GEMaC
Groupe d'Étude
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EFFICIENT, BRIGHT SINGLE-PHOTON EMITTERS THANKS TO A SILVER MIRROR

Researchers at GEMaC have coupled a nanometric layer of silver with a 2D material to unlock the secrets of the single-photon sources they have created in this crystal.

Hexagonal boron nitride (hBN) is a material consisting of a stack of atomic layers structured in a hexagonal lattice, which can be manipulated in the form of crystals of a few atomic layers (or 'flakes'). By irradiating these flakes with a localised electron beam, we can create point defects in the crystalline structure. These defects behave like atoms at two energy levels: when excited with a laser, they return to their lower energy state, emitting a particle of light, or photon. This is known as relaxation. This light emission always takes place at a very specific wavelength, corresponding in this case to the colour blue. Thanks to this remarkable property, these quantum objects, also known as colour centres (in this case blue centres), are promising tools for quantum computing, where single photons can be used to carry quantum information.

Previous studies have shown that blue centres have many other properties that make them suitable for use in quantum technologies. These include their stable, brilliant emission and their ability to emit photons that are all identical to each other (also known as indistinguishability).
The GEMaC team looked at the question of the quantum efficiency of blue centres. This involves determining the probability that, once excited, these blue centres will return to their low-energy state by emitting a single photon, and not by other de-excitation pathways induced by certain elements in the surrounding crystalline medium. These other pathways are known as ‘non-radiative’ and do not generate a photon! It is therefore crucial that the quantum efficiency is high. However, this is generally difficult to assess.

To estimate the efficiency of the blue centres, the GEMaC researchers took advantage of a useful property: the higher the quantum efficiency, the more sensitive the colour centre is to its electromagnetic environment. This environment is given by the optical index of the medium, the presence of optical cavities or even interfaces between media with different optical indices. It is this last option that has been exploited. The blue centres were successively exposed to two different electromagnetic environments. Initially, the colour centres were located in a plane of hBN placed between a layer of silica and a layer of air. Using a technique known as dry transfer, the GEMaC researchers used a polymer buffer to move the host flake to another substrate, on which a very fine silver mirror had been deposited beforehand (Figure 1). The colour centre then found itself between two reflective surfaces: the silver/hBN interface and the hBN/air interface. This is known as a planar cavity. In this new electromagnetic environment, the emissive properties of the colour centre are modified. In particular, the team was interested in the time it takes to relax to its lowest energy state, known as the lifetime. By measuring this time before and after transfer, we were able to assess the sensitivity of the blue centres to their electromagnetic environment (Figure 2). Using simulations, the team concluded that the blue centres have a high quantum efficiency. In other words, their relaxation systematically results in the emission of a photon. This property is favourable for application to quantum protocols.

In addition, the acceleration or deceleration of the emitter's lifetime depends on its vertical position in the flake. They were therefore able to estimate the vertical position of the emitters with nanometric precision. As well as enabling the position of the emitter in the flake and quantum efficiency to be measured accurately, this structure accelerated photon emission by a factor of 2 and improved collection of the emitted photons by directing them preferentially in the same direction, towards the top of the structure. This is an essential asset for quantum optics experiments and potential applications for optical

quantum technologies.

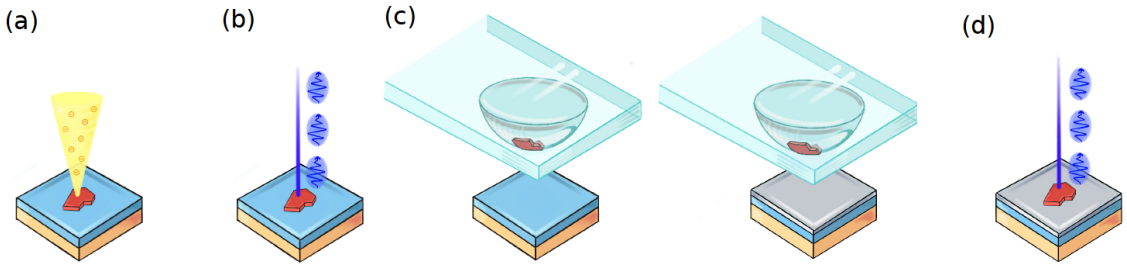


Figure 1: transfer of an hBN flake (a) irradiation of an hBN flake (b) characterisation of the activated blue centres (c) dry transfer of the flake from the Si/SiO2 substrate to a Si /SiO2/Ag substrate (d) characterisation of the same blue centres on the new substrate.

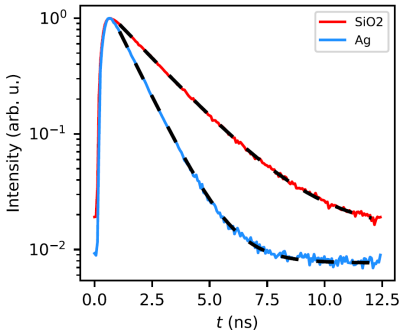


Figure 2: acceleration of the lifetime after transfer onto silver substrate

Reference :

D. Gérard, A. Pierret, H. Fartas, B. Bérini, S. Buil, J.-P. Hermier, A. Delteil, “Quantum efficiency and vertical position of quantum emitters in hBN determined by Purcell effect in hybrid metal-dielectric planar photonic structures”
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