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# Comment on "Large negative lateral shifts from the Kretschmann-Raether configuration with left-handed materials" [Appl. Phys. Lett. 87, 221102 (2005)]

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The negative shifts seen by Wang and Zhu [Appl. Phys. Lett. **87**, 221102 (2005)] are not due to the excitation of surface plasmons but to leaky modes of the slab propagating backward. Provided the characteristics of the left-handed material slab are chosen correctly, it is shown that a leaky surface plasmon can actually be excited using the Kretschmann-Raether configuration.
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In a recent letter,[1] Wang and Zhu studied the negative lateral shift of a beam reflected by a thin slab of left-handed material (LHM) in the Kretschmann-Raether (KR) configuration. They claimed that an "unusual standing wave" is responsible for this negative shift, and that this standing wave "becomes a surface wave." However, the authors studied a structure in conditions that could in no way allow to excite surface plasmons. For an interface between air and a LHM characterized by $\epsilon_2<0$ and $\mu_2<0$, a surface plasmon can exist,[2,3] provided (i) the propagation constant $\alpha$ along the interface is greater than $\sqrt{\epsilon_2\mu_2}k_0$ and $k_0$, which means that the field is evanescent in the two media and (ii) either $|\mu_2|<1$ and $\epsilon_2\mu_2>1$ (this case corresponds to a backward surface wave) or $|\mu_2|>1$ and $\epsilon_2\mu_2<1$ (forward surface wave). The dispersion relation of the surface plasmon is given by

$$\alpha_p = k\sqrt{\mu_2\frac{\epsilon_2-\mu_2}{1-\mu_2^2}}. \tag{1}$$

In their study of the KR configuration, Wang and Zhu (i) have propagative waves in the LHM medium since they take $k_0<\alpha<\sqrt{\epsilon_2\mu_2}k_0$ and (ii) have chosen $\epsilon_2=-5$ and $\mu_2=-1$. It is completely impossible to excite a surface wave in these conditions.

We attribute the observed lateral shifts to leaky modes of the slab. It has been shown that when a Fabry-Pérot resonance of the slab is excited by an incident beam with an incidence angle $\theta\neq 0$, it gives birth to a leaky mode of the slab[4] although this is not well known. Leaky modes are responsible for large lateral shifts.[4–6] In our case, the LHM slab supports a *backward* leaky mode,[5] which explains why the shift is found to be negative. The leaky mode cannot of course be seen using a plane wave analysis.[5] Figure 1 shows the result of our simulations: an incident beam with an incidence angle of 37.8° is reflected by a LHM slab. The leaky mode is clearly propagating towards the left and its amplitude is exponentially decreasing in this direction. This result is both new and interesting, but no surface resonance is involved in this phenomenon.

Let us now consider a configuration for which a backward surface plasmon may *a priori* be excited. We take $\epsilon_1=12$, $\mu_1=1$, $\epsilon_2=-5$ and $\mu_2=-0.5$ and $d=0.6\lambda$. No slab resonance can be excited in these conditions because the slab is too thin. The lateral shift for this configuration is represented Fig. 2. A very large negative shift can be seen for $\theta\simeq 29.94°$ when $\alpha\simeq\alpha_p$. This shift is even greater than in the case of slab resonances because the plasmon is less leaky and hence it propagates further. Let us stress that the field is evanescent in the LHM ($\sqrt{\epsilon_2\mu_2}k_0<\alpha$) and in the air so that this resonance is without any doubt a surface plasmon.

FIG. 1. (Color online) Modulus of the electric field when a leaky slab resonance is excited by an incident gaussian beam coming from the left.

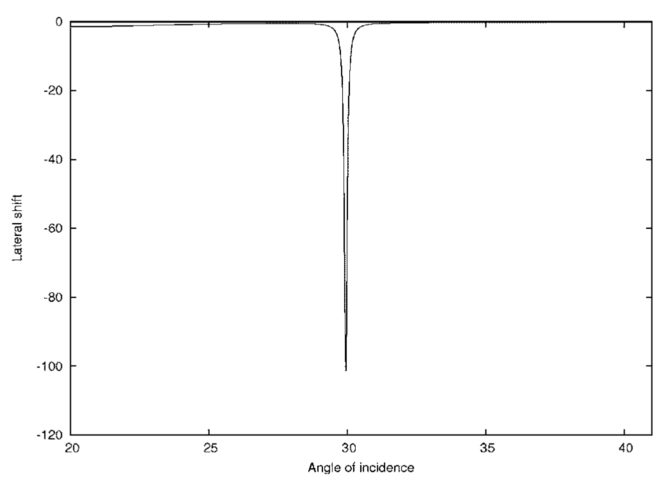


FIG. 2. (Color online) Lateral shift $\Delta/\lambda$ (Ref. 1 and 7) vs. the angle of incidence for $\epsilon_1=12$, $\mu_1=1$, $\epsilon_2=-5$, $\mu_2=-0.5$ and $d=0.6\lambda$. The angle above which the field is evanescent in the LHM is 27.16°.

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We came to the conclusion that the negative shifts seen by Wang and Zhu are not due to the excitation of surface plasmons but to leaky modes of the slab[4,5] propagating *backward*—which is an interesting result. Provided the characteristics of the LHM slab are chosen correctly, we showed that it is possible to excite a leaky surface plasmon[8] using the KR configuration.

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