Modeling and simulation of 2D materials based plasmonic structures for sensor applications

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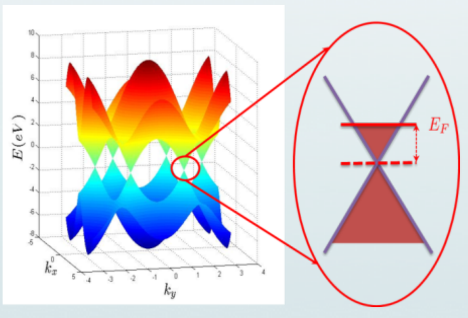
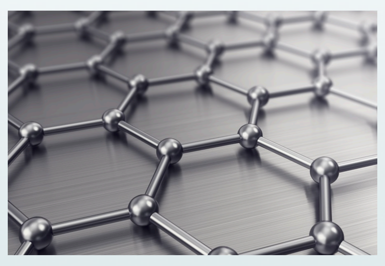
Motivations and objectives

Graphene ➡ 2 D honeycomb carbon crystal [1]





Unique electronic band structure : Linear Dirac spectrum

Unusual optical conductivity ➡ Particular and attractive optical properties :

- TM Graphene surface plasmons : low loss , high confinement
- TE Graphene surface plasmons : very difficult to excite in practice
- Electrically tunable conductivity

⇒ Various plasmonic applications in the IR and the THz regions of the EM spectrum [2,3]

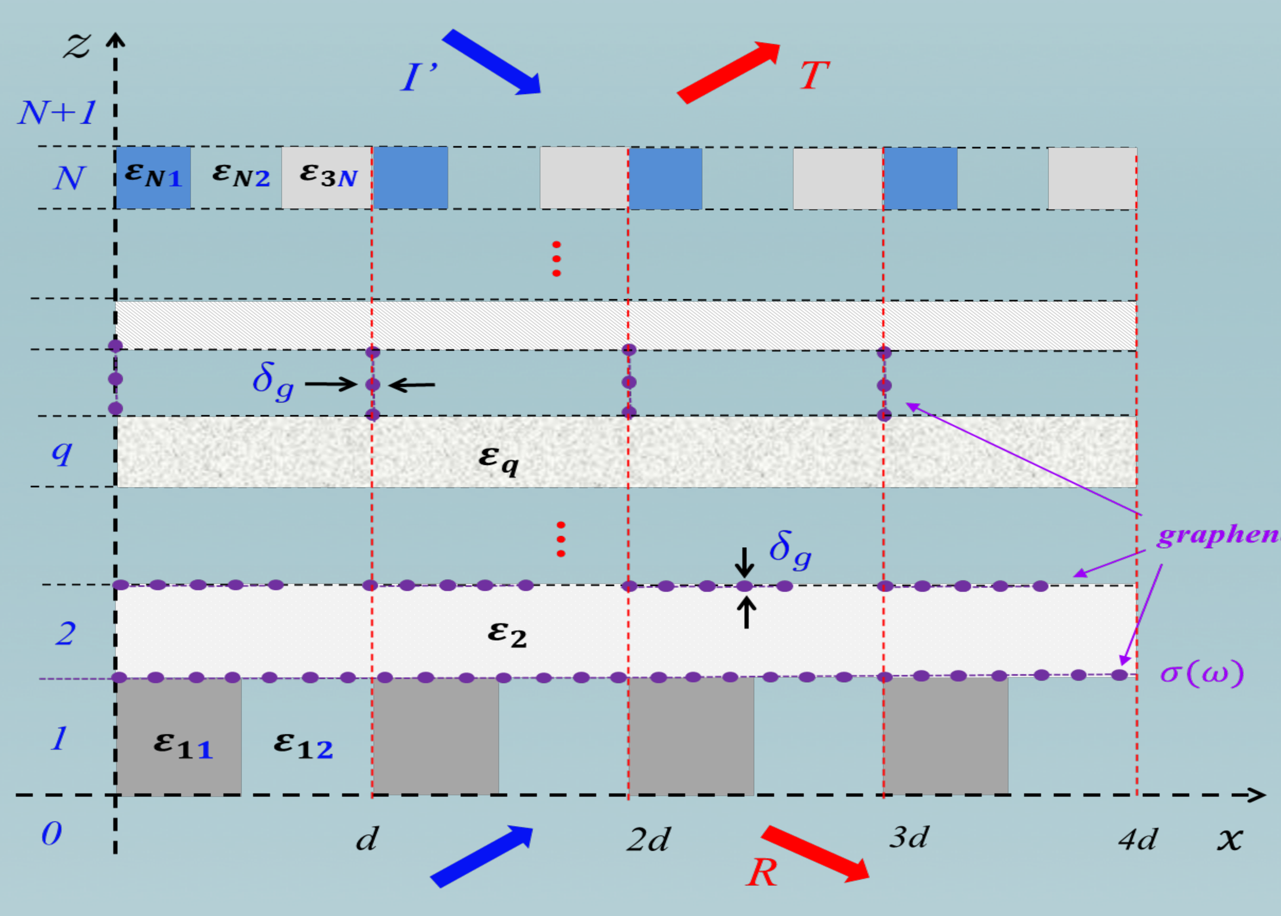
Antennas, Absorbers, Modulators → Sensors

Objectives

Develop theoretical and numerical methods in order to study graphene based plasmonic structures for sensor applications

Physical System and Methods

The generic structure



The Fourier Modal Method : FMM

In each medium (q), the fields can be expressed as:

$$U_{qy}(x,z) = \sum U_{nq}(z) e^{i\alpha_n x} \quad \forall \quad q \in \{0, ..., N+1\}$$

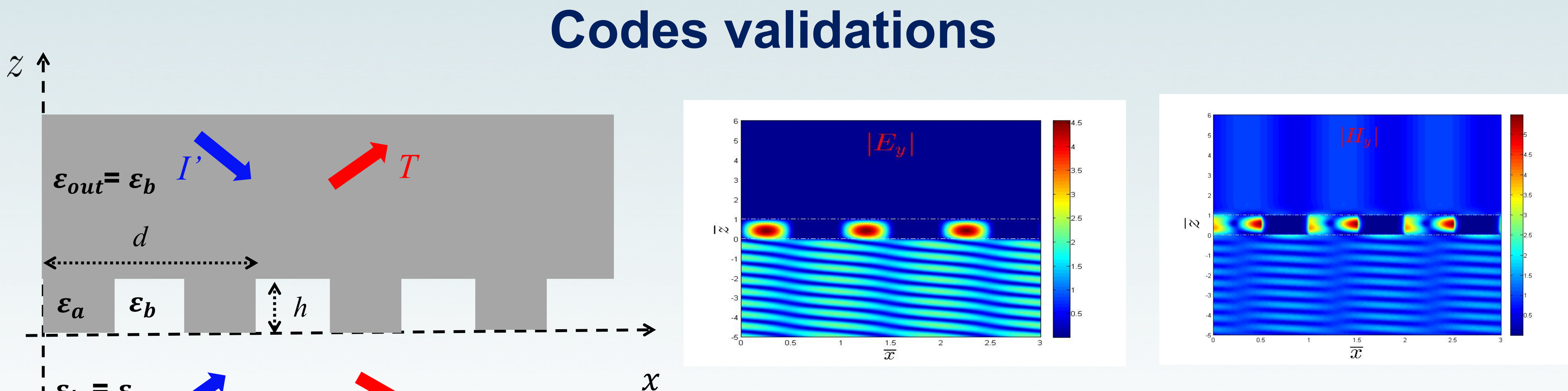
$$U_{qy}(x,y) = \begin{cases} E_{qy}(x,z) & \text{TE polarization} \\ H_{qy}(x,z) & \text{TM polarization} \end{cases}$$

The General solution :

$$\mathcal{U}_q(z) = P_q(e^{D_q(z-z_{q-1})} a_q + e^{-D_q(z-z_q)} b_q)$$

Boundary conditions ➡ S-matrix Algorithm $\begin{pmatrix} R \\ T \end{pmatrix} = S \begin{pmatrix} I \\ I' \end{pmatrix}$

Codes validations

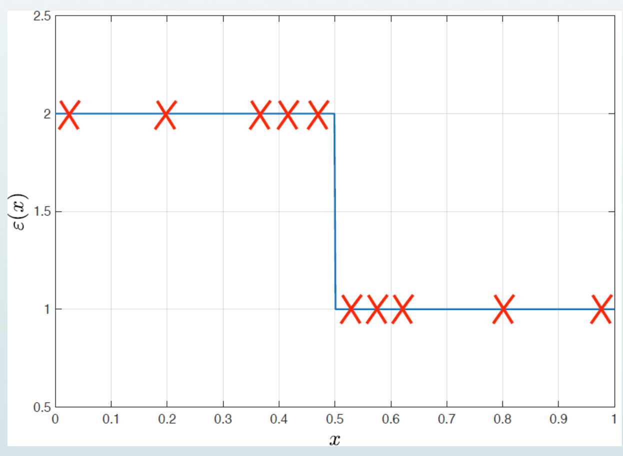


TE Polarization

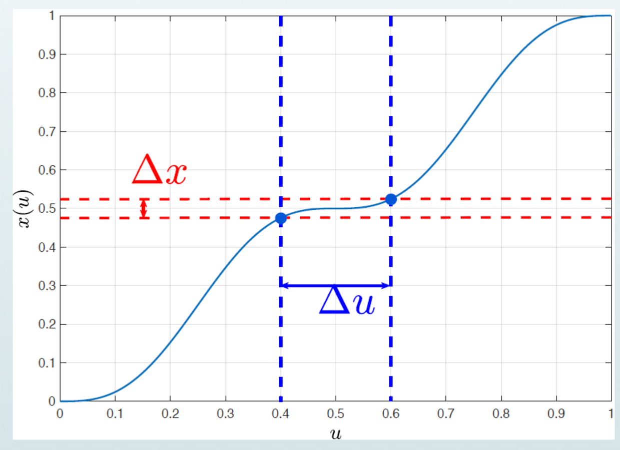
TM Polarization

FMMASR (Adaptive Spatial Resolution)

Stretched coordinates ➡ $x = f(u)$



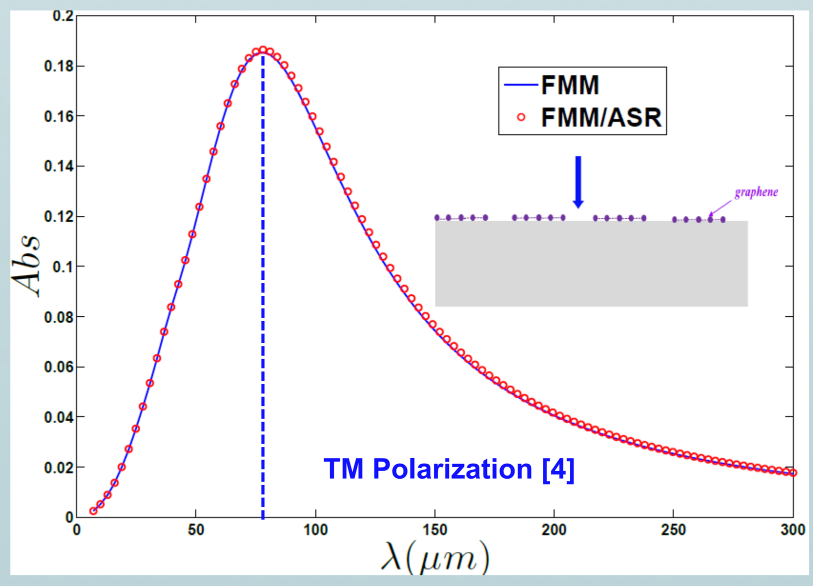
High Resolution @ Discontinuity Points



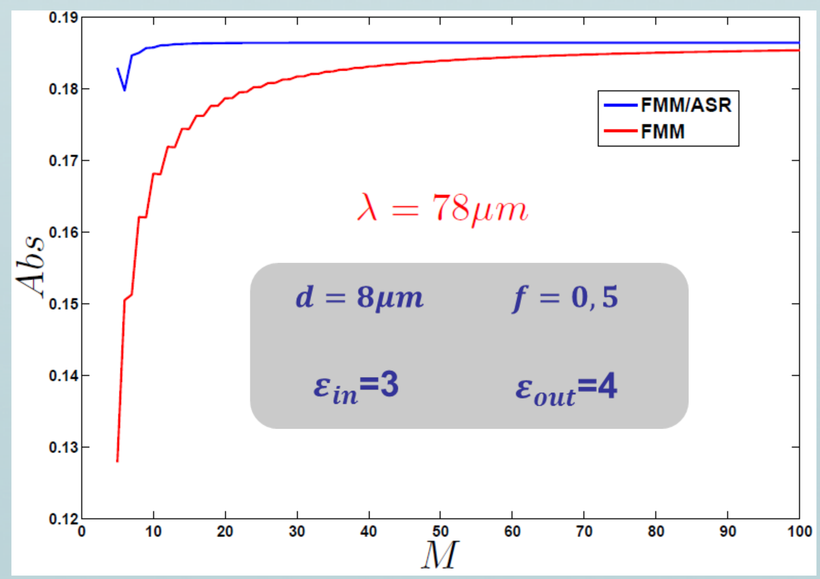
Results

Horizontal Strips

Absorption

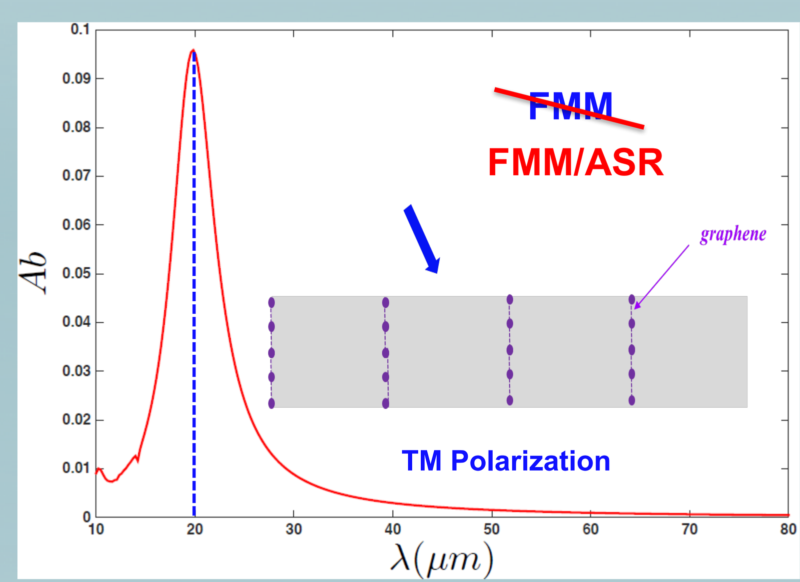


Convergence

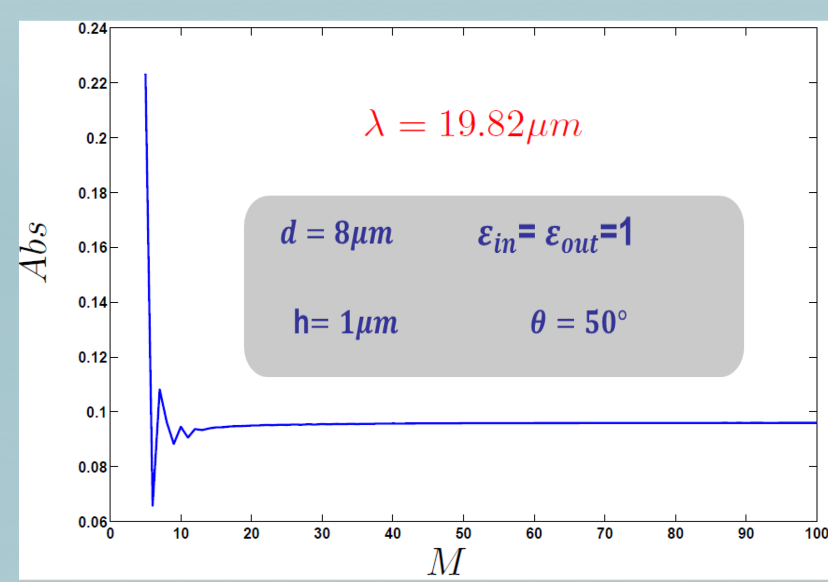


Vertical Strips

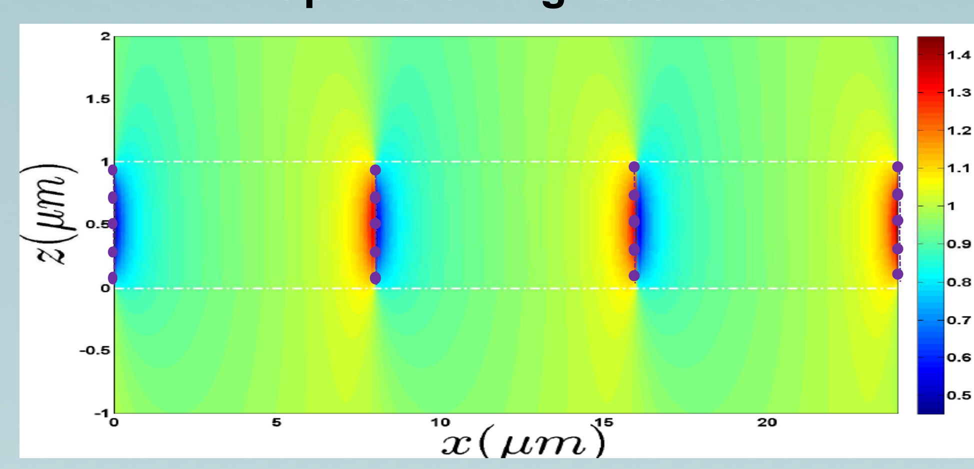
Absorption



Convergence



Map of the magnetic field



Conclusions

The former objective of the PhD work is achieved: the construction of general versatile and efficient codes for the modeling and simulation of graphene based nano-devices. Furthermore, we discovered a problem with the FMM in the case of pathological vertical gratings and proposed an efficient solution through the use of the ASR concept. We are now ready to begin the next step consisting on the exploration of graphene plasmonic devices.

Bibliography

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4. A. Nikitin et al, Phys. Rev. B 85, 081405 (2012)