Bloch Surface Waves Fabry- Pérot Nanocavity

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Abstract. We demonstrate the first cavity confinement of Bloch surface waves in the fundamental mode of a Fabry–Pérot cavity. The cavity consists of two distributed Bragg mirrors separated by a spacer of dimensions smaller than the wavelength (633nm). The cavity mode exhibits quality factor of 400. This quality factor is the highest recorded thus far for a subwavelength optical surface waves cavity.

1. Introduction
The capacity to confine optical surface waves within a cavity has been the subject of intensive research over the last years. This research is motivated by the strong light matter interactions that such a configuration can enable. However most of the efforts have been focused on the confinement of surface plasmon polaritons (SPPs) [1-4]. Recently another type of optical surface waves named Bloch surface waves (BSWs) received a lot of interest [5-8]. Bloch surface waves are electromagnetic modes that can be excited on the surface of an all-dielectric multilayer stack. Because they can be made of dielectric materials, they do not suffer from metal absorption and can theoretically offer higher quality factors if confined. Cavity confinement of BSWs has been studied both theoretically [9] and experimentally [10,11]. However, the confinement of BSWs in the fundamental mode of a cavity has not been achieved yet.

In this work we report on the first subwavelength confinement of BSWs in a Fabry–Pérot type nanocavity. We demonstrate that the dielectric nature of BSWs leads to higher Q-factors compared to SPPs nanocavities.

2. BSW multilayer platform and cavity design
Figure 1 is a schematic representation of the Fabry–Pérot type nanocavity on the top of the BSW multilayer substrate. The cavity consists of high reflectivity distributed Bragg reflectors (DBR) separated by a subwavelength spacer. The multilayer substrate is designed to support transverse electric (TE) polarization of surface waves in the visible spectrum. It includes six layer pairs of silicon dioxide (SiO$_2$) and silicon nitride (SiN$_x$) with respective thicknesses of 159 and 118 nm. An additional 42 nm thin SiN$_x$ defect layer terminates the multilayer periodicity and creates an allowed energy level inside the forbidden band of the multilayer stack. To realize the cavity mode, we introduce 100 nm ZEP on top of the multilayer structure. Figure 2 shows the dispersion diagrams correspond to the multilayer with and without 100 nm ZEP. The effective refractive index value is calculated to be 1.258 for multilayer and 1.389 for multilayer + 100 nm ZEP. The fundamental cavity mode design parameters (as shown in Fig. 1) are calculated using the effective refractive index values.
FIGURE 1. Schematic representation of the Fabry–Pérot cavity designed on a dielectric multilayer substrate. The 252 nm spacer is designed to support the fundamental resonance mode in the visible spectrum.

The multilayer stack is fabricated using standard plasma-enhanced chemical vapor deposition (PECVD). The electron beam lithography is used to transfer the Fabry–Pérot type cavity to the ZEP layer.

FIGURE 2. Dispersion diagram of the designed BSW substrate with/without 100 nm thin ZEP layer.

3. Results and discussions
A tunable light source in the visible spectrum with an appropriate coupling angle is illuminated to the left most edge of the entrance DBR using a Kretschmann coupling configuration. We use an optical spectrum analyzer (OSA) to measure the resonance spectrum and quality factor of the cavity. Figure 3 depicts the spectrum collected from the cavity. The constructive interference between Bloch surface waves being reflected back and forth by the DBRs lead to the formation of a standing waves, i.e. a resonance, at 627.8 nm wavelength. As can be seen from this figure, a Q-factor as high as 400 can be directly obtained by measuring the linewidth of the spectrum. To our knowledge, this is the highest Q reported for a fundamental surface wave cavity mode.
FIGURE 3. Spectrum of the BSW-based Fabry–Pérot nanocavity. A sharp resonance (1.56 nm linewidth) is observed at λ=627.8 nm and corresponding to a quality factor of ~ 400.

4. Conclusion
In summary, we experimentally demonstrate the first high quality factor fundamental mode cavity confinement of an optical surface wave. We show that the optical surface waves can be confined between two distributed Bragg reflectors separated by a subwavelength spacer. The surface waves are confined with a high quality factor of up to 400. This value is greater than reported quality factors for surface plasmon polaritons which is attributed to the dielectric nature of Bloch surface waves.

Acknowledgments
This research is supported by the Swiss National Science Foundation (SNSF FN200020-135455).

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