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Subject: Technical specifications and requirements for the procurement of a 4D fluorescence microscope

The procurement of a 4D high-resolution fluorescence microscope aims to establish a central, cross-faculty research infrastructure at Kiel University (CAU), closing a clearly identified methodological gap in high-end materials-science and chemical analytics. The microscope is intended for spatially, temporally, and spectrally resolved investigations of functional materials under static, in situ, and operando conditions, thereby enabling research in which the coupling of structure, dynamics, and function under realistic operating conditions is essential.

Scientifically, there is a specific need to characterize luminescent, photoactive, electron-beam-sensitive, and dynamically responding materials with high sensitivity and resolution under realistic conditions. This includes, in particular, lanthanide-doped phosphors, semiconductor nanoparticles and organic and hybrid organic-inorganic photoactive compounds, catalysts, nanostructured sensors, and battery and electrode materials, where spatially and temporally resolved changes in emission provide direct insight into phase transformations, defect formation, energy transfer, ion insertion, and degradation processes. The added value of the requested microscope lies in its ability to record such changes as 4D datasets (three spatial dimensions plus time) and correlate them with chemical or electrochemical operating states, rather than relying solely on ex situ or ensemble measurements.

The existing situation at CAU is characterized by a strong electron microscopy infrastructure and several fluorescence microscopes primarily tailored to biomedical applications. However, there is currently no dedicated microscope that meets the specific requirements of functional materials. The existing fluorescence microscopes are not sufficiently suited for materials-science applications, in particular with respect to UV excitation, physical accessibility for reaction cells, spectral flexibility, and compatibility with operando setups. For many of the intended applications, excitation in the short-wavelength UV range is essential, because key emission processes of inorganic and hybrid-inorganic materials can only be reliably detected under these conditions.

Against this background, the procurement of a specifically configured 4D fluorescence microscope in the upper performance class is scientifically necessary and institutionally justified. The planned microscope is intended to function as a high-resolution, modular, and quantitatively evaluable microscopy platform that enables real-time imaging of crystallization processes, particle growth, phase transitions in battery materials, light-induced processes in semiconductor and hybrid materials, and catalytic or chemical reactions. The intended use as shared infrastructure within the Solid-State Structure Analysis Platform and the KiNSIS research priority area underlines both the institutional character of the procurement and the expected high utilization.

The object of the procurement is a fully integrated, ready-to-use 4D fluorescence microscope in inverted configuration, including a confocal laser-scanning module, spectrally high-resolution detection, motorized axes, and appropriate analysis software, as well as all peripherals required for installation, commissioning, training, and operation. The microscope must allow combined 3D and time-series acquisition of fluorescence signals, spectral imaging, quantitative intensity and ratiometric analyses, and high-resolution post-processing of image data.

The technical specification is derived directly from the requirements of materials-science and chemical operando research and not from general-purpose laboratory microscopy. The equipment must therefore be implemented as a motorized inverted microscope, providing sufficient space for chemical reaction cells, electrochemical cells, microfluidic chips, and temperature-, gas-, or humidity-controlled environments. The inverted configuration is functionally necessary to integrate complex reaction environments with adequate mechanical stability and optical access.

A key technical objective is to ensure broadband, precisely controllable optical excitation. The microscope must therefore include an LED epi-fluorescence module with multiple spectral channels covering the range from UV through the visible into the red spectral region, including excitation at 340 nm. In addition, a laser excitation unit with at least the wavelengths around 405 nm, 488 nm, 561 nm, and 640 nm is required to address a broad spectrum of inorganic, hybrid, and organic emitters. This excitation flexibility is essential for the intended use, as it enables application-relevant and comparable studies of functional materials with very different chemical composition.

Equally important is a detection architecture that combines high sensitivity with spectral discrimination. The microscope must therefore be equipped with highly sensitive spectral detectors, in particular based on multi alkali photomultipliers or functionally equivalent technologies, and must support spectral imaging with a resolution on the order of 1 nm. This level of performance is necessary to unmix overlapping emission bands, resolve local shifts in emission maxima, and perform robust ratiometric evaluations of multicomponent systems.

The microscope must also provide high-resolution spatial imaging that can be improved into the range of roughly 100–120 nm lateral resolution by suitable optics,

high-numerical-aperture objectives, and deconvolution. This requires apochromatic high-performance objectives with numerical apertures up to approximately 1.2–1.4. At least one objective with correction collar is needed to compensate for varying cover glass and reactor window thicknesses, especially quartz windows, which is essential for low-aberration imaging in real reaction cells.

Temporal resolution is another key performance aspect, as many target applications involve rapid dynamic processes. The microscope must therefore support image rates of at least approximately 8 frames per second at a typical resolution of 512×512 pixels and be technically suitable for higher frame rates, up to about 50 frames per second in specific operando configurations. This capability is particularly important for observing fast crystallization, diffusion, and charge/discharge processes and must be appropriately reflected in the later evaluation.

The mechanical platform must be fully motorized and support reproducible positioning in all relevant axes. This includes, in particular, a finely resolving Z drive in the range of about 10 nm and a motorized XY stage with encoder-based position feedback and joystick control. This equipment is required for reproducible Z-stacks, long-term studies, multi-position experiments, stitching, and repeat measurements at identical locations.

The software must support quantitative scientific use in full. It must control all hardware components, handle acquisition of 3D, time-resolved, and spectral datasets, provide deconvolution and spectral unmixing, and enable 3D reconstruction as well as linear, ratiometric, and time-resolved analyses. Documented linear data processing is essential to ensure comparability of measurement series and to enable robust quantitative statements on changes in intensity, color, and lifetime in operando experiments.

From a procurement perspective, the specifications must therefore define technical minimum requirements as mandatory criteria, non-compliance with which leads to exclusion, and additional desirable or evaluative criteria that allow differentiation of functional added value within the permitted performance class. Mandatory criteria include, in particular, the inverted configuration, suitability for reaction and operando setups, UV-capable and visible multichannel excitation, spectrally high-resolution detection, motorized precision mechanics, high-performance objective equipment, and suitable analysis software. Evaluative criteria may include, among others, actual spectral flexibility, sensitivity and linearity of detection, achievable effective spatial and temporal resolution under realistic conditions, user-friendliness and degree of automation, suitability for site-specific operating conditions, and the scope of the service and training concept.

The criteria for scoring the offers are specified in the tables below. Two types of criteria are defined, namely “A” and “B”. The type “A” criteria must be met without a margin for deviation. The vendors should individually confirm the specifications of the following tables and/or clearly specify possible deviations.

1. Laser flexibility and excitation coverage

Position	Description	Type	Points
1.1	A 9-channel intensity-stabilized LED epifluorescence module (340–630 nm) shall support routine multicolor imaging, while four powerful diode lasers (405, 488, 561, and 640 nm) shall enable high-quality excitation for advanced photophysical studies involving a variety of luminescent materials—such as lanthanide complexes, organic fluorophores, and halide perovskite crystals.	A	20
1.2	Laser module with the following diode lasers: 405 nm, min 5 mW 488 nm, min 10 mW 561 nm, min 10 mW 640 nm, min 5 mW Lasers must be field-replaceable / retrofittable. All lasers must have a guaranteed lifetime of more than 10,000 hours (561: 5,000 hours).	B	10
1.3	The laser power for the scan module should be modulated directly. Lasers must be power regulated to ensure stable and reproducible output power. The 4 laser lines must be capable of simultaneous modulation and simultaneous reflection on the sample surface.	B	20

2. Adaptability to operando setups

Position	Description	Type	Points
2.1	A high-performance inverted stand must spatially allow a wide range of custom sample environments, including crystallization reactors, electrochemical and battery cells, temperature-controlled chambers, and microfluidic platforms. These accessories will enable us to monitor chemical and structural changes under well-controlled conditions such as variable temperature, humidity, gas or liquid flow, and voltage changes.	A	10

3. Spectral sensitivity and detector performance

Position	Description	Type	Points
3.1	Two independent galvanometer scanners with a minimum 85% duty cycle and a maximum 15% recovery time.	A	15
3.2	Detection bands should be freely adjustable using a variable secondary beam splitter. It should also be possible to detect directly via the laser's excitation line without seeing its reflection signal in the image.	A	15
3.3	Spectral resolution of 1 nm for spectral unmixing. Previously stored reference spectra (generated spectral database) must be available for their usage with linear unmixing or online fingerprinting. During a spectral acquisition the spectral range steps must be possible with 1 nm step resolution.	A	10
3.4	Main color separator tilted by 10 degrees with excellent laser suppression ($OD > 6-7$).	A	10
3.5	A 2-channel detector based on MA-PMT is to be used for spectral imaging and analysis. The detectors have to be calibrated for fluorescence measurements.	A	10
3.6	Emission fingerprint: reliable separation of fluorophores with highly overlapping spectra based on previous measurements and the generation of reference spectra.	A	10
3.7	The microscope must be upgradable and upgrade-ready for a multi-field detector (detector with at least 30 detector fields), significantly less laser intensity per pixel is required than with conventional detection; as a result, for example, less than 1/8 of the energy per excitation pixel reduces fluorochrome bleaching and phototoxicity. The pixel dwell time should remain high (at least 0.60 μs) while maintaining a light output of 1.20 AU (the pinhole must be open to during exposure). The resolution must be at least 120 nm lateral without deconvolution or 90 nm with additional deconvolution.	A	10
3.8	The microscope must be upgradable to detect multiple parallel lines by parallelizing the readout process; this enables up to minimum 18 frames per second at 512×512 pixels and a resolution of at least 140 nm (or better) in the XY direction.	A	10

4. Linear deconvolution

Position	Description	Type	Points
4.1	It should be possible to use a software module to improve the signal-to-noise ratio and the resolution of both LSM and super-resolution images. For LSM images, the following parameters should be achieved:	A	10
4.1.1	It should be possible to use data from any confocal imaging mode, including spectral and near-infrared.	A	10
4.1.2	The processing of the file should ensure a reliable quantitative result (linear).	A	15
4.1.3	XY resolution up to 120 nm.	A	10
4.1.4	Processing based on the Wiener filter.	A	15

5. Microscope camera

Position	Description	Type	Points
5.1	Microscopy camera including 64-bit driver software, USB 3.0 PCIe x1 interface, 3-meter USB 3.0 cable, and BK7 protective glass (coated). Number of pixels: At least 2400 (H) x 2000 (V), approximately 5 megapixels.	B	10
5.2	Sensor type: CMOS.	B	10
5.3	Pixel size: 3.50 μm x 3.50 μm or smaller pixel size.	B	10
5.4	Sensor size: At least 10 mm diagonal.	B	10
5.5	Spectral range: approx. 350 nm to approx. 1000 nm.	B	10
5.6	Max. charge per pixel: approx. 10,500 e (full well capacity).	B	10

6. Anti-vibration plate

Position	Description	Type	Points
6.1	Vibration compensation platform that can be placed between the microscope stand and the laboratory bench.	A	20

7. Safety

Position	Description	Type	Points
7.1	A laser safety system must be in place to protect the user.	A	10
7.2	Alert messages should be present to inform the users about possible crushing hazards due to motorized components.	B	10

8. Infrastructure

Position	Description	Type	Points
8.1	The setup with all accessories and lines should be fitted on a laboratory bench with the dimensions 3 meters of laboratory bench. It should also fit through a normal door entry with an opening of 930 x 2050 mm W x H; a freight elevator is available in-house.	A	10
8.2	The microscope preferably uses 230V/8A single-phase power supply.	A	10

9. Software/IT			
Position	Description	Type	Points
9.1	High-performance workstation based on a Windows 11 PC-64-bit.	A	10
9.1.1	64 GB RAM, graphics card with 8 GB RAM.	A	10
9.1.2	27-inch monitor.	A	10
9.2	Control software for image acquisition with all necessary modules for generating image data based on X, Y, and Z positions, Z-stacks, time points, fluorescence and transmitted light channels, and tiled images.	A	10
9.3	One-click button solution for starting experiments on the microscope.	A	10
9.4	Multilayer file format for X, Y, and Z positions, Z-stacks, time points, fluorescence and transmitted light channels, and tiled images, including stitching as well as storage of all system-specific parameters such as laser intensity, resolution, scan speed, beam path configuration, and incubation.	A	10
9.5	Basic functionality for analyzing dynamic and FRAP experiments and for calculating signal colocalization. The read out of intensity values for live fluorescence measurements must be assessable (on the fly) during live modus or time series. These measurements have to be possible frame-wise or on a region of interest (ROI) base.	A	10
9.6	3D visualization of fluorescence stack images.	A	10
9.7	Reuse function for loading all experiment data based on the image.	A	10
9.8	Optional "Direct Processing" technology.	B	10

10. Patents/Licenses			
Position	Description	Type	Points
10.1	The system comes with all the necessary software and patent licenses that allow the system to operate indefinitely.	A	10
10.2	There are no recurring license fees.	A	10

11. Installation/Trainings			
Position	Description	Type	Points
11.1	The microscope is installed by the manufacturer in the allocated laboratory at the Institute for Inorganic Chemistry at the University of Kiel (normal door entry with an opening of 930 x 2050 mm W x H; freight elevator is available in house).	A	10
11.2	The manufacturer has to carry out an acceptance test of the microscope system at the Institute for Inorganic Chemistry at the University of Kiel to prove that the device meets the required specifications.	A	10
11.3	The manufacturer must conduct a training program on the operation of the microscope at the Institute for Inorganic Chemistry at the University of Kiel.	A	10
11.3.1	The training program must be comprehensive to allow the operator run the setup safely and efficiently.	A	10
11.3.2	The training program must entitle at least four operators to participate.	A	10
11.3.3	The training program must include at least three separate training sessions.	A	10
11.4	The microscope system should be delivered and installed within six months following acceptance of the offer and submission of the purchase order.	B	10

12. Warranty			
Position	Description	Type	Points
12.1	The microscope system is warranted for 2 years, starting with a successful acceptance test and commissioning on site.	A	10

13. Tools/Spare Parts/Consumables			
Position	Description	Type	Points
13.1	The microscope setup must contain consumables (not the chemicals but anything which is needed for the setup functionality) needed for six months of operation.	B	10
13.2	10 years of supplies on spare parts/service should be warranted.	B	10

Sum of the points for the evaluation criteria: Maximum 550 points

Weighted award criteria

Rating Matrix

price offer	40%
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performance criteria	60%
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These are assigned by expert employees of the institute according to manufacturer specifications, whereby the evaluation criteria (A) in the specification serve as a basis. If a specification type (A) is not met, this leads to the exclusion of offers.