Grating metasurfaces as directional plasmon sources: applications in achiral and chiral sensing

G. Serrera*, J. González-Colsa, F. González, F. Moreno, J. M. Saiz & P. Albella**
Department of Applied Physics, Universidad de Cantabria
Email: * guillermo.serrera@alumnos.unican.es ; ** albellap@unican.es

3PM 2021 PHONONICS PHOTONICS PLASMONICS MAGNETO-OPTICS
November 23-25, 2021 – Bilbao (Spain)
UC UNIVERSIDAD DE CANTABRIA

Abstract & motivation

Optical biosensing is currently an intensively active research area, with an increasing demand of highly selective, sensitivity-enhanced and low-cost devices where different plasmonic approaches have been developed [1]. In this work, we propose the use of a grating-based gold metasurface that can act both, as a high sensitivity sensor device and as an unidirectional plasmon source [2]. Furthermore, adding chiral HRID unit cells [3] to another gold grating system, we demonstrate how the directional plasmon approach can be applied to chiral sensing, with a chiral structure that enhances chiroptical response [4].

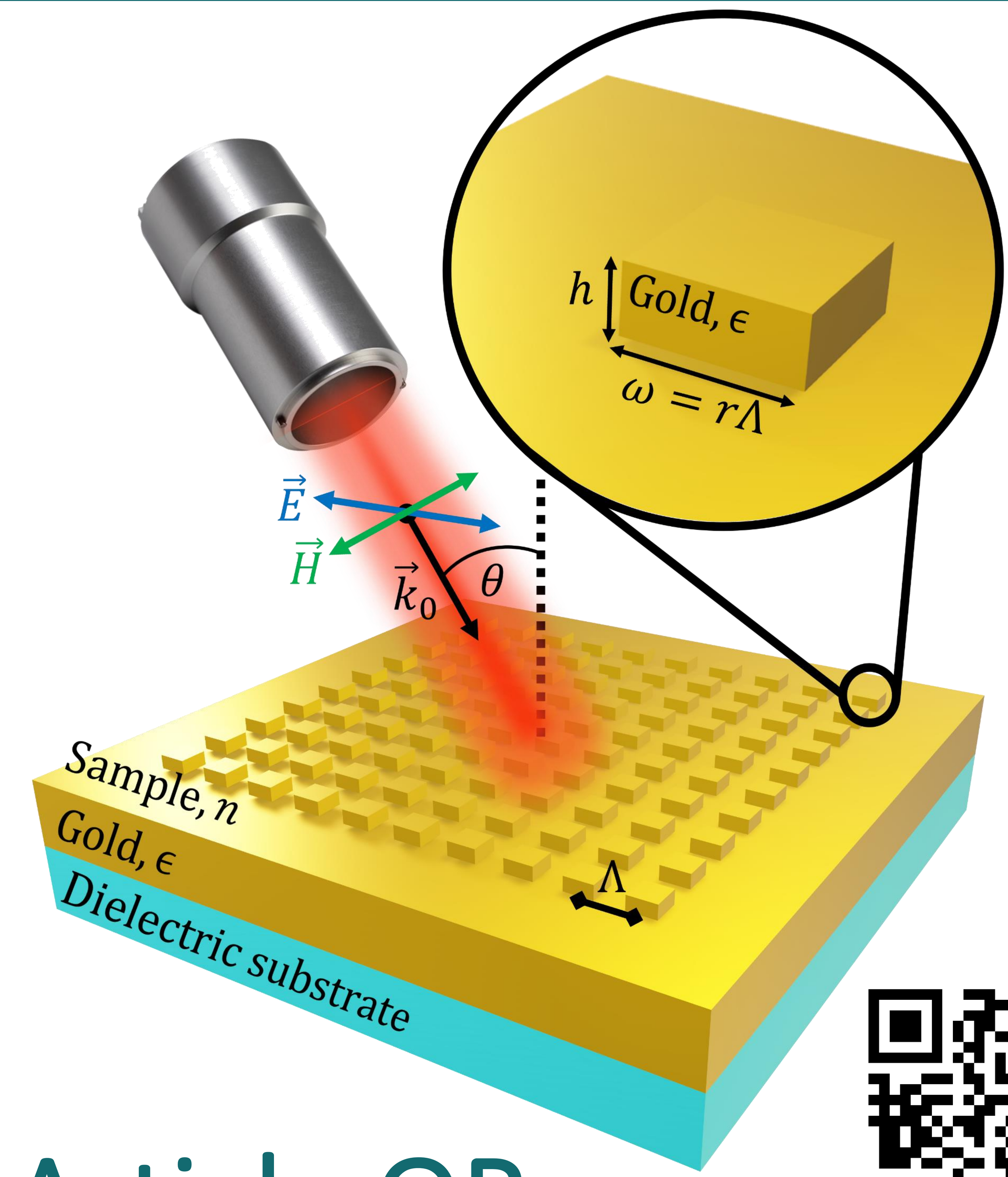
Theory of SPP generation

- When a **TM-polarized EM wave** with wavelength λ impinges on a metallic grating, a **Surface Plasmon Polariton (SPP)** can be generated at the metal-dielectric **interphase**. This coupling takes place when the incident radiation wavevector, assisted by the diffraction grating, is resonant with the plasmon wavevector (see Eq. 1). This shows a characteristic dip in the reflection pattern.

$$\vec{k_0} + \vec{k_g} = \vec{k}_{spp} \quad \Longrightarrow \quad k_0 n \sin\theta + \nu\frac{2\pi}{\Lambda} = \pm\, k_0\sqrt{\frac{n^2\varepsilon}{(n^2+\varepsilon)}} \qquad (1)$$

- Directional SPP launching can be achieved by manipulation of the diffractive mode ν or by means of a **double column-patterned grating** [5]. The dipole-like emitting unit cells in a column interact with the other, causing a phase dependency in SPP coupling that can be manipulated through the incident polarization.

System architecture



Article QR

Results (gold grating)

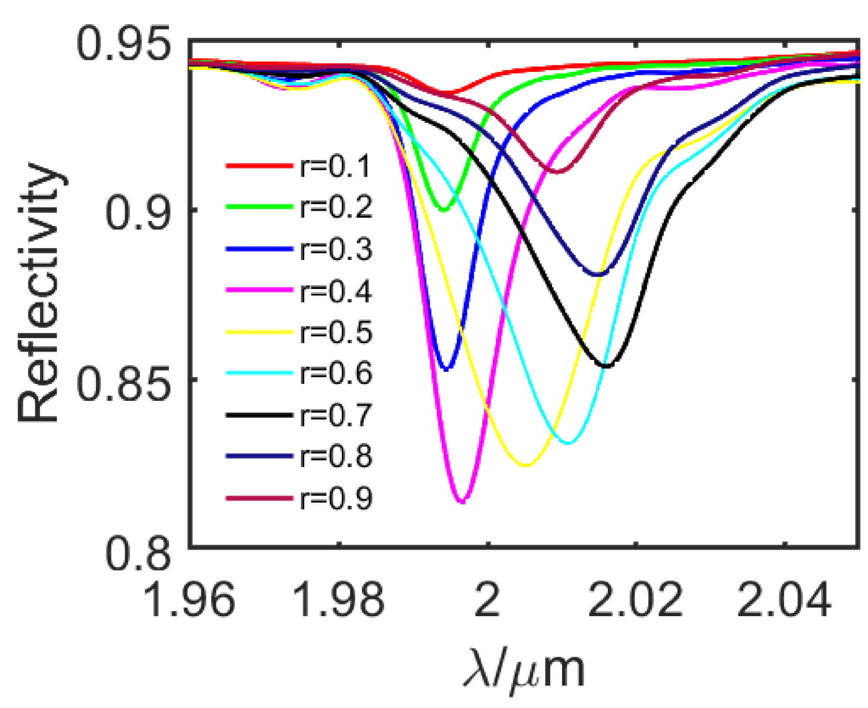
Optimization of the metasurface was done by variation of the grating parameters while allowing SPP generation. The quality properties of this configuration were calculated as a function of the duty cycle r with a period $\Lambda = 1500$ nm. Directional plasmon generation can be attained at non-normal incidences with a period $\Lambda = 700$ nm.

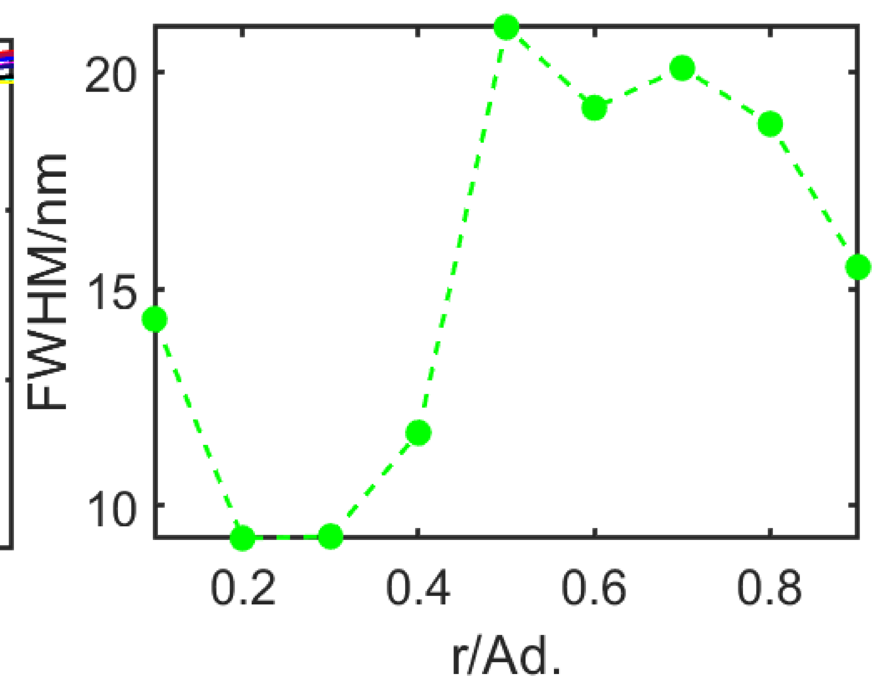
Best performance for $r = 0.3$

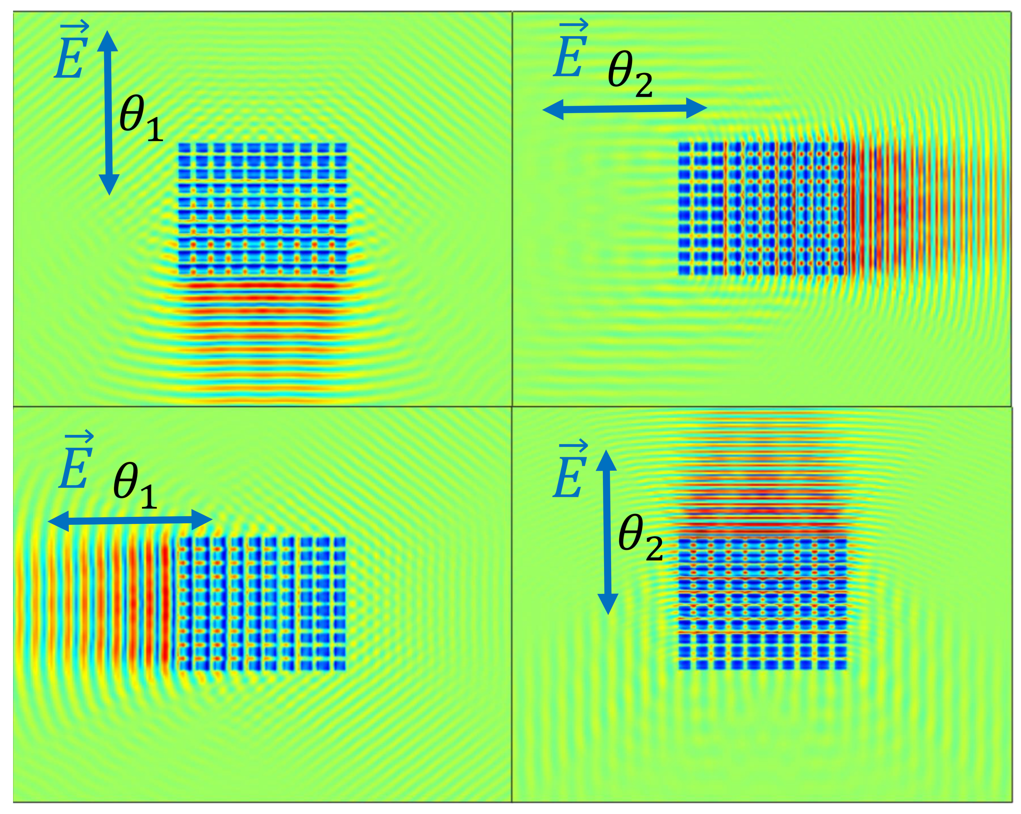
- Sensitivity: 1500 nm/RIU.
- FWHM: 9.29 nm
- FOM: 161.46 RIU[-1]
- Q-factor: 214.69

Directional plasmon emission

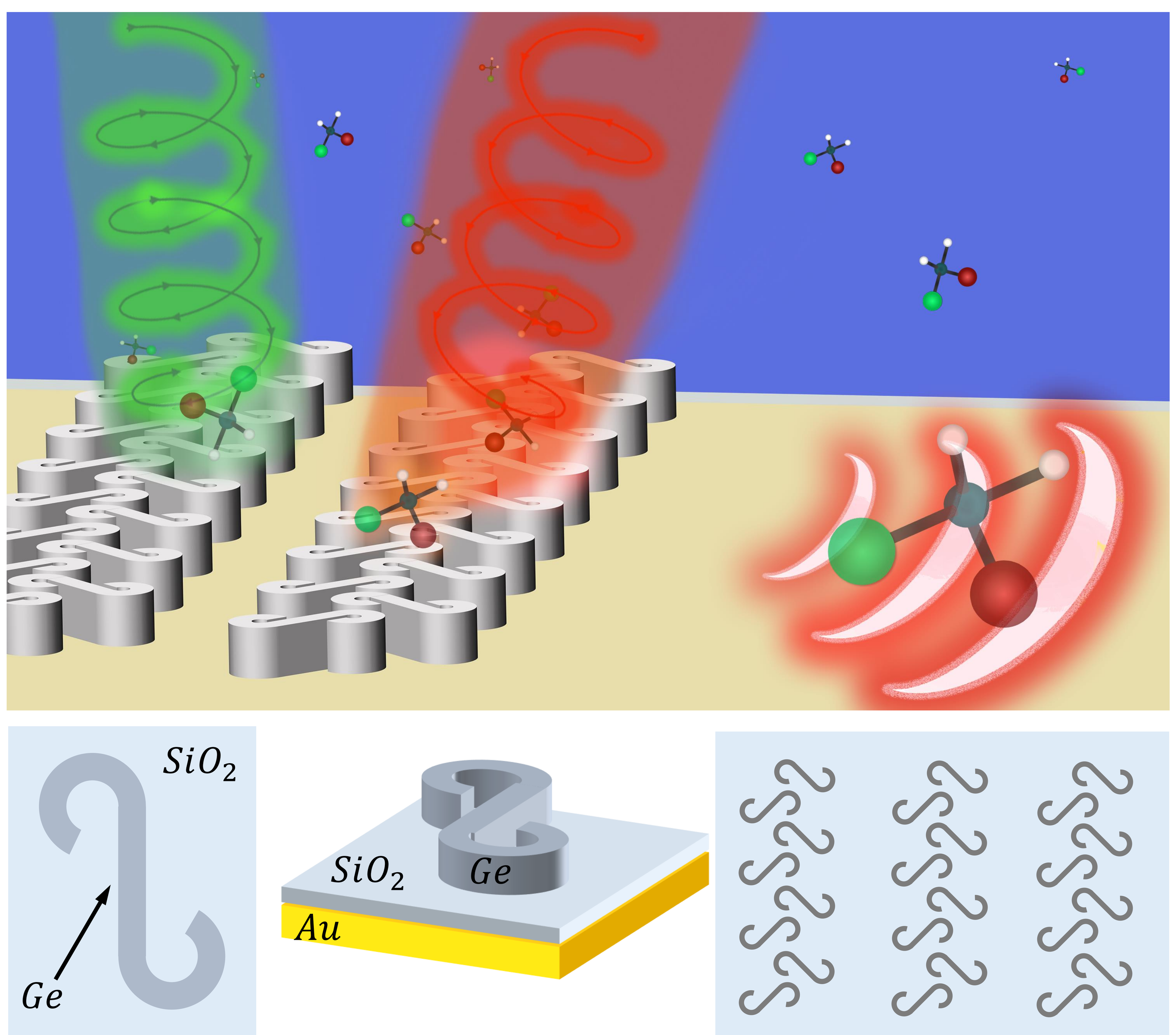
- $\theta_1 = 13.17°$
- $\theta_2 = 39.49°$







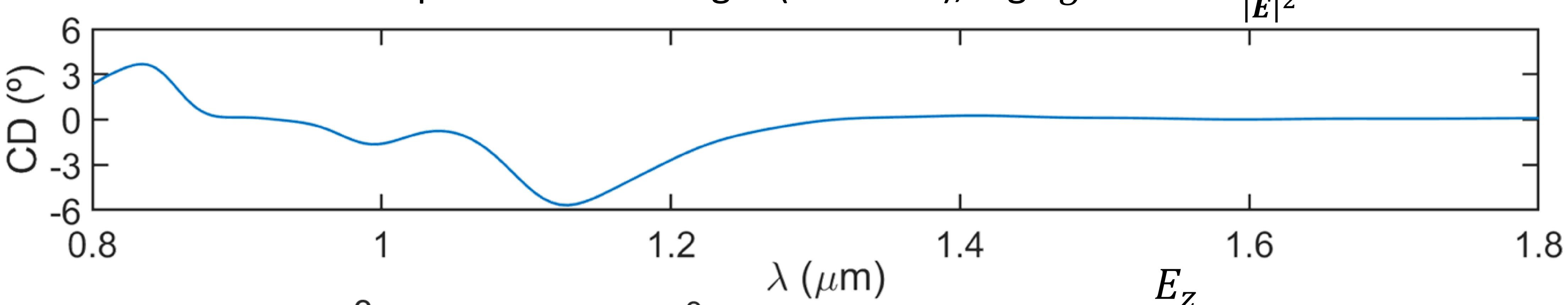
Chiral sensing system architecture

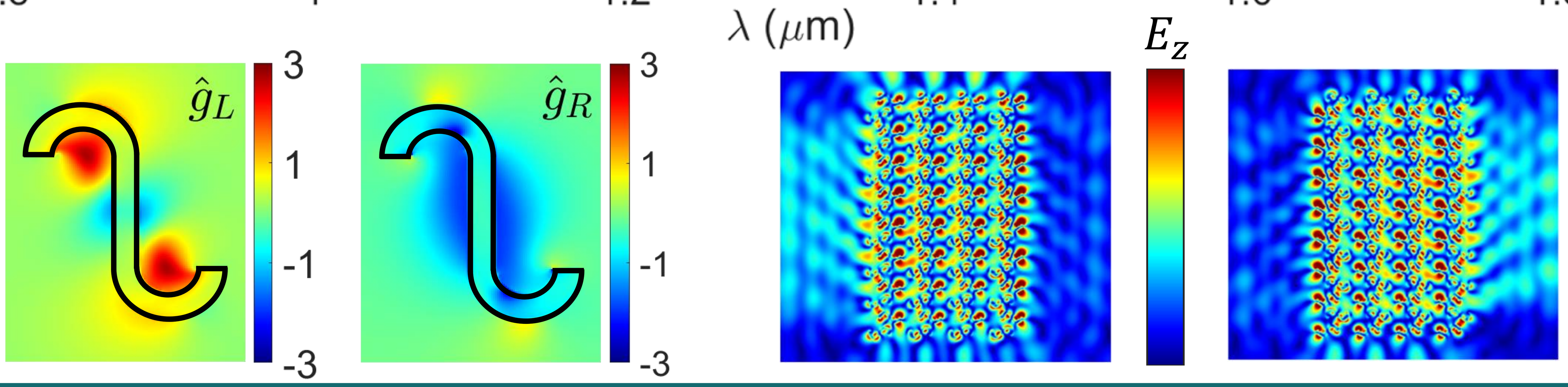


Results (chiral metasurface)

We propose a Ge "S-like" structure over thin glass and gold layers, which can be applied to a double column grating to obtain the directional plasmon emission effect.

- **In Far field** : $CD(°) = \tan^{-1}\left(\frac{\sigma_{RCP} - \sigma_{LCP}}{\sigma_{RCP} + \sigma_{LCP}}\right)$ signal with a peak of -6° at 1130 nm.
- **In Near field**: for the peak CD wavelength (1130 nm), high $\hat{g} = -c\frac{\Im m(\boldsymbol{E}^{*}\cdot\boldsymbol{B})}{|\boldsymbol{E}|^2}$ areas.





References

[1] C. M. Miyazaki et al. *Micro & Nano Tech,* 2017.
[2] J. González-Colsa et al. *Opt Exp*, **29**, 9, (2021).
[3] F. Reyes Gómez et al. *Phys. Rev. B* **101**, 155403, 2020.
[4] G. Serrera et al. (under review in *J Appl Phys),* 2021.
[5] J. Lin et al. *Science* **340**, 6130, 331-333, 2013.

Conclusions

- A rectangular gold grating can be used as an optimized biosensor (1500 nm/RIU at normal incidence) and as a directional plasmon coupler for non-normal incidences [2].
- The use of gold gratings, with chiral dielectric unit cells in a double-column pattern allows to both launch plasmons directionally and offer high chiroptical responses [4].

Acknowledgements: The authors acknowledge financial support from Spanish national project INMUNOTERMO. G. S. thanks the Ministry of Education for his collaboration grant. J. G-C. thanks the Spanish Ministry of Science for his FPI grant and P. A. acknowledges funding for a Ramon y Cajal Fellowship.