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Polarization Controlled Light Emitter based on Elongated Pyramidal Quantum Dots

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1.Introduction
Polarized light is the basis for a manifold of optoelectronic technologies ranging from telecommunication and LCD-displays to quantum cryptography. However, it is challenging to efficiently attain a strong polarization of spontaneously emitted light, in particular for the generation of single photons. In solutions of today, mainly filtering of unpolarized light is employed. In this process, a higher light transmission rate larger than 50 percent from the source can never be achieved. Such a loss is particularly devastating for quantum information technologies, in which each single quantum of light, i.e. each photon, literally counts.

1. Results
   Our approach is based on the unique properties of the III-nitride materials, known to be efficient light emitters in the blue and UV part of the spectrum. We have employed µm-sized GaN pyramids with six facets, formed in etched circular holes in a patterned substrate by Selective Area Growth (SAG). The holes are made in a SiN film on top of the substrate by means of standard UV lithography and RIE etching. The tips of the pyramids are made slightly truncated, as has been demonstrated to be advantageous for quantum dot (QD) formation. The pyramids are subsequently overgrown by a thin optically active InGaN quantum well and finally capped with a thin GaN layer. Due to the accumulated strain caused by the lattice mismatch between the GaN and InGaN well, InGaN QDs will evolve on the microscopic c-plane area in the apex of the pyramid. Well-defined single emission lines with a sub-meV line width have been monitored by means of µ-photoluminescence (µPL) from these deterministic QDs. So far, emission wavelengths have been demonstrated in the blue range, around 400 nm, but can be pre-defined by altering the growth conditions, such as the growth temperature, the well width and/or the In composition, for the InGaN layers.
   In a subsequent step, the circular holes in the patterned substrate have been replaced by elongated holes in a specified direction. As a result, elongated pyramids are formed with ridges characterized by typical dimensions of 1.0 µm length and 100 nm width on top of these asymmetric pyramids. The elongation directions 0o, 60o, and 120o are preferable due to the six-fold symmetry of the wurtzite crystal structure.
   The primary emission lines monitored are originating from electron-hole pairs, i.e. single neutral excitons, but also biexcitons and charged excitons have been monitored. Interestingly, the excitonic emission from the extended InGaN QDs on top of the elongated pyramids exhibit a strong degree of linear polarization, with a typical polarization ratio of about 85% achieved for the case of an elongation of the pyramid base by 1µm.
   For investigations of the exciton lifetime, µ-PL with a high spatial resolution combined with a streak-camera detector for recording the time spectral evolution under pulsed excitation with ps pulse duration was employed. The exciton lifetimes have been demonstrated to vary between 100 ps to 1 ns, with shortest lifetimes measured for the negatively charged QDs.
   In order to demonstrate the single photon characteristics of the dots, temporal photon correlation spectroscopy has been performed. These correlation measurements have been done in a setup of a Hanbury-Brown and Twiss interferometer equipped with sensitive single photon detectors. The excitonic single photon emission and biexcitonic photon bunching from the pyramidal dots are reported, confirming the sound single photon properties of these dots.

2. References

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No

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