# Surface Plasmon Resonance Sensors: Optimization of Diffraction Grating and Prism Couplers

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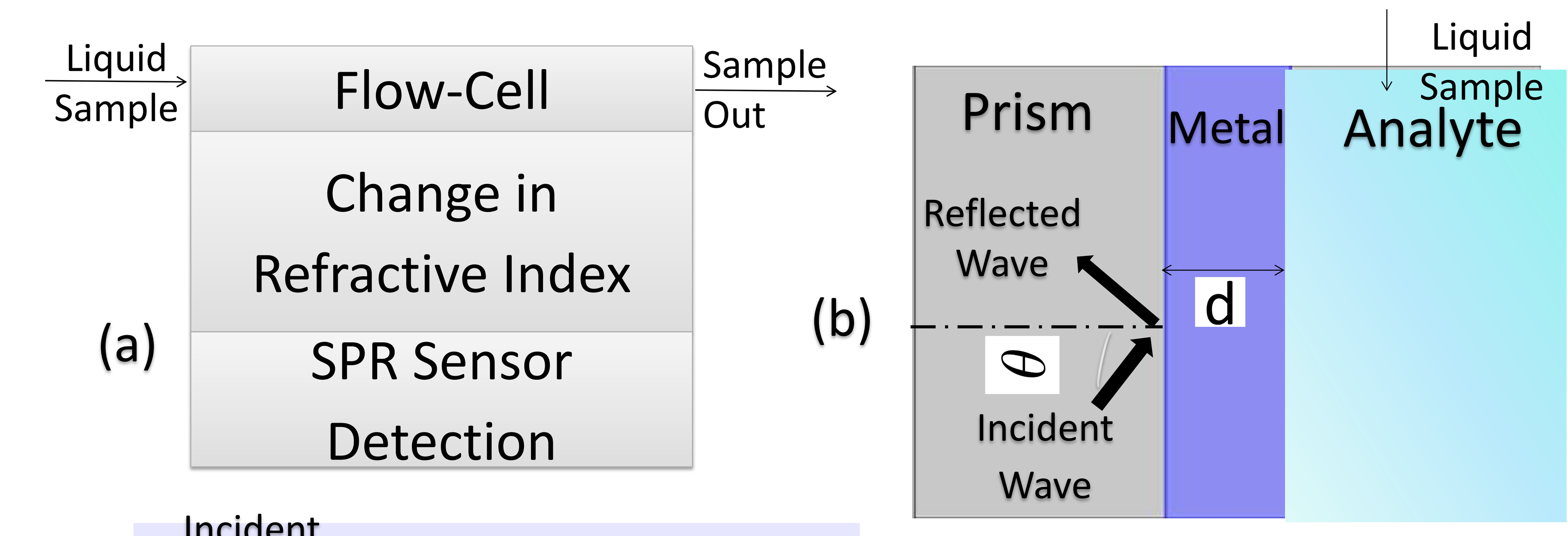
**Introduction**: Surface plasmon resonance (SPR) sensors proved themselves as a promising sensing device, for bio-sensing and nano-scale measurement applications [1,2,3]. In this project, a computational tool was developed to detect various protein postulate in human and animal blood [4] through most commonly used SPR sensor setups: Attenuated total reflection [Kretschmann configuration(K-C)] and grating couplers (G-C). Moreover, we illustrate a comprehensive design rule to optimize the two detection methods: Resonant angle, Resonant wavelength and Thickness of metal in SPR sensor setups.



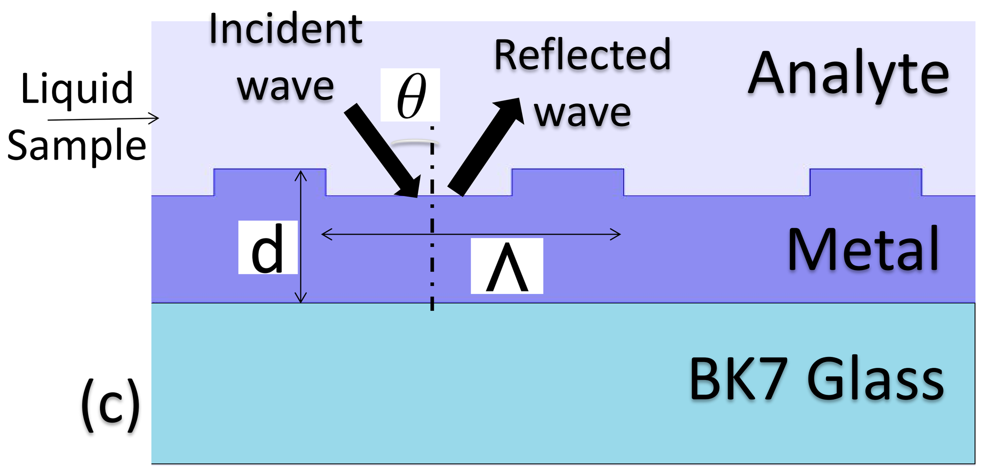
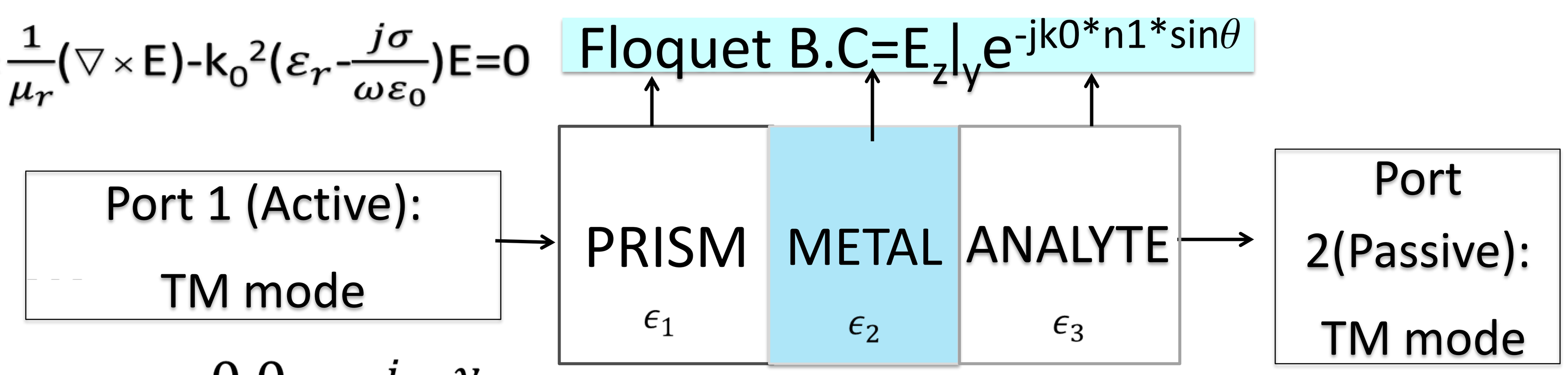




**Figure 1.** (a): Schematic design of SPR sensor. (b): Schematic diagram of Kretschmann configuration and (c): metallic grating coupled SPR sensor .

**COMSOL 2D Modeling**: We simulated a 2D model of a hetero-structure in which a metallic layer sandwiched between two dielectric claddings and we used Floquet and port (active and passive) based periodic boundary conditions(BC). Reflection (R.C), transmission (T.C) and Absorption coefficients (A.C) are calculated for three detection methods in both SPR sensor setups.

$$\nabla \times \frac{1}{\mu_r}(\nabla \times E) - k_0^2\left(\varepsilon_r - \frac{j\sigma}{\omega\varepsilon_0}\right)E = 0$$



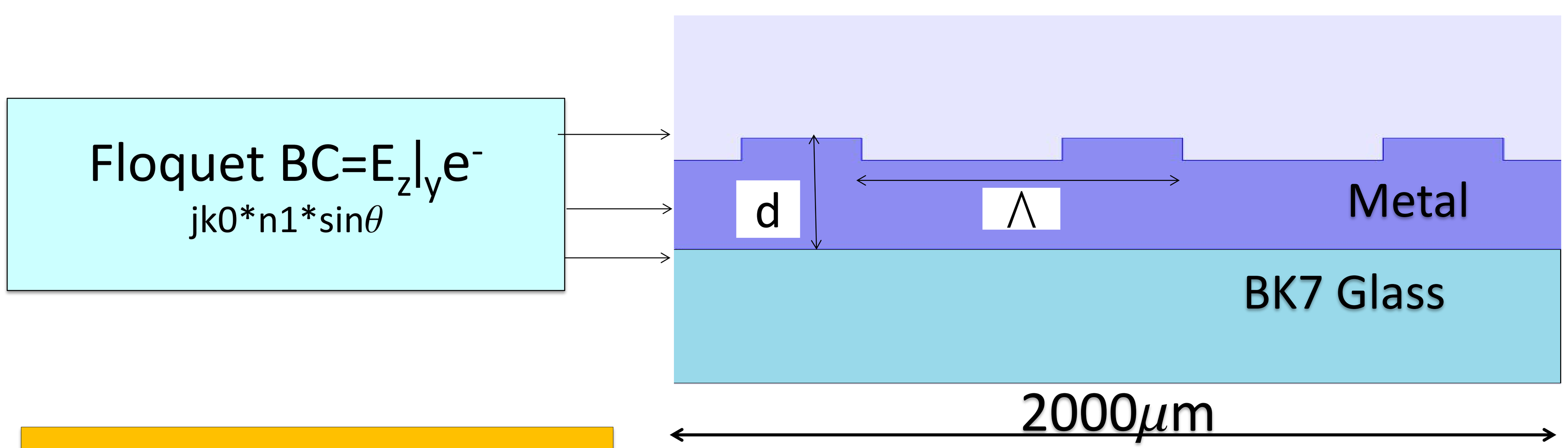

$$H_{TM} = [0, 0, e^{-jk_0 y}]$$

| Parameter | K-C | G-C |
|---|---|---|
| $\varepsilon_1$ | 3.02 (Dielectric Constant of Prism) | 2,25(BK-7 Glass) |
| $\varepsilon_2$(Dielectric Constant of Silver) | -16-0.5j | -16-0.5j |
| $\varepsilon_3$(Dielectric Constant of Protein) | User Dependent | User Dependent |
| d( Metal thickness) | 50 nm | 50 nm |
| $\lambda$(Wavelength) | 632nm | 632nm |
| $\Lambda$(Period) | - | 580nm |

$$S_{11} = \frac{\int_{port_1}((E_c - E_1).E_1)dA_1}{\int_{port_1}(E_1.E_1^*)dA_1} = R.C$$

$$S_{21} = \frac{\int_{port_2}(E_c.E_2^*)dA_1}{\int_{port_2}(E_2.E_2^*)dA_2} = T.C$$

$$A.C = 1 - (S_{11} + S_{21})$$




**Momentum Matching condition in G-C : Resonant Angle, Resonant Wavelength**

$$n * sin\theta + \left(m * \frac{\lambda}{\Lambda}\right) = \pm\left(\frac{\varepsilon_m * n^2}{\varepsilon_m + n^2}\right)^{\frac{1}{2}}$$

n= refractive index of analyte(protein); m=is an integer(0,±1,±2,..) indicating the diffracted order ; Λ= period of the grating; $\lambda$=Operating Wavelength;$\theta$ =Angle of Incidence, $\epsilon_m$: Dielectric constant of metal

**Momentum Matching condition in K-C : Resonant Angle, Resonant Wavelength**

$$k_0 n_p * sin\theta = k_0\left(\frac{\varepsilon_m * n^2}{\varepsilon_m + n^2}\right)^{\frac{1}{2}}$$

n= refractive index of analyte(protein); $k_0$=wave number(2*$\pi$/$\lambda$), where $\lambda$ denotes operating wavelength;$\theta$ =Angle of Incidence, $\epsilon_m$: Dielectric constant of metal;$n_p$=refractive index of prism.

**Results**:

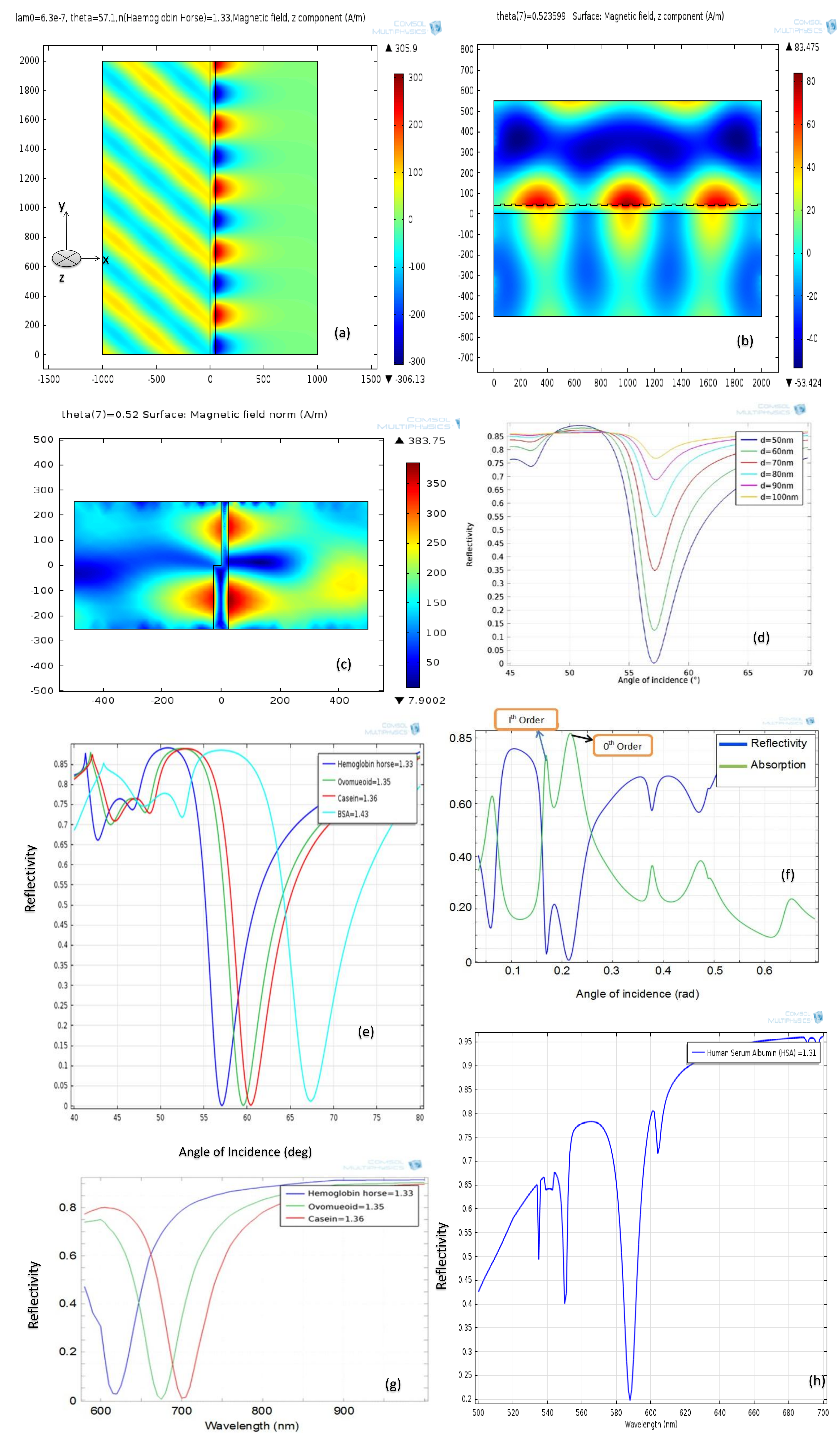


**Figure 2.** (a) Surface Plasmon (SP) generation for a K-C, and (b) in a G-C with 23 grating element,(c): SP resonance demonstration through single element with Floquet periodic B.C (d) Reflectivity as a function of the thickness of the metal with respect to the incidence angle calculated for the fibronegen protein (FIB) [5] in K-C. (e) Reflectivity as a function of the angle of incidence calculated at 632nm (Helium Neon Laser), various proteins (refractive indexes) were considered [4] in K-C (f) Reflectivity and absorption as a function of incidence angle for detecting HSA protein postulate by using grating coupler configuration. (g) Reflectivity as a function of wavelength calculated for various proteins in K-C, (h) Reflectivity as a function of wavelength for detecting HSA protein postulate in human blood sample using grating coupler configuration.

**Conclusions**: The results shows the generation of surface plasmon wave (SPW) in Kretschmann and grating coupler configuration. Moreover, from results we can see the sharp dip in the reflectivity curve due to resonant transfer of energy into SPW. Consequently, we can say that the resonant condition in which surface plasmons are excited depends on the change in the surrounding environment to the thin metal film. Furthermore, we suggested a design setup for detecting a protein postulates in blood sample with respect to the incident angle, wavelength and thickness of metal film as shown in fig. 2(d,e,f,g,h) .

**References**:

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