Quantum optics in photonic wires

J.M. Gérard

CEA, Institute for nanoscience and cryogeny, Grenoble, France

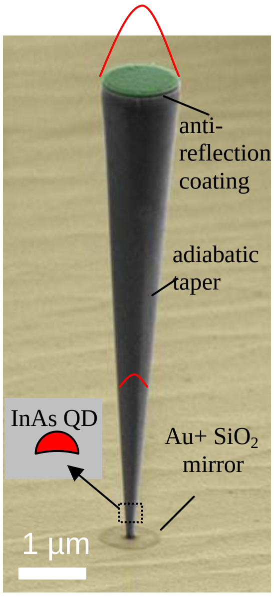

Figure 1: Colorized scanning electron micrograph of a GaAs photonic trumpet (from [4])

Over the last 20 years, major efforts have been devoted to the tailoring of the optical properties of semiconductor emitters using optical microcavities and photonic crystals. We have recently introduced photonic wires as a novel resource for quantum optics. I will review recent studies which demonstrate an excellent control over the spontaneous emission of InAs quantum dots (QDs) embedded in vertical single-mode GaAs photonic wires and first applications in the field of quantum optoelectronic devices.

On the basic side, we have demonstrated a strong inhibition (x 1/16 [1]) of QD SpE in thin wires ($d<\lambda/2n$) and a nearly perfect coupling of the SpE to the guided mode ($\beta>0.95$ for $d\sim\lambda/n$) in circular photonic wires [2]. The polarization of QD SpE can also be tailored by playing with the shape of the cross section of the photonic wire. For elliptical cross sections, a strong (>90%) linear polarization oriented along the long axis of the ellipse is observed [3].

In view of practical applications, a proper engineering of the radiation pattern of the photonic wire is required. We have therefore developed novel hybrid (metal+dielectric) mirrors displaying a high modal reflectivity, as well as integrated tip-shaped or trumpet-like adiabatic tapers, in order to reduce the divergence of the emitted beam. The recently developed photonic trumpet (shown in figure 1) exhibits superior performances in this context, since it ensures a perfect Gaussian far-field emission [4].

As a first application of SpE control in photonic wires, we have developed single mode QD single-photon sources (SPS). Unlike microcavity-based devices, such SPS display an excellent purity ($g^{(2)}(0) < 0.01$) under non-resonant excitation, over the whole range of excitation powers. Furthermore, efficiencies exceeding 0.7 photon per pulse (within NA=0.75) have been obtained for tip-shaped [5] as well as trumpet-like [4] SPS. Beyond these first results, photonic wires are also very attractive for developing high efficiency sources of entangled photon pairs or wavelength tuneable SPS, thanks to the broadband SpE control they provide.

More generally, photonic trumpets appear as a very promising template to explore and exploit in a solid-state system the unique optical properties of "one-dimensional atoms". Possible long term applications in the field of quantum information processing will be discussed.

This work has been done in collaboration with J Claudon, J Bleuse, M Munsch, NS Malik, A Delga (CEA Grenoble), N Gregersen, J Moerk (DTU Fotonik, Copenhagen), P Lalanne (Institut d'Optique, Palaiseau); it has been supported by the IST FET European project "HANAS" and by the French ANR project "WIFO".

References

[1] J Bleuse et al, Phys. Lett. Lett. 106, 103601 (2011)
[2] I Friedler et al, Opt Exp 17, 2095-2110 (2009)
[3] M. Munsch et al, Phys. Rev. Lett. 108, 077405 (2012)
[4] M. Munsch et al, Phys. Rev. Lett. 110, 177402 (2013)
[5] J.Claudon et al, Nature Photon. 4, 174 (2010)

**corresponding author: jean-michel.gerard@cea.fr*