DTU

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Climate Challenge Laboratory | Building 313

A Question of Time

Theme: Early commissioning

Campus Service
The Technical University of Denmark

A Question of Time

Climate change is well underway and the work on developing new sustainable energy sources cannot proceed quickly enough. So even though the Climate Challenge Laboratory is only partially complete the research center VISION has moved in and will soon put the new electron microscope to use to accelerate research in Power-to-X technologies.

A unique transmission electron microscope is the center of the research done in Climate Challenge Laboratory. The microscope is a facility - a super tool - that researchers will use in their efforts to develop new catalysts for the Power-to-X technology, which will enable the green transition.
In recent years, climate change has intensified, and there is no time to waste. Now, the research center VISION, which possesses the microscope, has exceptionally been granted access to their premises, even while the rest of the Climate Challenge Laboratory is still under construction.
From the beginning of the construction of the building, DTU has prepared for VISION to move in as early as possible so the center can kickstart its ambitious research plans.
In this newsletter, Nicolai Brogaard Bredal-Jørgensen, Campus Service DTU, Søren Schriver, commissioning construction manager from Børthy Schriver Lundemann, and Asger Barkholt Moss, who is Floor Manager of SURFCAT/VISION, DTU Physics, explain how they have approached this task and how they will install the specially-built microscope.



CLOSE COLLABORATION FROM START TO FINISH. Nicolai Brogaard Bredal-Jørgensen, from Campus Service, Søren Schriver, construction manager responsible for commissioning, Børthy Schriver Lundemann, from DTU, and Asger Barkholt Moss, the Scientific Floor Manager at SURFCAT, have found solutions for developing a new building for a sensitive microscope and putting it into operation while the construction site is still active.Fotos: Børthy Schriver Lundemann/DTU

"We need the microscope to truly realize our research ambitions and, hopefully, contribute to new knowledge and ideas for catalysts in the green transition."

– Asger Moss, Floor Manager, DTU Physics

No Time to Waste

In the middle of October, VISION received the keys to their laboratory in the basement of the Climate Challenge Laboratory, approximately 8 months before the building is fully completed and handed over to the users. This early access is because VISION is expecting the delivery of an electron microscope in November 2023.

The Climate Challenge Laboratory won't be fully finished until June 2024. Why is it so important for VISION to move in right now?
ABM: VISION is a basic research center operating over six years. We have received funding for the microscope, and it needs to be operational to realize our research plans. From a research perspective, it's also about being the first. Clearly, we want to get this microscope up and running as quickly as possible. It's important to note that VISION's research is already well underway with several of our Ph.D. students and Postdocs achieving some impressive results. However, we need the microscope to truly realize our research ambitions and, hopefully, contribute to new knowledge and ideas for catalysts in the green transition. We hope it will become a powerful tool in this specific field of research.
What are your roles and tasks?

Commissioning

Commissioning is a quality management process that verifies, documents, and tests whether a building meets the specified requirements. The commissioning process establishes measurable function-based requirements at the beginning of a project. These requirements are checked for compliance throughout all phases of the project: design phase, execution phase, and operation phase.

The commissioning process originates from the shipbuilding industry, where a commissioned ship is a ship that has been completed and is ready for sailing. Before a ship can obtain this title, it must pass a series of tests.

Source: Cx Wiki

ABM: Officially, I am the Scientific Floor Manager, but in this context, I usually refer to myself as the Technical Lab Manager. My task is to make the microscope operational, starting from planning the technical details with the manufacturer (Thermo Fisher Scientific Inc., red.) to ensuring it is brought into the building, made ready, and can be used. My role involves both the practical aspects of installation, getting it up and running, and ensuring its functionality in the future, as well as assisting the Ph.D. students, Postdocs, and researchers who will be using the instrument.

NBBJ: I am the client representative in DTU's building organization, Campus Service, and therefore responsible for ensuring that the construction is designed and executed for the purpose DTU has determined. In this case, it is particularly unique that such a large part of the building is being completed and put into use ahead of schedule. From the beginning, we knew that VISION should be integrated as early as possible and have incorporated it into all phases, which required careful planning.

SS: I am the Cx leader for commissioning (Cx, red.). I have been involved since the design phase, before we broke ground, and I will be involved until we are finished, meaning when the building is handed over to the users and for operations. We have around 60 Cx requirements for the project. My task is to drive the process and ensure that we meet these requirements and have everything tested and documented.

What is commissioning?

SS: Commissioning is a process that runs in parallel with the design and construction of the building, ensuring that the building meets the technical requirements. Here at DTU, a Cx team has been established that focuses solely on commissioning and is solely concerned with whether the facility can do what it's supposed to. At the same time, DTU has set various requirements for the operation of the buildings, which the building must comply with. For the Climate Challenge Laboratory, it's unique because we are constructing both a laboratory and an office section with very different requirements. Additionally, VISION had to take over their part of the building earlier. In the beginning, a team of consultants, the client, and the users figured out what technical requirements the building needed to meet, such as air volumes for ventilation and temperature requirements. In that phase, we clarified the requirements and set up parameters so that we can test whether we meet the goal.

ABM: It's a very sensitive instrument, so it's an exciting task to install it while there is construction work going on. The instrument requires very quiet surroundings to function, so it doesn't quite align with the construction site. However, it still needs to be shielded from other sources of noise, such as the upcoming light rail, which is why it will be placed in a room that is completely isolated from its surroundings.

A microscope with demands for the building

Housing such a sensitive instrument places significant demands on the building. VISION will have facilities in a high basement where the microscope will have its own room designed to create the optimal environment around it.

What are your specific requirements?

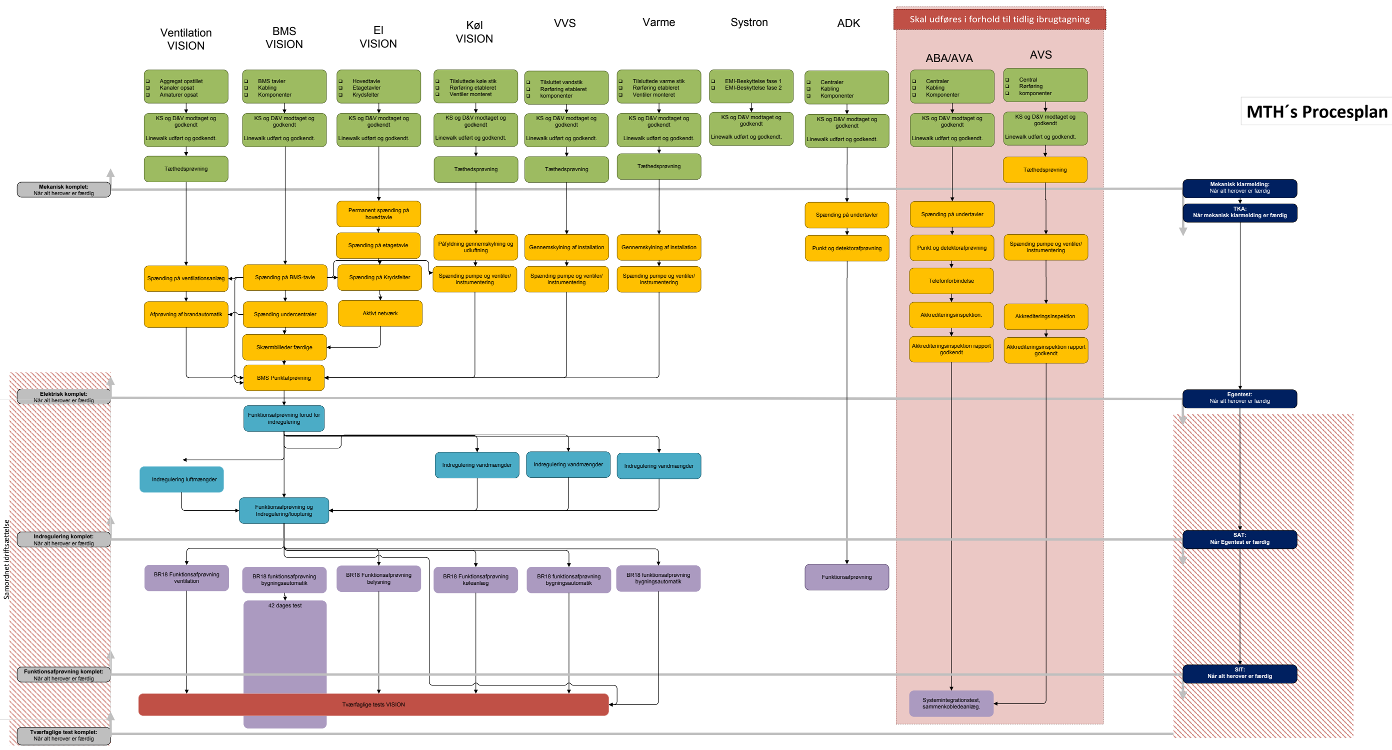
ABM: The environment must be as quiet and stable as possible, including both noise and temperature. The temperature should not vary by more than 0.8 degrees within 24 hours inside the room. The microscope is placed on its own 2-meter-deep foundation that doesn't shake or vibrate due to activities in other parts of the building. There should also be no external electromagnetic interference as it would significantly affect the microscope. Typically, similar laboratories around the world are located far away from any other sources of disturbance. However, the challenge here is that if we place the microscope somewhere south of Køge (where the S-train terminates, red.), it would be difficult to attract foreign researchers, and we would lose the synergy between VISION and the other researchers in the building (Climate Challenge Laboratory, red.). This includes both the theorists working to understand why catalysts function the way they do and the experimentalists who create and test the catalytic particles we need to examine. Instead of moving away from everyone else, we are moving the microscope to them and shielding it from the noise that may be present. This means that the rest of the building is almost constructed around this laboratory.

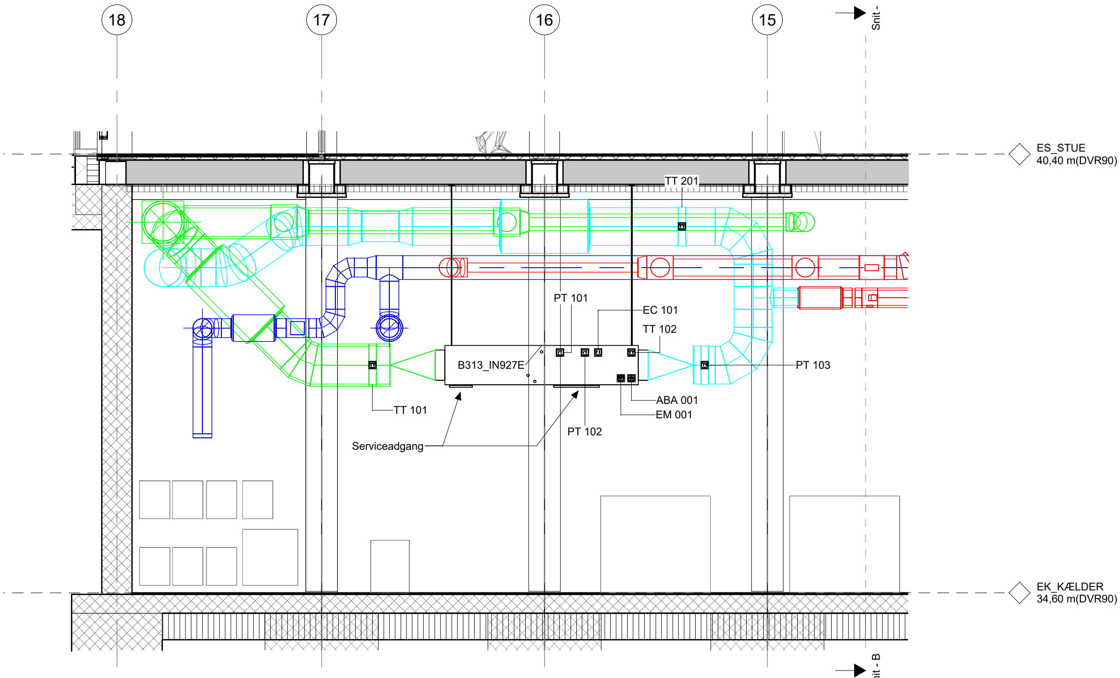
NBBJ: There's no doubt about that. The microscope has set many of the specifications for the building and even beyond. On the campus, there's a road passing by the laboratory which will be closed to car traffic because it will disrupt the microscope. So, we've examined the entire infrastructure in this quadrant. You might think it would have been better to place the microscope at DTU Risø, but this is the right location because of the synergy with all the other researchers.

How have you dealt with the scenario that you not only have to build a building around a microscope but also put it into use as early as the schedule allows?
SS: We've been running a commissioning process since the beginning of the project because the microscope needs to be operational before anything else. As Asger mentioned, the building has been constructed around it, but many of the installations are tailored to allow VISION to operate while there's still construction happening. This involves separate supplies of heat, cooling, water, gas, and electricity, so construction can continue in the rest of the building without the risk of interruptions to VISION. We've set up a temporary supply from B310, which is a secure supply, while we finish constructing B313 (Climate Challenge Laboratory, red.).
In some areas, we've also made different choices from Campus Service's standard solutions. For example, we've installed a ventilation system with stand-alone control instead of traditional Building Automation System (BAS) control to supply the room with fresh air to maintain stable temperatures. This system has its own control and a local system we can operate because the building and the network won't be operational when VISION moves in. These are the kinds of things we need to incorporate into the project very early to succeed. All the things with concrete, doors, and ceilings can be solved, but in my view, the technical part is the challenging one.

What has it meant for time and budget?
NBBJ: It has required a lot of planning, a tremendous amount of planning. Many questions have arisen precisely because it's so critical. When the case was tendered, we had a master schedule with staggered design and execution for VISION's area. Now we've mingled it in, so it happens simultaneously, resulting in an earlier commissioning. When we started the design, we weren't entirely sure about the microscope's specs, but we included time for changes

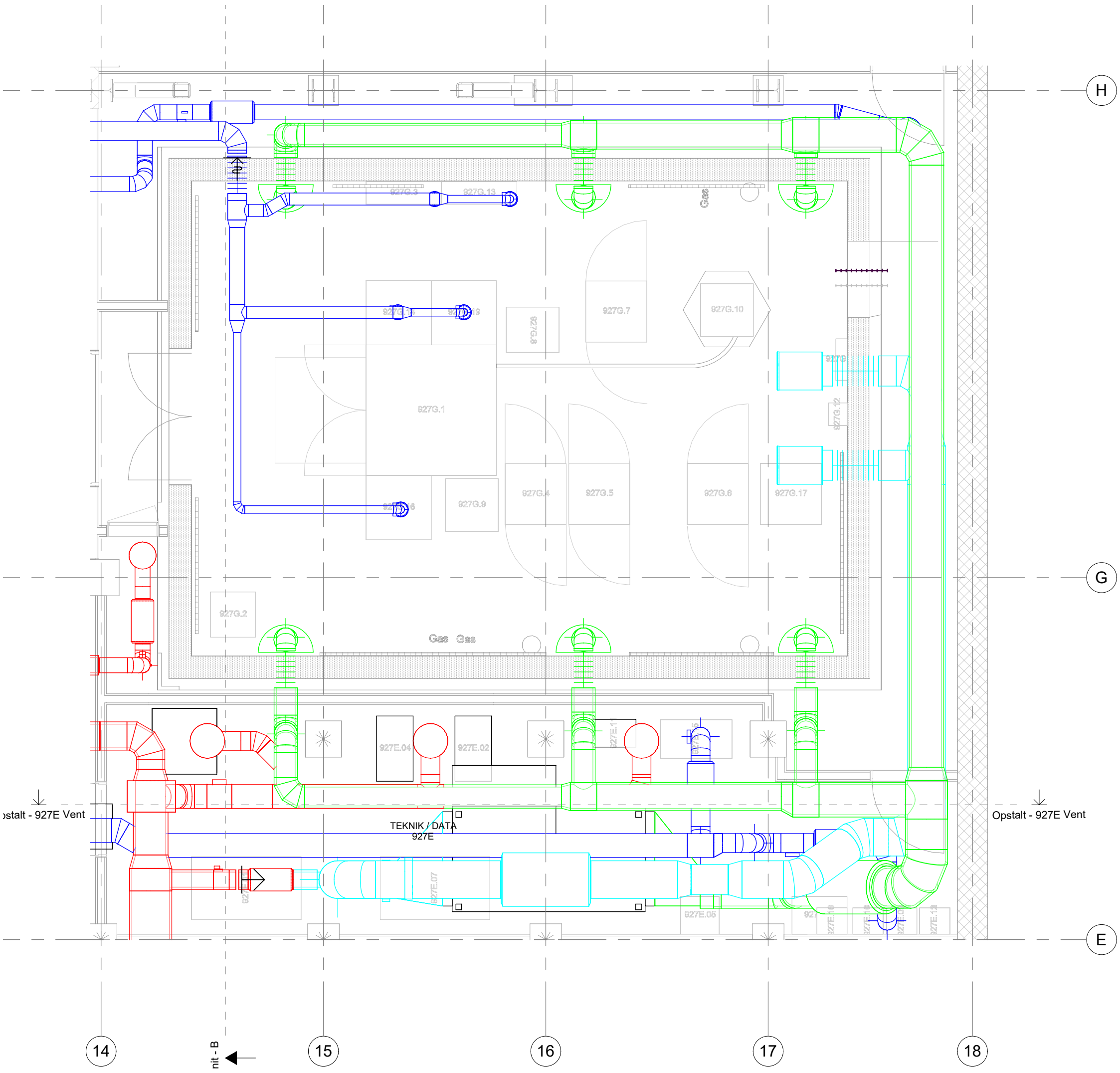
FLOWCHART FOR VISION. From the start of the construction process, DTU Physics and Campus Service have worked targeting the earliest possible commissioning of VISION's premises. Commissioning has therefore been envisaged in the plan from the initial phases. The diagram gives an idea of the complexity of the exercise. Illustration: DTU





A HOUSE FOR A MICROSCOPE. Special technical installations are needed for the microscope to be used. DTU has carried out a separate ventilation system for VISION's area in the Climate Challenge Laboratory. Drawings: DTU

Opstalt - 927E Vent - 1:100



Funktionsdiagram - Ventilation 927E - 1:100

in the schedule.

When we began, there was only funding for VISION, but not for the rest of the building. Only when we have an approved formal deed can we be certain about the budget, but we knew we had to build VISION. It was also crucial to secure funds for the rest of the building; otherwise, the entire concept of an interdisciplinary research environment would be lost.

Can you explain how the installation process will take place?

ABM: The manufacturer is responsible for the actual assembly. They built the microscope at their factory and tested everything down to each single cable. When they finish tuning and testing it, they disassemble it into as many large pieces as possible, pack it in boxes, and send it here. Then they come here and reassemble everything. I think you should imagine the most advanced LEGO set you could dream of.

Our part has been more in the planning. It's such a complex instrument that they want to know exactly how long each cable should be so that we can pinpoint what went wrong if something goes wrong. Therefore, it's been a continuous process to coordinate with the manufacturer on how the microscope will be installed, such as its position, the routing of cables, power sources, and so on. In this regard, I have coordinated between the manufacturer on one side and the construction management, architects, and engineers on the other.

The platform on which the microscope is built is a standard product. It's a relatively new series of electron microscopes, but there are several of them around the world. What makes this microscope unique is that we're asking for something extra. It's an upgraded version that has never been made before. It's like taking a regular Mercedes and putting a better engine in it. It becomes something entirely different.

Søren, what is your role when it comes to the site?

My role is not be here. We've fine-tuned everything with Asger down to the smallest detail. It's mostly logistics, ensuring that nothing obstructs it because there's a lot of equipment that needs to be brought into the building. We've also made a point of separating VISION from the rest of the building, even on the construction site, to keep construction workers away from VISION's area.

ABM: Yes, the normal procedure would be to construct a building, and then we'd install something inside it. In this case, the installation of the microscope has become part of the construction process. So, I often move around here (in Building 300, red.). It's a daily collaboration with very fluid boundaries about who does what.

INSTALLATION IN PHASES. Thermo Fisher began the installation in week 43 by setting up the cabinet, an acoustically isolated box in which the microscope will be placed in. As a result, a portion of the building was handed over and transferred to VISION in mid-October 2023, while the rest of the building is still under construction. The final delivery (AB) is scheduled for June 2024, and the handover to the users is set for July 2024.

Research from 2024

In November, the microscope will be installed, and test runs will begin. After that, VISION can start using it and invite other researchers into the laboratory. There are high expectations regarding its significance for research and the development of the technology that will be a cornerstone in the green transition.

What is the first thing that will happen from there?
ABM: The first thing is that we need to test whether the microscope can do what we expect it to do. Then we'll start the research and observe some of the things we hope to see. The goal is to observe chemical reactions happening at the building blocks of a catalyst, namely individual nanoparticles, at the atomic or molecular level. It's only when we can see that, that we can gain a deep understanding of what is actually happening, and we can relay this information back to the theorists who can continue their calculations, leading to the development of new catalysts that we can test and observe again. In this way, we hope to better understand and contribute to the development of new catalysts that can be used in Power-to-X production. We are looking at many different reactions. The microscope we are currently using has limited resolution and stability, which reduces sensitivity to the atomic details of nanoparticles and their interactions with molecules.

What can the microscope do that sets it apart?
ABM: There are two things that are quite special about the microscope and what VISION wants to achieve. First, we can have gas around the catalytic nanoparticles, which is necessary if we want to observe the chemical reactions. For example, we can introduce CO2 and observe how it is transformed. Normally, electron microscopes work by sending an electron beam through a very, very thin sample in a completely vacuum-sealed instrument.
The next unique aspect of the new microscope relates to its resolution. The way we observe very small things is by passing an electron beam through a sample. Microscopes have for long been unstable enough that this instability has defined the resolution. With the new microscope, we have new lenses and stability, allowing us to see details at 50 picometers. This is a resolution with 11 zeros - equivalent to the radius of the smallest atom, which is the hydrogen atom. So now, the resolution is determined by the atoms themselves, not the microscope. With such high resolution, we need to be very careful not to affect the vibrations and displacements of the atoms. Imagine shining a giant flashlight onto a surface; it becomes warm because the atoms start to vibrate. Similarly, the electron beam can affect the atoms, and we try to counteract this with sensitive detectors that can measure individual electrons at a time; we are truly dealing with the laws of quantum mechanics.
So, these two things - the ability to add gas and having a resolution determined by the atoms - make the microscope special. The dream is to be able to see atoms and molecular species and construct 3D models of catalytic nanoparticles to understand how they function in catalytic reactions.

Basic info

Construction work

The facade-works are completed. Accommodation is in process.

Project status

The area where VISION's electron microscope will operate has been handed over to DTU in mid-October. Installation will then start and it is expected that the microscope will be operational by the end of 2023.

Tidsplan

Spring 2023 — Construction on site

Summer 2024 — Users move-in

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A world class microscope

A transmission electron microscope is used to "see" or visualize materials at the atomic level. It has a similar structure to a regular light microscope but achieves its high resolution, which is approximately 1000 times better than that of a light microscope, by using a beam of electrons as the "light source."

The microscope is constructed with the "light source," an electron gun, at the top. Electrons behave like waves (similar to light). They are accelerated over a high electric voltage drop of 300,000 V, resulting in such a short wavelength that the microscope can resolve individual atoms. While a light microscope uses ordinary glass lenses to focus the light beam, an electron microscope uses a series of electromagnetic lenses to focus the electron beam on the sample (illumination optics). After passing through the sample, the objective lens forms an enlarged image of the sample. For a long time, the challenge was that the electromagnetic lenses distorted the images, much like the view through the bottom of a glass bottle. However, in modern electron microscopes, lens errors can be corrected using an image corrector, resulting in crystal-clear images of the atomic structure of materials. The objective lens and image correction together form the imaging optics that shape the image on a high-speed detector mounted at the bottom of the electron microscope. The detector can capture images and even film sequences in 4Kx4K pixel resolution. This image data provides a two-dimensional projection of the physical object, such as a nanoparticle.

VISION's microscope stands out for three key reasons, (1) It can introduce a reactive gas around the sample, allowing high-resolution observation of chemical reactions. (2) It achieves a resolution of about 50 pm, equivalent to the radius of the smallest atom in the periodic table, namely the hydrogen atom. (3) The microscope's high-quality images can be used to reconstruct the atomic structure of materials in three dimensions (3D).

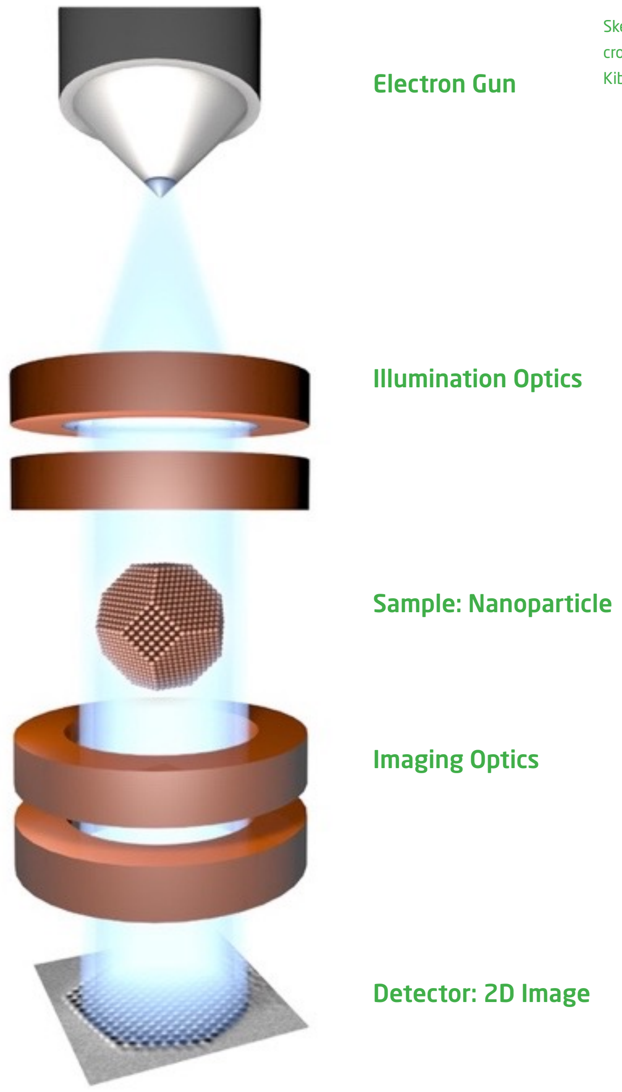
VISION

The Center for Visualizing Catalytic Processes (VISION) is funded by the Danish National Research Foundation. A grant of 85.5 million DKK has been awarded for the period from March 2020 to May 2026 (DNRF146). The center is led by Professor Stig Helveg at DTU Physics.

VISION is dedicated to catalysis. Catalysis is the science and technology of controlling chemical reaction rates and is key to the production of sustainable chemicals, fuels, and energy. Efficient catalysis of chemical reactions is achieved with nanoparticles, but understanding how their size, shape, and structure affect catalytic processes is a significant scientific challenge.

VISION aims to address this challenge by combining new and emerging platforms for observing the atomic structure, dynamics, and function of individual nanoparticles in catalytic reactions. VISION seeks to elucidate how individual nanoparticles catalyze chemical reactions at the atomic level. By answering this question, VISION aims to achieve scientific breakthroughs in thermal catalysis and electrocatalysis, which are essential to addressing the major environmental challenges of our time.

Source: DTU



Sketch of an electron microscope. Illustration: Jakob Kibsgaard/DTU