Introduction

In last decades there are many researchers proposed new designs for optical systems in order to integrate single-photon sources on chip. The deterministic sources are demanded in specific research areas such as bio-sensors, quantum computing and quantum cryptography. Further, the processing with single photons allows the propagation of individual energy quanta useful to study the interaction between light and matter at nano scale. Single photon detection promises to improve the parallel data processing and the data encryption. Moreover, the probabilistic sources are used in specific quantum information tasks as the quantum simulation and quantum processing. The excitation of light sources has been successfully implemented using several integrated optical devices within a few nano-meters. For example, the excitation of nano-emitters has been realised by surface plasmon polaritons (SPPs) in nano-antennas optical cavities with nano-crystals, nanowires and metallic waveguides. The used materials (silicon and noble metals) for the excitation process are characterized by high propagation losses in the visible spectral range. This will finally restrict the transmitted power In order to overcome this limitation we investigate the hybridization of the nano-emitter with a low-loss photonics platform. The effort is then focused on the coupling strategy and decreasing the attenuation.
Our choice has converged towards ion exchanged optical waveguides (IEW). IEW is a graded index waveguide with high compatibility to couple with standard optical fibres. Indeed IEW are characterized by a low refractive index contrast and can exhibit propagation losses as low as 0.1dB/cm. The coupling efficiency is very low between the nano-emitter and the IEW because of the effective index mismatch. In this work we report several implementations to enhance the field confinement in IEW to increase the coupling efficiency to get the lowest coupling attenuation. Hence, in this report the proposal is reported to enhance the field confinement in IEW to increase the coupling efficiency.

Firstly, dielectric thin film of high index material (TiO_2, SiC, ZnS, etc) deposited above IEW is used to increase the light confinement that will increase the coupling efficiency as well. The hybrid modes with higher effective indices occur because of the propagation of the guided mode through the structure. Furthermore, two waveguides coupled will appear, due to excited modes of the TiO_2 layer resulting from the evanescent wave of the guiding mode in IEW that will enhance the light confinement inside the IEW. The nano-source will be placed on the top of the structure and will be excited by an incident light.

Our mission during the secondment is to get out the best position for the nano-source to couple light inside the waveguide. Simulation results were obtained using the 3-D finite differential time domain (3-D FDTD) method using Lumerical software Package. In order to prove the high accuracy of the optical data and simulation technique that is used in our study. Our simulation is validated and compared with the published experimental results shows that the calculated results by numerical simulation agreed with very small error of less than 5%. Our proposed design will enhance light guidance through the IEW due to the presence of dielectric slab. In this work, the role of the dielectric slab is studied at different thicknesses, lengths, materials and widths to get the optimum dimensions of the slab and study their impacts on enhancing the light confinement and the measured transmission. We demonstrated that the proposed structures allow increasing the measured coupling efficiency to 50% and 68% for TiO_2 and SiC, respectively.

- ***Hybride structure***

In Secondment work, our main goal is to obtain the highest coupling efficiency from the IEW waveguide. One of the solutions is to enhance the field confinement inside the IEW by depositing a thin layer of TiO_2 on the top of the waveguide as shown in figure 1. TiO_2 has higher refractive index approximately equal 2. In this part the measured refractive index data of IEW is used. The used wavelengths are λ=542nm and λ=640nm which are the excitation and emission wavelength for the nano-diamond, respectively. A single photon source can be represented by a dipole point

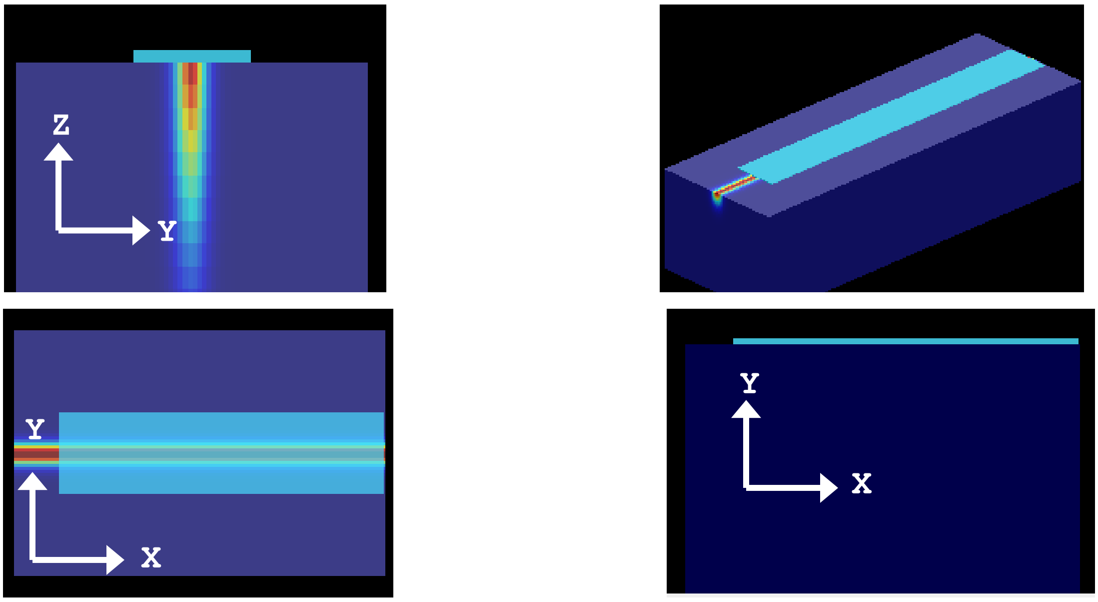

Figure 1 the unit cell of the proposed waveguide structure with the deposited layer of TiO_2 in the used software from different views of the structure.

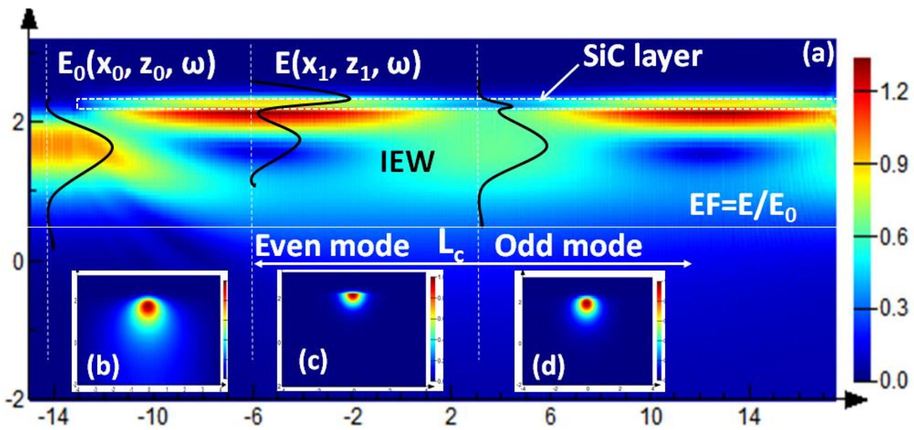

Figure 2 the propagation of light through the hybrid structure. a) The field profile of the electric field distribution inside the hybrid structure, generating hybrid modes with energy exchange between two waveguides. (b) shows the fundemental mode propagation in IEW. (c) and (d) shows the field profile of the even and odd modes into the hybrid structure, respectively.

As reported in the previous section the IEW has low field confinement so it will be difficult to place nano-emitters on the top surface it will be weakly excited so the TiO_2 layer is used. In The proposed structure the hybrid modes are created with high effective index during the propagation of the guided mode through the structure. The modes are excited in the TiO_2

layer because of the evanescent wave of the guided mode in IEW, resulting in two waveguides coupled system. The periodic energy transfer takes place between the two waveguides because of the hybrid modes as shown in the figure below.

The distribution of the electric field changes as the light propagates along the x axis due to the interference between the hybrid modes changing. The fundamental mode during propagation in our structure generates two different modes even (confined in IEW) and odd (confined in TiO_2 layer) modes as shown in figure 2.

We demonstrated that the proposed structures allow increasing the simulated coupling efficiency to 50% and 68% for TiO2 and SiC, respectively as shown in figures 3 (a) and (b).

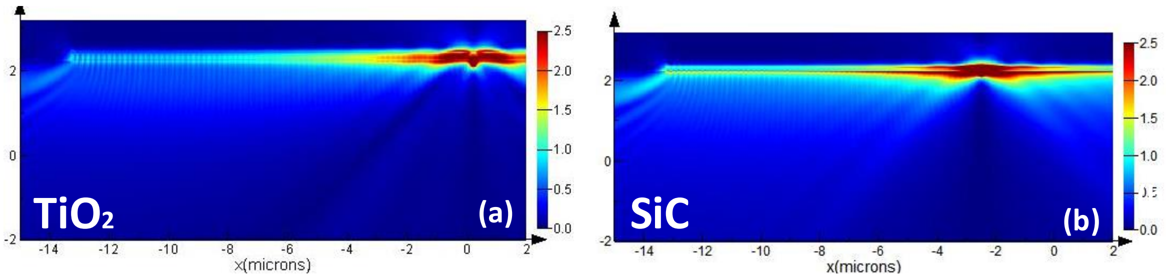

Figure 3 coupling nano-emitter with the hybrid photonics structure using different slab material (a) Tio_2 and (b) SiC

The presented design of hybrid photonics waveguide system can be used as a potential device to integrate a single-photon source on chip.

- ## *Conclusion*

The hybrid photonic structure proposed in this work promises to be an important milestone towards the integration of nano-emitters on waveguides. the 3-D FDTD via Lumerical software package is used to study the coupling effect of the slab put over the IEW. All the parametric effect, coupling efficiency, pure cell factor and the enhancement factor for our structure are calculated and investigated. This structure can be easily fabricated and adapted to several scientific applications. The observed coupling efficiency up to 68% for a dipole oscillating using SiC slab.