Portable BASI for Pathogen Detection

Product Requirements Document

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1.0	10/21/14	Release
2.0	11/11/14	Update
3.0	11/20/14	Update
3.0	12/2/14	Update
4.0	12/12/14	Update

Vision

A portable, handheld device that facilitates Brewster angle straddle interferometry for the detection of pathogens in both lab and field environments. This product will later be integrated with chemical binding technology and enclosed within a mechanical housing structure for a complete product.

Environment

As a portable product that may be subjected to various environments, the system needs to operate under the following conditions:

Temperature
60-80^{o}F – Indoor operation
50-110^{o}F – Outdoor operation
Humidity
Non-condensing – Ideal indoor operation
≤60% Nominal – Meets operation specifications

The purpose of this product is to be highly portable. It will be used in various outdoor environments (i.e. crop fields, remote areas).

The wafers are the limiting conditions for environment (which are beyond the scope of this product)

Regulatory Issues

The LED light source used in the optical system will be shielded within a mechanical housing structure, minimizing risk of eye injury.

Instruction or training may be required to ensure proper use of the final product, including methods for preparing and measuring sample cartridges.

Product will be processing biological fluids/pathogens; system must ensure they are appropriately isolated from the user (exact regulations/procedures are defined as per wafer, beyond scope of this product)

Fitness for use

System components:

- Polarized light source
    - 620nm wavelength

        - High contrast polarizer
        - Uniform light output
    - Lenses
        - AR coated for red wavelengths
    - Cartridge(s) for containing samples
        - Silicon wafer with native oxide layer
        - Aforementioned wafer with thin film of sample possibly containing pathogen on oxide layer
    - Detector
        - CCD sensor

The system will:

Illuminate a cartridge/wafer (air/SiO_2/Si thin film) with uniform, 620nm, p-polarized light at an angle straddling the Brewster's angles of the two interfaces (air/SiO_2, SiO_2/Si). (see figure 2)

Measure intensity profile of reflected light with a CCD; use image processing/pattern recognition to elucidate binary presence of pathogen.

Provide quantitative information of pathogen presence: characterize amount of pathogen by calculating sample thickness. (This will be done by calibrating with respect to wafer without pathogen.)

Have enough spatial resolution at image plane to distinguish spots (see figure 2).

Be smaller than previous design (.5m x .1m x .1m)

Cost less than or equal to $300.

It is desirable that:

There are minimum reflection losses at surface boundaries within the system.

The system is compact as possible.

That the system is .15m x .05m x .05m in dimension.

That the system weighs less than .5 kg

Brewster angle straddle calibration is automated for ease of use.

Scope

The scope of this project includes:

Design of an optical system to measure desired sample cartridges, including lens specifications, spacing and tolerances.

Design of a mechanism/function to determine presence/absence of pathogen amounts within sample for a given threshold.

Design of mechanical housing structure which encloses the optical system.

Design of sample cartridge/wafer dimensions (length, width, location and number of spots).

The scope of this project does not include:

Design of sample cartridge/wafer binding chemistry

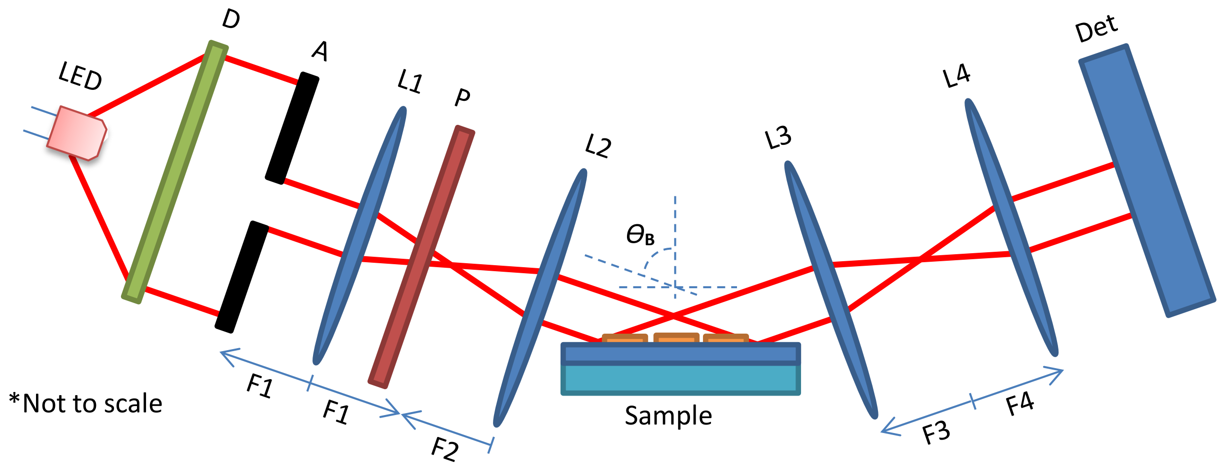
The scope of this project may include:

Design of a mechanism/function to characterize sample film thickness to determine pathogen amounts within sample

Software design that interacts with the optical system to automate Brewster angle calibration and data collection

Images/Schematics

Figure 1: Optical System (proposed)



LED – Red LED source

D – Diffuser

A – Variable aperture

L1, L2 – MgF2-coated convex-plano singlet lenses (27mm EFL)

P – Polarizer, 2000:1 contrast ratio

Sample – See Figure 2

θ_B – Brewster's angle between SiO_2/Si interface

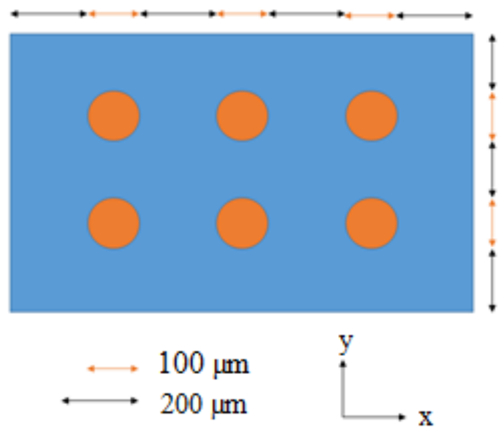
L3, L4 – MgF2-coated doublet lenses (25mm EFL)

Det – Detector CCD, AMScope md35

Proposed Design, based off of previous work. To be optimized to a more compact design.

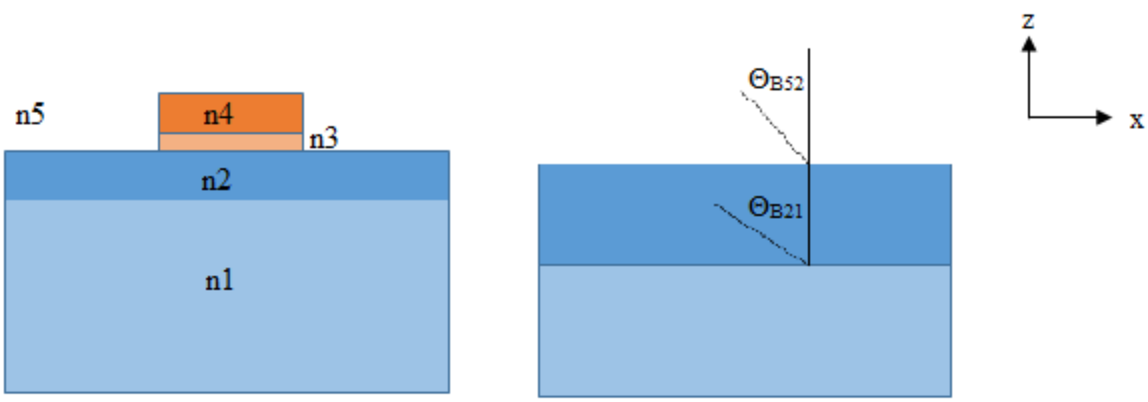
Figure 2: Wafer Schematics (proposed)

a)



Orange spots are locations of binding chemistry/pathogen.
Note: number of spots will change depending on design.

b)



n1: Silicon (Si), n=3.90582
n2: SiO2, n=1.54303
n3: binding chemistry
n4: pathogen
n5: air, n= 1.000293

Θ_{B52} = Brewster's angle for air/SiO_2 interface
Θ_{B21} = Brewster's angle for SiO_2/Si interface

Photon Budget

Transmission values over whole system:

	LED	D	A	L1	P	L2	Sample	L3	L4
T	1	0.981	1	0.981	0.5	0.981	0.98	0.981	0.981
T_{total}	0.454271								

Transmission of polarized light after polarizer:

	L2	SAMPLE	L3	L4
T_S	0.981	0	0.981	0.981
T_P	0.981	0.323	0.981	0.981
T_S total	0			
T_P total	0.3238			

*Transmission at SAMPLE given as amount that transmits to L3 and onto the final detector surface

**Transmission calculated using reflectance values from Thorlabs and experimental setup https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=3279

With current layout, transmission values show approximately 32.38% of p-polarized light reaches the detector for a clean sample (only the SiO_2 wafer with no thin-film). Given the sample is accurately positioned at Brewster's angle, the p-polarized light will reflect off the sample surface at an appropriate angle to reach the detector with some loss, while the s-polarized light is reflected at a separate angle (and mostly does not reach the detector). The MgF2-coated lenses provide high transmission within the wavelength range of our source (reflectance less than %2 total over both lens surfaces), minimizing losses.

Specifications Sheet

optical equipment		**other equipment**	
part	**cost**	**part**	**cost**
620nm LED	2	3D printer material	100
polarizer (1000:1)	10	silicon wafers	20
optical diffuser	15	electronics	80
lenses	260		
CCD: AMscope md35	120		
		total	607