Leibniz Gemeinschaft

Der Senat

9. Juli 2019

Stellungnahme zum Leibniz-Institut für Kristallzüchtung im Forschungsverbund Berlin e.V. (IKZ)

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Vorbemerkung

Die Einrichtungen der Forschung und der wissenschaftlichen Infrastruktur, die sich in der Leibniz-Gemeinschaft zusammengeschlossen haben, werden von Bund und Ländern wegen ihrer überregionalen Bedeutung und eines gesamtstaatlichen wissenschaftspolitischen Interesses gemeinsam gefördert. Turnusmäßig, spätestens alle sieben Jahre, überprüfen Bund und Länder, ob die Voraussetzungen für die gemeinsame Förderung einer Leibniz-Einrichtung noch erfüllt sind.[1]

Die wesentliche Grundlage für die Überprüfung in der Gemeinsamen Wissenschaftskonferenz ist regelmäßig eine unabhängige Evaluierung durch den Senat der Leibniz-Gemeinschaft. Die Stellungnahmen des Senats bereitet der Senatsausschuss Evaluierung vor. Für die Bewertung einer Einrichtung setzt der Ausschuss Bewertungsgruppen mit unabhängigen, fachlich einschlägigen Sachverständigen ein.

Vor diesem Hintergrund besuchte eine Bewertungsgruppe am 13. und 14. Dezember 2018 das IKZ in Berlin. Ihr stand eine vom IKZ erstellte Evaluierungsunterlage zur Verfügung. Die wesentlichen Aussagen dieser Unterlage sind in der Darstellung (Anlage A dieser Stellungnahme) zusammengefasst. Die Bewertungsgruppe erstellte im Anschluss an den Besuch den Bewertungsbericht (Anlage B). Das IKZ nahm dazu Stellung (Anlage C). Der Senat der Leibniz-Gemeinschaft verabschiedete am 9. Juli 2019 auf dieser Grundlage die vorliegende Stellungnahme. Der Senat dankt den Mitgliedern der Bewertungsgruppe und des Senatsausschusses Evaluierung für ihre Arbeit.

1. Beurteilung und Empfehlungen

Der Senat schließt sich den Beurteilungen und Empfehlungen der Bewertungsgruppe an.

Das Leibniz-Institut für Kristallzüchtung (IKZ) erforscht aktuelle Fragestellungen des Kristallwachstums, um auf dieser Grundlage wissenschaftliche Dienstleistungen zu erbringen. Diese umfassen die Bereitstellung von Kristallen mit speziellen Eigenschaften, die Charakterisierung kristalliner Festkörper sowie die Entwicklung von Anlagenkomponenten für die Züchtung und Charakterisierung von Kristallen. Die forschungsbasierten Serviceleistungen des IKZ auf den Gebieten der Mikro-, Opto- und Leistungselektronik, der Photovoltaik, der Lasertechnik oder der Sensorik werden in Wissenschaft und Industrie stark nachgefragt.

Die Arbeiten des IKZ gliedern sich in drei Kristallzüchtungsabteilungen, eine serviceorientierte Sektion sowie das 2017 neu eingerichtete Zentrum für Lasermaterialien. Die **Leistungen in den 13 Arbeitsgruppen** werden im Durchschnitt als „sehr gut“ bewertet (einmal „exzellent“, dreimal „sehr gut bis exzellent“, fünfmal „sehr gut“, dreimal „gut bis sehr gut“ und einmal „gut“).

Die überzeugenden Forschungs- und Entwicklungsarbeiten schlagen sich in einer angemessenen Publikationsleistung nieder. Das IKZ sollte nun wie geplant die Zahl der Veröffentlichungen weiter erhöhen und noch häufiger in hochrangigen Zeitschriften publizieren. Die Drittmittel für Forschungsvorhaben wurden gegenüber der letzten Evaluierung

[1] Ausführungsvereinbarung zum GWK-Abkommen über die gemeinsame Förderung der Mitgliedseinrichtungen der Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz e. V.

leicht gesteigert und liegen nun bei ca. 24 % des Gesamtbudgets; sie sollten in den nächsten Jahren auf die vom Institut avisierte Quote von 35 % erhöht werden. Es ist erfreulich, dass sich das Portfolio der Drittmittel in den vergangenen Jahren wie empfohlen diversifiziert hat. Neben Förderungen von Bund und Ländern sowie aus der Industrie gelingt es inzwischen erheblich besser als vor sieben Jahren DFG- und EU-Mittel einzuwerben. Dieser positive Trend sollte fortgesetzt werden.

Die umfangreichen Serviceleistungen des IKZ werden in der Regel im Rahmen von Kooperationsprojekten erbracht und beinhalten immer einen gewissen Anteil an Forschungs- und Entwicklungsarbeiten. Ein typisches Beispiel ist der internationale Verbund LEGEND (*Large Enriched Germanium Experiment for Neutrinoless Double Beta Decay*), in dem das IKZ die Aufgabe hat, für die benötigten Detektoren Germanium in bisher noch nicht erreichter Reinheit herzustellen.

Auch der Wissens- und Technologietransfer erfolgt über Kooperationsprojekte, insbesondere mit Beteiligung von Industrieunternehmen. Zudem verfügt das IKZ über ein umfangreiches Patentportfolio. Sehr zu begrüßen ist, dass es 2016 gelang, eine Firma aus dem IKZ heraus zu gründen, die eine innovative Plasmatechnologie zur Beschichtung und Mikrostrukturierung opto- und mikroelektronischer Bauelemente anbietet.

Es ist bemerkenswert, dass das IKZ sein Leistungsniveau seit der letzten Evaluierung halten und in einigen Fällen sogar Verbesserungen erzielen konnte. Nachdem der damalige **Direktor** 2013 einen Ruf an eine andere Einrichtung annahm, gelang es trotz intensiver Bemühungen erst 2018, die Position in gemeinsamer Berufung mit der HU Berlin wiederzubesetzen. Während der unerwartet langen Zeit der Vakanz dieser Leitungsposition leistete der Direktor des nahegelegenen Ferdinand-Braun-Instituts, Leibniz-Institut für Höchstfrequenztechnik, als kommissarischer Leiter gemeinsam mit den Beschäftigten des IKZ sehr erfolgreiche Arbeit, entwickelte das IKZ wissenschaftlich weiter und verantwortete unter anderem 2017 die wegweisende Entscheidung, das Zentrum für Lasermaterialien am IKZ einzurichten.

Der neue Direktor hat seit seinem Amtsantritt im Februar 2018 bereits viele Veränderungen am IKZ angestoßen. Insbesondere hat er gemeinsam mit den Gremien des IKZ eine überzeugende **Zukunftsstrategie** entwickelt, die nun schrittweise umgesetzt werden muss. Sie zielt darauf ab, die Wertschöpfungskette der entwickelten kristallinen Materialien am Institut bis hin zu einer prä-industriellen Kristalltechnologie zu verlängern und damit eine häufig bestehende Lücke in der Innovationskette zu schließen. Wie vom IKZ angestrebt, sollte dies die industrielle Verwertung der Arbeitsergebnisse weiter verbessern. Zur Umsetzung der Strategie wurden bereits die vorhandenen Arbeiten des IKZ im Rahmen einer Matrixstruktur neu organisiert. Außerdem ist ein schlüssiger Ausbau der apparativen und personellen Ausstattung geplant. Dafür sieht das Institut vor, dauerhaft zusätzliche Mittel der Bund-Länder-Förderung ("Sondertatbestand") in Höhe von ca. 2 M€ pro Jahr ab 2021 zu beantragen (zzgl. eines Eigenanteils von ca. 0,3 M€). Die Planungen werden nachdrücklich befürwortet.

Das IKZ unterhält verschiedene **Hochschulkooperationen**. Hervorzuheben ist ein 2016 gemeinsam eingerichteter Leibniz-Wissenschaftscampus mit der HU und der TU Berlin sowie das mit der HU Berlin seit 2009 betriebene *Joint Laboratory for Electron Microscopy*.

Derzeit ist das IKZ über jeweils eine gemeinsame Berufung mit der HU und der TU Berlin verbunden. Das Institut sollte die geplante Besetzung von zwei weiteren gemeinsamen Professuren nun auf die Zukunftsstrategie des neuen Direktors hin orientieren und anschließend mit geeigneten Hochschulen in Berlin oder an anderen Standorten mit hoher Priorität angehen.

Es wird begrüßt, dass das IKZ die Zahl der **Promovierenden** empfehlungsgemäß erhöht hat. Diesen Trend sollte das Institut fortsetzen. Es wird empfohlen, insgesamt für mehr personellen Austausch am Institut zu sorgen und Promovierte nach ihrem Abschluss nur in Ausnahmefällen am IKZ weiter zu beschäftigen. Dementsprechend sollten weiterführende Positionen am IKZ nur mit wissenschaftlichem Personal besetzt werden, das bereits längerfristig Erfahrungen an einem anderen Standort sammeln konnte.

Es wird begrüßt, dass der Frauenanteil im wissenschaftlichen Bereich von 17 % (2011) auf 29 % (2017) erhöht wurde. Von den derzeit 15 leitenden Positionen werden allerdings nur drei von **Wissenschaftlerinnen** wahrgenommen. Die in den nächsten Jahren vermehrt anstehenden Neueinstellungen müssen nun für eine deutliche Steigerung des Anteils an Wissenschaftlerinnen in Leitungspositionen genutzt werden.

Der **Wissenschaftliche Beirat** begleitet die Arbeit des Instituts kritisch und engagiert. Der Senat erwartet, dass zur Vermeidung von Interessenskonflikten künftig Beiratsmitglieder, mit denen zwischenzeitlich Kooperationen eingegangen worden sind, aus dem Beirat ausscheiden.

Das IKZ erfüllt die Anforderungen, die an eine Einrichtung von überregionaler Bedeutung und gesamtstaatlichem wissenschaftspolitischem Interesse zu stellen sind. Die anwendungsorientierte Grundlagenforschung und die darauf aufbauende kontinuierliche Entwicklung und Bereitstellung innovativer Serviceleistungen für externe Partner sind Aufgaben, die in dieser Form nicht an einer Hochschule durchgeführt werden können. Eine Eingliederung des Instituts in eine Hochschule wird daher nicht empfohlen.

2. Zur Stellungnahme des IKZ

Der Senat begrüßt, dass das IKZ mit seinen Arbeiten zu einer weiteren Stärkung der Leibniz-Gemeinschaft in Bereichen wie künstlicher Intelligenz, Kommunikation oder Energie und Gesundheit beitragen möchte. Bei der Weiterentwicklung des IKZ sollten die Empfehlungen und Hinweise aus dem Bewertungsbericht berücksichtigt werden.

3. Förderempfehlung

Der Senat der Leibniz-Gemeinschaft empfiehlt Bund und Ländern, das IKZ als Einrichtung der Forschung und der wissenschaftlichen Infrastruktur, die in erheblichem Umfang wissenschaftliche Infrastrukturaufgaben wahrnimmt, auf der Grundlage der Ausführungsvereinbarung WGL weiter zu fördern.

29 November 2018

Annex A: Status report

Leibniz Institute for Crystal Growth
in the Forschungsverbund Berlin e. V. (IKZ)

Contents

1. Structure, Tasks and Institutional Environment

Development and funding

The Leibniz Institute for Crystal Growth (IKZ) in the Forschungsverbund Berlin e. V. was founded in 1992 by merging two institutes and two working groups of the former East German Academy of Sciences.

Since then, the institute has been jointly funded by the Federation and the German *Länder* as a research institute with service function of supra-regional importance and of national scientific interest. The last evaluation took place in 2011/2012. In July 2012, the Joint Science Conference determined that IKZ continues to meet the requirements for joint funding.

Responsible department at *Länder* level: Senate Chancellery of the Mayor of Berlin

Responsible department at federal level: Federal Ministry of Education and Research

Legal form and organisation

Together with seven other Leibniz institutes, IKZ constitutes the Forschungsverbund Berlin e. V. (FVB) which acts as the legal entity of its members and provides them with administrative services while the institutes maintain their scientific autonomy.

IKZ is jointly led by a **scientific director** and the **managing director of the FVB**. The scientific director is appointed by the Board of Trustees of the FVB on recommendation of IKZ's Scientific Advisory Board. Appointments are for five years and renewable. The director develops the scientific work programme and is responsible for its implementation and further development. The managing director of the FVB is tasked with the administrative management of the institute and is responsible for its budget (Haushaltsbeauftragte).

The supervisory body of the institute is the **Board of Trustees of the FVB**. It is responsible for supervising all essential scientific policy, programmatic and financial matters of the Forschungsverbund. It consists of one state and one federal representative, one scientific representative nominated jointly by the Berlin universities, four scientific members who do not belong to a Berlin institution, and three members from the industrial sector.

The **Scientific Advisory Board** advises the director and the Board of Trustees of the FVB on IKZ's scientific programme and strategic planning. It consists of a minimum of six and a maximum of twelve members. They are appointed by the Board of Trustees of the FVB. The term of office is generally four years; one successive reappointment is admissible.

Mission, tasks and research structure

IKZ is a research institute with service function dedicated to investigate the scientific and technological fundamentals of crystal growth, from basic research to pre-industrial development. The **mission** of the institute, according to its statutes, includes in particular:

- The development of the scientific-technical basics for the growth of crystals including their characterisation,
- the growth of unique special crystals, and

– the provision of crystals and processed samples for research and development as a service function.

IKZ's research is organised in **five structural scientific units**, namely three departments, one section and the Center for Laser Materials (cf. organisational chart, appendix 1). Each department and the section consists of several scientific working groups that raise and execute scientific projects under the supervision of the department/section head.

National and international scientific environment

IKZ states, that there are some institutions with comparable activities in Germany and several other countries. However, their research agendas are usually more focused on specific topics. According to the institute, only a few institutes worldwide are comparable to IKZ with regard to mission, size and research focus. Institutions that best match IKZ's academic and technology profile are: a) State Key Laboratory of Crystal Materials at Shandong University, China b) 46th Research Institute in Tianjin, China, c) Institute for Single Crystals of the National Academy of Sciences of Ukraine, and to a lesser content, d) Korea Institute of Science and Technology and e) Fraunhofer Institute for Integrated Systems and Device Technology in Erlangen.

National interest and justification for funding as a non-university institution

As IKZ points out, crystalline materials are important technologies that have a high potential to foster innovation in industry and society. This applies in particular to the current challenges in the areas of health, energy, digital economy and artificial intelligence. IKZ aims to enhance innovation in these areas by investigating the scientific and technological fundamentals of crystal growth, the development of growth technologies as well as providing unique crystals and processed samples.

According to IKZ, the rationale for its funding as a non-university institution is based on a) the need of industry-oriented, applied research and the provision of service tasks, b) the broad spectrum of competences in different fields of crystal growth, and c) the efficient handling of material development issues and technological tasks that would exceed university capabilities.

2. General concept and profile

Development of the institution since the last evaluation

Between October 2013, when the former director left the institute, and February 2018, when the new director took his position, the IKZ had been under provisional management. During this interim period, the institute pursued its research and service tasks according to the institute's concept of 2013. The institute states that, in all these years it managed to continuously extend its scientific and technological expertise, ranging from equipment engineering and numerical simulation over crystal growth, numerical simulations on of fluids over crystal growth, including materials characterisation up to advanced crystal preparation and modern applications.

In 2016/2017, the institute established the Centre for Laser Materials (ZLM) by incorporating parts of the Laser Physics group of the Universität Hamburg at the IKZ with the help of BMBF funding. The ZLM works as a hub to coordinate, characterise and qualify in-house research and growth of laser crystals to make them available to research partners and industry users. However, under the provisional management, further long-term strategic decisions were not made in order to ensure the greatest flexibility for the next director to develop the institute. Moreover, measures like a) the further expansion of IKZ's personnel as recommended by the last evaluation were not translated into action and b) a long planned investment into equipment for Float Zone research (8'' Si crystal growth machine) was realised only when the new director took office in February 2018.

As a consequence of the long period under provisional management, IKZ now sees it of critical importance to implement various measures to ensure the future competitiveness of the institute (see 'Strategic work planning' below).

Results

In the period 2015-2017, IKZ scientists on average contributed to 61 peer-reviewed publications per year, often involving scientists from different IKZ units (see appendix 2).

In its publication strategy, the institute considers the *Journal of Crystal Growth*, *CrystEngComm*, *Crystal Growth & Design*, *Thin Solid Films* and *Crystal Research and Technology* as particularly suitable for its crystal growth groups. Some topics are published in journals such as *Semiconductor Science and Technology*, *Applied Physics Letters* and *Advanced Materials*. Before submission, the planned publications are reviewed internally. The institute states that particular emphasis is placed on the publication activities of doctoral students. Also, in cooperation agreements with industrial partners the institute tries to maintain the possibility of publishing. In some cases, though, this remains restricted due to confidentiality conditions.

Scientific services and infrastructure tasks:

IKZ provides services to other research institutions as well as to industrial parties. Thereby, as the institute elaborates, the term 'service' means services of a scientific nature such as the (further) development of technologies or the growth of unique crystals with special doping or composition, for which there are no standard methods yet or which are commercially unavailable. The services provided by IKZ include in particular:

- Growth of special and/or commercially unavailable crystals, layers, or crystalline samples
- Industrial contract research (process or material development)
- Crystal machining (cutting, lapping, polishing, formatting, development of preparation technologies)
- Characterisation of material samples with a wide range of methods (TEM, REM, LPS, LST, ICP-OES, DTA, XRD etc.)
- Feasibility studies and development of growth systems and processes by numerical modelling of energy and material flows, calculating thermodynamic equilibria

- Development of special components for industrial crystal growing systems
- Testing of auxiliary materials (e.g. wires for wafering, crucibles or insulation materials) under special conditions
- Education and training for employees of other institutions

Research and services are provided by scientists, engineers and technicians from all working groups. The institute highlights the following results:

- IKZ (Silicon & Germanium group) is part of a consortium working on a complementary strategy for defining the kilogram. On the world day of metrology in 2019, the International Bureau of Weights and Measures will announce the result where one of the two approaches to define in the kilogram unit by fundamental constants of nature will be based on an IKZ created single ultra-pure FZ silicon crystal.
- In the context of photovoltaics, IKZ has been part of a research alliance of 11 companies and 13 research institutes investigating the efficiency potential of multicrystalline material. The institute (Multicrystalline Silicon group) developed a directional solidification growth method using travelling magnetic fields (TMFs) based on KRISTMAG technology. One approach of the project was to avoid contamination and to measure the impact on the material.
- The Centre for Laser Materials (ZLM) was established as a one-stop-agency for laser material related questions in Germany. The institute states that ZLM increases the value chain of the research performed at the IKZ by qualifying in-house grown laser crystals before making them available to research partners and industry users. In 2018, researchers at the ZLM demonstrated highly efficient direct yellow emitting solid-state laser.
- In the context of UV-optoelectronics, aluminium nitride is a promising material, but its commercial availability is very limited. Crystals grown at IKZ enable partners (e.g. the Leibniz Institute for High Frequency Technology, FBH) to carry out research on applications based on this material.
- For mobile technology (e.g. GPS, WIFI), Silicium-Germanium alloys are a basic material. IKZ provides the SEMITHERM experiment of the European Space Agency (ESA) with samples of the relevant crystals with high germanium content. After first experiments in parabola flight in 2016, the next experiments will be performed with the Electromagnetic Levitator on the International Space Station ISS.
- Isotope pure ^{76}Ge crystals are investigated and grown at IKZ for the LEGEND consortium to work on questions in cosmology like the matter-antimatter asymmetry.

Knowledge and technology transfer

The institute's consulting services include, for example, feasibility studies, consultation on crystal growth technology or literature studies. Besides services provided to the scientific community as reviewer for journals and referee for funding agencies, members of the institute have also been involved in councils like the DIN standard committee for material control or the Commission on Crystal Growth and the Characterisation of Materials of the International Union of Crystallography (IUCr).

For Co-operation and Networking with industry see Chapter 4.

The IKZ patent strategy has been revised in 2018. It aims at establishing a suitable patent portfolio based on strategic and economic aspects with regard to long-term innovation potential. Measures for the implementation of the IKZ IP concept include the information of the scientific and technical staff, setting up financial incentives for inventors, advice on IP protection of rights and support during the filing process. In these activities, the IKZ is supported by the legal department and the patent office of the Forschungsverbund Berlin (FVB). Between 2014 and 2016, 5 patent families and 13 individual patents were granted (see appendix 2). Altogether, IKZ currently (November 2018) holds 22 patent families and 45 individual patents.

The institute supports its employees in the planning and implementation of start-ups, especially by involving the transfer service of the Leibniz Association. In 2016, in close collaborations with former SENTECH employees, the Golares GmbH was founded, offering services for the deposition of innovative coatings using plasma technology.

Academic events and public relations

Since 2011, IKZ continuously organises the triennial *International Workshop on Crystal Growth Technology* (IWCGT) in Berlin. Another scientific event at the institute is the IKZ summer school which has taken place annually since 2006, except in IWCGT years. Apart from these series, the IKZ and its scientists organise several national and international workshops that are held at the institute. In the recent years, the IKZ, for example, was hosting the *Laser Materials Meeting* (2017), the *German-Japanese Gallium Oxide Technology Meeting* (2016), and the *DGKK workshop on Massive Semiconductor Crystals* (2016). Furthermore, IKZ scientists are organising and chairing symposia at European (2014, 2016, 2018) and American Materials Research Society (2015) Meetings and are in numerous programme and steering committees of international conferences.

In 2018, IKZ established a new PR unit in its administrative services which is run by two persons. The goal is to improve internal information flow among staff and intensify external communication with the public. By appointment, IKZ offers lectures and guided tours for guests from Germany and international audiences from science, industry and politics as well as for pupils and student groups. It takes part in regular event formats such as the *Long Night of Sciences* which, in 2018, brought more than 1,400 visitors to the institute.

Strategic work planning for the next few years

IKZ today sees itself positioned among the worldwide research centres on innovations *in* crystalline materials, given decades of expertise on crystal growth and related topics. Now, the institute aims at making the next step, together with national and international partners, by also fostering innovations *by* crystalline materials. Thus, the development concept of 2013 has been further evolved into the 'IKZ Institute Concept 2019' describing the institute's aspiration to become an international state-of-the-art competence centre for innovations *in & by* Crystalline Materials.

According to the institute, this new research programme, called "Crystal Technology", requires a holistic consideration along the entire innovation chain of crystalline materials

and a synergetic interaction of all scientific departments plus the strategic science management. The programme represents a significant extension of the IKZ strategy that cannot be financed from the present budgetary resources. Therefore, the IKZ aims for additional institutional funding for the "Crystal Technology" action ("Sondertatbestand"). The institute estimates total costs of 2.3 M€ per year; from its own budget, the institute will finance approximately 0.3 M€ per year, so that the additional institutional funding needed by IKZ for the period 2021 to 2024 will be 2 M€ per year. In 2025, these funds are to be incorporated into the institute's budget.

Investment, for example, is needed for

- tools for crystal cutting, with high orientation precision, and metrology tools for final wafer / optical components specification measurements,
- growth equipment like Czochralski, Optical Float Zone,
- MO-CVD thin film deposition equipment combined with in-situ metrology like chemical analysis, thickness and temperature control.

Needs in personnel add up to 17 additional positions in 2024:

- 6 technician positions for crystal and thin film growth activities as well as materials science, application science and metrology activities.
- 11 scientific positions for nanostructures and thin films, volume crystals, materials science and application science research and development.

	2021	2022	2023	2024	From 2025 on
Research programme 'Crystal Technology'	2,302 k€	2,354 k€	2,250 k€	2,390 k€	
Contribution IKZ	304 k€	314 k€	314 k€	314 k€	
Additional institutional funding needed	1,998 k€	2,040 k€	1,936 k€	2,076 k€	2,000 k€

The new research programme also includes structural development. According to these plans, in the near future, IKZ will host four scientific departments each of which consisting of two sections (see appendix 1 and ch. 3).

- The scientific departments 'Classical Semiconductors' and 'Dielectrics & Wide Bandgap Materials' will be merged into one department: 'Volume Crystals'.
- The scientific department 'Layers & Nanostructures' will be renamed in 'Nanostructures & Thin Films'.
- The section 'Simulation & Characterisation' will be transformed into a full department named 'Materials Science'.
- A new scientific department 'Application Science' will be established aiming at reliable evaluation and benchmarking of crystalline materials. It will focus on two sections, namely 'Crystalline Materials for Electronics' (e.g. AlN, Ga_2O_3 etc.) and 'Crystalline Materials for Photonics' (e.g. Centre for Laser Materials, ZLM). The Crystal Preparation

Laboratory of IKZ will be part of this department and will function as the institute's key infrastructure unit to set up a common research platform between academia and industry.

The corresponding process is intended to be set up and initiated on 1 April 2019. In order to promote the new structure and strategy, it is planned to set up a 'seed money fund' and to establish the following Junior Research Groups on interdisciplinary research topics:

- Junior Research Group on 'Innovative Fluoride Crystals for Lasing Application'
- Junior Research Group on 'In-situ Transmission Electron Microscopy'
- Junior Research Group on 'In-situ/-operando Nano-Imaging XRD Microscopy'
- Junior Research Group on 'MOVPE Growth Fundamentals in Oxide Electronics'

Each group will be embedded in a corresponding IKZ science department.

Appropriateness of facilities, equipment and staffing

IKZ's usable area of laboratories and halls amounts to approx. 1900 m^2, consisting of two buildings with offices, small-scale laboratory use, two modern equipped crystal growth halls for large equipment, the related preparation labs, the workshop and crystal machining, a technical solitaire for the covered delivery of equipment, and a crane for moving large equipment into the larger hall and storage areas.

In 2010, the Joint Lab for Electron Microscopy (JEMA) at the Humboldt-Universität zu Berlin was established. In 2013, with a company a jointly used crystallisation laboratory for the development of equipment and production processes for photovoltaics based on crystalline silicon wafers was established, aiming at the acquisition and realisation of projects in this field, including an independent usage by IKZ with other external partners. Since the participating company was sold in 2015, the IKZ continues to operate the laboratory under its own management.

IKZ endeavours to keep the technical equipment at state-of-the-art level in order to fulfil the institute's mission and to conduct competitive research and development activities. This requires maintenance and further improvement of the existing machinery as well as targeted investment in new plants and equipment. During the interim management of the institute, strategic investments were restricted, so a larger part of the budget was used for the above-mentioned replacement or renewal of the facilities and the maintenance of the building and infrastructure.

IKZ sees it as the main task of the IT group to provide and to operate an IT infrastructure which on the one hand meets the requirements of the employees, and on the other hand takes into account the principles of IT security and best possible cost efficiency. This goal has been pursued through a combination of introducing new technologies and adjusting the workflows. In 2011, a high-speed backbone LAN was introduced, which constitutes the basis for a complete server virtualisation based on VMware vSphere products. According to IKZ, this led to a consolidation of resources and to a drastic reduction of power consumption for running central IT services at the institute.

For personnel see ch. 5.

3. Subdivisions of IKZ

Research of IKZ is organised in the three departments "Classical Semiconductors", "Dielectrics and Wide Bandgap Materials" and "Layers and Nanostructures" as well as the section "Simulation and Characterization", all of which are subdivided into working groups. A further structural unit is the Center for Laser Materials.

3.1 Department "Classical Semiconductors"

[19.48 FTE, thereof 10.51 FTE research and scientific services, 0.75 FTE doctoral candidates, and 8.32 FTE service staff]

The research focus of the department “Classical Semiconductors” is on the melt growth of volume crystals. This comprises element semiconductors silicon and germanium, as well as their solid solutions and III-V semiconductors. The research groups in the department address questions like the formation and control of defect configurations. Methods used are Floating Zone (FZ), Czochralski (CZ) and Vertical Gradient Freeze (VGF). Some of the crystal growing systems are equipped with patented heater-magnet-modules to allow effective control of the melt convection during the growth process by applying travelling magnetic fields. In this department, growth processes are developed up to a pre-industrial scale.

The department is structured into three working groups (WG):

- **WG “Silicon and Germanium”** [13.38 FTE, thereof 5.41 FTE research and scientific services, 0.75 FTE doctoral candidates, and 7.32 FTE service staff]

The group grows materials e.g. monocrystalline silicon for photovoltaics and power electronics, germanium for detectors and $Si_{1-x}Ge_x$ for radiation detectors and diffraction gratings by using the Float Zone (FZ) or Czochralski (CZ) method. The WG cooperates with the WG ‘Crystal Machining’ and ‘Physical Characterization’ of the section ‘Simulation & Characterization’. Special components and FZ inductors are developed in cooperation with the designers of the construction/plant engineering group and the workshop (both subunits of ‘Technical Service’).

In 2015-2017, the group issued 43 publications in refereed journals and had 1.9 M€ third party funding. In total, two patents were granted.

- **WG “Multicrystalline Silicon”** [2 FTE, thereof 2 FTE research and scientific services]

The group aims at growing multicrystalline silicon with improved quality using the VGF process in travelling magnetic fields (TMF). Various solidification techniques are investigated for the production of high efficiency material for photovoltaics at reduced costs. The research group cooperates with the groups ‘Crystal Machining’ and ‘Physical Characterization’ and carries out numerical modelling.

In 2015-2017, the group issued 5 publications in refereed journals and had 119 k€ third party funding. In total one patent was granted.

- **WG "Gallium Arsenide"** [4.1 FTE, thereof 3.1 FTE research and scientific services and 1 FTE service staff]

The group deals with the VGF growth of gallium arsenide and other III-V materials under the influence of TMF and ultrasonic fields to improve defect structure and homogeneity. These materials are used e.g. in WiFi communication and high-frequency technology. The research group cooperates with the research groups 'Crystal Machining' and 'Physical Characterization', as well as with the construction/plant engineering group and carries out numerical modelling.

In 2015-2017, the group issued 6 publications in refereed journals and had 1.4 M€ third party funding. In total one patent was granted.

In accordance with IKZ's new structure, it is planned to merge the department 'Classical Semiconductors' with the department 'Dielectrics & Wide Bandgap Materials' into one department 'Volume Crystals'. The new department will consist of a section 'Semiconductors' (materials like silicon & germanium, gallium arsenide and indium phosphide) and a section 'Oxide & Fluorides' (see below).

3.2 Department "Dielectrics and Wide Bandgap Materials" [14.74 FTE, thereof 7.9 FTE research and scientific services, 0.75 FTE doctoral candidates, and 6.09 FTE service staff]

The department "Dielectrics and Wide Bandgap Materials" focuses on growing volume crystals of nitrides, oxides and fluorides. Aluminium nitride, gallium oxide and related compounds are developed to be used as substrates for next generation optoelectronic and electronic devices. A variety of oxide compounds is also evaluated as substrate for thin films with new functionalities, as piezoelectric sensor material or as benchmark and reference crystals. Moreover, oxide and fluoride crystals are prepared for laser and non-linear optical applications.

The department is structured into two working groups (WG):

- **WG "Oxides/Fluorides"** [9.84 FTE, thereof 5 FTE research and scientific services, 0.75 FTE doctoral candidates and 4.09 FTE service staff]

The group is currently working on substrate crystals for perovskite layers (ferroelectric, multiferroic and superconducting layers) and for semiconducting oxide layers (Ga_2O_3, In_2O_3, SnO_2), piezoelectric crystals for high temperature pressure sensors and synthetic minerals for geophysical investigations. The Czochralski method at elevated temperatures (1600-2200°C) and a variety of other growth methods are employed for particular compounds, e.g. Vertical Bridgman, Micro Pulling Down, Edge-Defined Film-Fed Growth and Top Seeded Solution Growth. Within the activities to prepare laser crystals, the IKZ has installed one new Czochralski station and two new growth stations for crucible-free Optical Float Zone Growth at temperatures up to 3000°C. The research group cooperates with the research groups 'Chemical & Thermodynamic Analysis', as well as with 'Physical Characterization', 'Electron Microscopy' and 'Crystal Machining'.

In 2015-2017, the group issued 58 publications in refereed journals and had 1 M€ third party funding.

- **WG "Aluminium Nitride"** [4,9 FTE, thereof 2,9 FTE research and scientific services and 2 FTE service staff]

The focus of this group is on the technological development of AlN volume crystal growth with high structural quality, industry-relevant diameter and suitable doping (i.e. electrical and optical properties). Wafers find application as substrates for high-temperature-, power- and optoelectronics. Crystals are prepared by the Physical Vapour Transport (PVT) at temperatures exceeding 2000°C. The group cooperates with the groups 'Physical Characterization', 'Crystal Machining', 'Electron Microscopy' and 'Chemical & Thermodynamic Analysis', as well with the construction group and the workshop that design the AlN growth stations.

In 2015-2017 the group issued 3 publications in refereed journals, one individual contribution to edited volumes and had 1 M€ third party funding.

In accordance with IKZ's new structure, it is planned to merge the department 'Classical Semiconductors' with the department 'Dielectrics & Wide Bandgap Materials' into one department 'Volume Crystals'. The new department will consist of a section 'Semiconductors' (see above) and a section 'Oxide & Fluorides' (materials like sesquioxides, perovskites, pyrochlores etc.). Then, the new department "Application Science" / Section "Crystals for Electronics" will host the WG "Aluminium Nitride".

3.3 Department "Layers and Nanostructures"

[16.27 FTE, thereof 9.12 FTE research and scientific services, 5.25 FTE doctoral candidates, and 1.9 FTE service staff]

The subdivision "Layers & Nanostructures" at IKZ focuses its research activities on innovative crystallisation approaches / phenomena of structure formation (i.e. MBE & PLD approaches) as well as on the growth of metastable film / substrates (in particular through strain engineering by MOVPE). The interest in research on low-dimensional materials systems stems from the fact that nanostructures and thin films are in many cases grown on substrate crystals which are themselves grown and prepared in-house at IKZ by the volume crystal departments. In collaboration with the section 'Simulation & Characterisation', these studies aim at insights into the fundamentals of complex (hetero) epitaxy processes with respect to the tailored properties of crystals, substrate preparation effects and the growth parameters themselves. The groups of the department use 'feedback loops' between volume crystal growth, crystal preparation and epitaxy, in particular when crystal systems are used as substrates which are not yet available on a commercial basis. In the view of IKZ, successful examples are given by the MOVPE growth of transparent, semiconducting oxide layers on gallium oxide substrates as well as strain engineered, lead-free ferroelectric layers on rare earth scandate substrates with tailored substrate lattice parameters.

Current working groups of this department are:

- **WG "Si/Ge Nanocrystals"** [7.25 FTE, thereof 3.5 FTE research and scientific services, 3,75 FTE doctoral candidates]

The group deals with three research topics: the growth of Si and Ge nanowires, the deposition of micro-crystalline Si layers on glass, and the growth of regularly arranged $Cu(In,Ga)Se_2$ micro-islands. According to the IKZ, the first topic is of particular interest for the development of new thermoelectrics, while photovoltaics is the main motivation for research in both of the following activities. The study of fundamental phenomena of crystal growth plays a major role in both research areas. The methods currently used are: MBE for the growth of nanowires and a patented combination of physical vapor deposition processes developed in the group and the near-equilibrium growth of Si from metallic solution. The research group cooperates with the groups 'Physical Characterization' and 'Electron Microscopy' as well as with the construction/plant engineering group.

In 2015-2017, the group issued 19 publications in refereed journals and had 409 k€ third party funding.

- **WG "Ferroelectric Oxide Layers"** [5.02 FTE, thereof 2.62 FTE research and scientific services, 1.5 FTE doctoral candidates, and 0.9 FTE service staff]

This group is active in the field of functional ferroelectric layers. The aim is to develop lead-free materials as alternative to the widely used lead-containing compounds in the field of piezoelectric and ferroelectric applications. In cooperation with the group 'Oxides/Fluorides' the group works on the availability of perovskite substrates to systematically vary film properties by the incorporation of lattice distortions during epitaxial growth. Metal-organic Chemical Vapor Deposition (MOCVD) and Pulsed Laser Deposition PLD are used as growth methods to fabricate high-quality epitaxial films. Structural and electrical film characterisation is performed in particular by Piezoelectric Force Microscopy (PFM) within a close cooperation with the groups 'Physical Characterisation' and 'Electron Microscopy'.

In 2015-2017, the group issued 10 publications in refereed journals and had 111 k€ third party funding.

- **WG "Semiconducting Oxide Layers"** [4 FTE, thereof 3 FTE research and scientific services, 1 FTE service staff]

The group aims for producing layers in high crystalline quality and with targeted doping. Ga_2O_3, In_2O_3 and corresponding ternary compounds with a band gap between 4.9 eV and 3.7 eV are promising oxides with completely new properties, but, according to IKZ, have been little investigated so far. The cooperation with the group 'Oxide/Fluoride' provides a combination of substrates of Ga_2O_3 and In_2O_3 crystals grown in the institute with the homo- and heteroepitaxial deposition of these semiconducting oxide layers. The aim is to make available semiconducting, thin films of these transparent semiconducting oxides with high crystalline perfection and tuned electrical properties to determine their basic physical properties. The cooperation with the section 'Simulation & Characterisation' is the basis for analyses of the structural and electrical properties of the grown films.

In 2015-2017, the group issued 12 publications in refereed journals and had 83 k€ third party funding.

In accordance with IKZ's new structure, it is planned to rename the department 'Layers & Nanostructures' in 'Nanostructures & Thin Films'. There will be almost no change in the organisation of the department. The department will focus in future on the section 'Low Dimensional' (quantum dots & nanowires) and the section 'Two Dimensions' (e.g. functional thin oxide and semiconductor films)

3.4 Section "Simulation and Characterization" [23.37 FTE, thereof 8.87 FTE research and scientific services, 7.5 FTE doctoral candidates, and 7 FTE service staff]

The section 'Simulation and Characterization' supports the crystal growth departments and their partners by scientific service, performs fundamental and applied materials research in the field of crystalline materials and adopts scientific methods for characterisation to the specific needs of materials grown at the institute. In addition, the groups perform their own explorative research activities in their field of expertise with national and international partners both from academy and industry.

The division comprises four working groups (WG).

- **WG Physical Characterization** [7.25 FTE, thereof 2 FTE research and scientific services, 2.25 FTE doctoral candidates, and 3 FTE service staff]

The group provides scientific service for all crystal growth groups of the IKZ by the investigation of growth relevant physical properties of the crystals using X-ray diffraction, optical spectroscopy and imaging, electrical measurements, and related techniques. The group is also responsible for maintenance and upgrading of measurement facilities as well as for developing dedicated measurement techniques. Moreover, detailed investigations of fundamental as well as application relevant physical properties of crystalline materials are performed within the key subjects of IKZ.

In 2015-2017, the group issued 34 publications in refereed journals.

- **WG Electron Microscopy** [8.37 FTE, thereof 3.87 FTE research and scientific services, and 4.5 FTE doctoral candidates]

The group performs scientific service and basic research in the field of characterisation of crystalline material by a broad range of electron microscopy techniques. The group is focusing on the relation between physical properties and structure of semiconductors and oxides. Important topics are structure and physical properties of defects and interfaces, elementary growth mechanisms of epitaxial layers, thermodynamics and kinetics of alloys, phase formation of oxides as well as plastic and elastic processes during heteroepitaxial growth. Within the last five years the group established joint research projects together with groups in the department Layers and Nanostructures and Dielectric and Wide Bandgap Materials.

In 2015-2017, on average, the group issued 35 publications in refereed journals and had 1 M€ third party funding.

- **WG Chemical & Thermodynamic Analysis** [2.75 FTE, thereof 2 FTE research and scientific services, 0.75 FTE doctoral candidates]

The group characterises the crystals grown at IKZ with regard to their chemical composition and investigations of phase equilibria with the aim of optimising crystal growing processes and testing the 'growth ability' of new materials.

In 2015-2017, the group issued 23 publications in refereed journals, 5 contributions to edited volumes and had 7.85 M€ third party funding.

- **WG Crystal Machining** [5 FTE, thereof 1 FTE research and scientific services, and 4 FTE service staff]

The group produces wafers by cutting, grinding and polishing the crystals grown in-house. This is done for characterising the materials and for providing epi-ready wafers (the latter in collaboration with companies like Crystec etc.) for the groups in the department 'Layers and Nanostructures' or to external partners. The work includes development of new CMP polishing technologies for nitrides and semiconducting oxides. Cooperation between the 'Physical Characterization', 'Electron Microscopy' and 'Crystal Machining' groups in particular with all growing groups is according to IKZ close, because seeds oriented with X-ray methods and prepared by sawing, grinding and polishing are generally indispensable prerequisites for crystal growing processes.

In 2015-2017, the group issued 5 publications in refereed journals.

In accordance with IKZ's new structure, it is planned to transform the section 'Simulation & Characterisation' into a full department named 'Materials Science' with the sections 'Experimental Characterisation' and 'Fundamentals' (numerical simulation/solid state physics). It will include the Test Structure Lab at HU Berlin. The Crystal Machining will be a central part of the new department 'Application Science'.

3.5 Center for Laser Materials [2 FTE, thereof 1 FTE research and scientific services, and 0.75 doctoral candidates]

The establishment of the Center for Laser Material was started in 2017 with funding by the Federal Ministry of Education and Research (BMBF). The Center focuses on the development, characterisation and laser qualification of optically active crystalline materials for innovative applications in medicine, microscopy and others. It works with the 'Oxides/Fluorides' group, as well as with 'Crystal Machining'. IKZ states that synergies emerge from exchanging knowledge and equipment with the group 'Physical Characterization'.

Since its establishment in 2017, the group issued 12 publications in refereed journals and acquired 1 M€ third party funding.

In accordance with IKZ's new structure, the new department 'Application Science' / Section 'Crystals for Photonics' will host the Center for Laser Materials.

4. Collaboration and networking

Collaboration with universities

The IKZ and universities in Berlin are connected via the following joint appointments:

- Humboldt-Universität zu Berlin (HU Berlin): Professorship for Crystal Growth [W3, since 2018, Thomas Schröder]
- Technische Universität Berlin (TU Berlin): Professorship for Fundamentals and Methods of Crystal Growth [W3, since 2011, Matthias Bickermann]

Additionally, the IKZ holds a cooperation agreement with the Brandenburg University of Technology Cottbus-Senftenberg (BTU Cottbus). At each of these universities, IKZ senior scientists provide lectures at the respective institutes for physics or chemistry. Also, the institute hosts joint research projects as well as bachelor and master thesis studies under scientific supervision of IKZ personnel. The IKZ strategy envisages to further strengthen the ties to Berlin universities via additional joint full professorships (W2/W3). The aim is to initiate the process in 2019, when search symposia will be held at IKZ to identify promising future trends and potential candidates in the respective areas of crystal growth and applications of crystalline materials.

Since 2009, IKZ and HU Berlin operate a 'Joint Laboratory for Electron Microscopy' (JEMA) which is used by partners from both science and industry (e.g. Osram, Siltronic etc.) as a research contact for analysis of advanced materials and interfaces, in particular to evaluate oxide, silicon-germanium and nitride layers as well as nanostructures for electronic, optoelectronic and piezo-/ferroelectric applications. IKZ states that the establishment of a test structure laboratory as part of the nanostructure laboratory facility in the institute of physics at HU Berlin for joint education and research activities is intended to improve the study of materials by simple device structures. Furthermore, IKZ plans to set up a common research and education platform on modern X-ray diffraction methods for structure research with the HU Berlin Physics department.

Regarding TU Berlin, the IKZ is part of the 'Advanced UV for Life' consortium. Various education and research activities exist within the area of AlN-based UV materials science and applications.

At BTU-Cottbus IKZ is part of the Graduate School, section 'Functional Materials and Film Systems for Efficient Energy Conversion' (FuSion) where the Leibniz Institute for Innovative Microelectronics (IHP) in Frankfurt/Oder and the Fraunhofer Institute for Photonic Microsystems (IPMS) in Dresden are also involved.

Collaboration with other domestic and international institutions

The IKZ sees itself embedded in the domestic, EU and international R&D communities on crystalline materials. Collaborative projects include, for example:

- the Leibniz ScienceCampus 'Growth and Fundamentals of Oxides (GraFOx) for electronic applications' which combines the work and expertise of five Berlin-based partner institutions in the field of oxide research. Besides the Paul Drude Institute for Solid

State Electronics (PDI) as lead partner, also HU and TU Berlin and the Fritz Haber Institute of the Max Planck Society take part;

- the 'Advanced UV for Life' consortium in the BMBF 'Unternehmen Region'-programme, a total of 30 research and corporate partners including TU Berlin and Ferdinand-Braun-Institut (FBH) aiming at the development and marketing of globally competitive UV-LED-based components, systems and processes;
- the joint research project InTerFEL in the frame of the Russian-German collaboration Research on 'Time-resolved and nonlinear infrared and terahertz spectroscopy with a Free Electron Laser' in cooperation with Helmholtz-Zentrum Dresden-Rossendorf, TU Berlin, Karpov Institute of Physical Chemistry (RU) and Budker Institute of Nuclear Physics (RU);
- the Marie Curie Innovative Training Network 'SPRInG – Short Perod Superlattices for Rational (In, Ga)N' with the Paul Drude Institute for Solid State Electronics (PDI) as coordinator and a partner in Poland (TopGaN).

Other collaborations and networks

IKZ states that between 2015 and 2017, research activities with industry accounted for an average of approximately 60% of total third-party funding, either by bilateral contracts or in the frame of public funding. In this regard, the cooperation with small and medium-sized enterprises in the framework of the BMWi's ZIM programme is a regularly used option but also long-term bilateral R & D activities with industry (e.g. Kistler AG on high temperature piezoelectrics for industrial process control) are actively served. According to IKZ, the use of networks in scientific, technological and industrial communities, as well as politics is relevant for the institute and will be strengthened in future by the Strategic Science Management. For example, this management activity will also target to actively promote IKZ's capabilities to provide service in crystalline materials (e.g. unique crystalline materials for research & development).

5. Staff development and promotion of junior researchers

Staff development and personnel structure

As of 31 December 2017, the IKZ employed 120 people (103 full-time equivalents [FTE]), 62 (54 FTE) of them in research and scientific services. 40 persons (37 FTE) were working in service positions and 9 persons (7 FTE) in the administration. Additionally, IKZ employs 2 trainees (2 FTE) and 6 student assistants (1.2 FTE, see appendix 4).

35.5% of IKZ's scientific staff are currently employed on a permanent basis, 23% are female and 22% have a foreign nationality. IKZ states that within the next five to ten years, the institute has to face the challenge of generational change on all levels. Until 2027, 22% of IKZ's personnel of today will be retired.

According to IKZ, during the interim phase of the director position (2013-2018), there was no strategic HR development. As a consequence, e.g. positions of retiring co-workers were

not refilled. Since the new director took office in February 2018, the institute has developed a structured personnel concept which was approved by the Scientific Advisory Board in May 2018. First steps already taken to implement the concept include: outlining a strategy to fill department head positions by starting preparations to appoint two new W-Professorships within the next 2-3 years, strengthening activities on students and apprentices level, revisions of the guidelines for PhD students, providing guidelines for postdocs and expansion of person-specific funding with the aim of attracting and promoting young (international) talent (e.g. by initiating Junior Research Groups), revisions of the concept for fostering gender balance, and working on strategies to increase staff exchange on a national and international level. More concretely, from January 2019, internal funds will be provided to promote interdisciplinarity, early independence and internationalisation (by e.g. providing 'seed funding' for Junior Research Groups) as well as gender balance.

Promotion of gender equality

On 31 December 2017, 29% of the employees in research and scientific services were women compared to 17 % in 2011. On the leadership level, 29% of the group leader positions were held by women whereas there were no women among either the department heads or the professors at IKZ.

IKZ states that the institute has established a gender equality plan which outlines current and futures measures for the promotion of women and for providing employees with the conditions to combine family and work. It follows the five guidelines of the gender equality standards of the Leibniz Association. IKZ has established target quotas for the scientific personnel according to the 'cascade model,' thus striving to recruit scientists at the gender ratio realised at the next lower career level.

According to IKZ, parts of the planned 'strategy fund' to support the future personnel plan will be used to finance equal opportunity measures (e.g. for childcare). Additionally, the plan aims at the provision of transparent career guidelines taking into account possible family-related leaves.

Promotion of junior researchers

As recommended in the last evaluation, IKZ increased the number of PhD students. In December 2017, IKZ had 18 PhD students employed, in July 2018 there were already 23. The document 'Guidelines for the employment of PhD students at the Leibniz Institute for Crystal Growth' describes the internal regulations for employment and work process of a PhD student. Each PhD student has a personal scientific supervising committee, consisting of senior scientists and university professors.

The doctoral thesis at the IKZ is carried out as part of an employment relationship with a competitive salary: The new management board increased the PhD salary by end of 2017 to 75% part-time employment, salary group E 13 TVöD. IKZ initially employs PhD students on this basis for three years with the possibility of one-year prolongation. Currently, the average duration of a doctoral programme at the institute is around four years with few exceptions. Between 2015 and 2017, nine students completed their doctorate, the median duration was 3.9 years.

The establishment of a competitive postdoc programme will be supported by offering 'seed funding' for four junior research groups.

Vocational training for non-academic staff

Technicians at IKZ are hired into permanent positions. Further training opportunities include professional qualification courses for database management, licensing of patents or science communication, for operating special equipment, industry-level workshops in the field of materials processing or website programming and design of presentation material. For the administration (personnel, finances, purchasing), further training courses are regularly conducted by the Forschungsverbund Berlin, including English language courses.

IKZ offers training positions in the following occupations: Office Administrator, Cutting Machine Operator, IT Specialist for System Integration, Electronics Technician. As of December 2017, there were two trainees at IKZ. In the period 2015-17 in total 5 apprenticeships were successfully completed.

6. Quality assurance

Internal quality management

Internal quality management instruments of IKZ include a system of internal reviewing to ensure the quality of scientific publications and presentations, an ombudsperson and rules of good scientific practice (based on guidelines issued by the DFG). Furthermore, IKZ wants to set up a customer survey to measure the contentment with the services provided by the institute. Participation and representation of the members of the institute is provided by three internal boards:

- Steering Committee (*Lenkungskreis*) to take strategic decisions regarding IKZ's research activities and organisational issues (e.g. invest plans etc.),
- Scientific Council (*Wissenschaftlicher Rat*) to act as discussion platform on upcoming research topics, to advise the scientific director and the steering committee on future strategic decisions and to assure information flow to the working groups,
- Funding Meeting (*Drittmittelakquise*) to promote, monitor and coordinate third party funding actions by IKZ in a concerted way and to advise young scientists.

Quality management by the Scientific Advisory Board

The Scientific Advisory Board (SAB, see also chapter 1) assesses IKZ's scientific work and gives advice on the institute's strategic development. The board meets annually and advises the director and the Board of Trustees of the FVB on the scientific work programme of IKZ. The SAB is also involved in strategic decisions and comments on the draft programme budget. Between two external evaluations, the SAB conducts an audit.

Implementation of recommendations from the last external evaluation

IKZ responded as follows to the nine recommendations of the last external evaluation (highlighted in italics, see also statement of the Senate of the Leibniz Association issued on 18 July 2012):

General Concept and Profile

1. *Since the last evaluation, the IKZ has made positive progress. It has significantly improved its organisational structure and devised a development concept in 2008. In order to achieve the goal formulated in this concept of becoming the European competence centre for crystal growing, the IKZ should expand the progress made in identifying innovative research topics and further sharpen its research profile. Research and services should receive even greater support through independent and high-quality research.*

The IKZ states, that it strengthened research and development activities on the preparation of oxide semiconductors, bulk crystals, thin films and ferroelectric layers to a level that IKZ became an internationally acknowledged institute in materials for 'Oxide Electronics'. Furthermore, research and development activities on AlN bulk growth and wafer preparation activities were consolidated for UV applications and the 'Centre for Laser Materials' was established.

According to the institute, it has also earned an internationally high reputation as partner for the growth of crystals with the highest perfection of isotopically enriched material and/or specific parameters. In the diminution of silicon photovoltaics research funding, the IKZ kept its industry contacts to continue its service with new topics and concepts. Furthermore, the institute invested in its research and development capabilities on up to 8'' Float Zone Si for future collaborations.

Cooperation with universities

2. *The Senate welcomes the fact that, since the last evaluation, cooperation with universities has been improved, as recommended, in particular through closer links with personnel. In addition to the director of the institute, another of the three department heads has been appointed in a joint appointment with a Berlin university in 2011. The Senate expects that the third, currently vacant department head will now also be filled together with a neighbouring university. It is welcomed that, independently of this, two further joint appointment procedures are already planned. Traditionally, the IKZ's cooperation with universities was limited to the field of physics. With the second joint appointment, chemistry was included. Further subjects for university cooperation should now be considered in order to further strengthen interdisciplinarity at the IKZ.*

As the IKZ states, the two planned joint professorships with the TU Berlin were put on hold due to the interim management of IKZ and vacant department head positions were filled with 'acting heads'. The aim to jointly appoint these two professorships remains unchanged. Within the next two to three years, IKZ will identify the most relevant research areas – beyond physics – for these positions, in accordance with the institute's future development concept. Apart from this, in recent years, IKZ has strengthened its relations to universities in Berlin e.g. with the expansion of teaching assignments as well as the collaboration in the Leibniz ScienceCampus and further projects in the frame of the Leibniz Competition.

Exploitation strategy

3. *The Senate recommends that the individual activities for the exploitation of work results should be combined in an integrated exploitation strategy. The institute should systematically identify market-relevant research results and their possible ways of exploitation.*

IKZ used the initiative by the German Ministry for Education and Research (BMBF) to initiate two projects with focus on exploitation and transfer. The first (2011-2014) was focused on the development of an exploitation concept suitable for the IKZ and was carried out with support from an external company active in knowledge and technology transfer. This project resulted in a conception with recommended courses of action. In 2015, the second project started aiming at the implementation and professionalisation of this conception.

According to the IKZ, the envisaged new 'Application Science' department will interact in a reliable and reproducible way with partners from technology platforms and industry on crystal applications for electronics and photonics and will thus help to identify market-relevant research results.

Publication-oriented mode of operation

4. *In the course of further sharpening its scientific profile, the management of the IKZ should establish a more publication-oriented working method as part of an overall intensified scientific communication. The IKZ should ensure that all scientific employees publish their work results appropriately in addition to few high performers.*

The institutes states, that given the IKZ's mission of – besides conducting basic research – providing service, the right balance of scientific output and service applications has to be maintained. Thus, substantial effort is placed in applied research and service activity, which – especially when industry is involved – is not a 'publication friendly' area. Especially, because industry projects often suffer from limited interests by the company to publish results.

Still, a broader participation of IKZ scientists in the publishing process is part of the personnel development concept that has been developed and set into effect recently. Currently, hiring people with a strong will to publish in high quality, peer-reviewed journals will be a crucial and vital step to see a substantial publication increase in the next years.

Promoting young researchers and non-scientific trainees

5. *Since the last evaluation, improvements have been made in the promotion of young scientists, which the Senate believes should be further expanded. The IKZ has the capacity to increase the number of doctoral students beyond the target of 15 set by the institute and also to increase the number of postdocs. In order to improve networking within the scientific community, the IKZ should fill postdoctoral positions with external candidates to a considerably greater extent than before. In the area of non-scientific trainees, the IKZ should be able to offer far more than the currently available two training positions.*

According to IKZ, the institute took strong action to hire young people for a PhD thesis in natural sciences. Currently, the number of PhD students is 23 (as of 31.7.2018), which means almost 20 % of the institute's employees. Nine Postdocs are currently employed at the institute and 44 % of these positions are filled with external candidates. The introduction of three to four junior research groups is a further strong effort to recruit talented people from outside of the institute. Moreover, IKZ is active in international networks (e.g. EU Innovative Training Networks) and is using these networks to attract and recruit (young) scientists.

Personnel development

6. *As part of the recommended enhanced networking within the scientific community, it is recommended that the IKZ does not generally provide for permanent employment for new scientific staff. In the technical field, however, efforts should be made to remove fixed-term contracts from appropriately qualified staff who have been employed at the Institute for many years.*

During the interim management, IKZ did hire only two scientists on permanent positions. Since the last evaluation, five technicians were transferred to permanent positions. Because of legal restrictions, though, technical positions are only announced to maintain the competences on the long term, for example, when staff members are retiring.

Institutional funding by federal and state governments

7. *An additional increase of the personnel number by six staff headcounts as it is envisaged in the programme budget for 2013 is necessary in order to successfully complete the institute's development concept of 2008.*

The IKZ states, that this personnel measure has not been implemented as the director position became vacant in 2013. Since then strategic decisions have accumulated and there is a need to increase the number of IKZ's personnel and to extend IKZ's science and technology infrastructure in order to stay competitive. This measure is now targeted again by the application for the additional institutional funding for the "Crystal Technology" action (see ch. 2).

Third-party funding

8. *It is expected that the IKZ will be able to continue the positive trend regarding the acquisition of third-party funding and, in particular, significantly increase its participation in DFG-funded projects.*

According to the IKZ, the institute has successfully increased its third party funds steadily since the last evaluation and reached more than three Mio. Euro in 2017. The IKZ has also increased the number of successful DFG projects since the last evaluation. Furthermore, a monthly funding meeting was implemented to distribute third party funding activities on more shoulders to achieve a benefit for the institute as well as for the career of young people.

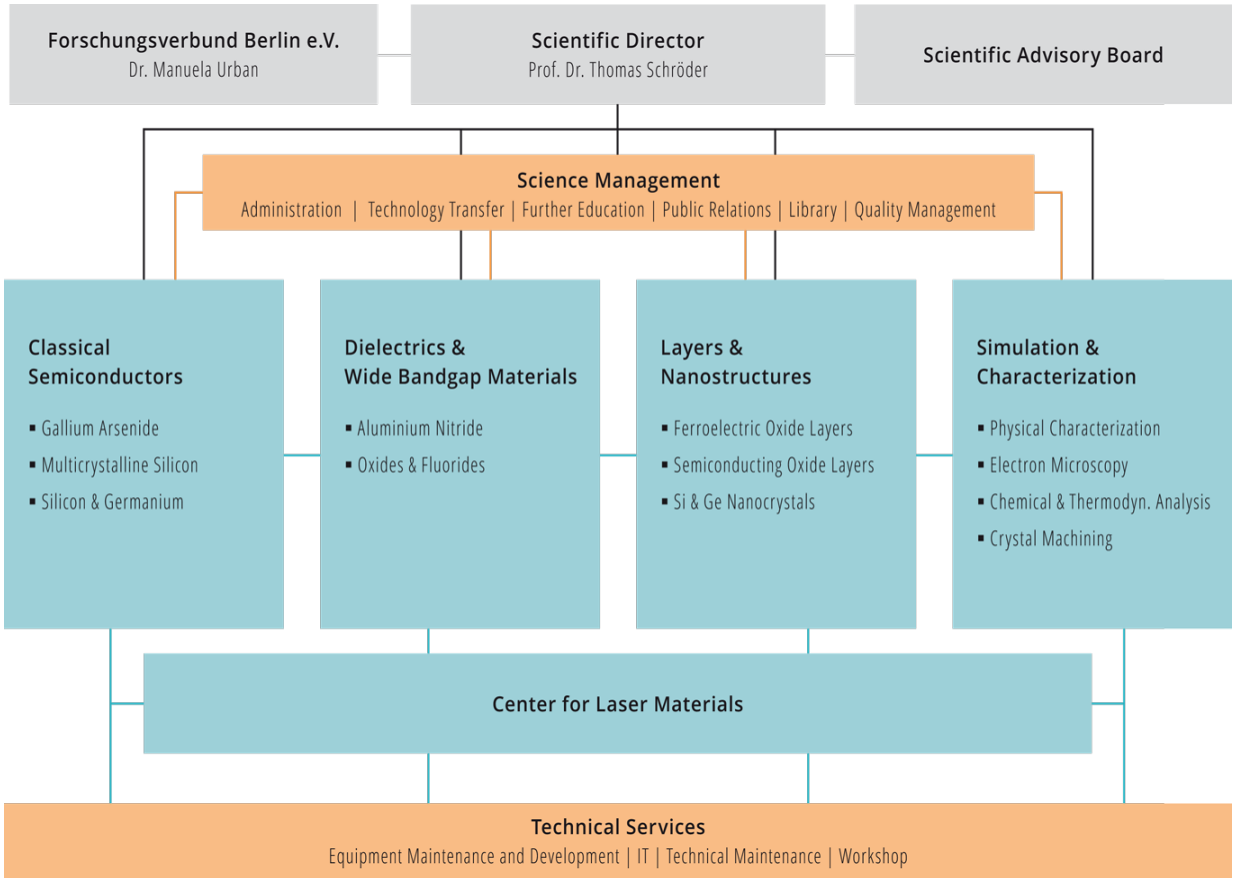
Gender Equality

9. *It is good that the IKZ has implemented measures and guidelines in the field of gender equality. However, the number of female scientists is not yet sufficient. Above all, the institute should therefore make use of the opportunities offered by the increase in personnel to increase the number of female scientific and technical staff.*

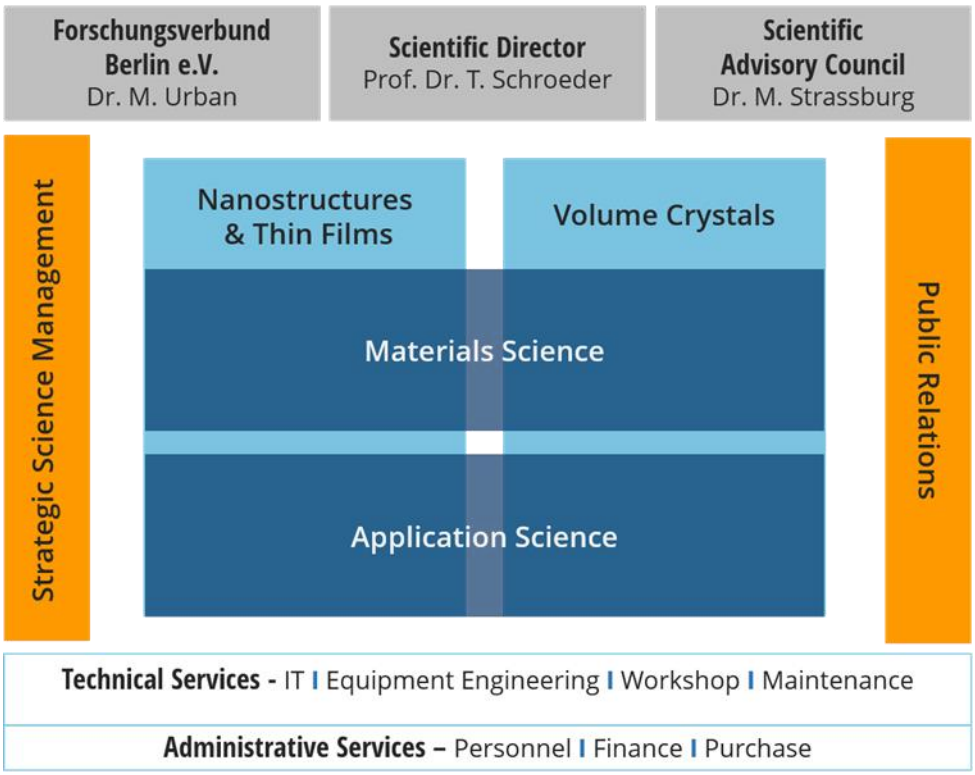
The female ratio for scientific employees (without doctoral students) has increased from 14.5 % in 2011 to 22% in 2017. For management positions (group leader), the ratio is 29%, compared to 20% in 2011. However, there is still no woman at the department head level, and in general, women are underrepresented in upper salary groups, both among scientific and non-scientific staff. The new "IKZ Institute Concept 2019" foresees to implement female scientists on the department head level as well as on leading the 'Strategic Science Management'.

Appendix 1

Organisational Chart



Organisational chart (from 1 April 2019)



Appendix 2

Publications and patents

	Period		
	2015	**2016**	**2017**
Total number of publications			
Monographs			
Individual contributions to edited volumes	1	3	
Articles in peer-reviewed journals	42	70	88
Articles in other journals	1		
Working and discussion papers			
Editorship of edited volumes			

Industrial property rights (2014-2017) [1)]	Granted	Registered
Patents	13	14
Patent families	5	4
Other industrial property rights	0	
Exploitation rights / licences (number)	0	

[1] Concerning financial expenditures for revenues from patents, other industrial property rights and licences see Appendix 3.

Appendix 3 Revenue and Expenditure

Revenue		2015			2016			2017 [1]		
		K€	% [2]	% [3]	K€	% [2]	% [3]	K€	% [2]	% [3]
Total revenue (sum of I., II. and III.; excluding DFG fees)		12.265,3			13.318,5			14.162,5		
I.	**Revenue (sum of I.1., I.2. and I.3)**	12.013,9	100		13.062,3	100		13.857,4	100	
1.	INSTITUTIONAL FUNDING (EXCLUDING CONSTRUCTION PROJECTS AND ACQUISITION OF PROPERTY)	9.304,1	77,4		9.897,1	75,8		10.442, 1	75,4	
1.1	Institutional funding (excluding construction projects and acquisition of property) by Federal and *Länder* governments according to AV-WGL	9.144,8			9.737,8			10.282,8		
1.2	Institutional funding (excluding construction projects and acquisition of property) not received in accordance with AV-WGL[4]	159,3			159,3			159,3		
2.	REVENUE FROM PROJECT GRANTS	2.570,9	21,4	100	3.071,0		100	3.343,6	24,1	100
2.1	DFG	276,6		11	290,6		9	340,2		10
2.2	Leibniz Association (competitive procedure and Leibniz Science Campus)	166,4		6	177,4		6	683,6		21
2.3	Federal, *Länder* governments	1.229,8		48	1.683,3		55	1.206,2		36
2.4	EU	240,9		9	140,2		5	181,6		5
2.5	Industry	656,3		26	777,7		25	713,4		21
2.6	Foundations	0,0		0	0,0		0	16,8		1
2.7	Other sponsors (conference contributions, refunds)	0,9		0	1,8		0	201,8		6
3.	REVENUE FROM SERVICES	138,9	1,2		94, 2	0,7		71,7	0,5	
3.1	Revenue from commissioned work	131,0			94, 2			71,7		
3.2	Revenue from publications	0,0			0,0			0,0		
3.3	Revenue from exploitation of intellectual property for which the institution holds industrial property rights (patents, utility models etc.)	7,9			0,0			0,0		
3.4	Revenue from exploitation of intellectual property without industrial property rights	0,0			0,0			0,0		
3.5	Revenue from other services	0,0			0,0			0,0		
II.	**Miscellaneous revenue** (e.g. membership fees, donations, rental income, funds drawn from reserves)	251,4			256,2			305, 1		
III.	**Revenue for construction projects** (institutional funding by Federal and *Länder* governments, EU structural funds, etc.)	0,0			0,0			0,0		

Expenditures		T€	T€	T€
Expenditures (excluding DFG fees)		12,208.8	13,211.6	14,055.3
1.	Personnel	6,306.2	7,158.8	7,165.8
2.	Material expenses	3,429.2	3,301.3	3,396.8
2.1	Proportion of these expenditures used for registering industrial property rights (patents, utility models etc.)	51,4	34,0	61,9
3.	Equipment investments	1,293.5	798.5	2,514.8
4.	Construction projects, acquisition of property	0,0	0,0	0,0
5.	Other operating expenses (Membership fees)	299,4	369,0	387,7
6.	Miscellaneous (Cash holdings and revenues from the last year)	880,5	1590,0	590,2
DFG fees (if paid for the institution – 2.5% of revenue from institutional funding)		227,2	242,2	255,2

[1] Preliminary data: no
[2] Figures I.1, I.2 and I.3 add up to 100 %. The information requested here is thus the percentage of "Institutional funding (excluding construction projects and acquisition of property)" in relation to "Revenue from project grants" and "Revenue from services".
[3] Figures I.2.1 to I.2.7 add up to 100 %. The information requested here is thus the percentage of the various sources of "Revenue from project grants".
[4] Additional funds for administrative tasks of the FVB are formally booked at the IKZ, but are not available to the IKZ for research tasks. This amounts to 642.1 k€ in 2015, 597.6 k€ in 2016 and 560.9 k€ in 2017. These funds are not included in the table above.

Appendix 4

Staff

(Basic financing and third-party funding / proportion of women (as of: 31/12/2017)

	Full time equivalents		Employees		Female employees	
	Total	on third-party funding	Total	on temporary contracts	Total	on temporary contracts
	Number	Percent	Number	Percent	Number	Percent
Research and scientific services	**54,2**	**30,7**	**62**	**64,5**	**18**	**83**
Professors / Direct. (C4, W3 or equivalent)[5]	1	0	1	0	0	0
Professors / Direct. (C3, W2, A16 or equi.)	0	0	0	0	0	0
Academic staff in executive positions (A15, A16, E15 or equivalent)	13	15,4	13	7,7	3	0
Scientists in non-executive positions (A13, A14, E13, E14 or equivalent)	27,4	31	31	71	7	100
Doctoral candidates (A13, E13, E13/2 or equi.)	12,8	52,9	17	100	8	100
Service positions	**37,3l**	**19,6**	**40**			
Laboratory (E9 to E12,upper-mid-level service)	16,42	36	19			
Laboratory (E5 to E8, mid-level service)	3,9	36,1	4			
Technical service (E5 to E8, mid-level service)	9	0	9			
Technical service (from E9, senior service)	4	0	4			
Information technology - IT (E9 to E14, upper-mid-level service)	4	0	4			
Technical (large equipment, service) (E5 to E8, mid-level service)	0	0	0			
Administration[6]	**6,9**	**34,5**	9			
Head of the administration	0	0	0			
Staff positions (from E13, senior service)	2,8	56,5	3			
Staff positions (E9 to E12, upper-mid-level service)	0,8	100	1			
Internal administration (financial administration, personnel etc.) (from E13, senior service)	1,5	0	2			
Internal administration (financial administration, personnel etc.) (E9 to E12, upper-mid-level service)	1,9	0	2			
Building service (E1 to E4)	1	0	1			
Student assistants	1,2	0	6			
Trainees	**2**	0	2			
Scholarship recipients at the institution	1	100	1			
Doctoral candidates	1	100	1			
Post-doctoral researchers	0	0	0			

[5] The new director took up his duties on 1 February 2018 and is not included in this list.
[6] IKZ has only few administrative staff members. As a member of Forschungsverbund Berlin, the main part of the administration is affiliated to the "Joint Administration" which works for all eight institutes of the Forschungsverbund.

17 April 2019

Annex B: Evaluation Report

Leibniz Institute for Crystal Growth in the Forschungsverbund Berlin e. V. (IKZ)

Contents

1. Summary and main recommendations

The Leibniz Institute for Crystal Growth (IKZ) successfully addresses issues relating to crystal growth with the aim of providing scientific infrastructures and services. Activities range from fundamental research to industry-related technology development. The materials developed at the institute form the basis for modern, technical applications in, amongst others, micro-, opto- and power electronics, photovoltaics, laser technology and sensor technology. Based on its convincing research results, IKZ offers services that are in great demand amongst research institutions and industrial enterprises and are to some extent unique. These include fabricating crystals according to special specifications, the physical/chemical characterisation of crystalline solids and the development and/or construction of system components for growing, processing and characterising crystals.

IKZ's activities are conducted in three growth departments, one service section and the newly-established Center for Laser Materials. On average, the performance of the 13 working groups is rated as "very good" (one as "excellent", three as "very good to excellent", five as "very good", three as "good to very good" and one as "good"). IKZ has maintained its level of performance since the last evaluation. In some areas, there have even been improvements, such as in the acquisition of third-party funding. Moreover, in 2017, the institute took the landmark decision to establish the Center for Laser Materials.

This positive outcome is remarkable because, structurally, IKZ has experienced a difficult phase in recent years. For more than four years, the position of Director remained vacant after the previous incumbent accepted an appointment at another institution in 2013; despite intensive efforts, it was only possible to fill the position in 2018. During this unexpectedly long vacancy, the highly dedicated Director of the nearby Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, temporarily assumed the leadership position on a part-time basis. Together with the staff, who took on greater responsibilities than their positions demanded, he did an outstanding job.

The Board of Trustees understandably postponed important personnel decisions at second management level until the new Director was appointed. This affected two joint appointments that had already been in the pipeline seven years ago as well as further leadership positions that fell vacant due to retirement. Furthermore, another six scientific positions that had been deemed necessary at the last evaluation were not filled. Nonetheless, as IKZ's Scientific Advisory Board repeatedly pointed out, the long delay in the re-appointment process led to some significant compromises. Most importantly, some central structural recommendations issued at the last evaluation and related to continuing to build the profile of the institute have not yet been implemented.

It is, therefore, extremely important and positive that the position of Director was finally filled on 1 February 2018 with a distinguished researcher in a joint appointment with HU Berlin. In the follow-up to the work of the interim Director and in the short period since assuming office, he has already devoted himself to kick-starting many changes at all levels of IKZ.

In particular, he has elaborated a convincing strategy for IKZ's future, which now has to be implemented step by step. It aims to extend the value-added chain of the crystalline materials developed at the institute to pre-industrial crystal technology and thus to close a common gap in the innovation chain. For certain selected materials that have strong market potential the institute intends to produce small batches of the type required by partners in industry and research for their own further work. This will significantly reinforce the exploitation of IKZ's products.

Special consideration should be given to the following main recommendations in the evaluation report (highlighted in **bold face** in the text):

General concept and profile (Chapter 2)

1. IKZ plans to implement its future strategy in two stages. Initially, it wants to restructure the organisation of its activities. So far, the matrix structure to be introduced in 2019 is convincing. It should further reinforce communication and collaboration at IKZ.

   In order to embark on the second stage of extending activities through to pre-industrial applications it is necessary to extend the institute's equipment and human resources. To this end, IKZ plans to apply for additional long-term support from Federal and *Länder* Government funding ("extraordinary item of expenditure") of approx. € 2 m per year starting in 2021 (plus its own contribution of approx. € 0.3 m). In the initial funding years, various items of equipment shall be purchased. Subsequently, IKZ envisages gradually establishing positions for a total of 11 scientists, five technicians and one administrative assistant. IKZ's plans are explicitly endorsed by the review board. The written statements originally submitted by IKZ were convincingly reinforced by the institute during the evaluation visit; these statements should be included in the final application.

2. As planned, IKZ should continue increasing the number of publications and gear its publication strategy more towards publications in prestigious journals.

3. At the last evaluation, it was recommended that IKZ develops an exploitation strategy that would make market-relevant results and their potential exploitation paths (collaborations, patents, start-ups) more visible to external partners. This recommendation has only been partially implemented so far. Improved exploitation is, however, a central element of IKZ's convincing future strategy. It is, therefore, expected that significant improvements will be made in the coming years.

4. In comparison with the last evaluation, third-party income has grown slightly and is still on a good level. In 2017, it amounted to 24 percent of the overall budget. As planned, IKZ should continue to increase third-party income. The institute's own target of 35 percent is appropriate. IKZ should continue the positive trend in funding from the DFG and the EU. Given that some of its activities are rated as excellent, IKZ should aim high and, for example, try to acquire an ERC Grant.

Collaboration and networking (Chapter 4)

5. IKZ should implement its plans to establish two joint professorships as soon as possible. Should it prove difficult to do so with a university in Berlin, universities outside of Berlin should be considered as possible partners. Moreover, IKZ should also think about other subjects than physics and chemistry for university collaborations in order to continue reinforcing its interdisciplinarity. This would also be advantageous in terms of recruiting junior researchers.

Staff development and promotion of junior researchers (Chapter 5)

6. IKZ is facing a major generation change. By 2027, 22 percent of its current personnel will have retired. It is welcomed that the institute has developed a structured personnel concept that envisages concrete measures to hire and develop human resources in all sectors of the institute. IKZ should only fill post-doctoral scientific positions, particularly leadership positions, with individuals who have already been able to acquire longer-term experience at another location.
7. It is welcomed that the proportion of women in research and scientific services has been increased from 17 percent in 2011 to 29 percent in December 2017. IKZ must, however, continue this improvement, particularly at leadership level. Currently, none of the departments is headed by a woman, and of the 13 working groups only three are headed by women.
8. It is welcomed that, as recommended, IKZ has increased the number of doctoral candidates beyond the target of 15 it had set itself at the last evaluation. IKZ should continue this trend. With regard to publications, the institute should encourage doctoral candidates to publish in high-ranking journals from the very beginning and to feature as lead authors more frequently. Only in exceptional cases should they continue to be employed at IKZ once they have completed their doctorates.

Quality assurance (Chapter 6)

9. In order to avoid conflicts of interest, Scientific Advisory Board members should not be involved in collaborative relationships with IKZ. Members of the Board who enter into collaborations at any time should step down from the Board. More women should be included as Scientific Advisory Board members.
10. It is welcomed that IKZ is planning to conduct user surveys of its scientific service portfolio. In this context it should consider whether a User Advisory Board should be established. In contrast to the Scientific Advisory Board, this could include representatives of collaborative partners, especially in industry.

2. General concept and profile

The Leibniz Institute for Crystal Growth (IKZ) successfully addresses issues relating to crystal growth with the aim of providing scientific infrastructures and services. Activities range from fundamental research to industry-related technology development. The materials developed at the institute form the basis for modern, technical applications in,

amongst others, micro-, opto- and power electronics, photovoltaics, laser technology and sensor technology. Based on its convincing research results, IKZ offers services that are in great demand amongst research institutions and industrial enterprises and that are to some extent unique. These include fabricating crystals according to special specifications, the physical/chemical characterisation of crystalline solids and the development and/or construction of system components for growing, processing and characterising crystals.

Results

IKZ's activities are conducted in three growth departments, one service section and the newly-established Center for Laser Materials. On average, the performance of the 13 working groups is rated as "very good" (one as "excellent", three as "very good to excellent", five as "very good", three as "good to very good" and one as "good"). See Chapter 3 for the evaluation of the working groups and IKZ's ongoing scientific projects.

Research

The institute's very good research and development results are reflected in an appropriate publication record. **As planned, IKZ should continue increasing the number of publications and gear its publication strategy more towards publications in prestigious journals.**

Scientific services and infrastructure tasks

IKZ offers an extensive portfolio of services which are usually provided in the context of collaborative projects with research institutions or industrial enterprises; they always entail a certain proportion of research and development activities. A typical example is IKZ's involvement in the international consortium GERDA (GERmanium Detector Array) and its successor project LEGEND (Large Enriched Germanium Experiment for Neutrinoless Double Beta Decay), which is funded by the BMBF. IKZ's role is to develop growth technology for germanium of unprecedented purity to be used in the experiments' detectors.

IKZ also offers several much sought-after services to external users, such as providing the materials grown at IKZ for research purposes, preparing samples according to special requirements, providing and developing processing technologies, developing system components that are not available commercially, performing numerical modelling and the characterisation and analysis of crystalline materials as well as providing scientific advice on growth processes.

Knowledge and technology transfer

Knowledge and technology transfer are conducted in various ways. Here too, one important element is collaborative projects, especially those involving industrial enterprises. IKZ is, for example, part of the BMBF-funded consortium Advanced UV for Life, in which 45 businesses and research institutions seek to drive the technical development, availability and use of ultraviolet light-emitting diodes on a wide scale.

Furthermore, IKZ has an extensive portfolio of patents which is continuously being expanded. Between 2014 and 2017, five patent families and 13 individual patents were granted. Altogether, IKZ currently (November 2018) holds 22 patent families and 45 individual patents. The revenue from exploitation rights is, however, well below the costs of maintaining the patents. In the context of the envisaged improvement in the exploitation of research results (see recommendation below), IKZ should, therefore, review its patent portfolio, as planned.

It is very positive that IKZ managed to launch a start-up in 2016: GOLARES GmbH provides coatings and microstructuring for opto- and micro-electronic components using innovative plasma technology.

At the last evaluation, it was recommended that IKZ develops an exploitation strategy that would make market-relevant results and their potential exploitation paths (collaborations, patents, start-ups) more visible to external partners. This recommendation has only been partially implemented so far. Improved exploitation is, however, a central element of IKZ's convincing future strategy. It is, therefore, expected that significant improvements will be made in the coming years.

Development of the institution since the last evaluation

IKZ has maintained its level of performance since the last evaluation. In some areas, there have even been improvements, such as in the acquisition of third-party funding. Moreover, in 2017, the institute took the landmark decision to establish the Center for Laser Materials.

This positive outcome is remarkable because, structurally, IKZ has experienced a difficult phase in recent years. For more than four years, the position of Director remained vacant after the previous incumbent accepted an appointment at another institution in 2013; despite intensive efforts, it was only possible to fill the position in 2018. During this unexpectedly long vacancy, the highly dedicated Director of the nearby Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, temporarily assumed the leadership position on a part-time basis. Together with the staff, who took on greater responsibilities than their positions demanded, he did an outstanding job.

The Board of Trustees understandably postponed important personnel decisions at second management level until the new Director was appointed. This affected two joint appointments that had already been in the pipeline seven years ago as well as further leadership positions that fell vacant due to retirement. Furthermore, another six scientific positions that had been deemed necessary at the last evaluation were not filled. Nonetheless, as IKZ's Scientific Advisory Board repeatedly pointed out, the long delay in the re-appointment process led to some significant compromises. Most importantly, some central structural recommendations issued at the last evaluation and related to continuing to build the profile of the institute have not yet been implemented.

It is, therefore, extremely important and positive that the position of Director was finally filled on 1 February 2018 with a distinguished researcher in a joint appointment with HU Berlin. In the follow-up to the work of the interim Director and in the short period since assuming office, he has already devoted himself to kick-starting many of the changes at all levels of IKZ. In particular, he has elaborated a convincing strategy for IKZ's future, which

now has to be implemented step by step (see below). Against this backdrop, the new Director will be tasked with extensive managerial tasks for some time to come. He should then be able to devote more time to research once again.

Strategic work planning for the next few years

IKZ's future strategy is convincing. It aims to extend the value-added chain of the crystalline materials developed at the institute to pre-industrial crystal technology and thus to close a frequent gap in the innovation chain. For certain selected materials that have strong market potential the institute intends to produce small batches of the type required by partners in industry and research for their further work. This will significantly reinforce the exploitation of IKZ's products. **IKZ plans to implement its future strategy in two stages:**

i) New structure

Initially, IKZ wants to restructure the organisation of its activities. The institute plans to establish a matrix structure that will come into force on 1 April 2019 (see also Appendix 1 in the Status Report). Two crystalline materials growth departments will form the vertical dimension of the matrix, focusing on innovations *in* materials, and will be constituted as follows:

- The "Classical Semiconductors" and "Dielectrics & Wide Bandgap Materials" departments will be transformed into one new department, "Volume Crystals".
- The "Layers & Nanostructures" department will remain more or less unchanged and will be renamed "Nanostructures & Thin Films".

The horizontal dimension of the matrix will be formed by two crystalline materials validation departments that will focus on innovations *by* materials and will be constituted as follows:

- The "Simulation & Characterisation" section will be transformed into a department named "Materials Science".
- The Center for Laser Materials (CLM) forms the basis for a new scientific department, "Application Science", aiming at reliable evaluation and benchmarking of crystalline materials.

Whilst the first three new departments comprise groups that have been active at IKZ for some time, the "Application Science" Department is new. With the establishment of CLM in 2017 (see Chapter 3), an excellent basis for this was created. CLM is set to develop crystalline materials for photonics. Moreover, the long-term work on aluminium nitride and gallium oxide (see Chapter 3), which is also promising from an industrial point of view, will also be integrated in the "Application Science" department. The aim is to develop crystalline materials for electronics. IKZ's plan to integrate the working group on "Crystal Machining" into this department, as well, is also conclusive. It is welcomed that IKZ intends to use its own funding to establish a junior research group in each of the four new departments**. So far, the matrix structure to be introduced in 2019 is convincing. It should further reinforce communication and collaboration at IKZ.**

ii) Extraordinary item of expenditure

In order to embark on the second stage of extending activities through to pre-industrial applications it is necessary to extend the institute's equipment and human resources. To this end, IKZ plans to apply for additional long-term support from Federal and *Länder* Government funding ("extraordinary item of expenditure") of approx. € 2 m per year starting in 2021 (plus its own contribution of approx. € 0.3 m). In the initial funding years, various items of equipment shall be purchased. Subsequently, IKZ envisages gradually establishing positions for a total of 11 scientists, five technicians and one administrative assistant. In 2025, the additional funds are to be incorporated into the institute's budget. They will then be used to finance the human resources and the maintenance of the equipment acquired. **IKZ's plans are explicitly endorsed by the review board. The written statements originally submitted by IKZ were convincingly reinforced by the institute during the evaluation visit; these statements should be included in the final application.**

Appropriateness of facilities, equipment, and staffing

The level of institutional funding from the Federation and the *Länder* is sufficient to enable IKZ to carry out its current range of tasks. In 2017, institutional funding totalled € 10.4 m.

In comparison with the last evaluation, third-party income has grown slightly and is still on a good level. In 2017, it amounted to 24 percent of the overall budget. As planned, IKZ should continue to increase third-party income. The institute's own target of 35 percent is appropriate.

It is extremely positive that in addition to the continued extensive funding from the Federation and *Land,* the institute now raises funding from the DFG; since 2013, the DFG fees paid in the last few years have been recovered many times over. At EU level, too, funding income has been increased. **IKZ should continue the positive trend in funding from the DFG and the EU. Given that some of its activities are rated as excellent, IKZ should aim high and, for example, try to acquire an ERC Grant.** An appropriate level of third-party funding from industry has also been raised. IKZ's future strategic planning suggests, however, that an increase can be expected here, too. The institute's positive performance in the Leibniz Competition is also very convincing. Since 2016, it has acquired four projects.

IKZ only earns a very modest income from the exclusive provision of services. The majority of services the institute offers always include a share of research and development activities which are provided in the context of collaborative projects and financed by third-party funding (see above). Income for services is only generated by the most straightforward preparation and analysis activities for external users.

The provision of office space is appropriate. Since the FVB (*Forschungsverbund Berlin e.V.*) joint administration's IT Group, which was previously located at IKZ, moved to other premises in autumn 2018, the institute now has additional space at its disposal. This will be required for the planned increase in human resources.

The provision of laboratory space is also appropriate. The equipment for growing and characterising crystals and films is state-of-the-art. The IT infrastructure meets employees' requirements and observes the principles of IT security.

3. Subdivisions of IKZ

Research at IKZ is organised in the three departments, "Classical Semiconductors", "Dielectrics and Wide Bandgap Materials" and "Layers and Nanostructures" as well as the service section "Simulation and Characterization". These units are subdivided into working groups. The Center for Laser Materials forms a further structural unit.

"Classical Semiconductors" Department

[19.48 FTE, thereof 10.51 FTE research and scientific services, 0.75 FTE doctoral candidates, and 8.32 FTE service staff]

This department conducts research and development in the growth of volume crystals involving silicon (Si) and germanium (Ge) as well as their solid solutions and III-V semiconductors. These activities have been a focus at IKZ for a long time. On the one hand, the department conducts application-related research, frequently in collaboration with partners in industry. On the other, it delivers unique crystals for fundamental research. Since the last evaluation, no groups have been discontinued or newly established in the department.

WG "Silicon and Germanium" [13.38 FTE, thereof 5.41 FTE research and scientific services, 0.75 FTE doctoral candidates, and 7.32 FTE service staff]

IKZ's largest group conducts highly successful work on the growth of Si and Ge crystals as well as their solid solutions. The group can boast major successes in optimising the production process with regard to product quality (purity, size, form) as well as production costs. The main methods used are Floating Zone and Czochralski.

One of the group's extremely successful focus areas is the optimised growth of monocrystalline Si for applications in photovoltaics and power electronics. Its excellent results are in great demand not only amongst industrial enterprises but also fundamental research institutes. One very good project relates to the growth of isotopically pure ^{28}Si crystals which are used as part of a new approach to more precisely redefining the kilogram based on a natural standard. A very promising future measure is the planned launch of a new float zone facility, which is scheduled for 2019. This will make it possible to grow crystals with a diameter of up to eight inches, which has not yet been achieved in the non-industrial sector.

A further very successful focus is the growth of ultrapure ^{76}Ge crystals for detectors. IKZ is a partner in the international consortium GERDA (GERmanium Detector Array) and its successor project LEGEND (Large Enriched Germanium Experiment for Neutrinoless Double Beta Decay). In this consortium, IKZ has the important role of developing a growth technology for germanium of unprecedented purity to be used in the experiments' detectors. The relevant research and development activities conducted at IKZ are also extremely

interesting from a fundamental point of view, irrespective of whether the ambitious level of purity can actually be achieved.

The working group manages excellently to combine application-related development activities with fundamental research questions. This is reflected in its large number of publications and high third-party income, particularly for projects with partners in industry. In its field, the working group is one of the leading groups in Europe.

The group is rated as “very good to excellent”.

WG “Multicrystalline Silicon” [2 FTE, thereof 2 FTE research and scientific services]

The work of this group and of the “Gallium Arsenide” group (see below) deals with growing crystals employing the innovative Vertical Gradient Freeze method (VGF) in travelling magnetic fields (TMFs). In this context the KRISTMAG© technology, which IKZ developed and registered as a trademark, is used. In the past, it has been starting point for many very successful research and development activities at IKZ, particularly in the “Multicrystalline Silicon” group. The group’s results enabled it to optimise the production of high-quality multicrystalline silicon blocks.

The relatively small group pursues this goal with activities that continue to be based on convincing methods. The publication record is good. The general conditions have, however, changed significantly since the last evaluation which explains the group’s comparatively low third-party income. On the one hand, this research area, which was the subject of intensive work in the past, is no longer appropriate for generating fundamentally new research results. The essential processes have been elucidated and the technologies developed here can now be provided by industrial enterprises. On the other hand, the demand for multicrystalline silicon in the main area of applications, the photovoltaics industry, has fallen dramatically across Europe in recent years.

Meanwhile, the group has adopted further research topics in order to adapt to the changed general conditions. The group must, however, consider how it should re-orientate itself in the long term to new, more future-orientated issues and materials. The growth technology used should certainly be retained at IKZ as it is also an option for growing other materials (see below).

The group is rated as “good”.

WG “Gallium Arsenide” [4.1 FTE, thereof 3.1 FTE research and scientific services and 1 FTE service staff]

Using the same VGF technology as the “Multicrystalline Silicon” group (see above), this group successfully investigates the growth of the traditional semiconductor material gallium arsenide (GaAs). Its very good results attract great interest amongst industrial users in the field of WLAN communications as well as in microwave and high-frequency technology. Due to the increasing demand for smartphones, further growth in the markets for GaAs components is to be expected.

Industry’s serious interest is reflected in the concomitant high level of third-party income in this group. Special mention should be made of its successful long-term cooperation with

the Freiberg Compound Materials GmbH. It is welcomed that the group now also collaborates with other partners in industry. Since the group often has to observe confidentiality rules in projects with partners in industry, it cannot always publish its consistently very good research results (see also Chapter 4: Collaborations). Against this backdrop, the publication record is appropriate.

The group is rated as "very good".

"Dielectrics and Wide Bandgap Materials" Department

[14.74 FTE, thereof 7.9 FTE research and scientific services, 0.75 FTE doctoral candidates, and 6.09 FTE service staff]

This department investigates the growth of volume crystals of nitrides, oxides and fluorides. The crystals are also used outside of IKZ in fundamental research in materials physics and as a substrate for epitaxy in producing novel components (see below: "Layers and Nanostructures" department). Fields of application include optics, photonics and power electronics. As recommended at the last evaluation in 2012, the head of department employed resources from two groups that have since been discontinued ("Zinc Oxide" and "Gallium Nitride") to reinforce the other two groups and thus hone the department's profile.

WG "Oxides/Fluorides" [9.84 FTE, thereof 5 FTE research and scientific services, 0.75 FTE doctoral candidates and 4.09 FTE service staff]

In a field that has been established at IKZ for many years, this group produces extremely successful results with its activities in the field of growing oxide and fluoride volume crystals as well as developing the relevant growth technologies. It uses various innovative technologies to grow transparent semiconducting oxides, high-temperature piezoelectric materials and perovskites, largely employing the Czochralski method. The crystals, some of which are exclusively produced at IKZ, are made available to research institutions across Europe as reference crystals and thus constitute an essential basis for diverse outstanding research results. In addition, the group's results are of great interest to industrial enterprises in multiple fields of application. Due to high demand, the group cannot meet every external request and therefore sets convincing priorities.

Amongst the group's diverse, highly successful projects, special mention should be made of its excellent work on growing gallium oxide (Ga_2O_3), which has been successfully continued since the last evaluation. After IKZ had managed to grow the world's first high-quality Ga_2O_3 single crystals with the desired electrical and optical properties, their applications are now being studied (amongst others at the Leibniz ScienceCampus GraFOx). It is logical to integrate this work, which is of enormous interest to industry, in the new "Application Science" Department.

Further very good work is conducted in the field of developing substrates. For the first time, semiconducting substrate material for transparent oxide electronics has been produced and characterised as a crystal (e.g. In_2O_3). Moreover, very successful research is being done on producing perovskite structure crystals for ferroelectric layers with new functionalities.

The group manages excellently to combine fundamental research with application-related developments and service activities. This is reflected in its large number of publications, some of which appear in high-ranking journals. Its third-party income is high, particularly for application-related projects. The group's excellent work holds potential for continuing to increase third-party income for fundamental activities of the type funded, for example, by the DFG.

The group is rated as "very good to excellent".

WG "Aluminium Nitride" [4,9 FTE, thereof 2,9 FTE research and scientific services and 2 FTE service staff]

This group's long-term work on developing the Physical Vapour Transport (PVT) growth technology for application-relevant aluminium nitride (AIN) volume crystals and substrates has been successfully continued since the last evaluation. It focuses on the continued improvement of reproducible crystal production of a commercially exploitable diameter. Together with its industrial and research partners in the BMBF-funded consortium, Advanced UV for Life, it seeks to achieve industrial use of growth technology and the development of a value-added chain right up to components. To this end, IKZ aims to make the production of AIN crystals with a minimum diameter of 25 mm reproducible. The institute should formulate concrete interim targets on its path to achieving this goal.

Furthermore, the group conducts successful work on controlling the electrical and optical properties of AIN crystals, which are of relevance to various areas of application. In a DFG-funded project, for example, it examines how by appropriately varying the process parameters AIN crystal discs can be produced that exhibit the optimum material properties for high-temperature piezoelectrics.

The group's third-party income is high. It is welcomed that, despite the fact that activities tend to be application orientated, it has not only managed to acquire industrial funding but also DFG projects. Overall, the group has improved its performance since the last evaluation but still does not completely exploit its high potential. Its publication performance should be further enhanced. Given its applications bias it is logical to integrate the group under its new head, who joined IKZ in September 2018, into the new "Application Science" Department and continue its activities there. In combination with industrial interest in the group's important work, this should lead to a further improvement in performance.

The group is rated as "good to very good".

"Layers and Nanostructures" Department

[16.27 FTE, thereof 9.12 FTE research and scientific services, 5.25 FTE doctoral candidates, and 1.9 FTE service staff]

This department investigates crystalline layers and nanostructures which have great application potential in transparent oxide electronics and power electronics. Thanks to its proximity to the two volume crystal departments, which provide the substrates required for coating deposition, the department has a unique opportunity to develop novel materials with tailored properties. In comparison with other departments, more third-party funding for

fundamental research is raised (e.g. from the DFG) whilst activities focus to a greater extent on publishing results. Industrial funding, on the other hand, is considerably lower. Since the last evaluation, no groups have been discontinued or newly established in the department.

WG "Si/Ge Nanocrystals" [7.25 FTE, thereof 3.5 FTE research and scientific services, 3.75 FTE doctoral candidates]

This group very successfully investigates fundamental phenomena of growth and the characterisation of crystalline micro- and nanostructures. Its results flow into the development of cost- and material-saving energy conversion and storage. The group's convincing activities focus on the growth of crystalline Si layers on economical substrates like glass. Until 2018, it was involved in a European collaborative project which sought to produce efficient, economical solar cells in the context of the European Energy Research Alliance (EERA). Following on from this, research is being conducted on providing material for CIGSe (copper indium gallium selenide) micro-islands in the framework of a DFG-funded project.

Third-party income is high, and the publication record is very good. The work launched in 2018 on the growth of isotope-enriched, high-purity, elastically strained ^{28}Si layers for the development of quantum computers is very promising and a good basis for further very good results.

The group is rated as "very good".

WG "Ferroelectric Oxide Layers" [5.02 FTE, thereof 2.62 FTE research and scientific services, 1.5 FTE doctoral candidates, and 0.9 FTE service staff]

This group conducts successful research on the growth and characterisation of ferro-, piezo- and dielectric oxide layers of the kind used, for instance, in storage media and sensors. One focus area is the investigation of anisotropic tension to facilitate novel domain patterns and electrical properties. IKZ provides the ideal environment for these convincing activities as the required substrates can be acquired directly from the "Oxides and Fluorides" group. Chemical MOVPE (metalorganic vapour-phase epitaxy) and physical PLD (pulsed laser deposition) are the growth methods used by the group.

The group's activities are conducted at a very high level and achieve a balance between fundamental research and application-relevant development. Its publication record is very good, particularly in terms of quality, and, with regard to quantity, it should continue the positive trend of recent years. The group successfully acquires third-party projects, including from the DFG. Its very good research results offer scope for further increases in third-party income.

The group is rated as "very good".

WG "Semiconducting Oxide Layers" [4 FTE, thereof 3 FTE research and scientific services, 1 FTE service staff]

For many years, this group undertook extremely successful research on silicon-carbide epitaxy. These activities have now, quite rightly, been discontinued, as planned at IKZ's last evaluation. Having successfully acquired a project (2012-2015) in the Leibniz

Competition, work has since been successfully launched and expanded on developing and characterising layers and layer structures in oxidic semiconducting materials. This group also benefits from being able to acquire the necessary substrates directly from the "Oxides and Fluorides" group at IKZ.

Work focuses on the metalorganic chemical vapour deposition (MOCVD) of gallium oxide, which forms the potential material basis for novel components in power electronics and photo detectors. Amongst others, an interesting comparative study was conducted which identified the scientific basis for differences in the gallium oxide layers produced at IKZ and elsewhere. The group's publication record is appropriate but definitely has the potential to be enhanced. Third-party income should also be raised. It is welcomed that the group has been involved in a DFG-funded project since 2017.

The group is rated as "good to very good".

"Simulation and Characterization" Section

[23.37 FTE, thereof 8.87 FTE research and scientific services, 7.5 FTE doctoral candidates, and 7 FTE service staff]

With their preparatory numerical simulations and various measuring procedures, the groups in the service section make a significant contribution to the activities in the three departments. Moreover, they also address very good research projects themselves. Publication figures in the section groups are comparatively high as they are involved in many of the projects in the three departments. By contrast, third-party income is often lower because the projects are usually acquired by the three departments themselves. No new groups have been established in the section since the last evaluation. The "Numerical Modelling" group was discontinued and the relevant expertise re-allocated to other groups. It is welcomed that, in the framework of the new institute structure, an independent group is scheduled to be created once again for this important work.

WG Physical Characterization [7.25 FTE, thereof 2 FTE research and scientific services, 2.25 FTE doctoral candidates, and 3 FTE service staff]

At the highest technical level, this group examines the volume crystals and epitaxial layers grown at IKZ employing innovative methods such as X-ray diffraction, optical spectroscopy and imaging, and electrical measurements. It cooperates closely with other groups in the section, especially the "Electron Microscopy" group. The group's findings serve, on the one hand, to optimise growth processes and, on the other, to help reach a better understanding of fundamental and application-relevant crystal properties.

Apart from these important services, which are also performed for external partners, the group successfully addresses its own scientific questions. Very good work has been done, for example, on the domain engineering of epitaxial layers to improve piezoelectric properties. The group's plan to investigate ferroelectric phase transitions in in-situ X-ray diffraction experiments is coherent. The work on UV transparent AIN that is conducted in the context of a DFG project with the "Aluminium Nitride" group is also convincing. Due to its involvement in many IKZ projects, the group's publication record is very good. Whilst it did

not raise any third-party funding itself, it is involved in the three growth departments' third-party funded projects.

The group is rated as "very good".

WG Electron Microscopy [8.37 FTE, thereof 3.87 FTE research and scientific services, and 4.5 FTE doctoral candidates]

This group does excellent research and service work in the field of characterising crystalline materials. Its thematic focus is set on structural property relationships in semiconductors and oxides. To this end, it employs a wide range of state-of-the-art electron microscopy techniques, such as scanning electron microscopy, transmission or scanning transmission electron microscopy. The group's convincing research activities are not so much geared to developing methods but, rather, to attaining a fundamental physical understanding of growth processes. In many cases, the group's excellent results are the starting point for very interesting theoretical work or simulations which are conducted at the institute or with collaborative partners.

Together with HU, the group has run the Joint Laboratory for Electron Microscopy (JEMA) since 2009. The alliance lab acts as a materials analysis consultant for scientific establishments and industry. Thanks to its internationally recognised expertise it is involved in various projects with external partners. The group's publication record is very good, and it acquires many of its own third-party projects. It should also be mentioned that a large number of doctoral students are integrated into the group's activities.

The group is rated as "very good to excellent".

WG Chemical & Thermodynamic Analysis [2.75 FTE, thereof 2 FTE research and scientific services, 0.75 FTE doctoral candidates]

This group conducts essential chemical and thermodynamic analysis of starting materials and grown crystals both for IKZ's growth departments and for external partners. In addition to measurements, thermodynamic calculations are also carried out. The convincing results are important on the one hand for preparing growth experiments and, on the other, for the quantitative characterisation of the growth process.

Just like the other groups in this section, this group is closely integrated in a raft of projects conducted by the three growth departments. It is consequently represented in a host of publications. Due to the group's function and focus, it is logical that it only has a small income from third-party projects.

The group is rated as "very good".

WG Crystal Machining [5 FTE, thereof 1 FTE research and scientific services, and 4 FTE service staff]

This working group also delivers essential technical foundations for the work of IKZ's departments as well as for external partners, such as cutting and polishing not only for the preparation and follow-up of crystal growth processes but also for fabricating samples for various measuring procedures. For this purpose, it also develops its own novel surface

preparation methods. These activities are extremely relevant, especially for the production of substrates for epitaxial deposition of oxide layers. Whilst the publication figures are low, they are in line with the group's profile which includes a very high percentage of services. Against this backdrop, it is logical that the group does not have any third-party income of its own.

Given the importance of its function at IKZ, the group should be better integrated. In particular, communication with the respective growth groups on what is required of the samples to be prepared must be improved. Moreover, with the establishment of the Center for Laser Materials (CLM, see below), the group will be faced with new challenges with regard to the plane-parallel polishing of crystals. With this in mind, it is most welcome that the group is to be transferred to the new Application Science Department together with CLM. In view of the even greater future importance of these activities for IKZ's overall strategy, it is logical that some of the additional funding foreseen should be used to expand the group both in terms of human resources and equipment. The group should then have the capacity to pursue more activities in the technology development sector in addition to providing services.

The group is rated as "good to very good".

Center for Laser Materials

[2 FTE, thereof 1 FTE research and scientific services, and 0.75 doctoral candidates]

The establishment of the Center for Laser Materials (CLM) at IKZ was an excellent and, for the institute, pathbreaking decision which was taken under IKZ's interim Director. From 2012, the group was funded within a Cluster of Excellence at the University of Hamburg as a junior research group. In 2017, it was relocated to IKZ with funding from the Federal Government. As of 2019, it is being funded from IKZ's budgetary resources.

The group's excellent work focuses on the investigation, qualification and development of innovative laser materials. It concentrates on fundamental research and the spectroscopic, structural and thermo-mechanical characterisation as well as the chemical analysis of known materials. Such laser materials are used in microscopy, medicine and materials processing. In a most promising fashion, CLM thus reinforces the link between IKZ's traditional crystal growth and the laser industry.

CLM's results are outstanding in every respect. Special mention should be given to its innovative work on materials for direct yellow laser emission and on the single crystal growth of sesquioxides. Its publication record is excellent and includes publications in very high-ranking journals. Third-party income is also high. Another positive aspect that should be emphasised is the group's success in recruiting young researchers from abroad. IKZ's plans to build the new Application Science Department, in which other important application-related activities are to be integrated around CLM, are convincing.

The group is rated as "excellent".

4. Collaboration and networking

Collaboration with universities

At present, IKZ is affiliated with universities in the vicinity by two joint appointments. Since 2018, the Director of IKZ has held the Chair in Crystal Growth at Humboldt-Universität zu Berlin (HU Berlin). The head of the Dielectrics and Wide Bandgap Materials Department, who has been at IKZ since 2011, holds a joint professorship in the Institute of Chemistry at Technische Universität Berlin (TU Berlin).

The plans presented at the last evaluation to create two additional joint appointments were not implemented due to the position of director remaining vacant. It is welcomed that they are now scheduled to be filled jointly with a university in the context of the leadership of one of the new departments. **IKZ should implement its plans to establish two joint professorships as soon as possible. Should it prove difficult to do so with a university in Berlin, universities outside of Berlin should be considered as possible partners. Moreover, IKZ should also think about other subjects than physics and chemistry for university collaborations in order to continue reinforcing its interdisciplinarity. This would also be advantageous in terms of recruiting junior researchers.**

IKZ cooperates closely with HU and TU Berlin on various scientific endeavours. Special mention should be made of the Leibniz ScienceCampus Growth and Fundamentals of Oxides for electronic applications (GraFOx), which was established in 2016 and which also involves the Paul Drude Institute for Solid State Electronics (as leading partner) and the Max Planck Society's Fritz Haber Institute.

The Joint Laboratory for Electron Microscopy (JEMA) is another important collaboration with HU Berlin that was established in 2009. It focuses on elucidating structure-property relationships in crystalline materials (see also Chapter 3, WG "Electron Microscopy"). JEMA is used by partners from both science and industry as a research contact for the analysis of advanced materials and interfaces. As well as developing state-of-the-art electron microscopy techniques and methods, JEMA also focuses on training.

Other collaborations and networks

IKZ cooperates successfully with various non-university institutions, especially in the Leibniz Association. Its partners include Berlin-based institutes like the Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, and the Paul Drude Institute for Solid State Electronics as well as the Leibniz-Institut für innovative Mikroelektronik, which is located in Frankfurt an der Oder.

The consortium Advanced UV for Life, which was constituted by the German Federal Ministry of Education and Research in 2012, is another important collaboration in which various companies and research institutions drive the availability and use of UV LEDs.

Industrial collaborations

IKZ's various industrial collaborations are of special importance for the institute as they generate high third-party income. The long-standing volume crystal growth groups, in

particular, are excellently established and in great demand for joint activities and development. IKZ's plans to extend the value-added chain at the institute (see Chapter 2) should make it attractive for additional partners in industry. When concluding contracts with partners in industry IKZ should always have an eye to its own interests, such as publishing results and appropriate remuneration for unique services.

5. Staff development and promotion of junior researchers

Staff development and personnel structure

IKZ's personnel structure is appropriate for its current range of tasks. As of 31 December 2017, the institute employed 120 people, 62 of them in research and scientific services, 40 in service positions and nine in the administration, which is largely borne by the Forschungsverbund Berlin e. V. (FVB).

IKZ is facing a major generation change. By 2027, 22 percent of its current personnel will have retired. It is welcomed that the institute has developed a structured personnel concept that envisages concrete measures to hire and develop human resources in all sectors of the institute. IKZ should only fill post-doctoral scientific positions, particularly leadership positions, with individuals who have already been able to acquire longer-term experience at another location.

It is welcomed that the contracts of five members of the technical staff have been extended indefinitely, as recommended at the last evaluation. This ensures that the institute can retain important expertise for permanent tasks.

Promotion of gender equality

It is welcomed that the proportion of women in research and scientific services has increased from 17 percent in 2011 to 29 percent in December 2017. IKZ must, however, continue this improvement, particularly at leadership level. Currently, none of the departments is headed by a woman, and of the 13 working groups only three are headed by women. At doctoral level the share of women is 44 percent. This indicates that by employing the target quotas it has defined in line with the DFG's cascade model, IKZ can achieve a further increase in the percentage of women.

IKZ's employees benefit from appropriate measures to reconcile work and family life. This was certified by the audit *berufundfamilie* in 2015 and re-confirmed in 2018.

Promotion of junior researchers

It is welcomed that, as recommended, IKZ has increased the number of doctoral candidates beyond the target of 15 it had set itself at the last evaluation. On 31 December 2017, 18 doctoral candidates were employed at IKZ, by the time of the evaluation visit this figure had increased to 23. **IKZ should continue this trend. With regard to publications, the institute should encourage doctoral candidates to publish in high-ranking journals from the very beginning and to feature as lead authors more frequently. Only in exceptional cases should they continue to be employed at IKZ once they have completed their doctorates.**

It is welcomed that under the new Director IKZ has developed new guidelines for the employment of doctoral candidates. All doctoral candidates are also given the opportunity to take part in FVB seminars. Every year, courses in soft skills like time management, presentation techniques and communications are offered there.

The number of postdocs has also increased since the last evaluation and has now reached nine. It is very much to be welcomed that IKZ is planning to introduce four self-funded tenure-track junior research groups (for three plus two years). As planned, the leadership positions should be advertised internationally.

Vocational training for non-academic staff

IKZ offers appropriate continuing education measures for its non-academic staff (see Status Report). Further training courses are regularly conducted by FVB.

IKZ offers training positions in various occupations. In the period 2015-17, a total of five apprenticeships were successfully completed. As of December 2017, there were two trainees at IKZ. The institute should consider to what extent it could increase the number of trainees. The required capacity should be available at an institute the size of IKZ.

6. Quality assurance

Internal quality management

IKZ employs appropriate measures for internal quality assurance. Rules of good scientific practice (based on guidelines issued by the DFG) have been elaborated and an ombudsperson instituted. The internal review process for scientific publications and presentations is highly commended. Special mention should also be made of the various internal communication formats. These have helped to ensure that the new overall strategy and organisational structure have been embraced by all IKZ staff.

Quality management by the Scientific Advisory Board and the Board of Trustees

In its role as supervisory body, the Board of Trustees conducts its business convincingly.

The Scientific Advisory Board is both constructively critical and engaged in mentoring the institute's activities. In 2016, it conducted the audit, which is normally held at Leibniz institutions between two evaluations, assessing both the departments and IKZ as a whole. **In order to avoid conflicts of interest, Scientific Advisory Board members should not be involved in collaborative relationships with IKZ. Members of the Board who enter into collaborations at any time should step down from the Board. More women should be included as Scientific Advisory Board members.**

It is welcomed that IKZ is planning to conduct user surveys of its scientific service portfolio. In this context it should consider whether a User Advisory Board should be established. In contrast to the Scientific Advisory Board, this could include representatives of collaborative partners, especially in industry.

Implementation of recommendations from the last external evaluation

Due to the length of time during which the position of Director remained vacant, some of the recommendations issued at the last evaluation were not implemented. Nevertheless, under the leadership of the interim Director some notable improvements were made. Building on this, the new Director has now introduced convincing measures to implement the remaining recommendations. With reference to the recommendations issued at the last evaluation (in italics, numbered according to the relevant page A-18ff of the Status Report), the Review Board noted the following:

1. Since the last evaluation, the IKZ has made positive progress. It has significantly improved its organisational structure and devised a development concept in 2008. In order to achieve the goal formulated in this concept of becoming the European competence centre for crystal growing, the IKZ should expand the progress made in identifying innovative research topics and further sharpen its research profile. Research and services should receive even greater support through independent and high-quality research.

IKZ's plans for re-focusing and re-structuring are convincing (see Chapter 2).

2. The Senate welcomes the fact that, since the last evaluation, cooperation with universities has been improved, as recommended, in particular through closer links with personnel. In addition to the director of the institute, another of the three department heads has been appointed in a joint appointment with a Berlin university in 2011. The Senate expects that the third, currently vacant department head will now also be filled together with a neighbouring university. It is welcomed that, independently of this, two further joint appointment procedures are already planned. Traditionally, the IKZ's cooperation with universities was limited to the field of physics. With the second joint appointment, chemistry was included. Further subjects for university cooperation should now be considered in order to further strengthen interdisciplinarity at the IKZ.

The envisaged plans could not be implemented. IKZ should now press ahead with the planned joint appointments as quickly as possible (see Chapter 4).

3. The Senate recommends that the individual activities for the exploitation of work results should be combined in an integrated exploitation strategy. The institute should systematically identify market-relevant research results and their possible ways of exploitation.

This recommendation has only been partially implemented so far. Improved exploitation is, however, a central element of IKZ's convincing strategy for the future (see Chapter 2).

4. In the course of further sharpening its scientific profile, the management of the IKZ should establish a more publication-oriented working method as part of an overall intensified scientific communication. The IKZ should ensure that all scientific employees publish their work results appropriately in addition to few high performers.

IKZ has embraced this recommendation and improved its publication record in general. There is, however, still potential for further enhancement as IKZ itself recognises (see Chapter 2).

5. Since the last evaluation, improvements have been made in the promotion of young scientists, which the Senate believes should be further expanded. The IKZ has the capacity to increase the number of doctoral students beyond the target of 15 set by the institute and also to increase the number of postdocs. In order to improve networking within the scientific community, the IKZ should fill postdoctoral positions with external candidates to a considerably greater extent than before. In the area of non-scientific trainees, the IKZ should be able to offer far more than the currently available two training positions.

IKZ has largely implemented this recommendation. The number of doctoral candidates and postdocs has been increased, including postdocs from outside of IKZ. Now the institute must perpetuate this trend. The number of trainees still needs to be increased (see Chapter 5).

6. As part of the recommended enhanced networking within the scientific community, it is recommended that the IKZ does not generally provide for permanent employment for new scientific staff. In the technical field, however, efforts should be made to remove fixed-term contracts from appropriately qualified staff who have been employed at the Institute for many years.

This has been implemented. During the interim management, IKZ only hired two scientists on permanent contracts. Since the last evaluation, five technicians have been transferred to permanent positions.

7. An additional increase of the personnel number by six staff headcounts as it is envisaged in the programme budget for 2013 is necessary in order to successfully complete the institute's development concept of 2008.

This recommendation was not implemented due to the absence of a permanent Director. IKZ has now presented coherent plans for increasing personnel numbers (as well as the provision of equipment) which are explicitly endorsed (see Chapter 2).

8. It is expected that the IKZ will be able to continue the positive trend regarding the acquisition of third-party funding and, in particular, significantly increase its participation in DFG-funded projects.

This recommendation has been implemented. The positive trend with regard to DFG third-party funding should be continued (see Chapter 2)

9. It is good that the IKZ has implemented measures and guidelines in the field of gender equality. However, the number of female scientists is not yet sufficient. Above all, the institute should therefore make use of the opportunities offered by the increase in personnel to increase the number of female scientific and technical staff.

IKZ has managed to raise the percentage of women. However, improvements, especially at leadership level, are still necessary (see Chapter 5).

Appendix

1. Review Board

Chair (Member of the Leibniz Senate Evaluation Committee)

Cynthia **Volkert**	Institute of Materials Physics, University of Göttingen

Deputy Chair (Member of the Leibniz Senate Evaluation Committee)

Evamarie **Hey-Hawkins**	Institute of Inorganic Chemistry, Leipzig University

Reviewers

Stefanie **Dehnen**	Department of Chemistry, Inorganic Chemistry, Philipps-Universität Marburg
Joff **Derluyn**	EpiGaN NV, Hasselt, BE
Natalia **Dubrovinskaia**	Material Physics and Technology at Extreme Conditions, Laboratory of Crystallography, University of Bayreuth
Thomas **Dekorsy**	Institute of Technical Physics, German Aerospace Center (DLR), Stuttgart
Lena **Kourkoutis**	Applied and Engineering Physics, Cornell University, Ithaca, NY, USA
Bernard **Nacke**	Institute of Electrotechnology, Leibniz University Hannover
Antonia **Neels**	Center for X-ray Analytics, Empa - Swiss Federal Laboratories for Materials Science and Technology
Elias **Vlieg**	Institute for Molecules and Materials (IMM), Radboud University, Nijmegen, NL
Peter **Wellmann**	Chair of Materials for Electronics and Energy Technology, University of Erlangen-Nürnberg

Representative of the Federal Government

absent with apologies

Representative of the Länder *Governments (Member of the Leibniz Senate Evaluation Committee)*

Heide **Ahrens**	The Senator for Research, Health and Consumer Protection, Bremen

8 May 2019

Annex C: Statement of the Institution on the Evaluation Report

Leibniz Institute for Crystal Growth
in the Forschungsverbund Berlin e. V. (IKZ)

IKZ wishes to thank all members of the evaluation committee for the dedicated and excellent work done during its Leibniz evaluation 2018. The evaluation committee emphasizes that the institute maintained its internationally leading position in the area of science & technology as well as service & transfer for crystalline materials over the past evaluation period. As acknowledged by the review board, this success was possible - despite the difficult situation of the vacant scientific director position for more than four years - by the commitment of the interim director Prof. Günther Tränkle and many staff members far beyond their main job activities. For the coming years, the institute presented a modern IKZ institute concept 2019 for its future mission, strategy and structure which the review board considers convincing to further strengthen the institute's internationally leading position. Here, the review board explicitly endorses IKZ's plans to apply for an extraordinary item of expenditure called "Crystal Technology" to put this strategy in practice and overcome a central innovation gap in research & development of innovative crystalline materials for future electronics & photonics. IKZ management and staff are highly motivated and look forward to the coming years to work along this roadmap and deliver by excellence in science state-of-the-art crystalline materials for technology solutions to society. IKZ will thus strengthen by this important and unique expertise in materials science the international visibility of the Leibniz association in important areas like artificial intelligence, communication, energy & health.