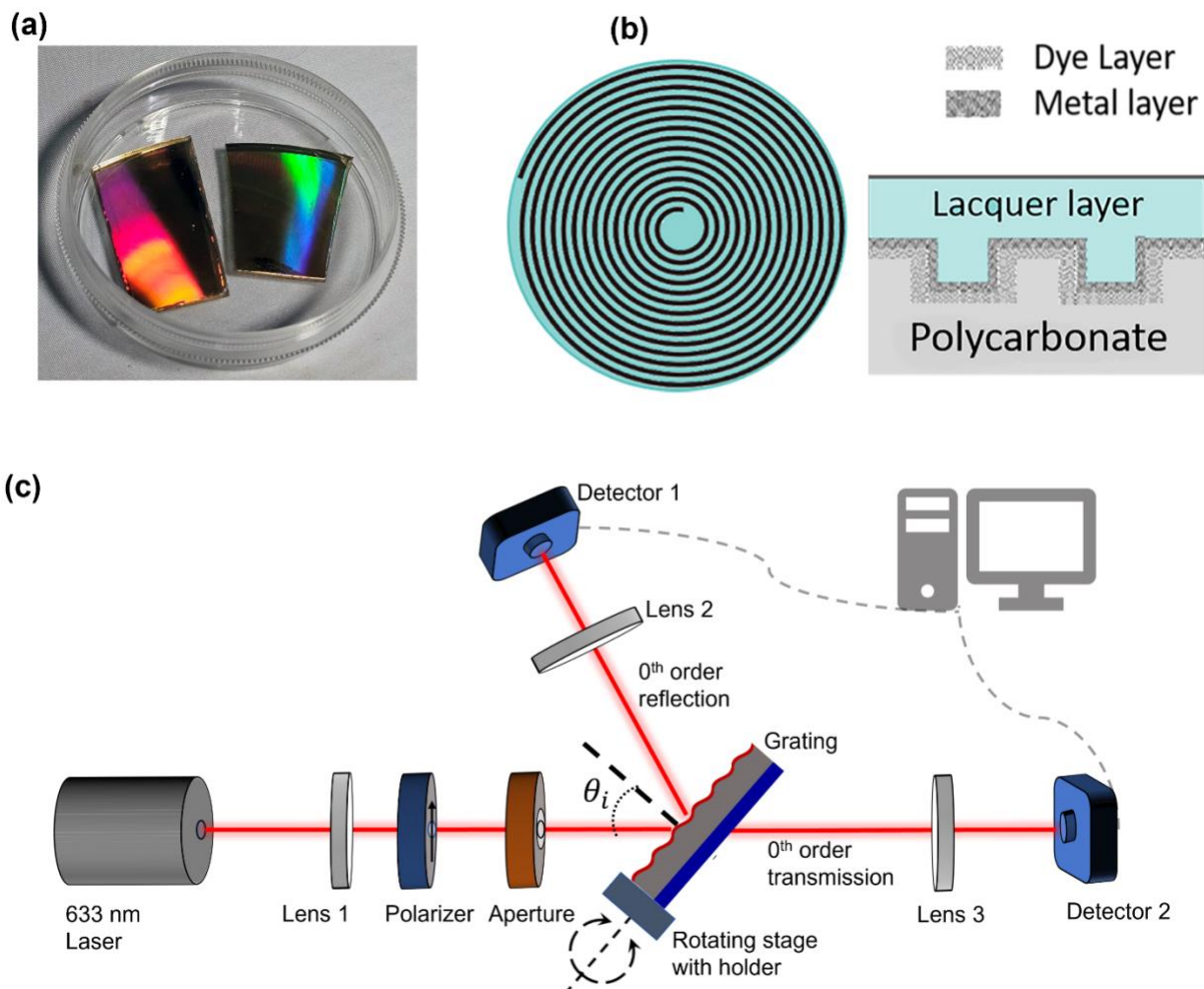


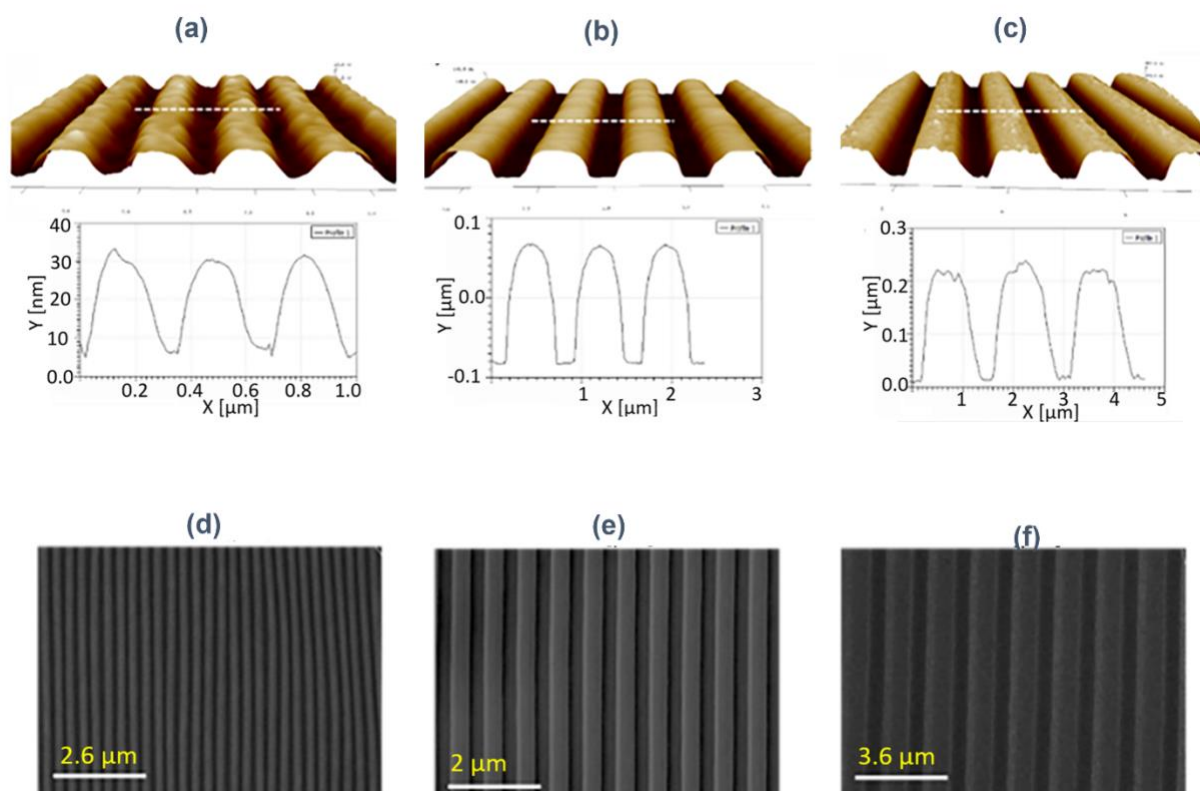
Supplementary Information

Figure S1



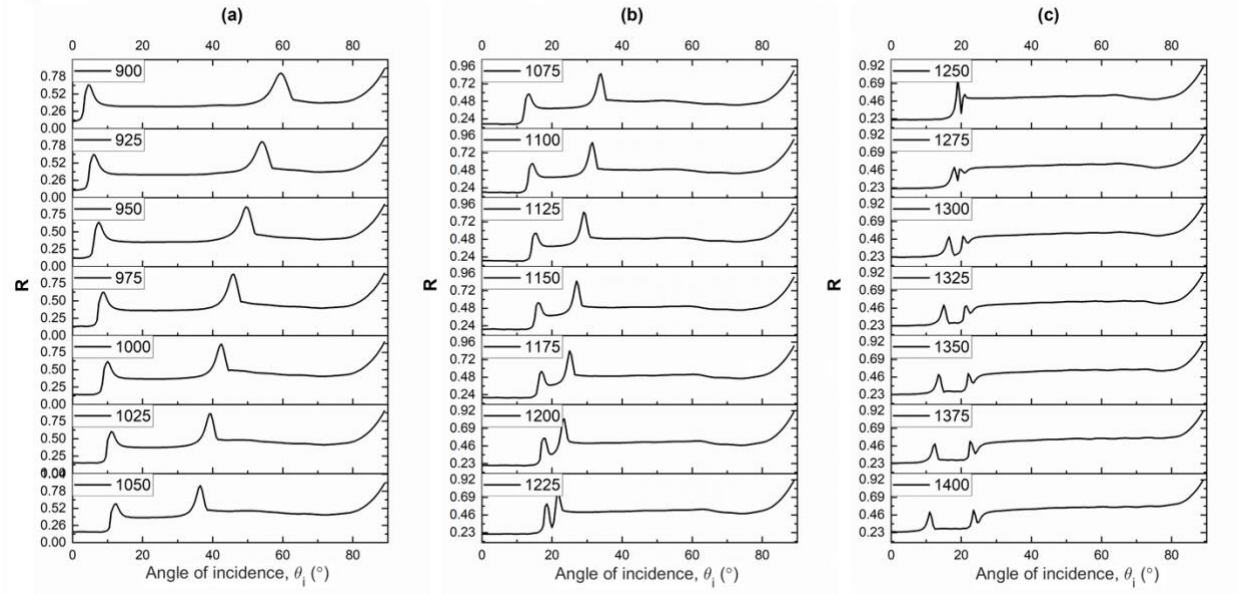
S1. Commercial optical discs (OD) as substrates for grating-coupled surface plasmon excitation. (a) The photograph of gold-coated gratings prepared using ODs. (b) The illustration of the top view and cross-sectional structure of a commercial OD (c) Schematic showing the experimental set-up used for the angle interrogation of GCSPP.

Figure S2

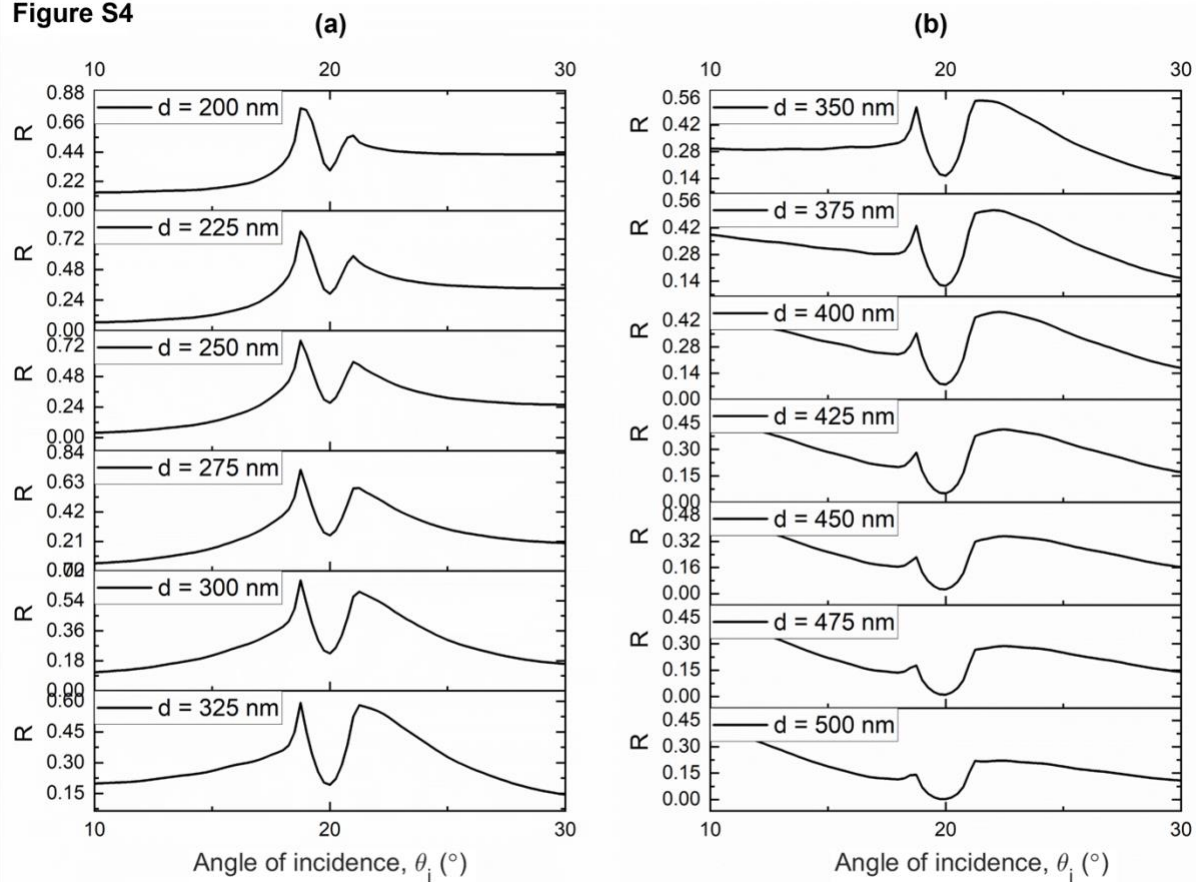


S2. AFM and SEM characterization of the three optical discs. Atomic Force Microscopy (AFM) images showing 3D topography of (a) BD, (b) DVD, and (c) CD. The respective cross-sectional profiles are shown underneath. Scanning Electron Microscope (SEM) images showing the top view of a (d) BD, (e) DVD, and (f) CD respectively. Magnetic field intensity calculated at the SPR condition for a sinusoidal ($\Lambda = 320 \text{ nm}$) and metal-dielectric grating. (Bruker Dimension Icon, Nanoscope 9.7, URL: www.brukersupport.com)

Figure S3

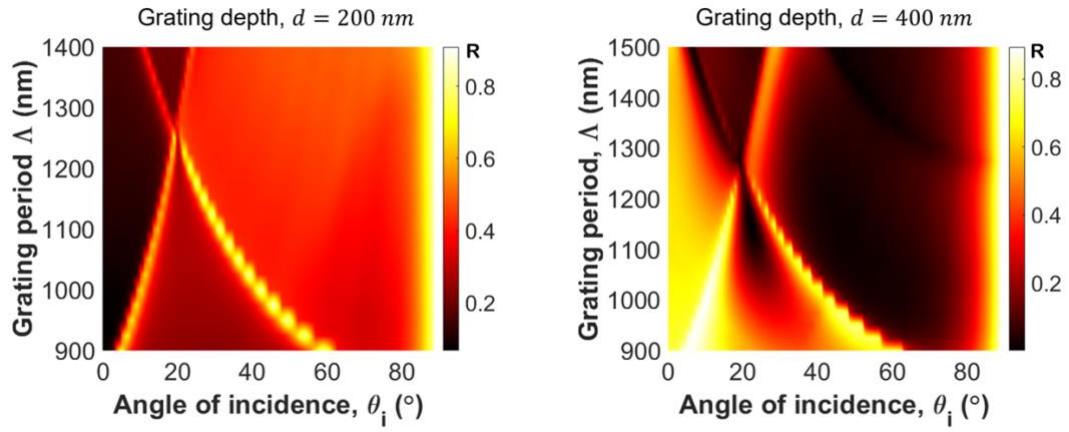


S3. Stacked plots showing the evolution of SPR reflection band with grating period ($900 \text{ nm} \leq \Lambda \leq 1400 \text{ nm}$) for the grating depth $d = 180 \text{ nm}$ at the excitation wavelength $\lambda = 850 \text{ nm}$.

Figure S4

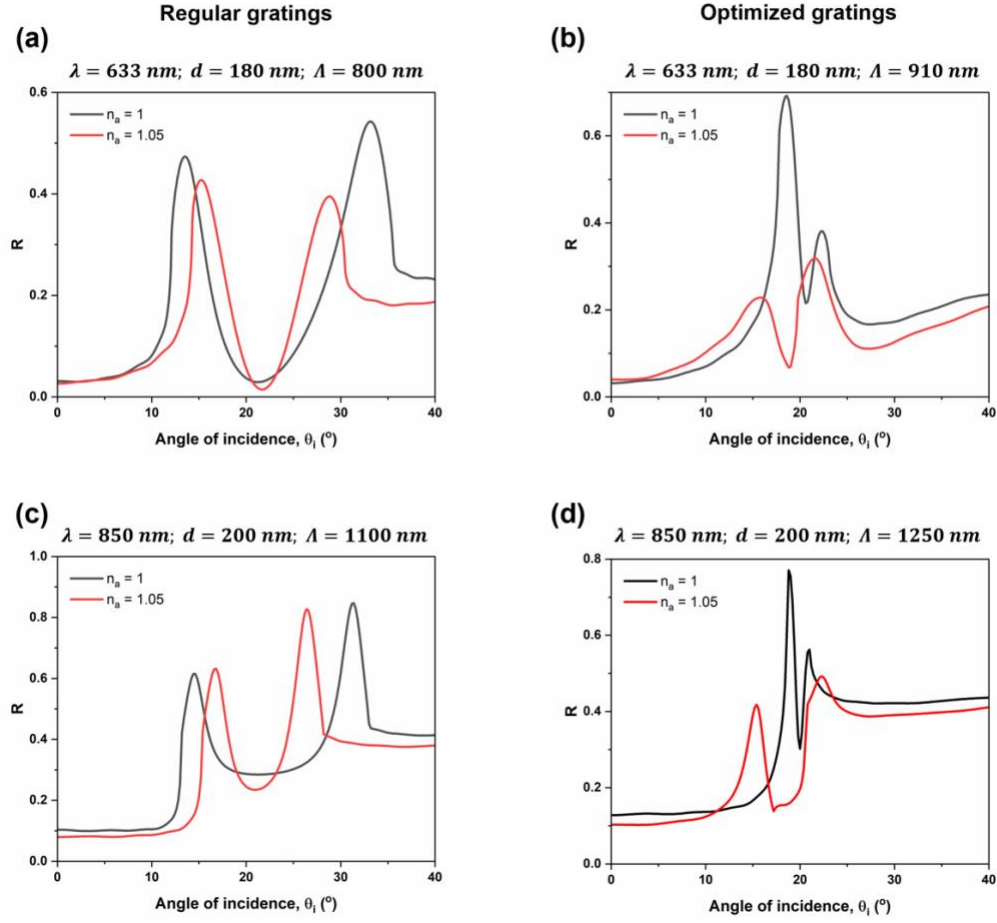
S4. Stacked plots showing the SPR reflection band reduction for very large grating depths ($200 \text{ nm} \leq d \leq 500 \text{ nm}$) (band width reduction occurrence for the grating period $\Lambda = 1250 \text{ nm}$ at the excitation wavelength $\lambda = 850 \text{ nm}$).

Figure S5



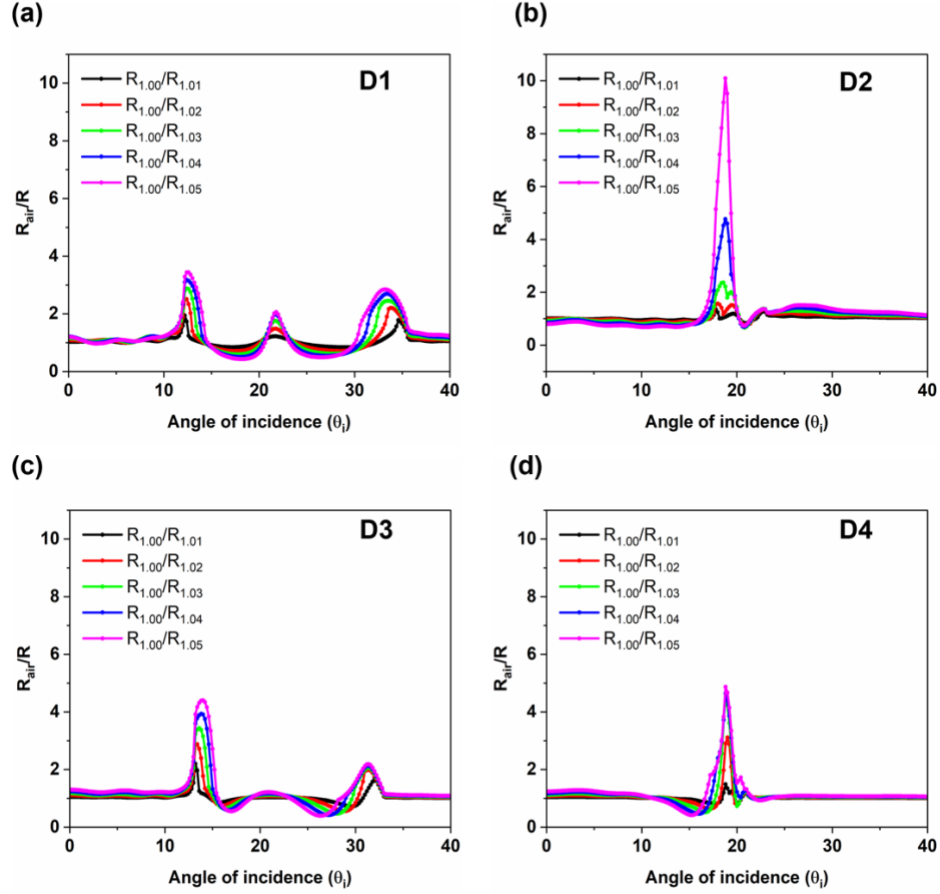
S5. 2D reflection maps showing the reflection bandgap closure for the grating period $\Lambda = 1250 \text{ nm}$ at the excitation wavelength $\lambda = 850 \text{ nm}$, when (a) grating depth $d = 200 \text{ nm}$, and (b) grating depth $d = 400 \text{ nm}$. (MATLAB R2022b, URL: www.mathworks.com)

Figure S6



S6. Angular sensing performance comparison of optimized and unoptimized gratings with large modulation depths at two distinct operating wavelengths. The black curves represent the angular reflection response when the incident medium is air ($n = 1$), while the red curves correspond to the response when the refractive index of the medium increases by 5% ($n = 1.05$). Reflection responses are shown for: (a) regular grating D1 and (b) optimized grating D2 at an operating wavelength of 633 nm; and (c) regular grating D3 and (d) optimized grating D4 at an operating wavelength of 850 nm.

Figure S7



S7. Reflection intensity-ratio-based performance comparison of optimized and unoptimized gratings with large modulation depths at two distinct operating wavelengths. The colored curves represent the ratio of the reference reflection response at $n = 1$ (air) to the reflection response when the refractive index of the medium is varied from 1.00 to 1.05. Shown are the reflection ratios for: (a) regular grating D1 and (b) optimized grating D2 at an operating wavelength of 633 nm; and (c) regular grating D3 and (d) optimized grating D4 at an operating wavelength of 850 nm.

Discussions of S6 and S7. To demonstrate the utility of our optimization analysis, we compare the angular responses of grating devices with large grating modulation depths—considering regular and optimized grating periods, for a given grating depth and operating wavelength combination. We examine four GCSPR device cases: D1 with a grating period of $\Lambda = 800$ nm, grating depth $d =$

180 nm, and operating wavelength of 633 nm; D2 with the corresponding optimized period of $\Lambda = 910$ nm; D3 with a grating period of $\Lambda = 1100$ nm, grating depth $d = 200$ nm, and operating wavelength of 1250 nm; D4 with the corresponding optimized period of $\Lambda = 1250$ nm. Sensitivity (S) and figure of merit (FOM) performances of these devices were evaluated based on the angular shift in the reflection dip corresponding to a 5% change in refractive index n ($\Delta n = 0.05$, from 1.00 to 1.05).

Supplementary Fig. S6 shows a comparison of the angular responses of regular and optimized geometries. D1 exhibits a $FWHM$ of 12.9° , whereas the corresponding optimized geometry D2 yields a narrow $FWHM$ of 1.4° at an operating wavelength of 633 nm (S6 a–b). For gratings operating in the NIR wavelength range, D3 shows a broad $FWHM$ of 13.2° , while the optimized geometry D4 yields an ultra-narrow bandwidth of 0.8° (S6 c–d). This significant reduction in angular bandwidth results in an improvement in the figure of merit (FOM) and detection accuracy (DA) by an order of magnitude, even though the angular sensitivities remain comparable. The achievable sensitivity is inherently constrained by the relative permittivities of the metal and sensing medium, as well as by the wavelength of interrogation, which fundamentally limits the sensitivity for a given geometry—for example, the uniform sinusoidal single-metallic grating considered in this work. Therefore, by precisely optimizing the grating geometry to achieve ultra-narrow angular bandwidths, the overall performance of the angular interrogation sensing device is enhanced, even under conditions of large grating modulation depths.

Furthermore, we used the change in the ratio of reflection intensity with refractive index as an additional metric for comparing the performance of optimized and unoptimized geometries. The drop in intensity at the side peak position, expressed as a fraction of the initial intensity, serves as a direct indicator of refractive index variation. This approach is particularly useful when there is a

significant change in the sensing signal intensity in response to a small change in the refractive index of the sensing medium. Supplementary Fig. S7 compares the reflection intensity ratio–based sensing performance of regular and optimized grating geometries when the refractive index of the incident medium is varied from 1 to 1.05. The ratios for optimized geometries D2 and D4 exhibit maxima centered at 18.8° , which corresponds to the position of the dominant side peak when the incident medium is air ($n = 1$). For D2, the maximum ratio for a 5% refractive index change is 9.17, while for D4, the maximum ratio is 4.87. By leveraging the pronounced intensity fluctuations occurring at the side peaks near the reflection bandgap closure, we demonstrate that the optimized geometries are suitable for reflection intensity–based sensing schemes as well.