Nitride nanophotonics from the deep ultra-violet to the near infrared: non-linear optics and microlasers

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Abstract-The recent developments of nitride nanophotonics, based on photonic crystal membrane nanocavities and microdisk resonators, pave the way to a novel nanophotonic platform. Here we present two recent achievements: first we demonstrate the room-temperature operation of a nitride microlaser emitting in the deep UV spectral range (λ=275 nm) with GaN/AlN multiple quantum wells. Secondly we tailor the second-harmonic generation of a cw near infra-red radiation coupled to a high quality factor photonic crystal cavity.

Nitride semiconductors (GaN and nitride alloys) provide a spectrally-broad transparency -expanding from the near-infrared to the ultraviolet- as well as robust excitons that are efficiently interacting with light and stable up to room temperature. They offer a promising playground for non-linear optics and micro- or nano-lasers at 300K. Over the last decade, the progresses of the nitrides' processing has allowed fabricating nanophotonic resonators and devices such that the interaction between excitons and photons can be tailored on demand. We will review our recent achievements, ranging from near-UV high Q photonic crystal cavities [1], to UV-C GaN/AlN microdisk lasers [2] and second- and third-harmonic generation in photonic crystal cavities [3].

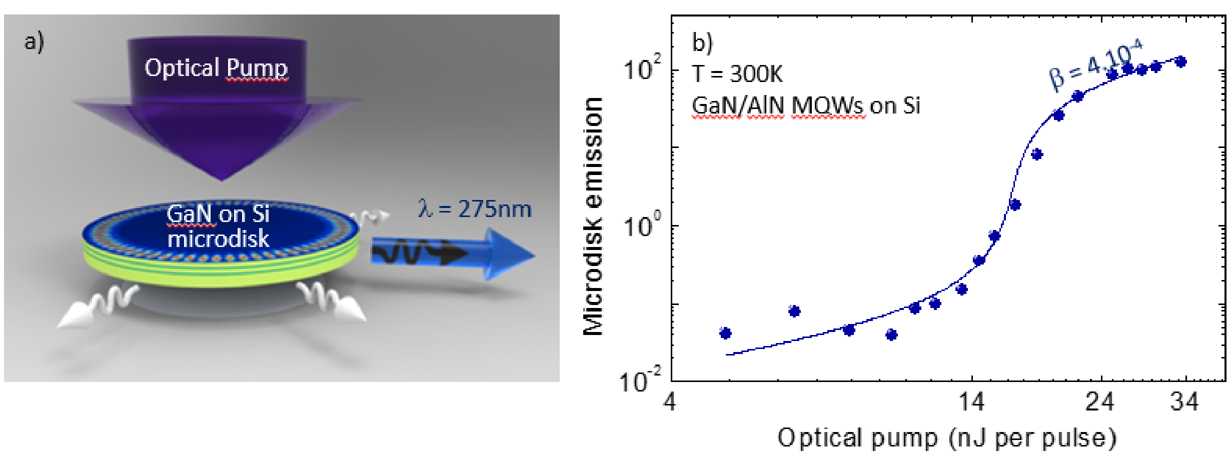

Figure 1: a) Scheme of the microlaser, with the optical pump from the top of the nitride microdisk and the emission collected from the edge ; b) Input-output characteristics of the microlaser, and its modelling through a microlaser rate equation model.

Figure 1 presents the demonstration of the first UV-C microlaser operating at room temperature [2]. It is based on an AlN microdisk photonic resonator with a quality factor of about 4000, embedding very thin GaN/AlN multiple quantum wells (MQWs). It operates at 4.5 eV/275 nm under pulsed quasi-resonant optical pumping (266nm, 400ps pulses), with a threshold excitation density of 17 nJ/pulse. The input-output characteristics of the microlaser and the line narrowing at threshold allow extracting the spontaneous emission coupling factor of the microlaser: $\beta=4\pm2\ 10^{-4}$. This demonstration underlines the interest of simple binary GaN/AlN MQWs, grown on a thin AlN buffer on a silicon substrate, compared to much more complex approaches based on thick engineered buffer layers, that are presently employed in UV-C ridge lasers. We exploit the possibility to selectively under-etch the silicon substrate in order to form membrane photonic resonators, that was previously only used in the visible and near-UV spectral range with bulk GaN and InGaN MQW active layers.

The same nanophotonic platform has been exploited without internal emitters, and operated within the GaN transparency window. Larger quality factors, up to 34000, have been obtained for photonic crystal membrane cavities in the near-infrared spectral range due to the larger dimension of the photonic pattern [4]. We have demonstrated the second and third harmonic generation of a 1.57 µm continuous-wave pump brought into resonance with such a suspended nanocavity [3]. The emission pattern is correlated to the simulated harmonic polarization and allows identifying the nonlinear process involved in the frequency conversion.

Those two results demonstrate the versatility of the nitride-on-silicon nanophotonic platform for future developments of integrated nanophotonics in the near-IR, visible and UV spectral range.

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