Hybrid photonic quantum computing with semiconductor quantum dots.

Pascale Senellart
Center for Nanoscience and Nanotechnology, CNRS, University Paris Saclay. 11 Bd Thomas Gobert 91120 Palaiseau France
Quandela, 7 rue Léonard de Vinci, 91300 Massy, France

pascale.senellart-mardon@universite-paris-saclay.fr

Photons are excellent carriers of the quantum information, with infinite coherence time in highly transparent media and allowing for interconnection between quantum processors as well as long distance communications. For a long time, the generation of photons was hindered by the intrinsic low efficiency of single photon sources based on frequency conversion. However, in the last decade, a new generation of single and entangled photon sources has emerged based on quantum emitters, unlocking a new path to quantum computing exploiting photons. The leading technology in this context are quantum dots based on III-V semiconductors – generating both single and entangled photons in the near infrared.

In this talk, I will present our contribution to the development of hybrid photonic quantum computing platform exploiting single InGaAs quantum dots in cavities. We will first see how we have progressively developed efficient sources of highly indistinguishable single photons [1] and turned them into plug and play devices [2]. We will virtually visit our first quantum computing platform, based on single photons and integrated photonic chips and present first proof of concept applications [3]. We will then discuss various possible roadmaps for scaling up, all pertaining to the category of measurement-based quantum computing and requiring photonic graph states. Exploiting the spin degree of freedom of an electron trapped in a quantum dot, we recently achieved an important milestone in this context, with the generation of various spin-multi -photon entangled states [4,5].

We will finally discuss the potential of this hybrid approach of quantum computing, exploiting both spins and photons. As a first example, we will study the resources needed to generate a typical state sought for implementing a logical qubit, comparing the full photonic approach to the hybrid one [6].

References

[1] N. Somaschi, V. Giesz et al, Nature Photonics 10, 340 (2016)
[2] N. Margaria et al, arXiv:2410.07760
[3] N. Maring et al., Nature Photonics 18, 603 (2024)
[4] N. Coste et al., Nature Photonics 17, 582 (2023)
[5] H. Huet et al, arXiv:2410.23518
[6] S. C. Wein et al, arXiv:2412.08611

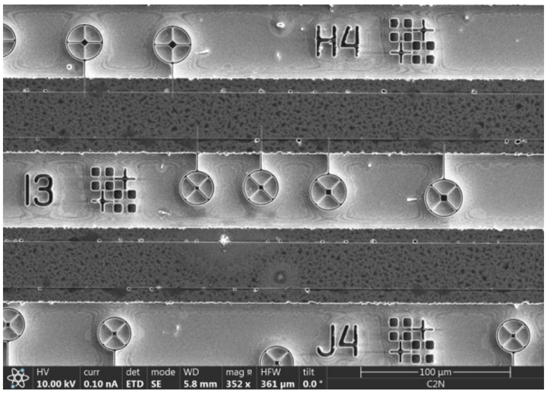

Figure: SEM image of spin-photon interfaces based on quantum dot in cavities.