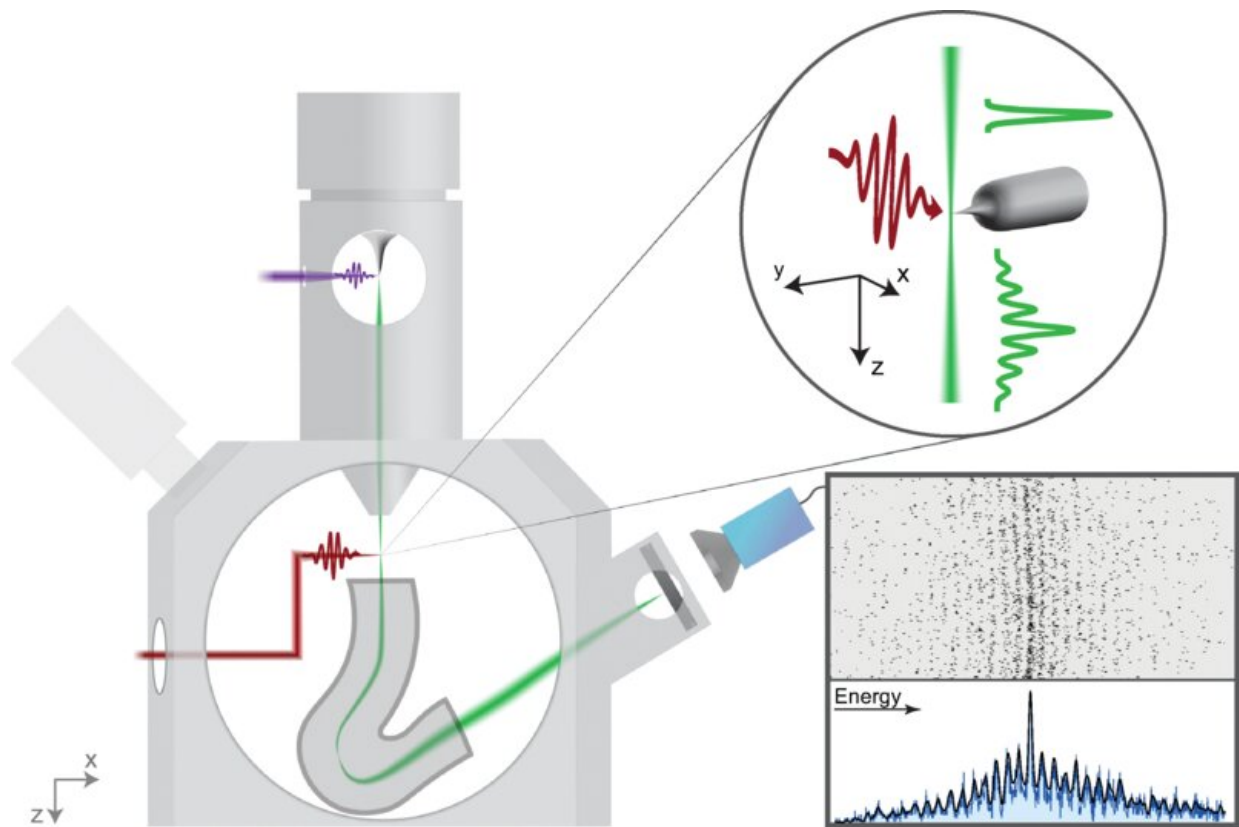


Investigating electrons with a traditional scanning microscope

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Quantum coherent electron-light coupling in an ultrafast SEM. Electrons photoemitted by ultraviolet laser pulses (purple) propagate through the column of a commercial SEM. The electron beam (green) is focused close to a tungsten needle tip (inset), where it interacts with the optical near-field excited by 1030-nm laser pulses, coupled into the SEM through a CF-100 window in the SEM sample chamber. The aspherical focusing lens (not shown) is 25 mm away from the tip, inside of the chamber. Electron spectra are recorded with a home-built compact double-stage magnetic sector electron spectrometer based on the

Omega filter, placed inside the SEM. The dispersion plane of the spectrometer is imaged onto a microchannel plate detector, whose phosphor screen is optically recorded from outside of the vacuum chamber with a CMOS camera. An example image (bottom right inset), where individual electron counts (black dots) and photon orders (vertical dotted lines) can be easily seen by the eye. The PINEM spectrum is obtained by integrating the camera image vertically [38]. The incoherently averaged experimental spectrum (black), with the raw, binned data (blue), show 24 PINEM orders, 12 on each side, the maximum we observed. Credit: *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.128.235301

Physicists at Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) have designed a framework that allows scientists to observe interactions between light and electrons using a traditional scanning electron microscope. The procedure is considerably cheaper than the technology that has been used to date, and also enables a wider range of experiments. The researchers have published their findings in the journal *Physical Review Letters*.

The quantum computer is just one example of how important an understanding of the fundamental processes underlying interactions between photons and [electrons](#) is. Combined with ultra-[short laser pulses](#), it is possible to measure how photons change the energy and speed of electrons. This photon-induced [electron microscopy](#) (PINEM) has until now relied entirely on transmission electron microscopes (TEM). Although these have the resolution to pinpoint [individual atoms](#), they are considerably more expensive than scanning electron microscopes (SEM), however, and their sample chamber is extremely small, only a few cubic millimeters in size.

Measuring differences down to a only a few hundred thousandths of a whole

Researchers at Prof. Dr. Peter Hommelhoff's Chair of Laser Physics have now succeeded in modifying a traditional SEM to conduct PINEM experiments. They designed a special spectrometer based on magnetic forces which is integrated directly into the microscope. The underlying principle is that the [magnetic field](#) diverts electrons to a greater or lesser extent depending on their speed. Using a detector that transforms electron collisions into light, an accurate reading of this deviation is given. The method allows researchers to measure even the smallest changes in energy, up to differences of merely several hundred thousandths of the original value—enough to differentiate the contribution of a single light energy quanta—a photon.

A wider spectrum of experiments possible in the future

The Erlangen [physicists'](#) discovery is pioneering in more ways than one. From a financial point of view, being able to research photon-electron interactions without using TEM, that cost several million euros, could make research more accessible. Furthermore, as the chamber of an SEM generally has a volume of up to 20 cubic centimeters, a much wider range of experiments is now possible, as additional optical and [electronic components](#) such as lenses, prisms and mirrors can be placed directly next to the samples. The researchers expect that in few years' time, the entire field of microscopic quantum experiments will shift from TEM to SEM.

More information: R. Shiloh et al, Quantum-Coherent Light-Electron Interaction in a Scanning Electron Microscope, *Physical Review Letters* (2022). [DOI: 10.1103/PhysRevLett.128.235301](https://doi.org/10.1103/PhysRevLett.128.235301)

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