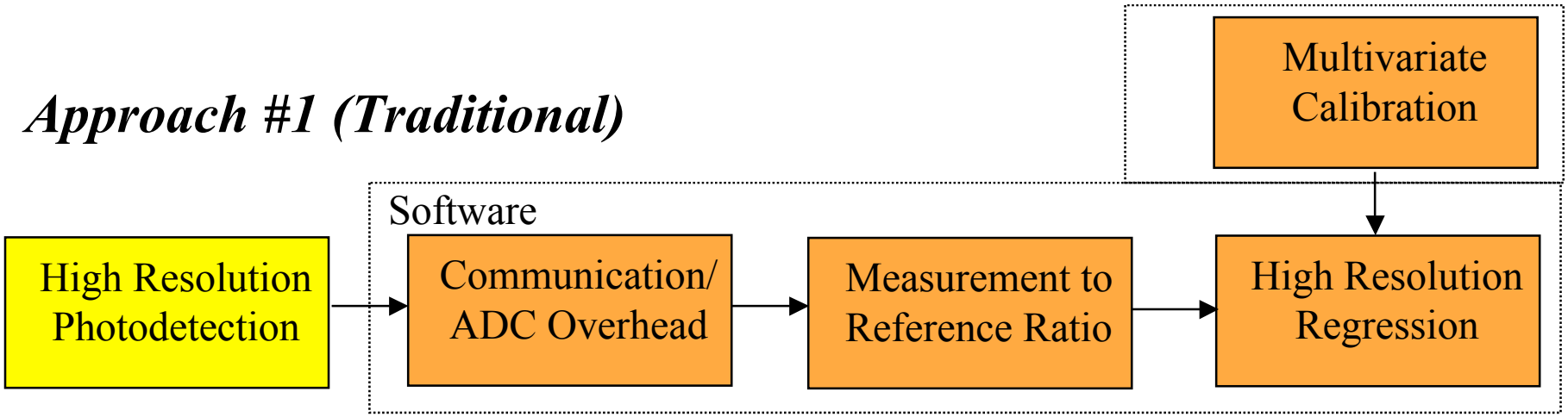
Constant Angle is chosen here because it enables an inexpensive light source (LED), easy and stable optical alignment, and simpler, more compact configuration.



Signal Processing: (Cumbersome) Traditional Approach

In the traditional approach, many, many photodetector signals are scanned off of the sensing plane and then transferred to a PC for signal processing

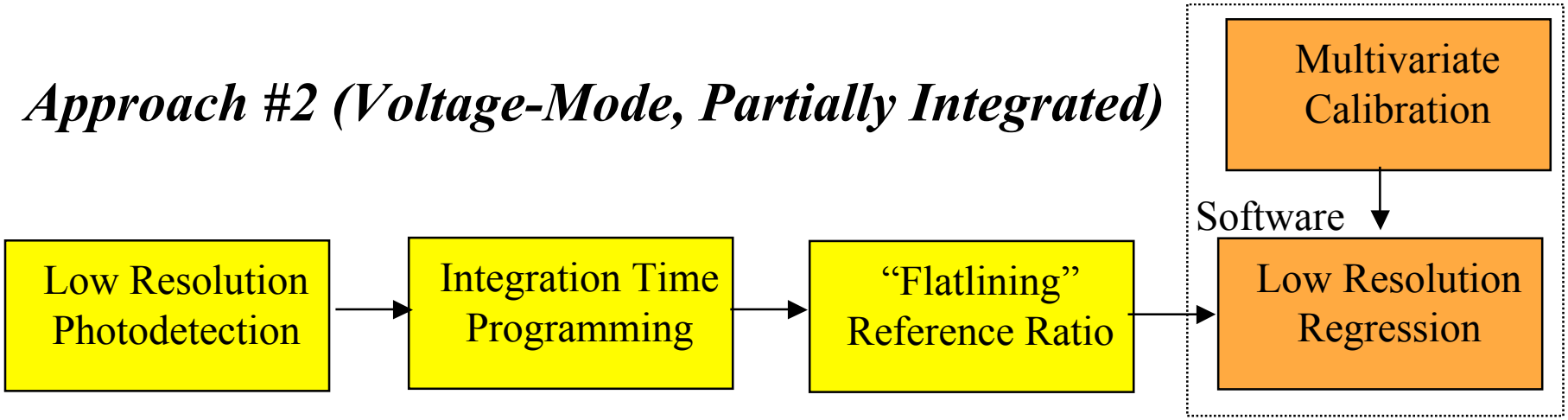
Approach #1 (Traditional)



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)



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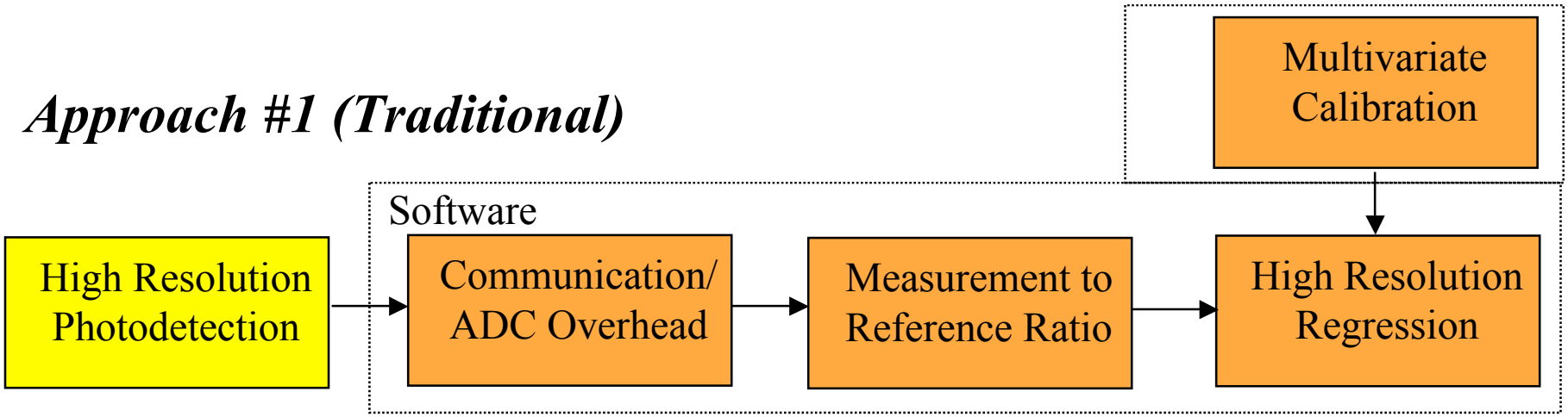
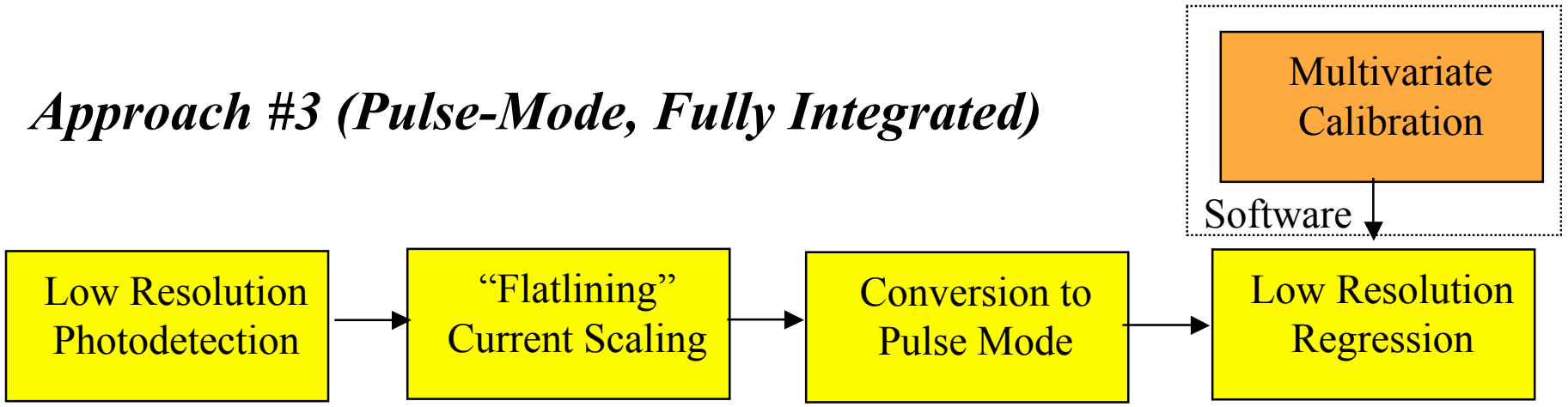


Signal Processing: (Fully) Integrated Approach

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

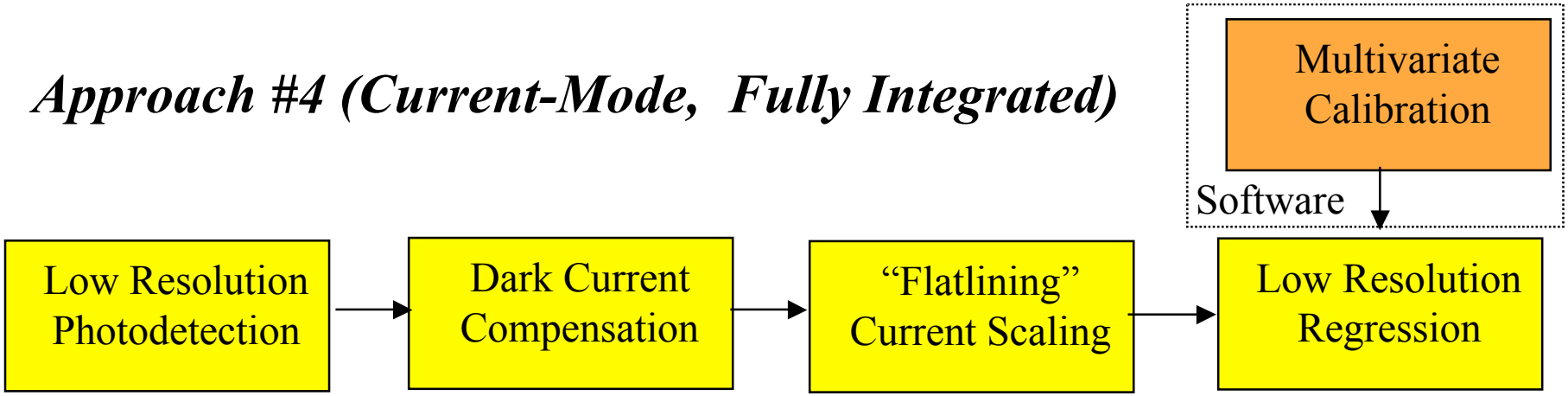
Approach #3 (Pulse-Mode, Fully Integrated)



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.

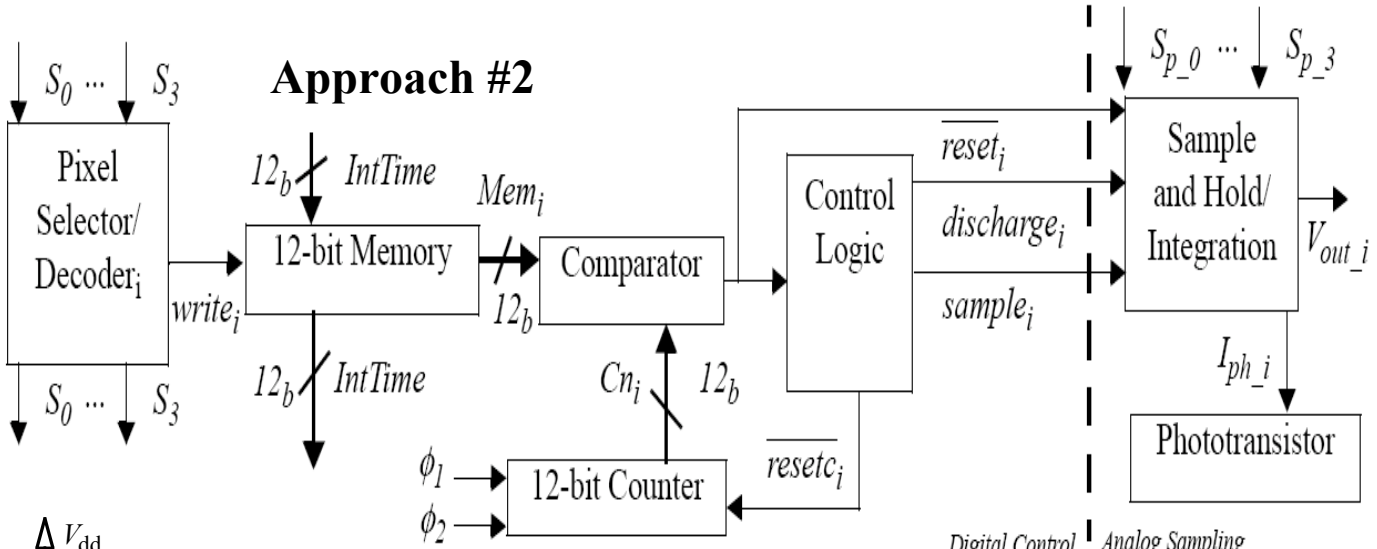
Approach #4 (Current-Mode, Fully Integrated)

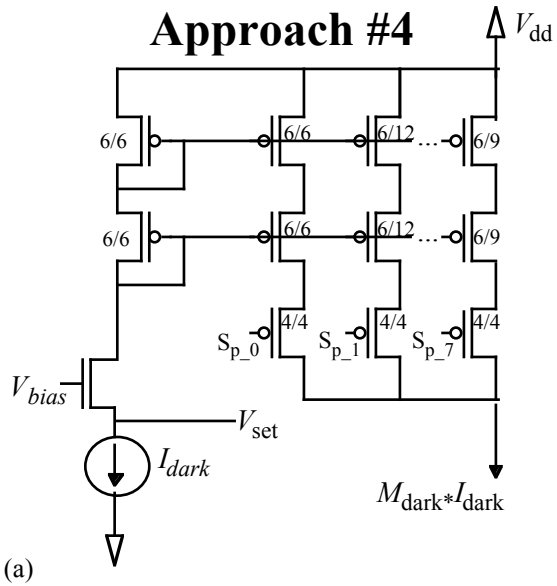


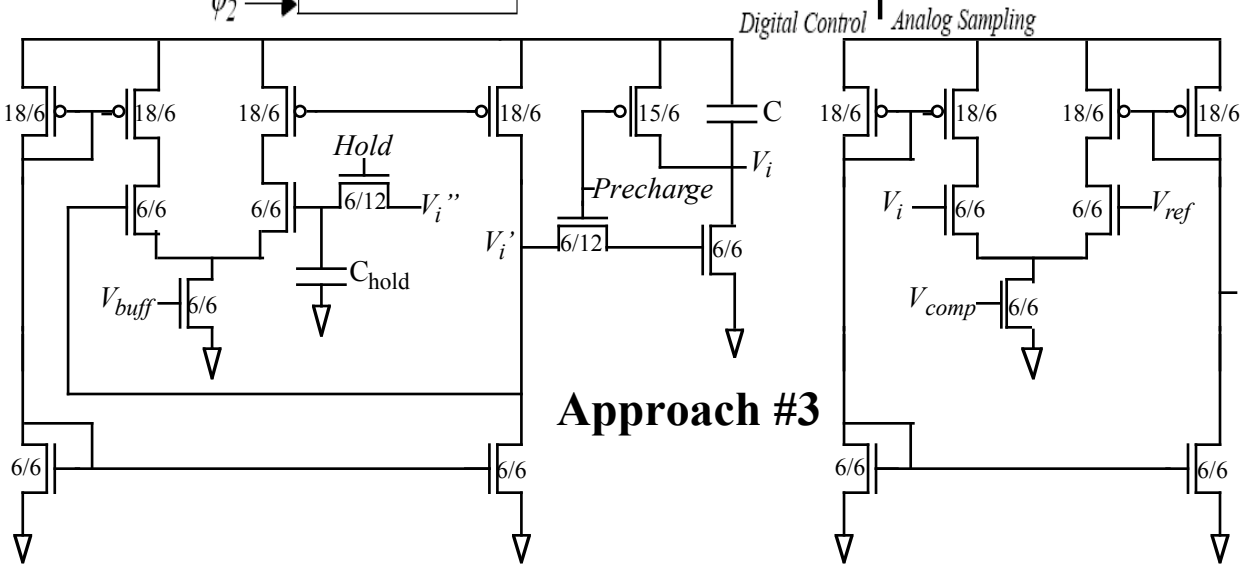
Surface Plasmon Resonance

Portable Systems: Do they work?

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



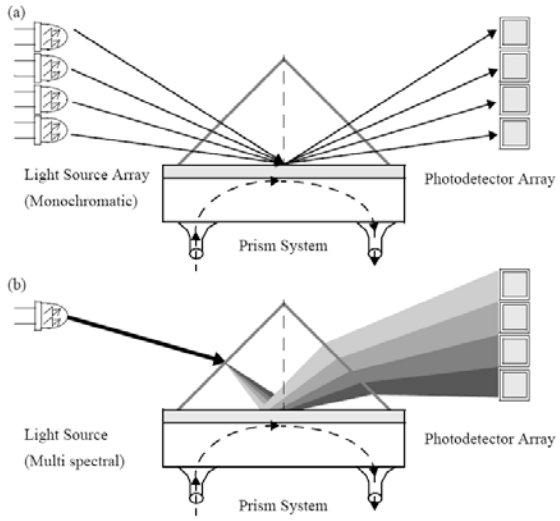




Surface Plasmon Resonance

Creating System Portability: Can it be Done Effectively?

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



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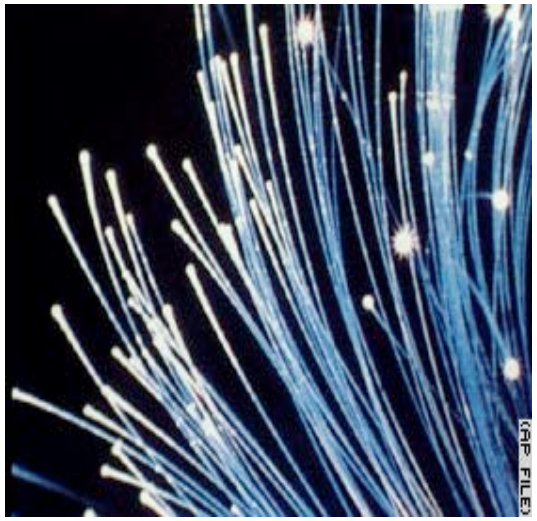

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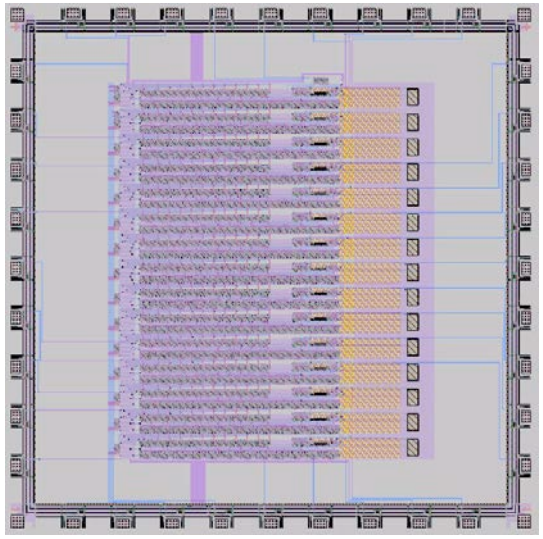

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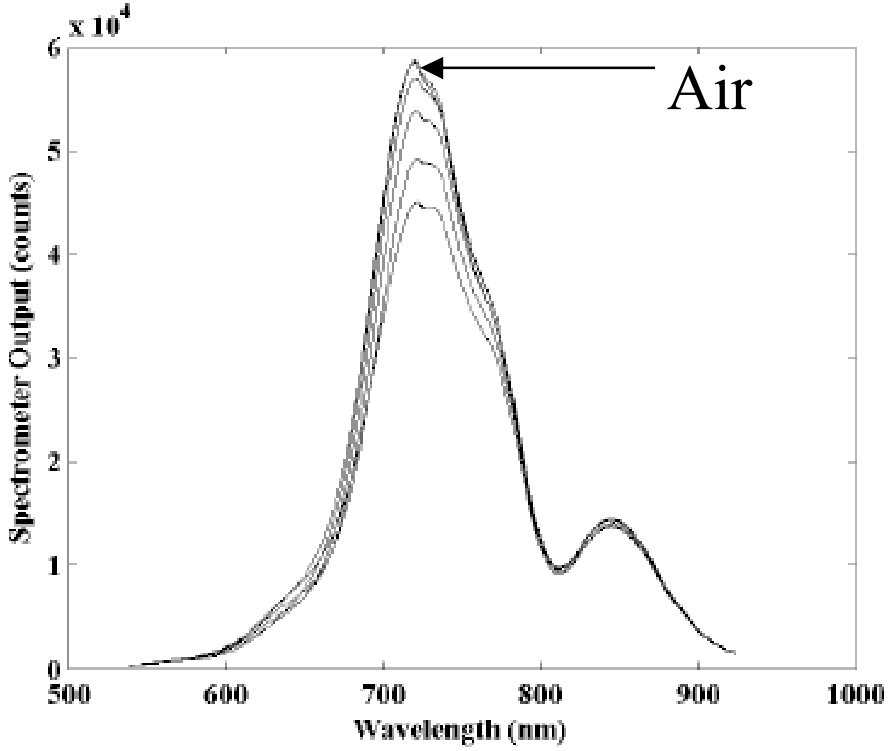
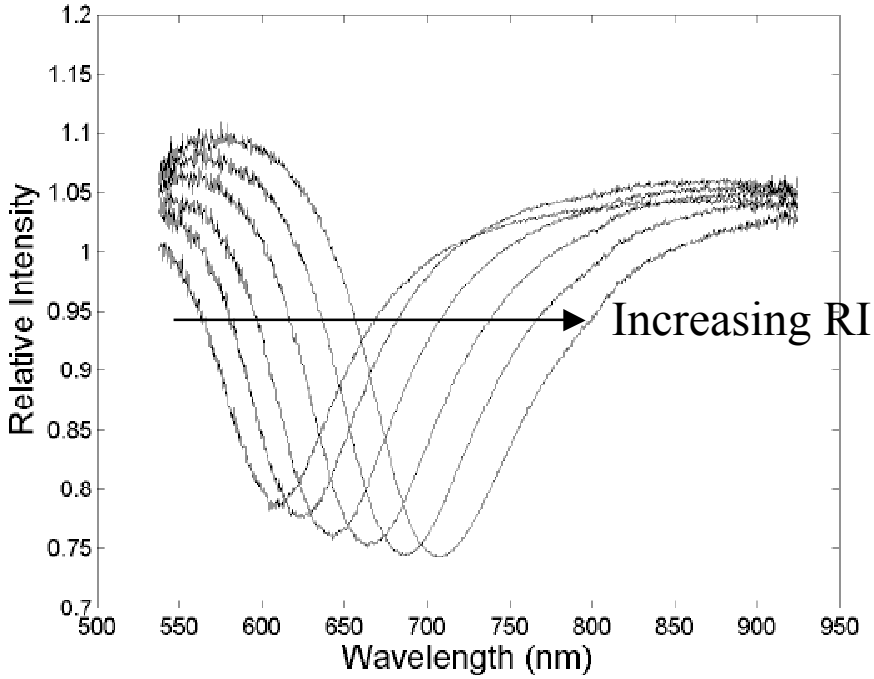
Surface Plasmon Resonance

Output Generated by Portable Approach
Clearly Indicates point of Resonance



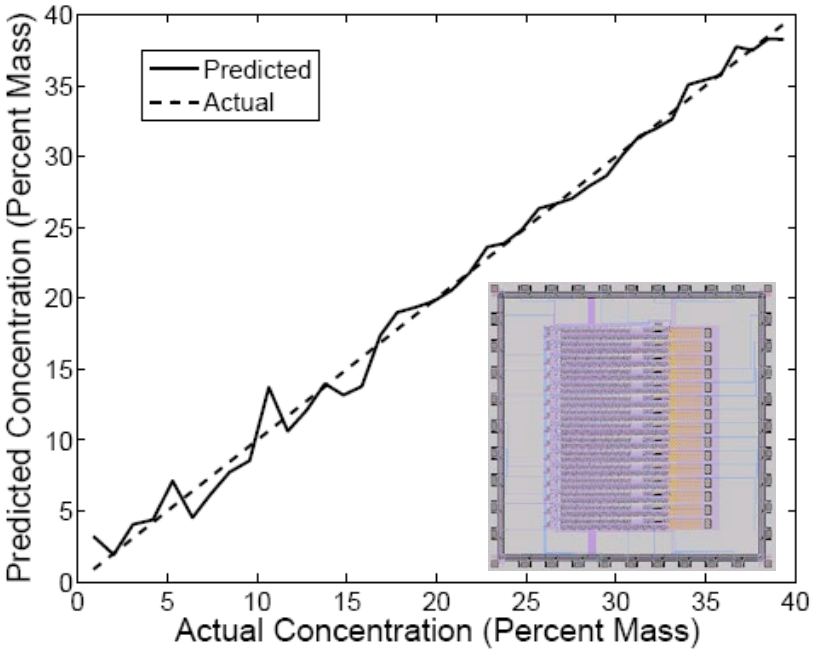
Raw Data (*background overwhelms resonance)*



Referenced Data (*Resonance is evident*)

Surface Plasmon Resonance

Comparable Performance is Achieved!



Approach	**Level of Integration**	**Size (λ X λ)**
Traditional	None	Big
Voltage Mode	Partial	200 X 1800
Pulse Mode	Full	200 X 1200
Current Mode	Full	200 X 1000

Approach	*Traditional*	*Voltage Mode*	*Pulse Mode*	*Current Mode*
Prediction Error	6.07%	3.53%	2.72%	2.54%
RI Resolution	5×10^{-4}	2×10^{-4}	6.9×10^{-4}	6.8×10^{-4}

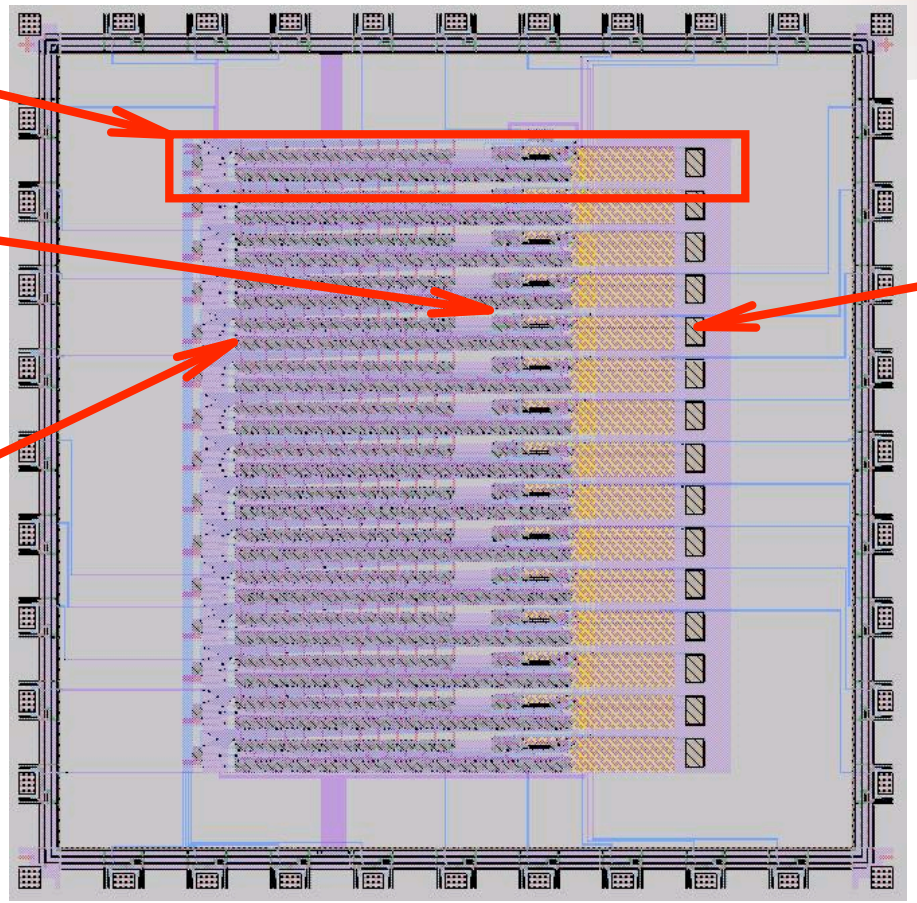
DMS LAB

UNIVERSITY OF WASHINGTON

Surface Plasmon Resonance

The Story of Portable Systems

National Science Foundation # ECS0300537



The End