# Next Generation Sensors for Biological Agents

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# Outline

- The First Responder Requirement
  - Large Markets
- The Technologies
  - Existence Proof
  - Taxonomy
- The Message
  - International Programs

# The First Responder Requirement

# Project Atlanta (Nov 2000)

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# Project Atlanta (Nov 2000)

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# Presidential Visit (March 2002)

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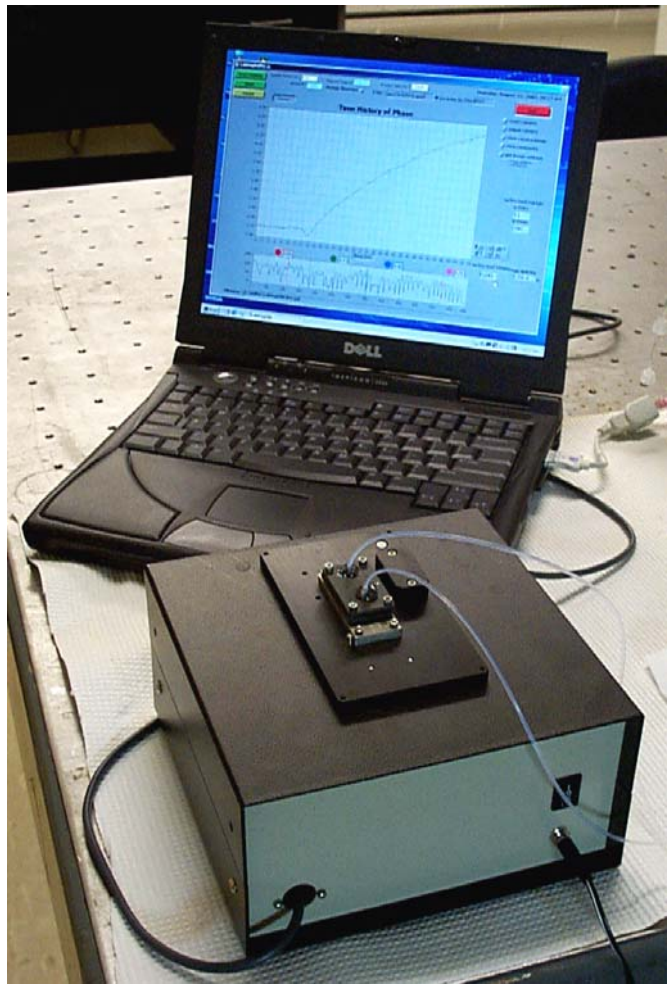
# Chem-Bio Warning Network Sensor (CBWN)

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# Immunoassays

- **BT550**
  - Aerosol Collector & Strip Reader (MesoSystems Technology, Inc.)
    - http://www.mesosystems.com
  - Strips (Tetracore, Inc.)
    - http://www.tetracore.com
  - Combines BT500 aerosol collection device with test strips

  - Agents identified
    - Anthrax
    - Ricin
    - SEB
    - Botulinum Toxin
    - Plague
    - Bacillus Thuringiensis
    - Tularemia
    - Orthopox
    - Brucella
    - Q Fever
  - Cost
    - Collector ~$12,000
    - Strips ~$25 each
  - Aerosol Collector & Reader
    - Weight = 10 lbs.
    - Dimensions = 12 x 5 x 6 in
    - Power = 12 V DC battery

# Polymerase Chain Reaction (PCR)

- **Bioseeq / Mini-PCR**
  - Developed by Lawrence Livermore National Laboratory
  - Commercial development by Smith Group
    - http://www.smithsdetection.com

- Specifications
  - Total Weight
    - 6.5 lbs
  - Dimensions
    - 11” x 3.5” x 7”
  - Power
    - 12V DC Internal Batteries
    - Vehicle Power
  - Cost
    - ~$22,000
  - Typical Test Time
    - 20 minutes
- Advantages
  - Small
  - Ease of Use
  - Specificity
- Disadvantages
  - Cost

# First Responder Requirements

- Small size
- Low power requirements
- Real-time (<10 minutes)
- Low false positives and negatives
- Minimum logistics
- Maximum sensitivity – no enrichment
- Low cost - $100's not $1000's
- Durable
- Chem and Bio Desirable
- Reliable
- Mass producible
- No special training required

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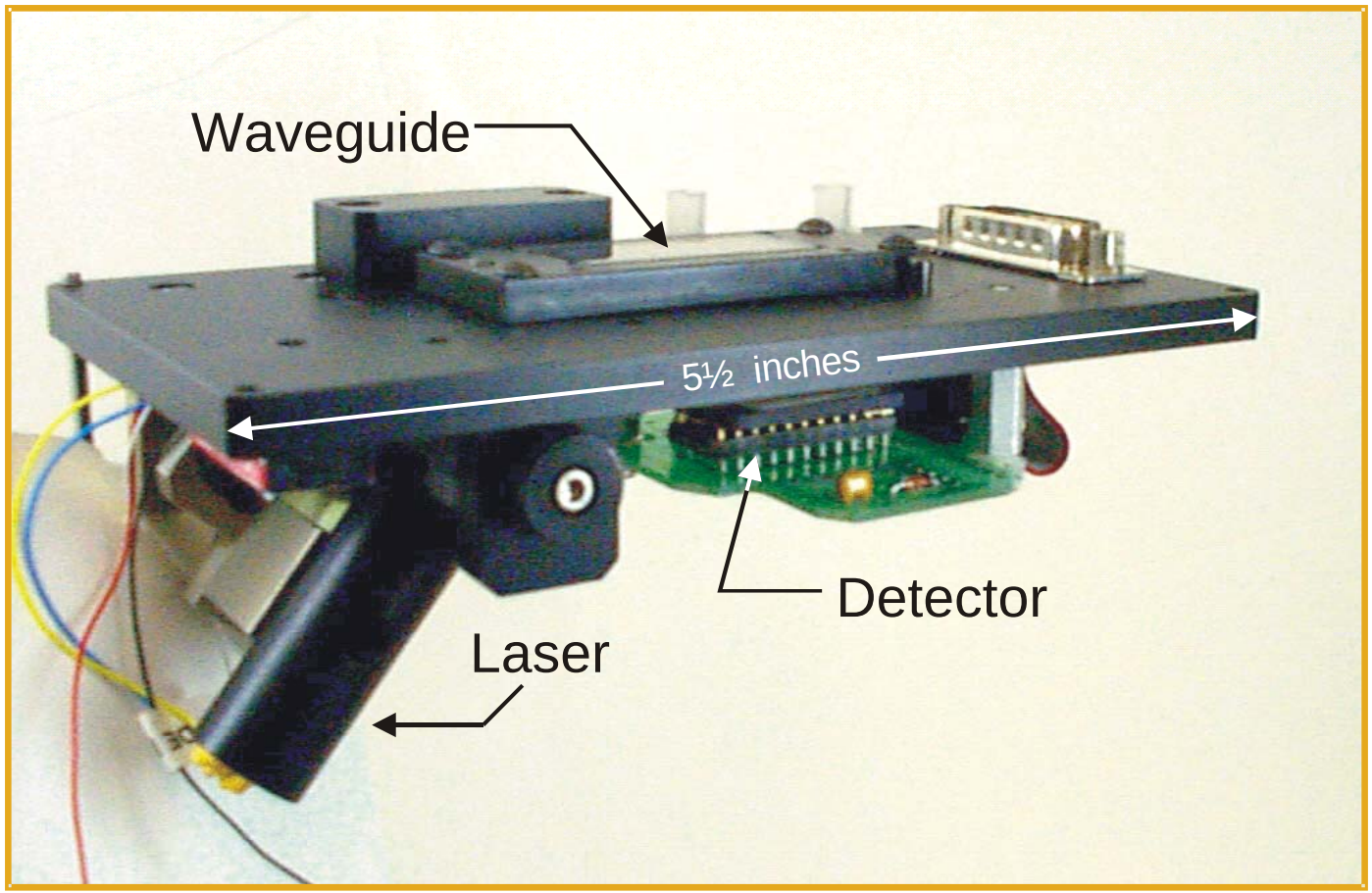
# Other Applications

- Fixed Facilities
  - Emergency Rooms
  - Airport and Port Security
  - Chemical Storage
- Point-of-Care Assessment
  - Biomedical assays
- Environmental
  - Water Quality
  - Air Quality
- Bionetworks of Distributed Sensors
- Food Safety
- Process Control
- Laboratories
  - Pre-screening of Laboratory Samples
  - Safety Monitoring

# The Technologies

# Integrated Optic Interferometric Sensor

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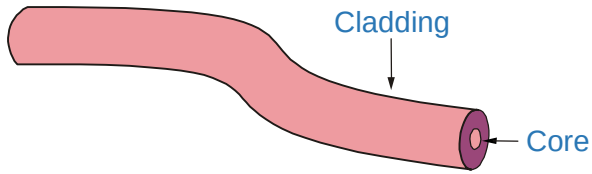
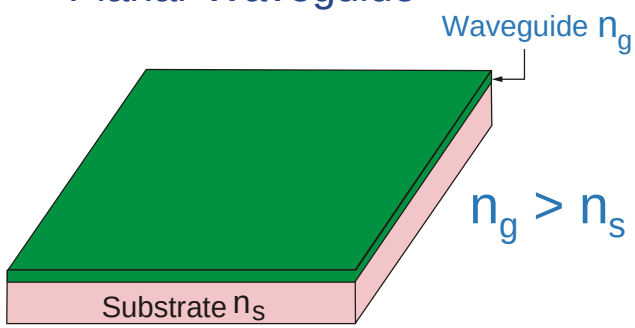
# Waveguides

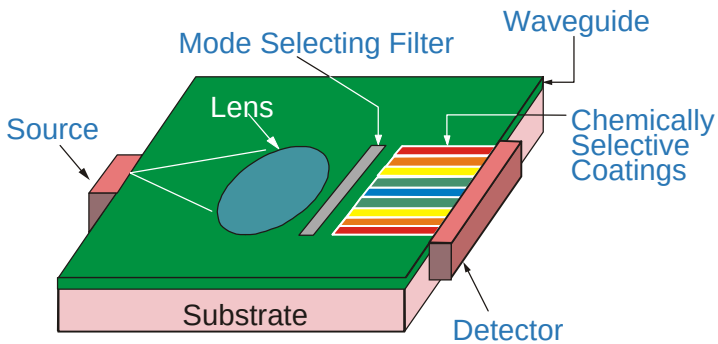
Fiber



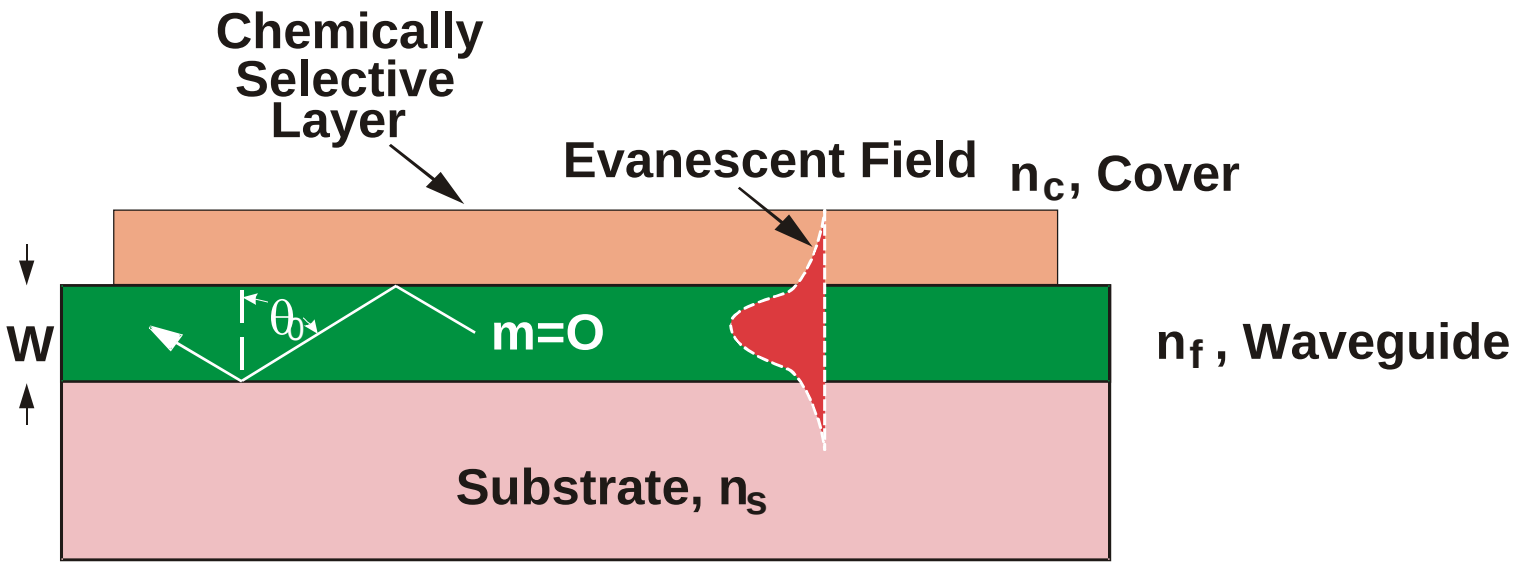

Planar Waveguide



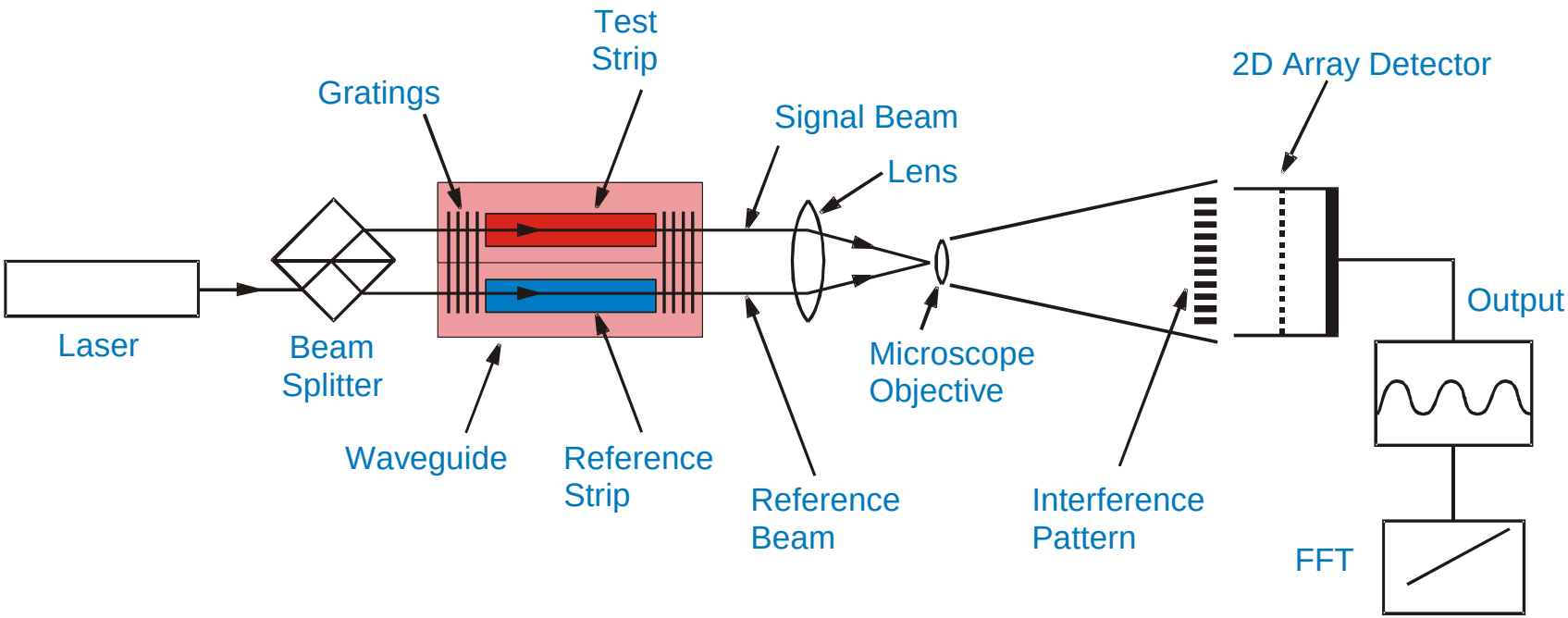

Integrated Optics



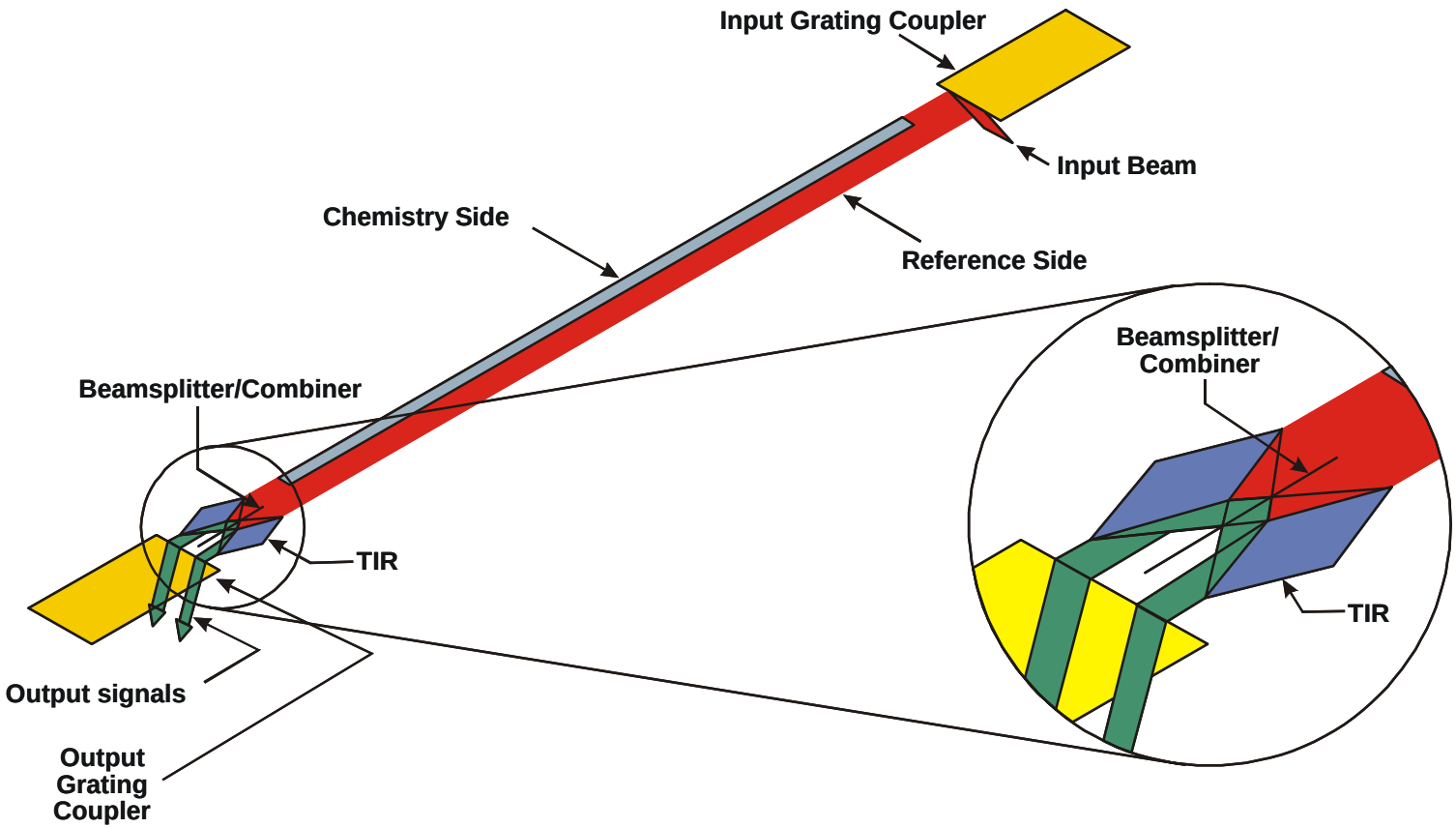
# Chemical Sensing Mechanism



# Components of a Benchtop Interferometer



# Single Integrated Interferometer

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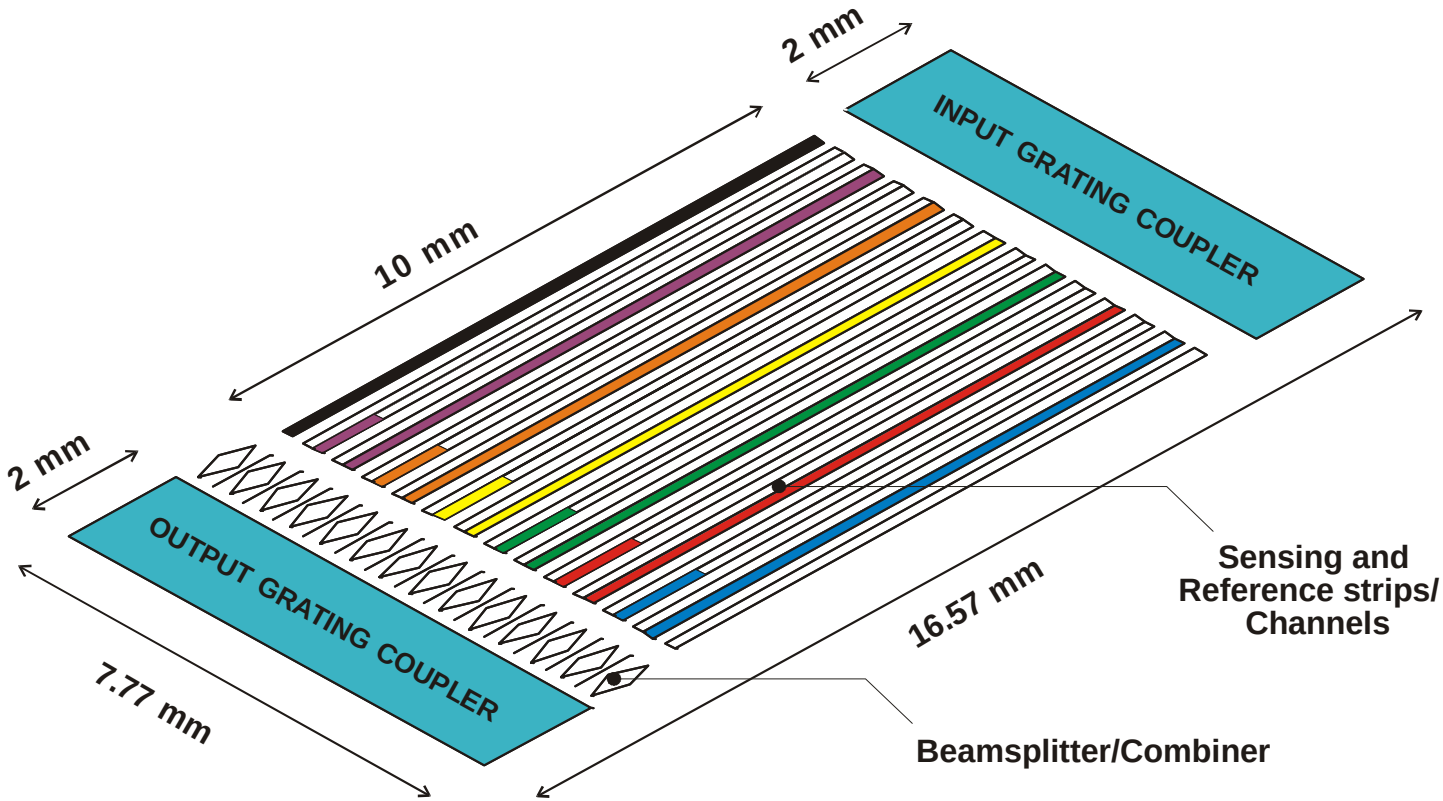
# 13 Sensing Interferometers On a Chip

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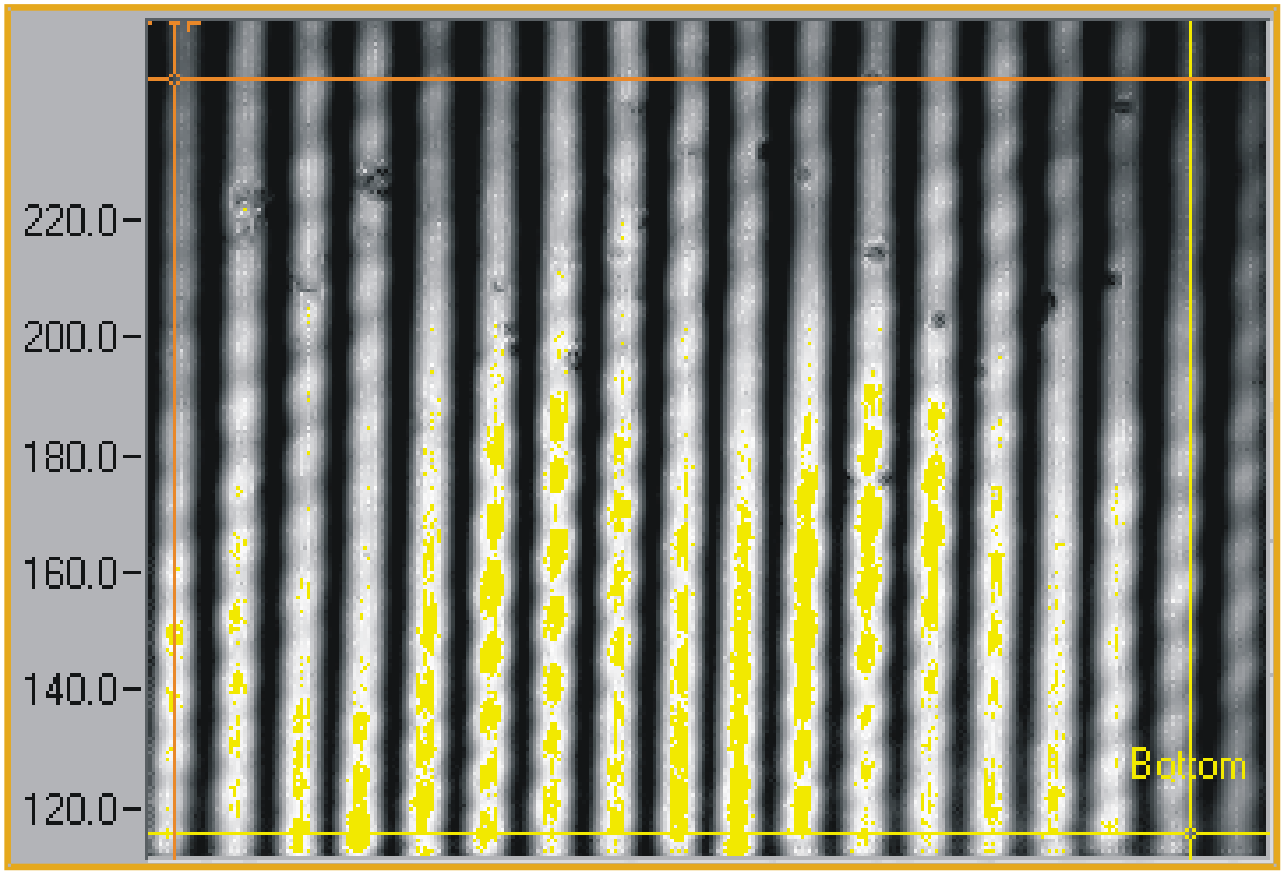
# Webcam Image of Interference Fringes

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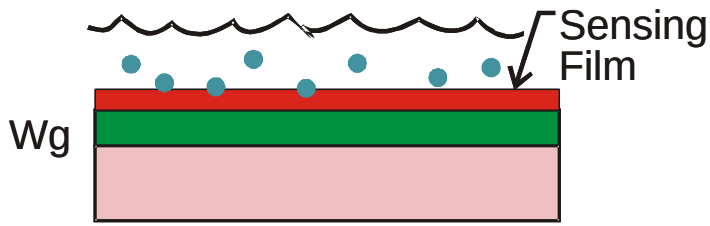
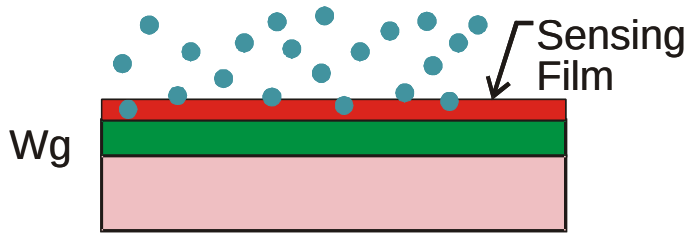
# Waveguide Sensing

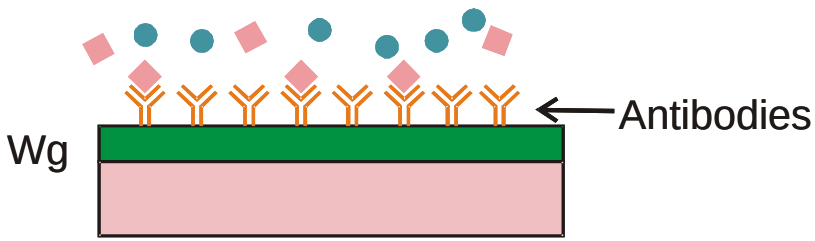
**Analytes in Solution**




**Analytes in Air**




**Bioconjugate Reactions**



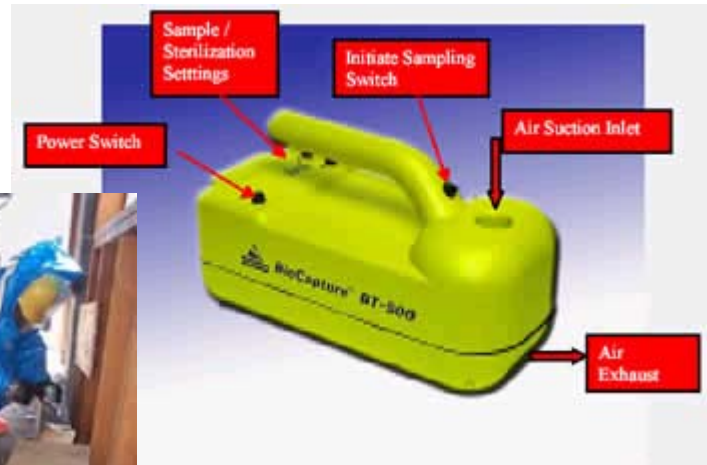
# Sample Collectors

MRI's
SpinCon

- Proven effective with both biological and chemical threats
- Covers a wide range of particle sizes - from chemicals and viruses to spores
- Superior concentration factor improves detection
- Operates in batch or continuous mode, providing much longer surveillance periods
- Compatible with most analytic assay methods, including on-site detection equipment

MesoSystems
BioCapture

BioCapture - A highly efficient, portable, easy to use bio-aerosol collection system with handheld assay detection media port

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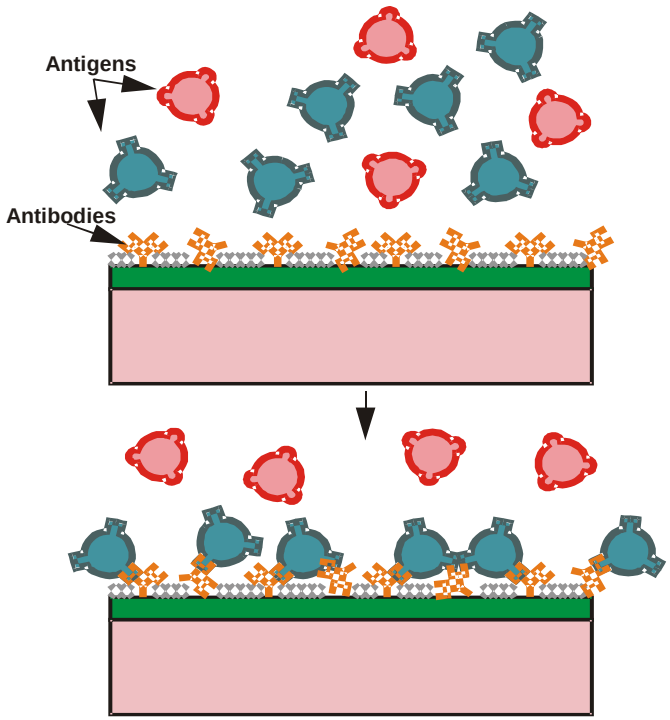
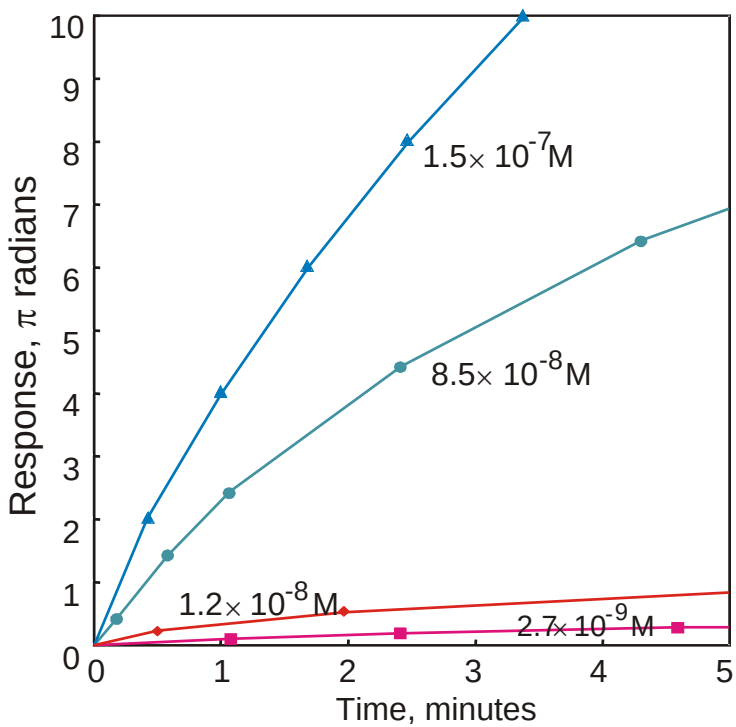
# Biosensor - Protein Antigen

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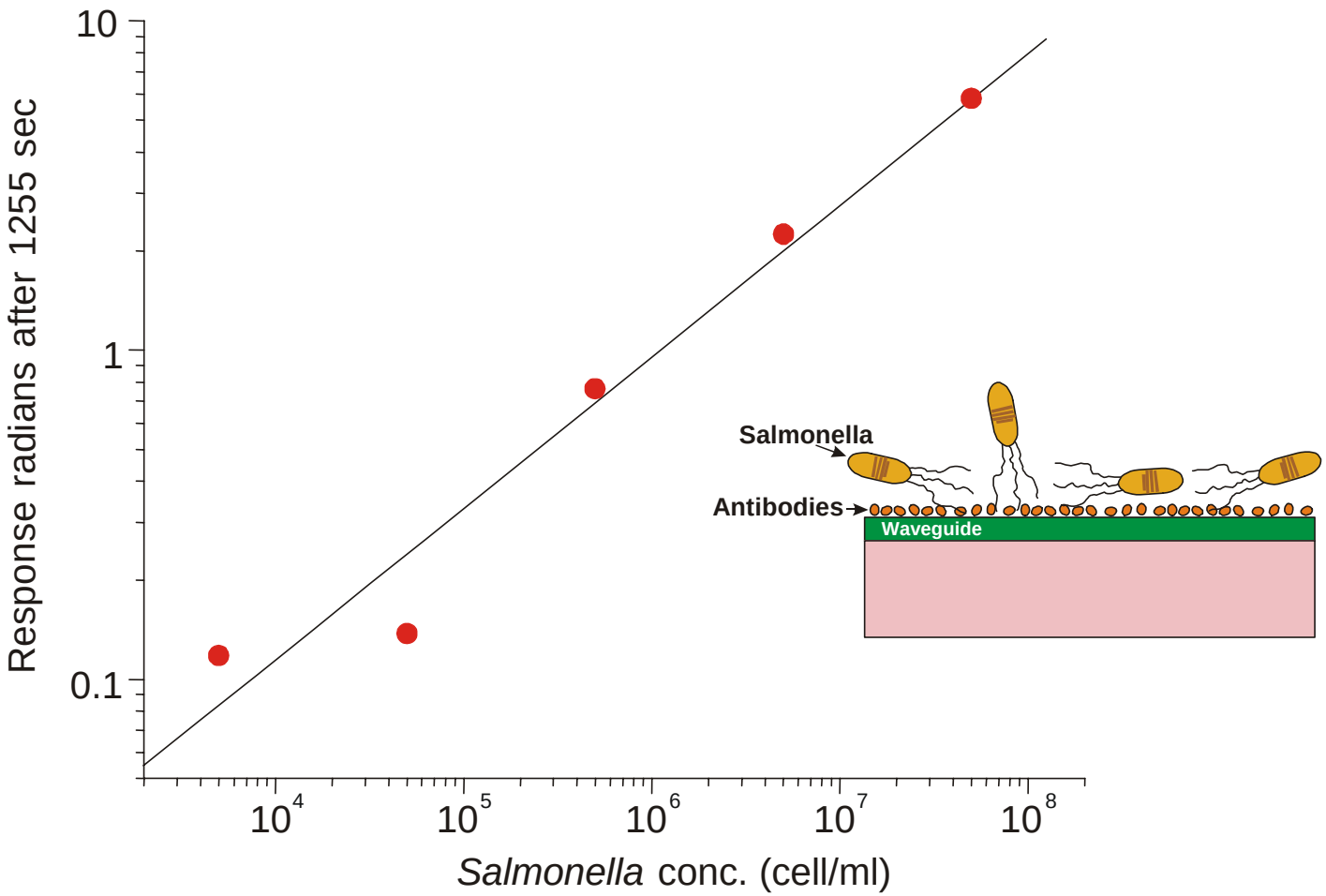
# Whole *Salmonella* Detection

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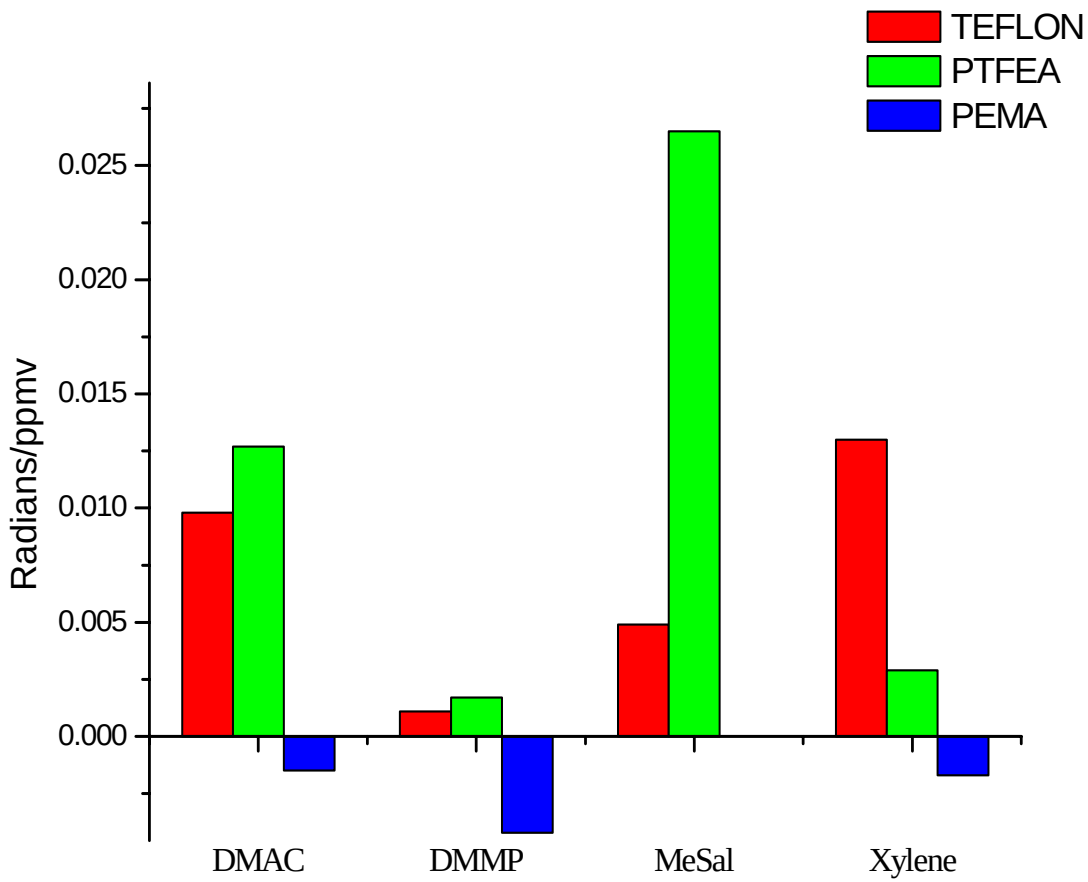
# Response of Different Polymers to Chemical Warfare Simulants

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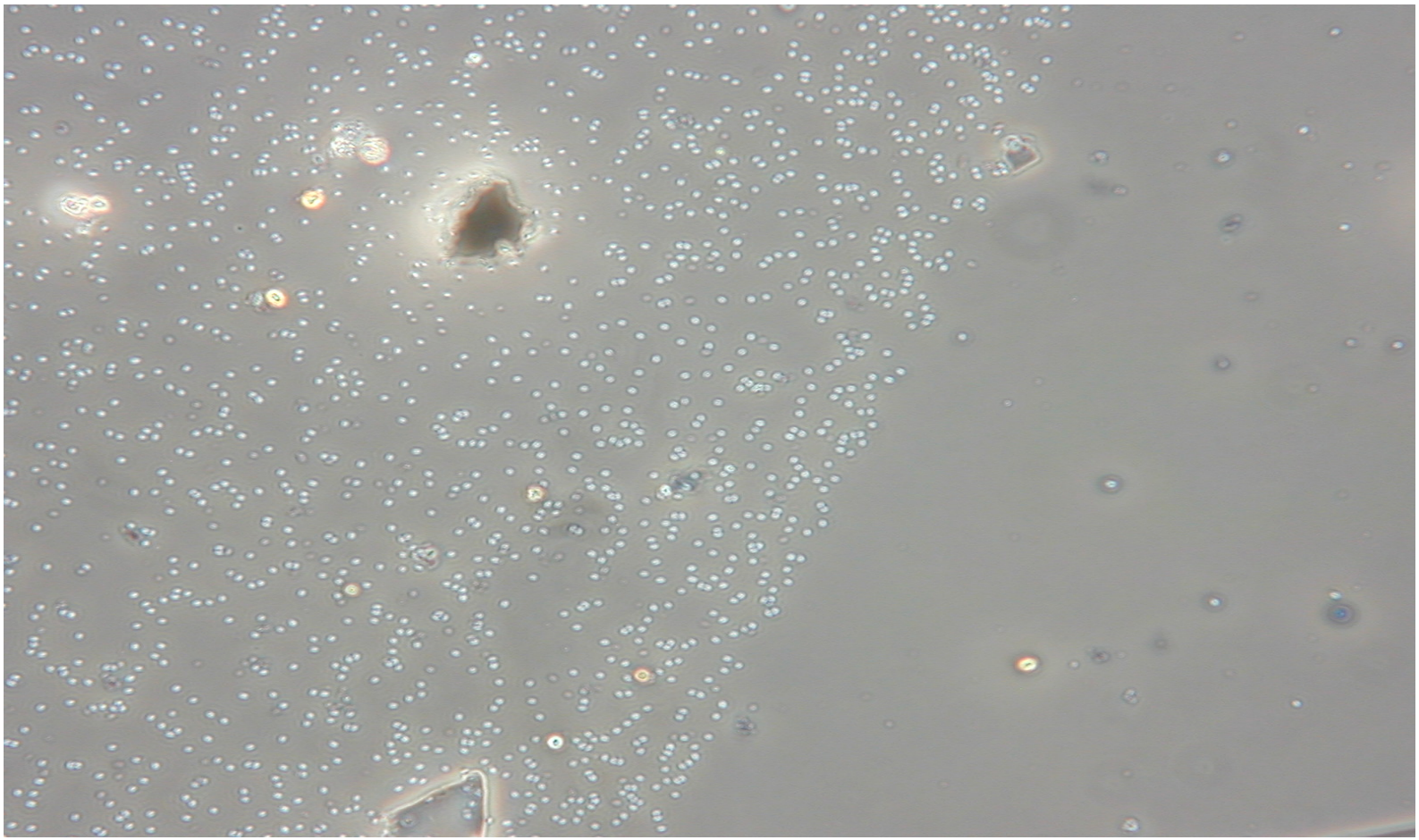
# Anthrax Spores Bound to Waveguide Surface



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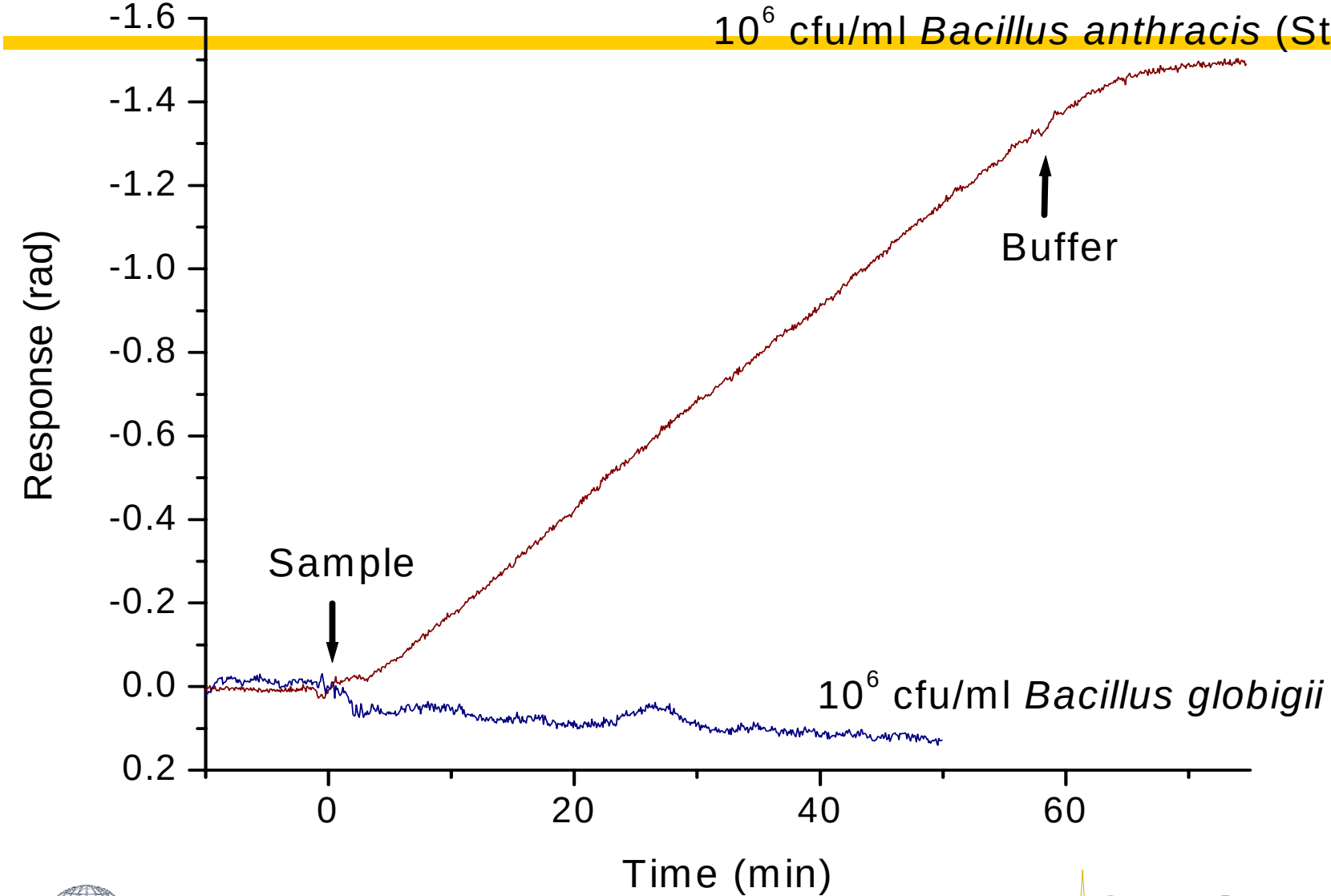
# Anthrax Spore Detection

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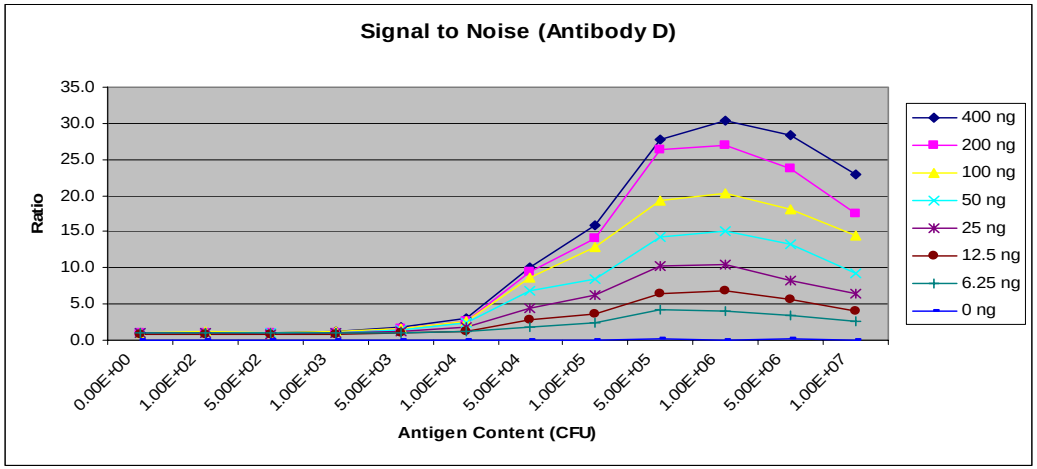
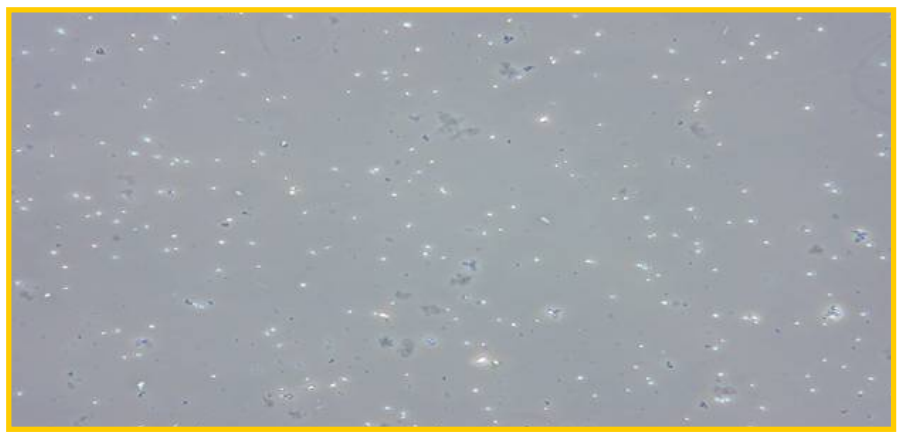
# Anthrax/Antibody Results




Anthrax/Capture Antibody Sensitivity Measurements

Anthrax captured by antibody-derivatized glass



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# Limits of Detection

*Vapor Phase -*

| | |
|---|---|
| *Xylene* | *300 ppbv* |
| *Toluene* | *<1 ppmv* |
| *Benzene* | *1 ppmv* |
| *TCE* | *1 ppmv* |
| *Chloroform* | *1 ppmv* |
| *Ammonia* | *50 ppbv* |

*Aqueous Phase -*

| | |
|---|---|
| *BTEX* | *<50 ppb* |
| *TCE* | *<50 ppb* |
| *Chloroform* | *<100 ppb* |
| *pH* | *<.01 units* |
| *Protein* | *<1 ng/ml* |
| *Salmonella* | *$<10^4$ cells/ml* |

*Chem Warfare Simulants - <300 ppbv*

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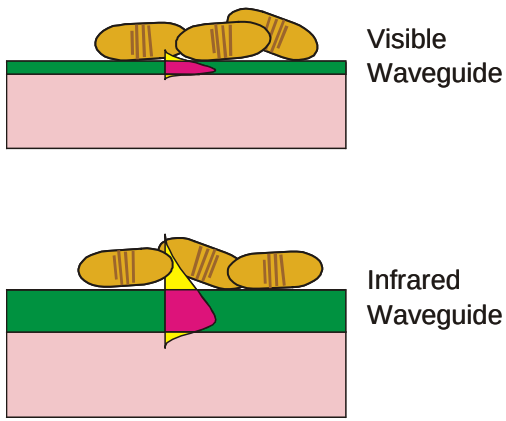
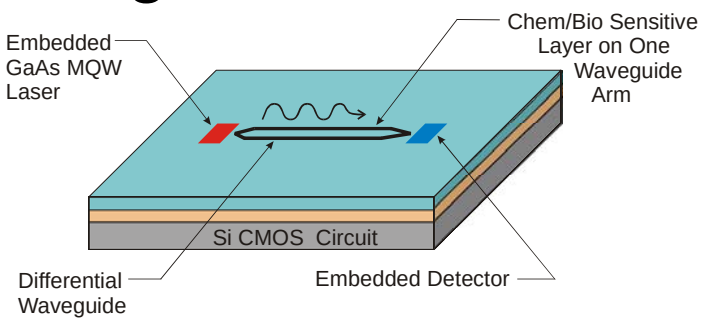
# Future Research

- IR Waveguide




- Integration




- Chemistry
  - Molecularly imprinted polymers or sol-gels
    - Moderate affinity, reusable, long shelf life
  - Aptamers – nucleic acid based receptors
    - High affinity, reusable, long shelf life
  - Electric Field Assist

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# Sensor Technologies

- Optical
  - Surface Plasmon Resonance
  - Resonant Mirror
  - Evanescent Waveguide Devices
    - fiber optic planar waveguide
    - planar waveguide interferometers
  - Chemiluminescence/ Electrochemiluminescence
- Mass
  - Piezoelectric Immunosensor
  - Surface Acoustic Wave/Acoustic Plate
  - Quartz Crystal Microbalance
  - Cantilever Devices
- Electrochemical
  - Light Addressable Potentiometric
  - Immunomagnetic Square Wave Voltammetry
  - Immunomagnetic Amperometry
  - Flow Injection Amperometric Immunofiltration Assay

(Mass spectrometers and Ion Mobility spectrometers do not fall under the Biosensor guidelines)

# The Message

# International Program Vision

- US and Other Nations Must Initiate Programs to Develop Next Generation of Sensors for Biological Agents
- Design for Affordability and the Programs Will Pay for Itself In Terms of Commercial Sales
- Decisions Based on Technical and Economic Merit
  - Minimize Political Influence
- Fund Scientists and Development in All Types of Organizations: Academic, Not-for-profit, National Labs, For-profit

# Program Elements

- Support for Science and Technology
  - Proceed to Engineering Development Models
  - Parallel Technologies with Down-Selection at Critical Milestones
- Technical Elements
  - Transducers
  - Collection
  - Chemistry
  - Signal Interpretation
  - Integration
- Testing Methodology Development
  - Statistical Models
  - Test Procedures
- Developmental and Operational Testing
- Proceed to Low-rate Initial Production ASAP

# Challenges

- Research and Development Management
  - Build on DHS BAA for Chem-bio Sensors
  - DHS Spans Federal Agencies and Labs
  - The Better is the Enemy of the Good Enough
- Funding
  - User Representatives Not Used to R&D Technology Advocacy
  - Program Funding $50-75 Million/Year for 5 Years
  - Insure that Researchers Actually Receive the Funding

# Acknowledgements

Dr. Daniel P. Campbell

Dr. Christina Baxter

For more information:

www.certip.org

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