Bragg reflector enhanced attenuated total reflectance

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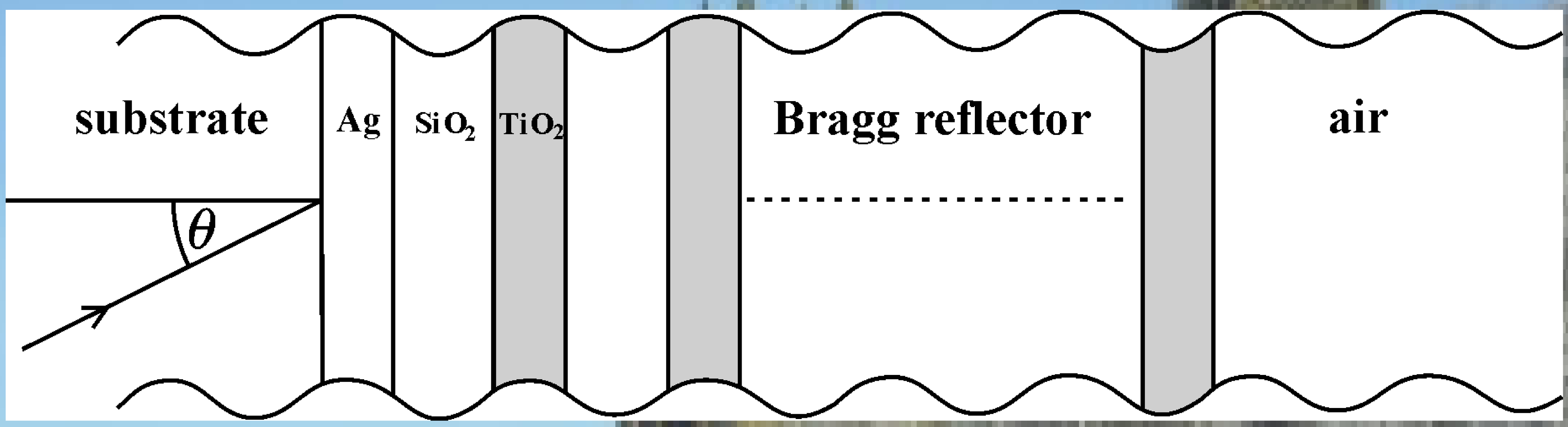
We model the effects of a quasi-bound photonic state that can exist within a substrate/metal film/Bragg reflector/air structure. The photonic state is confined as a result of total internal reflection at the air interface coupled with the effect of the photonic band gap of the Bragg reflector. The presence of the thin metallic film ensures that distinctive features are observable in the associated reflectivity spectrum. With an appropriately chosen metal layer thickness, light is able to penetrate into the structure but is then effectively trapped, leading to a greatly increased field intensity at the air interface and an associated sharp feature in the reflectivity. The sensitivity of the reflectivity feature to structural details and angle of incidence and the property of substantial field enhancement suggest that the structure could be of use in sensor/detector technology and non-linear optics applications.

[See J. Appl. Phys. Vol. 106 Article no. 113109 (2009) for more details of this work.]

FIG. 1 The basic structure employed in the calculations, consisting of a left-hand substrate (SiO_2 in this case) with a thin silver (Ag) overlayer and a SiO_2 /TiO_2 Bragg reflector (BR) on top. For the reflection coefficient calculation light is incident at an angle θ from the left. The refractive indices of SiO_2 and TiO_2 are taken to be 1.47 and 2.37 respectively.



For silver we take $\varepsilon(\omega) = 1 - \dfrac{\omega_p^2}{\omega(\omega + i\omega_c)}$ **with a plasma frequency, ω_p such that the associated energy is 7.2 eV and with collision frequency, ω_c which determines the losses in the metal, with equivalent energy of 0.05 eV.**

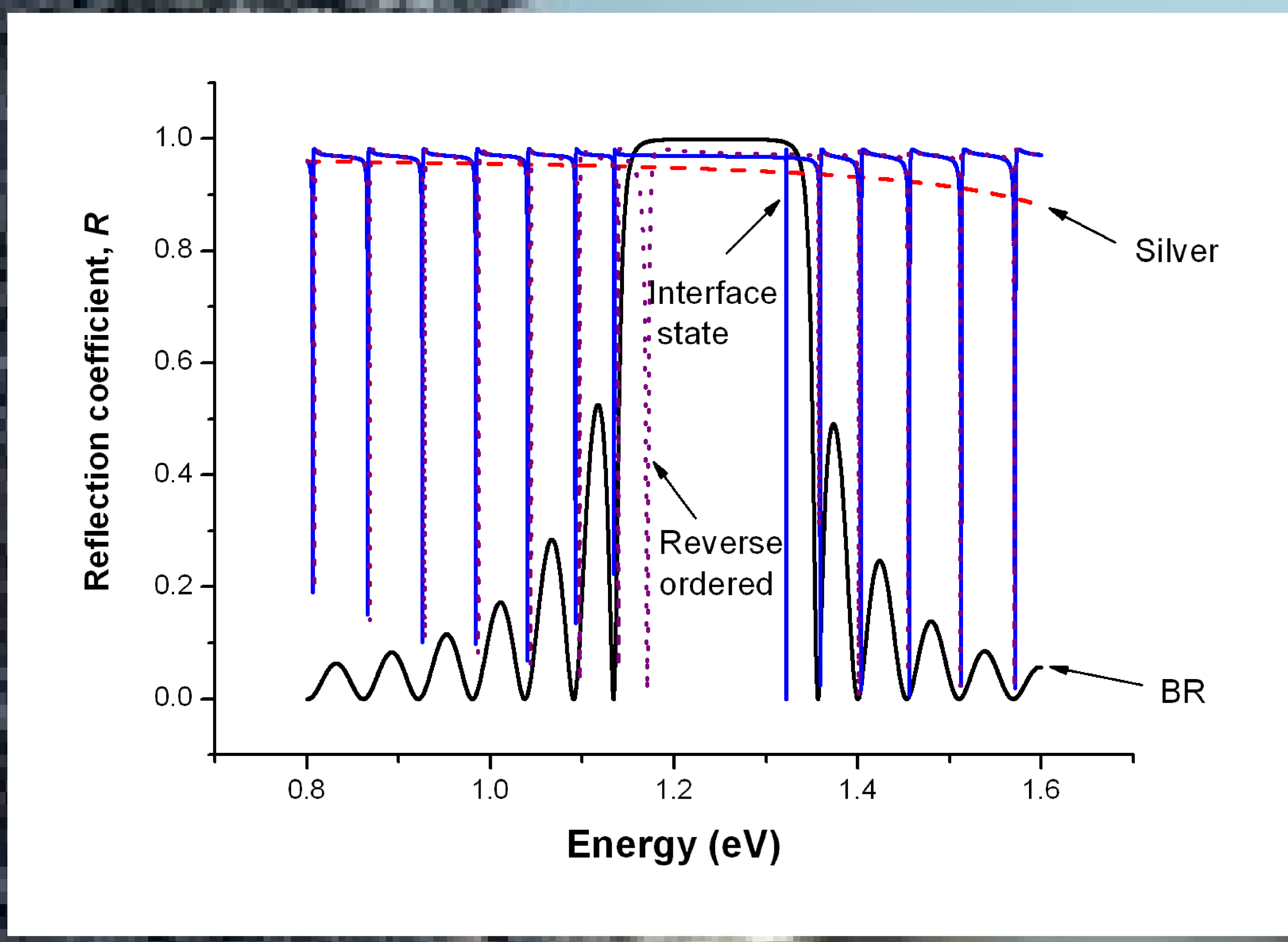


FIG. 2 The reflection coefficient as a function of energy with light incident from the SiO_2 substrate at an angle of $\theta = 45°$. The plot labelled BR corresponds to that for a 40- layer SiO_2 /TiO_2 stack surrounded by SiO_2 on both the left and right. Results for light impinging on a single 57 nm layer of silver followed by air are shown by the dashed line. There are two other curves. One is for the model structure with a SiO_2 layer adjacent to the silver layer and clearly indicates the existence of an interface state at 1.32 eV. For comparison the results for the reverse-ordered BR structure consisting of a 40-layer Bragg reflector with a high index TiO_2 layer adjacent to the silver are also shown.

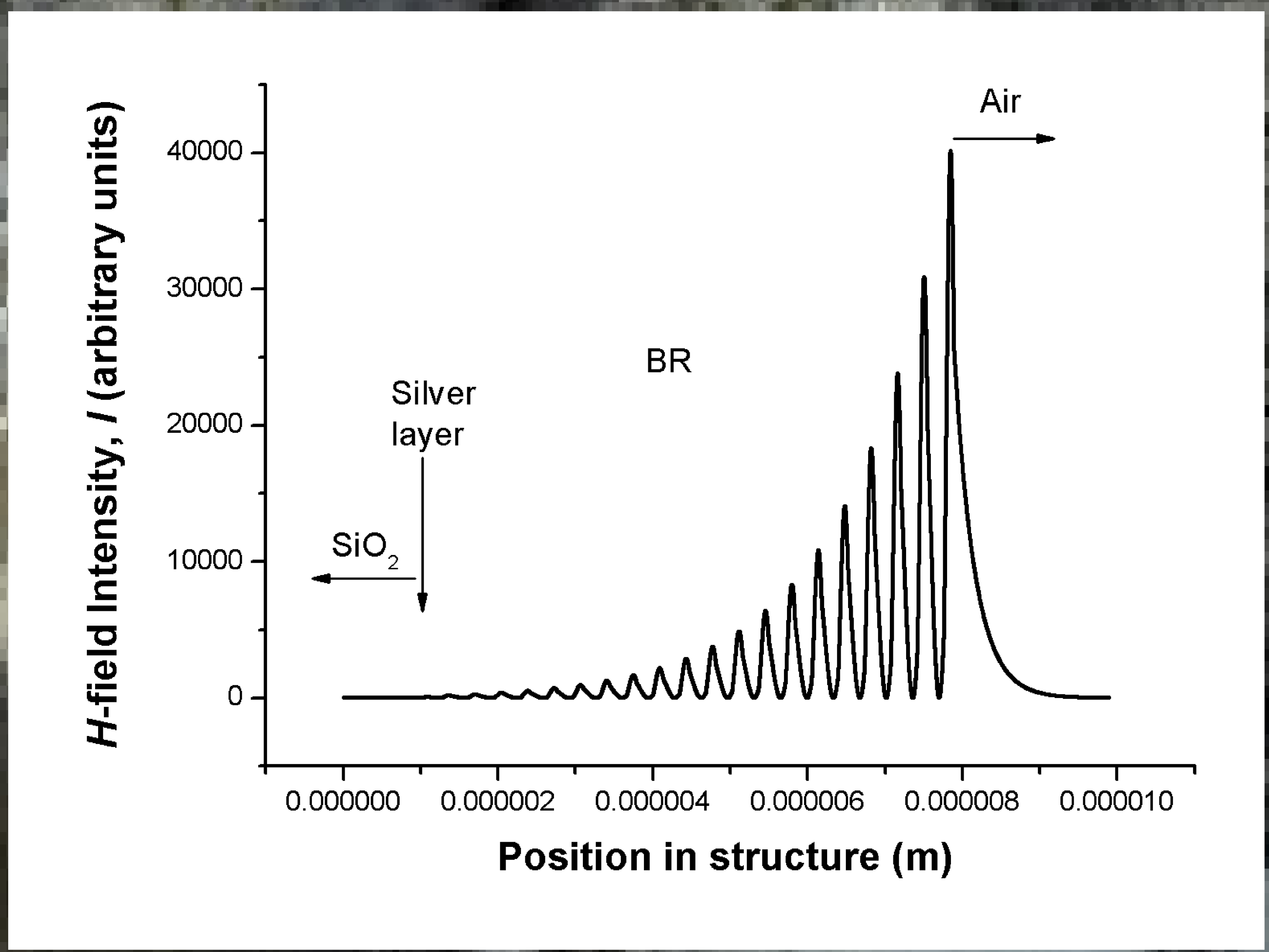


FIG. 3 The time-averaged *H*-field intensity associated with the 1.32 eV interface state. The region considered is composed of 1000 nm of SiO_2 substrate, 57 nm of silver and 20 pairs of SiO_2/TiO_2 layers giving a 6833 nm wide Bragg reflector and with a 2000 nm region of air on the right.

A 57 nm wide layer of silver is chosen because this leads to a situation in which there is almost no detectable reflected wave from the structure and the system is tuned such that virtually all of the incoming energy is dissipated within the metallic layer. Further increase in metal layer thickness leads to a more confined quasi-bound interface state but it becomes more difficult to access the state and so the reflectivity increases. Layers thinner than 57 nm give rise to an increase in reflectivity,decreased confinement and a broadening of the reflectivity feature.

To summarize, we propose a Bragg-reflector-related structure in which the associated quasi-bound photonic state leads to a distinctive narrow feature in the reflectivity spectrum and a high field intensity at the externally accessible interface. This feature is much sharper and gives rise to a much greater field intensity than would be experienced in the case of a standard attenuated total reflection experiment without the Bragg reflector, or with the Bragg reflector in the absence of the metal layer. This suggests that the structure may have applications for sensor/detector or non-linear optics applications, as the nature of the resultant interface state and the consequent features in the reflectivity are sensitive to conditions at the external interface. The structure acts as a highly selective notch filter which can be designed to absorb virtually all of the incoming energy at a particular energy and this may also have useful applications. The materials employed and thicknesses of all layers in the structure, as well as the angle of incidence considered, can be adjusted in order to tune the response of the structure.

**All results are for TM polarisation with *H* polarised parallel to the interfaces.
The Bragg reflector is designed such that the centre of the photonic band gap is at 1 eV at normal incidence.
Calculations are performed using the transfer matrix method.**