Surface plasmon tunable filter and flat panel display device

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Surface plasmon tunable filter (SPTF) is a new technology underdevelopment at Jet Propulsion Lab. I had discussed the theoretical model and possible applications of using surface plasmon tunable filters for flat panel display device in several SPIE meetings. Now a prototype of surface plasmon tunable filter has been fabricated at JPL, and the experiment measurement will be discussed in this paper.

Keywords: surface plasmon, tunable filter, flat panel display, LCD

The surface plasmon has been studied since the 1960's. It can be described as a collective oscillation in electron density at the interface of a metal and a dielectric. At surface plasmon resonance, the reflected light vanishes. This resonance is referred to as attenuated total reflection, and is dependent upon the dielectric constant of both the metal and the dielectric. If an electro-optical (EO) material is used as the dielectric and a voltage is applied to change the surface plasmon resonance condition, the reflected light can be modulated[1]. A surface plasmon laser light modulator with a contrast ratio greater than 100:1 has been reported[2].

If we consider the surface plasmon light modulator in the frequency space, the photons at surface plasmon resonance will be absorbed and the photons out of the resonance will be totally reflected. If a voltage is applied on the EO material, the index of refraction of the EO material will change, the surface plasmon resonance frequency will change, therefore the reflection spectrum can be controlled by the applied voltage, and an electronically tunable notch color filter is formed[3]. Experiment has shown when a 30-v voltage is applied on a surface plasmon tunable notch color filter, the resonance frequency can be shifted from red (640 nm) to blue (450 nm).

In 1996, the SP tunable bandpass filter using coupled SP waves was invented at JPL[4,5]. The structure of this SP tunable bandpass filter is shown in Fig. 1. A symmetric geometry of metal/dielectric/metal is employed. Two glass prisms are used for the coupling. A thin metal film is evaporated on each prism respectively. A thin EO material layer or an air gap is sandwiched by the two prisms. The dielectric layer is in the order of wavelength. When a SP wave is excited on one side of metal/dielectric material interface by the incident photons, the energy of resonance photons will be converted into film. And the optical field will penetrate the thin dielectric layer and excite another SP wave with the same frequency at the other dielectric/metal interface because of the symmetric structure. The resonance photons then will be re- radiated out as the transmitted light. When the coupling mechanism is changed by an index change (if an EO material is used), or by a thickness change (if an air gap is used), the SP resonance frequency will change, and the transmission spectrum will change.

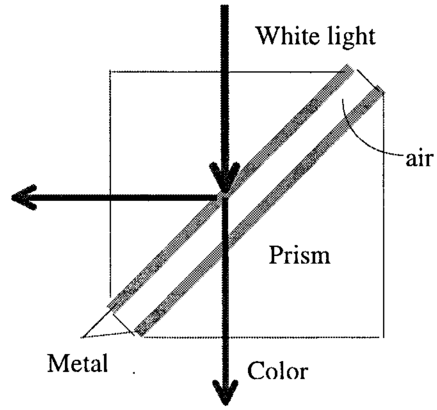

Fig. 1 Structure of surface plasmon tunable filter (SPTF).

Though looks like Fabry-Perot tunable filter, the physics of SPTF is totally different with Fabry-Perot tunable filter. Here two evanescent waves are coupled together instead of two traveling eaves. Therefore, the tunable range is net limited by frequendy double like Fabry-Perot tunable filters. Fig. 2 shows a theoretical calculation of transmission versus wavelength of the air gap SPTF and its effective tuning ability. Using silver as the metal films, when the thickness of the air gap changes from 300 nm to 5000 nm, the peak transmission shifts from 400 nm to 1600 nm.

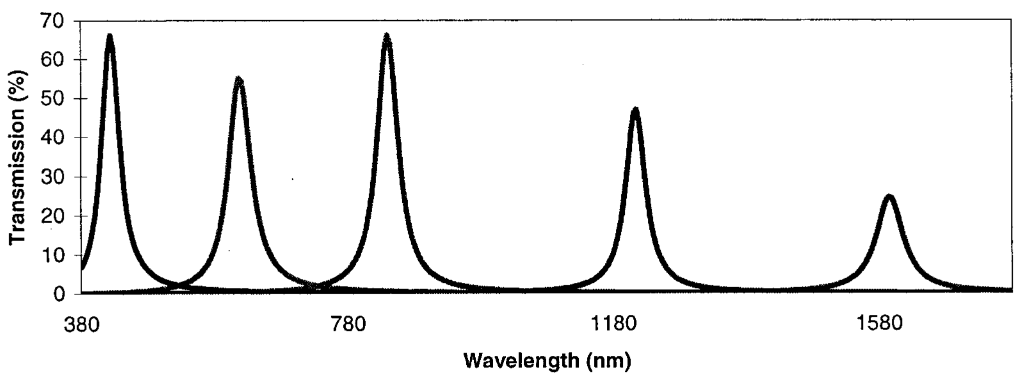

Fig. 2. Tuning ability of the air gap SPTF.

The first experiment of SPTF had proved the theory quantitatively. Two BK-7 glass prisms with a 400 angstrom silver coating on the hypotenuse were separated by an air gap. The air cap is controlled by three AE0203D8 pizeo-electric spacers manufactured by NED. The size of the device is about 6 cm x 6 cm x 5cm.

Test result of the prototype sample is shown in Fig. 3. The x-axis is applied voltage while the y-axis is the transmission intensity. When applied voltage increased from zero to 90-v, the peak transmission shifted form 625nm to 450 nm.

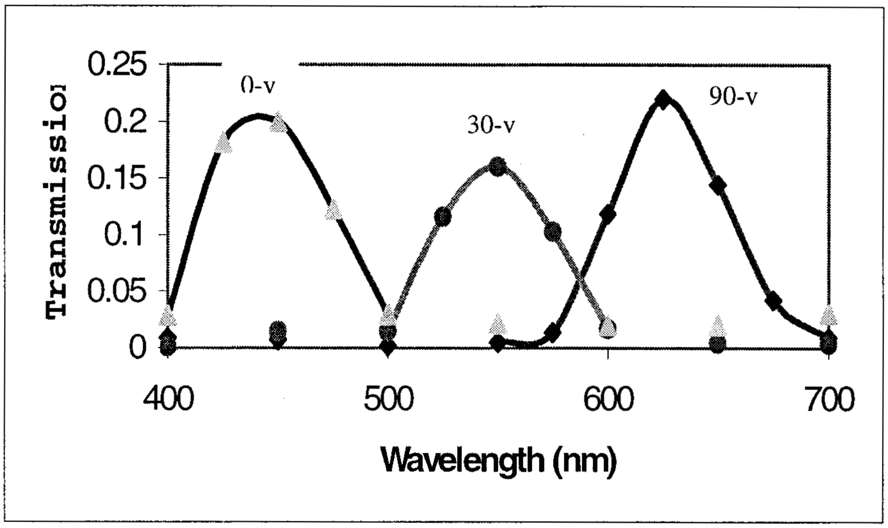

Fig.3. Experiment result of SPTF.

The experiment result showed a lower peak transmission (~20%), in comparison to the theoretical calculation predicts a peak transmission over 60%. Cause of this discrepancy is that the metal films were not prepared under an optimum condition. This led to bigger imaginary part of the dielectric constant of the metal film for which causes a lower transmission peak. This problem will be solved by carefully choosing the evaporation conditions. The about 90-v driving voltage will be reduced to about 10-v in future device by using another mechanical design without strong springs.

Being a fast switching device, and able to generate field sequential red, green and blue colors, surface plasmon tunable filter can be used for both projection and direct view display devices[6,7,8]. For single panel projection display, the surface plasmon tunable filter can be used to replace the color wheel to generate the field sequential red, green and blue colors to shine on either a liquid crystal display panel or a digital micro-mirror device to generate a color image.

When applying to LCD projectors, SPTF can simplify the system structure, and enhance the efficiency. A scrolling SPTF which consists three SPTFs can generate scrolling red, green and blue colors, is able to enhance the efficiency of a single panel LCD projector up to the same level as a three panel LCD projector. A scrolling SPTF which consists six SPTFs and can generate two set of scrolling RGB colors, will enable a single panel LCD projector to be 100% more efficiency than the current three panel LCD projector[9].

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