# Ordered InGaN/GaN nanowires as arrays of classical and quantum light sources: growth, characterization and modeling

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With the realization of (In)GaN based blue light emitting diodes (LEDs) in the early 90s, the set of primary color LEDs was completed, revolutionizing the market of solid state lighting [1]. Due to a high lattice mismatch with the underlying substrates, the full exploitation of III-nitride semiconductors is still constrained by their limited crystal quality, when grown as compact (3D) epitaxial layers. In that sense, the strain-free GaN nanowires (1D), characterized with a virtually perfect crystal quality, offer a plenty of possibilities for further technological improvements.

The realization of efficient phosphor-free LEDs with only one family of materials, would lead to further design simplifications and energy savings. Due to their exceptionally high band offsets, the III-nitrides are also convenient for room temperature single photon emission [2], whereas their bandgap tunability (from near UV to near IR) facilitates their employment in fiber- and/or free-space quantum communications. In this work, we address growth, characterization and modeling of InGaN nanodisks, fabricated on pencil-like GaN nanowires (NWs), emphasizing the potential of this particular nanostructure for classical and quantum light generation.

The studied NWs, grown by selective area growth homoepitaxy [3], are: site-, diameter-, height- and shape-controlled and exhibit exceptional crystal quality. They are grown in hexagonal matrices with 280 nm pitch, 180 nm diameter, 600 nm height and with a truncated pyramidal top, consisting of one top *c*- and six side *r*-facets. The InGaN nanodisks are grown with varying thickness (10 - 30 nm) and InGaN compositions (10 – 25%), and capped with a 50 nm thick GaN. The InGaN nanodisk consists of polar (on *c*-facet) and semipolar (on *r*-facets) sections. The two sections are characterized by different: composition, internal electric field and strain. These differences lead to the nanodisk two-color emission, as evidenced by the combination of scanning electron microscopy and cathodoluminescence measurements [4]. Micro photoluminescence experiments performed on single NWs reveal sporadic appearance of intense and narrow (< 500 μeV) quantum-dot-like emission lines, originating from the InGaN nanodisks. This light, tunable over blue and green spectral range, is strongly linearly polarized (polarization ratio >90%). Photon correlation measurements performed on these emission lines, show pronounced antibunching. We find the $g^{(2)}(0) < 0.3$, which is a clear signature of the quantum nature of the emitted light [5].

REFERENCES
[1] S. Nakamura et al., Berlin, Springer (1997).
[2] M. J. Holmes et al., Nano Lett. 14, 982 (2014).
[3] Ž. Gačević et al., Nano Lett. 15, 1117 (2015).
[4] Ž. Gačević et al., submitted to Nano Lett.
[5] S. Lazić et al., (invited paper), Proc. of SPIE Vol. 9363 93630U-1 (2015).

# Design and analysis of diffractive surfaces in lens for optical disk system

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The presented research is devoted to the design of diffractive surfaces and their influence on the optical aberrations in the optical disk lens. Considering that diffractive optical elements have the known disadvantages, like possible parasitic diffraction orders and probable decrease of the transmission, we analyzed the optical disk lens with combined aspherical and diffractive surfaces. By using aspheric and diffractive surfaces the correction of optical aberrations was investigated in the lens for optical disk systems. The characteristics of designed diffractive surfaces were controlled in Software DIFSYS 2.30 which can show profile and fabrication limits of diffractive optical element (DOE).
Performances required on an optical disk lens are originally diffraction-limited performances represented by Marechal's criterions, which was to make the wave front aberration to be 0,07 λ. When aberration up to a certain image height also needs to be eliminated, it is necessary to make both surfaces of the single lens to be aspherical. In the case of a diffractive element, on the other hand, spherical aberration turns out to be under-corrected when wavelength dependency of the spherical aberration is larger and the wavelength is longer. When a 650 nm wavelength is used for DVD and 780 nm is used for CD, the degree of under-correction is higher for CD [1]. Nevertheless it is possible to make the sum total of spherical aberration of both the refraction and diffraction system to be satisfactory value by utilizing this wavelength difference. These so-called hybrid achromats exploit the fact that the dispersion of refractive elements is opposite that of diffractive elements, so they can neutralize each other [2, 3]. We investigated a design of the disk lens for 780 nm, which is an application for DVD optical system with NA (numerical aperture) = 1. The starting point for aspheric disk lens is limited by technology on 2 variable parameters, radii and thicknesses. By using default merit function for best focus using the RMS Spot Radius, Centroid RA 18x18 and additional parameters for decreasing spherical aberration, the starting point of disk lens was optimized. The conic and 6$^{th}$ order aspheric coefficients were defined additionally on both surfaces of disk lens. We used Zemax's Even Asphere to define aspheric surfaces in our design. With additional 7 more parameters (2 coefficients for conic, 5 coefficients for