Quantum emitters: Beyond crystal clear to single-photon pure

September 2 2021

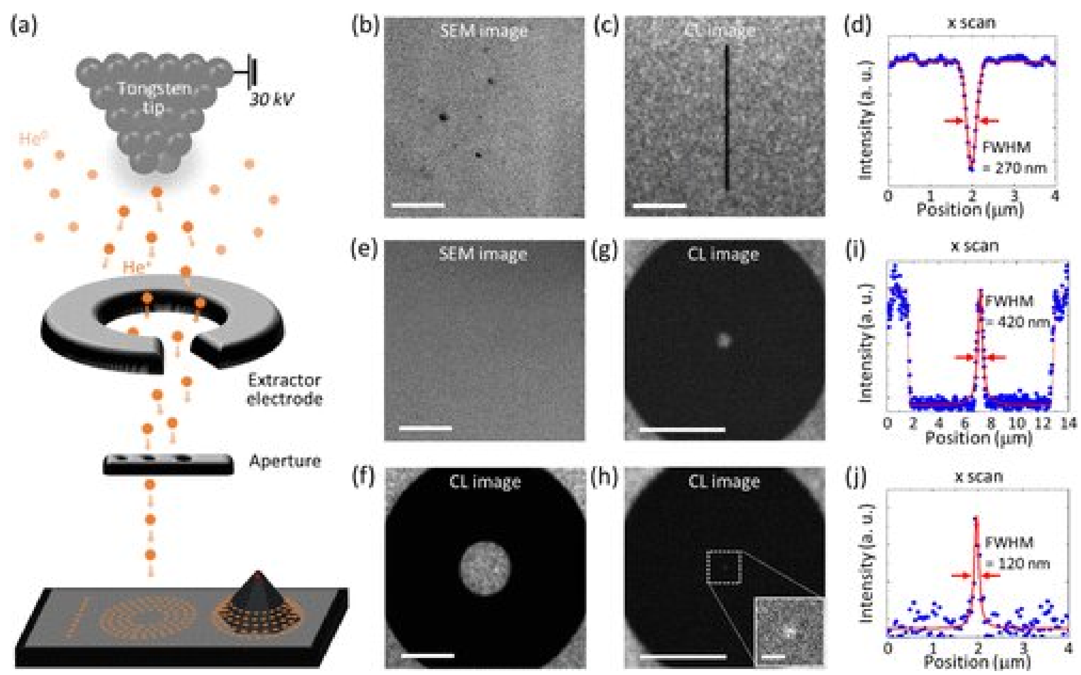

Figure 1. Concept of the NFP technique using HIM. (a) Schematic illustration of the helium ion source and the various implantation patterns on planar/pyramidal samples. (b, c) SEM and monochromatic CL (at the wavelength of QW emission, 400 nm) images of the planar QW after line-patterned helium ion implantation. (d) Line scan of the CL intensity and fitting curve. (e–h) SEM and monochromatic CL images of the planar QW after doughnut-patterned helium ion implantation. (i, j) Line scan of the monochromatic CL intensity of (g) and (h), respectively. All the scale bars except the inset image have a length of 4 μm, while the scale bar of the inset image in (h) has a length of 0.5 μm. Credit: DOI: 10.1021/acsnano.1c00587

Photons, fundamental particles of light, are carrying these words to your eyes via the light from your computer screen or phone. Photons play a key role in the next-generation quantum information technology, such as quantum computing and communications. A quantum emitter, capable of producing a single, pure photon, is the crux of such technology but has many issues that have yet to be solved, according to KAIST researchers.

A research team under Professor Yong-Hoon Cho has developed a technique that can isolate the desired quality emitter by reducing the noise surrounding the target with what they have dubbed a 'nanoscale focus pinspot." They published their results on June 24 in *ACS Nano*.

"The nanoscale focus pinspot is a structurally nondestructive technique under an extremely low dose ion beam and is generally applicable for various platforms to improve their single-photon purity while retaining the integrated photonic structures," said lead author Yong-Hoon Cho from the Department of Physics at KAIST.

To produce single photons from solid state materials, the researchers used wide-bandgap semiconductor quantum dots—fabricated nanoparticles with specialized potential properties, such as the ability to directly inject current into a small chip and to operate at room temperature for practical applications. By making a quantum dot in a photonic structure that propagates light, and then irradiating it with helium ions, researchers theorized that they could develop a quantum emitter that could reduce the unwanted noisy background and produce a single, pure photon on demand.

Professor Cho explained, "Despite its high resolution and versatility, a focused ion beam typically suppresses the optical properties around the bombarded area due to the accelerated ion beam's high momentum. We focused on the fact that, if the focused ion beam is well controlled, only the background noise can be selectively quenched with high spatial resolution without destroying the structure."

In other words, the researchers focused the ion beam on a mere pin prick, effectively cutting off the interactions around the quantum dot and removing the physical properties that could negatively interact with and degrade the photon purity emitted from the quantum dot.

"It is the first developed technique that can quench the background noise without changing the optical properties of the quantum emitter and the built-in photonic structure," Professor Cho asserted.

Professor Cho compared it to stimulated emission depletion microscopy, a technique used to decrease the light around the area of focus, but leaving the focal point illuminated. The result is increased resolution of the desired visual target.

"By adjusting the focused ion beam-irradiated region, we can select the target emitter with nanoscale resolution by quenching the surrounding emitter," Professor Cho said. "This nanoscale selective-quenching technique can be applied to various material and structural platforms and further extended for applications such as optical memory and high-resolution micro displays."Korea's National Research Foundation and the Samsung Science and Technology Foundation supported this work.

More information: Minho Choi et al, Nanoscale Focus Pinspot for High-Purity Quantum Emitters via Focused-Ion-Beam-Induced Luminescence Quenching, *ACS Nano* (2021). DOI: 10.1021/acsnano.1c00587

Provided by The Korea Advanced Institute of Science and Technology

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