APPLIED NANOPHOTONICS:
THERE'S MORE TO LIGHT THAN MEETS THE EYE

AUTHORS:
SIMON HUISMAN
MARCEL HORSTMANN
PEPIJN PINKSE

Many readers of Focus might not be familiar with the existence of Strategic Research Orientations, or SRO in short. The SRO's are instruments within the MESA+ institute whose role is to concentrate and focus research in a certain direction. The SRO Applied NanoPhotonics (ANP) was started by MESA+ in September 2009 with the arrival of Pepijn Pinkse as SRO director. ANP is both a research program and a research collaboration of existing chairs. ANP fosters collaboration between all MESA+ groups doing optical research. In practice this concentrates in the five chairs COPS, IOMS, LPNO, NBP, and OS. We have common monthly group meetings and once per year over 70 researchers from these groups gather somewhere off campus – in a nice surrounding – to discuss science and get to know each other better.
Pepijn Pinkse supervises students on ANP central projects. They are usually members of two chairs and in this way form a bridge between the participating groups. In the following we will talk to two such PhD students.

Simon Huisman

Quantum Nanophotonics with Photonic Crystal Waveguides

Simon, in which group do you work?
I work in both Complex Photonic Systems (COPS) and Optical Sciences (OS).

Isn't it confusing to work in two groups?
Of course it is.

And the advantages?
It is actually a privilege to work in two chairs. We have the opportunity to combine research, expertise and materials of two very different groups to start-up something completely new.

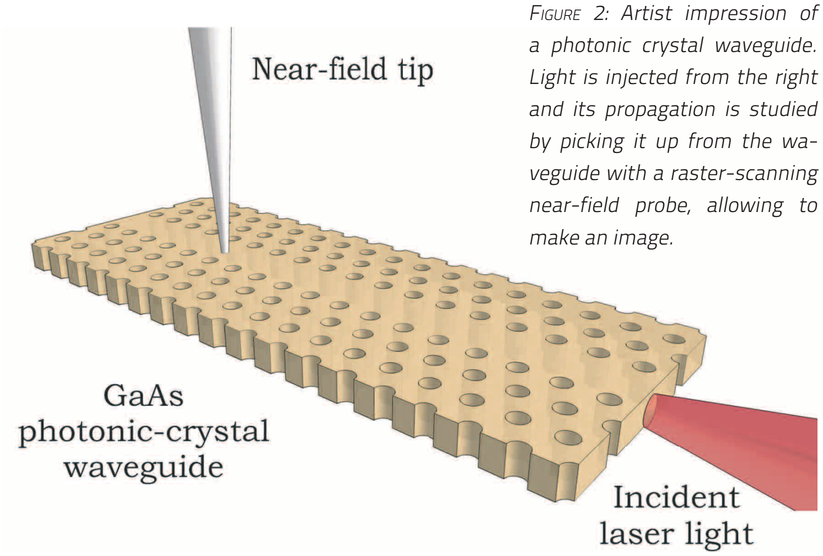


Figure 2: Artist impression of a photonic crystal waveguide. Light is injected from the right and its propagation is studied by picking it up from the waveguide with a raster-scanning near-field probe, allowing to make an image.

What do you work on?
I have been studying light transport in photonic-crystal waveguides. These waveguides are a special class of integrated optical structures that strongly interact with light. Light would normally propagate through such a waveguide. However, even the smallest amount of disorder, which is always present, causes light to become trapped at specific wavelengths. Disorder forms small cavities at random locations. Surprisingly, these randomly occurring cavities have similar properties as nanophotonic cavities that have been engineered on purpose. It is very hard to engineer a good cavity, but would it not be great if one can exploit a cavity that is created by disorder? I would like to put a light emitter inside such a random cavity and see how they interact. Will we observe strong coupling, i.e., can we see a photon oscillating between the emitter and the cavity a few times before it is lost?

Can you give an example of an experimental challenge you had to face?
A big challenge was to get light into such a random cavity. It actually turns out that disorder helps us to couple light more efficiently into such a random cavity.

Why is this relevant?
Disorder is everywhere and it is fundamental for optics, acoustics and solid-state physics. Our waveguides form excellent model systems to investigate the effects of disorder. It would be useful if one can exploit disorder as a platform for integrated photonics. For people who want to build integrated photonic devices, our research demonstrates how disorder affects the performance.

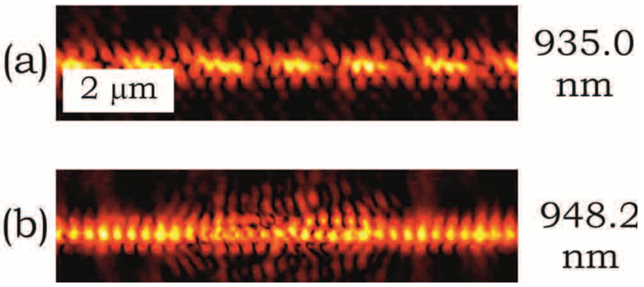


FIGURE 3: (a) Measured amplitude of light propagating through a photonic crystal waveguide. (b) Measured amplitude at the same location for a different wavelength. The effect of disorder is that light becomes trapped in a random 'cavity' in the center of this picture [3].

Do you work on this alone?
Pepijn and I are the main actors on this project. We work in close collaboration with COPS and OS, the FOM-institute AMOLF (Amsterdam) and the Niels Bohr Institute (Copenhagen) and just this month a new PhD student, Amandev Singh, from India joined in. About 10 people are involved with this project.

Your biggest success so far?
For me the biggest success is when I started to observe near-field patterns of localized light. This has led to some impact and disturbance in the scientific community, and was acknowledged recently by winning an award for a presentation about it. On the other hand, I have some high-profile papers accepted [1,2], which is also nice.

Marcel Horstmann

Quantum Optics with trapped Nanoparticles

Marcel, in which group do you work?
I actually work in two chairs, COPS and LPNO.

Isn't it confusing to work in two groups?
It sometimes is! When I am asked twice each day to come by and have some lunch together, for example...

And the advantages?
Well, first of all I can get advice from people with different scientific backgrounds. This is very helpful and has already saved me from running into quite some pitfalls. I can also use the equipment of both chairs for my research, which allows me to do complicated experiments without having to build everything from scratch.
I also have a lot of nice colleagues to drink some beer with, and even more occasions to do so...

What do you work on?
I work on the trapping of tiny luminescent nanoparticles in a vacuum chamber. We call these particles 'quantum dots' or 'artificial atoms' because they resemble some of the optical properties of real atoms.

Why is this interesting?
Quantum dots are very promising candidates for making the next generation of LEDs and solar cells even more efficient. Many researchers, also here in Twente, are currently working hard to achieve this goal. I hope I can assist in this process with my PhD project - by developing a better understanding of the fundamental physical behavior of these light emitters. Apart from that, a well-controlled nanoparticle in a trap is a very promising system for fundamental studies in quantum optics and might allow quantum opto-mechanics, that is, the interaction of mechanical vibrations with the quantum-optical properties of the nanoparticle [4].

And how do you want to do this?
We want to isolate them from the influences of the surrounding material. This can be done by levitating the particle inside a so-called Paul trap. Such a trap is shown in the figure below, where we have trapped a small grain of milk powder (diameter of about 30μm, about one third of a human hair) and illuminated it with a laser beam. It is therefore visible as a bright spot in the center of the trap. Currently I am working to build a trap that is able to trap the much smaller quantum dots, which contain only a few thousand atoms...

Can you give an example of an experimental challenge you had to face?
In order to trap a single quantum dot in a Paul trap, I first have to separate one single dot and additionally charge it. I found out that this can be done using the technique of electro-spraying, and was very happy to hear that researchers from an American university have already successfully applied this technique to quantum dots. ▶

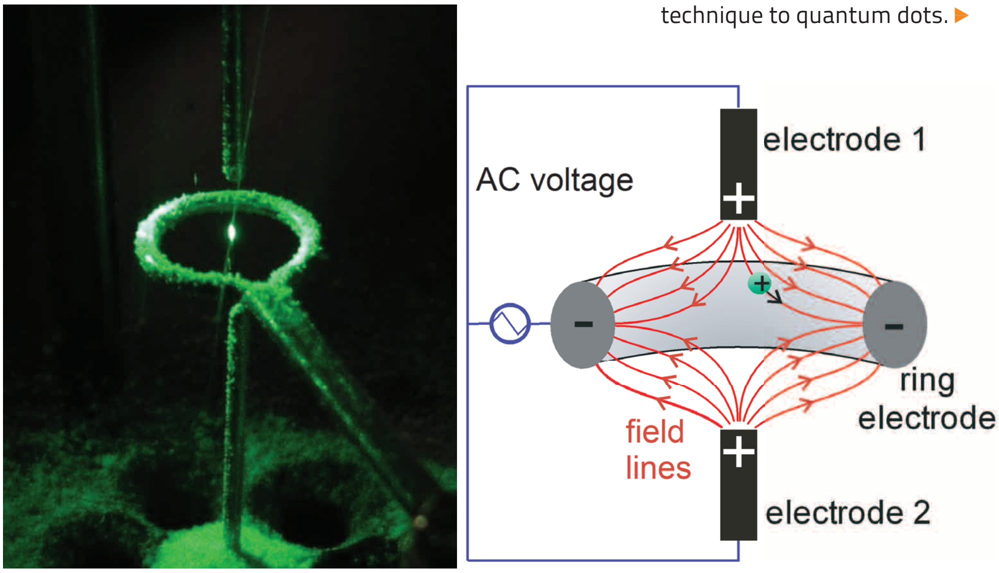
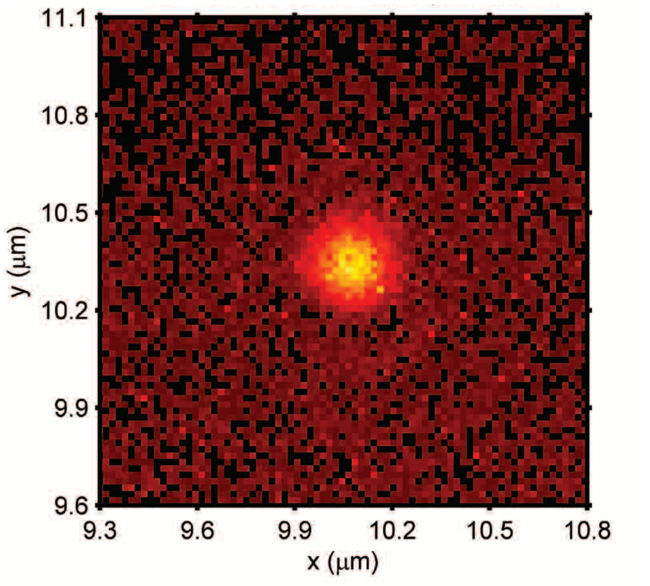


FIGURE 4: (left) Demonstration model of a Paul trap with a grain of milk powder caught in the center of the high-voltage electrodes. (right) Instantaneous electric field lines in the trap showing the direction in which a positively charged particle would fly. Before the particle hits an electrode, though, the polarity is flipped. This AC electric field causes a micromotion effectively trapping the particle in the center of the trap.

FIGURE 5: *Image of a single CdSe quantum dot on a surface.*



You are still in the beginning of project, what have you achieved so far?

Well, in the first few months I did a lot of literature research to find out if – and how! – it is possible to trap such a nanoparticle. At the same time, master student Rob Scheers has started to develop the optical setup which I am going to use to study the isolated quantum dots in the trap.

He recently succeeded in taking an image of a single CdSe quantum dot [4] lying on a cover slip (see FIGURE 5).
I also tried (and partly succeeded) in learning Dutch by attending an intensive one-week Dutch course here at the UT... ■

We thank Simon and Marcel for the interview and wish them success.
If you want to know more about this research or about possibilities for joining the ANP team, feel free to contact Simon, Marcel or Pepijn.
More info can be found on the SRO website:
http://www.mesaplus.utwente.nl/anp

References

[1] S.R. Huisman, R.V. Nair, A. Hartsuiker, L.A. Woldering, A.P. Mosk, and W.L. Vos, *Observation of sub-Bragg diffraction of waves in crystals*, Phys. Rev. Lett 108, 083901 (2012)
[2] M.D. Leistikow, A.P. Mosk, E. Yeganegi, S.R. Huisman, A. Lagendijk, and W.L. Vos, *Inhibited spontaneous emission of quantum dots observed in a 3D photonic band gap*, Phys. Rev. Lett. 107, 193903 (2011)
[3] S.R. Huisman, G. Ctistis, S. Stobbe, A.P. Mosk, J.L. Herek, A. Lagendijk, P. Lodahl, W.L. Vos, and P.W.H. Pinkse, *Photonic-Crystal Waveguides with Disorder: Measurement of a Band-Edge Tail in the Density of States*, submitted.
[4] C. Blum, F. Schleifenbaum, M. Stopel, S. Peter, M. Sackrow, V. Subramaniam, A.J. Meixner, Beilstein, *Room temperature excitation spectroscopy of single quantum dots*, J. Nanotech. 2, 516-524 (2011)