Precise Alignment to Quantum Dots

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"Precise lithographic alignment to site-controlled quantum dots is of major importance for numerous nano-photonic, nano-electronic and nano-spintronic devices," Sven Höfling tells *PhysOrg.com*.

Höfling continues: "So far, most of the devices based on single quantum dots use a layer of self-organized quantum dots, where the dots are at random positions and a post-fabrication screening is employed to select devices with proper spectral and spatial alignment, for example, with respect to a cavity mode. After all, whether or not you can find a proper quantum dot is largely a matter of chance"

Höfling and his colleagues at Julius Maximilians University in Würzburg, Germany believe that they have come up with a scheme that would make it much easier to produce single dot-based devices to be used in the fabrication process of nano devices. The results from the team in Würzburg are reported in *Applied Physics Letters*: "Lithographic alignment to site-controlled quantum dots for device integration."

"Previously used approaches were sufficient for the realization of single, research type devices, whose main purpose is the study of basic physics," Höfling concedes, "but it does not allow for large scale device fabrication needed for widespread applications." Right now, he points out, in many cases the yield of these nano devices is close to zero.

In order to usher in an era of widespread applications for nano devices, the Würzburg team combined two processes to produce single dot device with higher yield: a site-controlled quantum dot growth by pre-patterning and an accurate alignment technique. “People have pioneered this pre-patterned quantum dot growth before,” says Höfling. “Others have made accurate alignment. By combining them together, we are investigating a serious scheme that is scalable. This will significantly increase the yield of single quantum dot based devices.”

By using the accurate alignment, it is possible to know where the quantum dots are, allowing fabricators to pinpoint them and “use, for instance, a pulsed laser to excite them so that they emit single photons on demand,” Höfling says. “Before, it was guesswork. A random distribution of quantum dots would have to be used, shining light on it and hoping to find a proper located quantum dot in the device. Now, it’s much easier”.

Höfling does point out that the work needs to carry on further. “Right now, this work addresses spatial aspects only. We know in advance where the quantum dots are, but they can still have different properties. We also need to control better their properties, namely we need additionally a spectrally deterministic technology. That is what we are working on now, but site-control can here also be very useful to manipulate the properties of the quantum dots.”

Even without the spectral aspect, though, Höfling thinks that the work done by him and his peers has the potential to be very useful in the future. He says that single photon sources, single quantum dot lasers, electron memory devices, entangled photon pair emitters and the semiconductor building blocks for quantum information processing could all advance with help from this technology.

“Everything is decreasing in size,” Höfling points out, “and we need smaller and smaller devices. At some point, we are going to need to be able to produce single quantum dot based devices.”

“We have, in the meantime, succeeded to couple a single quantum dot spatially in a spatially deterministic way with a single photonic crystal mode,” he continues, “yielding a device which is capable of efficiently emitting single photons on demand.”