



Determination of radial quantum dot position in trumpet nanowires from far field measurements

Østerkryger, Andreas Dyhl; Gregersen, Niels; Fons, Romain; Stepanov, Petr; Jakubczyk, Tomasz; Bleuse, J el; G rard, Jean-Michel; Claudon, Julien

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

Citation (APA):
 sterkryger, A. D., Gregersen, N., Fons, R., Stepanov, P., Jakubczyk, T., Bleuse, J., G rard, J-M., & Claudon, J. (2017). *Determination of radial quantum dot position in trumpet nanowires from far field measurements*. Poster session presented at 17th International Conference on Numerical Simulation of Optoelectronic Devices, Lyngby, Denmark.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Determination of radial quantum dot position in needle nanowires from far-field measurements

Andreas Dyhl Osterkryger* and Niels Gregersen

DTU Fotonik, Department of Photonics Engineering, Technical University of Denmark, Ørsted's Plads, DK-2800 Kongens Lyngby

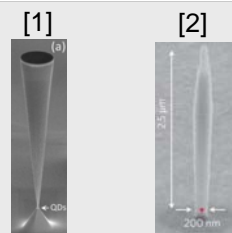
*presenting author, E-mail: adyh@fotonik.dtu.dk

Romain Fons, Petr Stepanov, Tomasz Jakubczyk, Jöel Bleuse, Jean-Michel Gérard and Julien Claudon

Univ. Grenoble Alpes, INAC-PHELIQS and CEA, INAC-PHELIQS, "Nanophysique et semiconducteurs" group, F-38000 Grenoble, France

I. Tapers for single-photon sources

- Quantum dots embedded in tapered nanowires have been shown as good candidates for realising an efficient single-photon source [1,2].
- For optimal efficiency the quantum dot should be placed on-axis. In this work we want to develop, a method for determining the quantum dot position in the nanowire based on the far-field emission pattern. The modelling is done using an open-geometry Fourier modal method [3], and a near-field to far-field transformation [4].



II. Modes and spontaneous emission rates in a nanowire

- The coupling of the quantum dot to the optical modes depends on the radial position of the quantum dot.
- Interference between the HE11 and TE01 modes leads to different power distributions in the NW, that should be visible in the far-field.

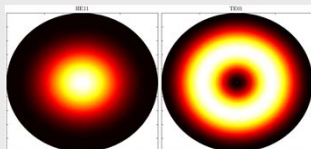


Figure 1: Mode profiles for the HE11 and TE01 modes.

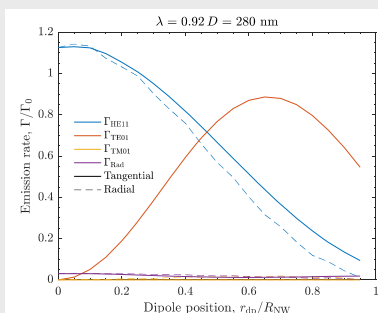


Figure 2: Spontaneous emission rate for a dipole in a nanowire.

III. oFMM and near-field to far-field transformation

- Field is expanded on eigenmodes:
- $$E(r, \phi, z) = \sum_{n,j} a_{nj}(r) E_{nj}(r) \exp(in\phi) \exp(i\beta_j z)$$
- Eigenmodes are expanded as a Fourier integral – open BCs:
- $$E_{r,nj} = i \int [b_{nj}^E(k) J_{n+1}(kr) - c_{nj}^E(k) J_{n-1}(k)] k dk$$
- Far-field is computed as:

$$E_{\theta,nj, \text{far}} \cong -\frac{ik_0 \exp(-ik_0 r)}{4\pi r} (L_{\phi,nj} + \eta N_{\theta,nj}),$$

where,

$$N_{\theta,nj} = 4(-i)^n \pi \cos \theta \cos n\phi \sum_m \Delta k_m (b_{mjn}^H - c_{mjn}^H) \delta(k_m - k_0 \sin \theta)$$

$$L_{\phi,nj} = 4(-i)^{n-1} \pi \cos n\phi \sum_m \Delta k_m (b_{mjn}^E + c_{mjn}^E) \delta(k_m - k_0 \sin \theta)$$

IV. Far-fields for needle structure

- Measured far-fields for needle with $D_{\text{Bot}} = 182 \text{ nm}$ (to be confirmed) and $\text{NA} = 0.75$.
- Simulated far-fields with $D_{\text{Bot}} = 200 \text{ nm}$, have good agreement with measurements.
- Cut-off for TE01 mode is at $d/\lambda = 0.23$, interference is still present – how?

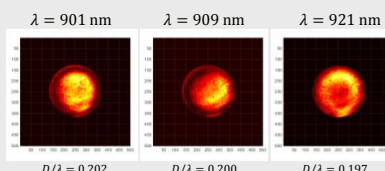


Figure 3: Measured far-fields for three different quantum dots.

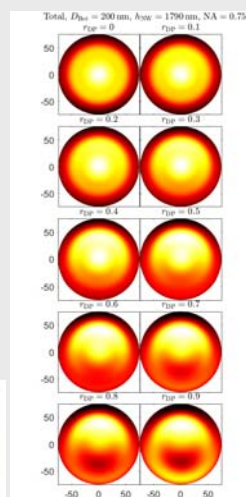


Figure 4: Simulated far-fields, where $D/\lambda = 0.22$

V. Radiation mode or guided mode?

- The guided modes exist as radiation modes just before they are guided.
- These semi-guided radiation modes will interfere with the guided HE11 mode, and only slowly escape the nanowire.
- A simple 2-mode model is therefore not enough.

Guided modes: $k_0^2 \leq \beta^2 < (nk_0)^2$
Radiation modes: $0 \leq \beta^2 < k_0^2$
Evanescent modes: $\beta^2 < 0$

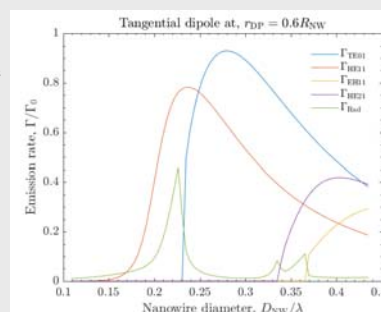


Figure 5: Spontaneous emission rate for a dipole in a Nanowire placed $0.6 R_{\text{NW}}$ off axis.

[1] Stepanov, P. et al., "Highly directive and Gaussian far-field emission from "giant" photonic trumpets," Appl. Phys. Lett. 107, 141106 (2015)

[2] J. Claudon, J. Bleuse, N. S. Malik, M. Bazin, P. Jaffrennou, N. Gregersen, C. Sauvan, P. Lalanne, and J.-M. Gérard, "A highly efficient single-photon source based on a quantum dot in a photonic nanowire", Nature Photonics 4 (2010)

[3] T. Häyrynen, J. R. de Lasson, and N. Gregersen, "Open-geometry Fourier modal method: modeling nanophotonic structures in infinite domains", J. Opt. Soc. Am. A 33, 1298 (2016).

[4] C. A. Balanis, *Advanced Engineering Electromagnetics* (Wiley, 1989), vol. 1, chap. 6