Leibniz Gemeinschaft

Der Senat

15. März 2022

Stellungnahme zum
Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden e. V. (IFW Dresden)

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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. Der für das IFW zuständigen Gruppe stand eine von der Einrichtung erstellte Evaluierungsunterlage zur Verfügung. Die wesentlichen Aussagen dieser Unterlage sind in der Darstellung (Anlage A dieser Stellungnahme) zusammengefasst.

Wegen der Corona-Pandemie musste der für den 6. und 7. Juli 2021 vorgesehene Evaluierungsbesuch am IFW in Dresden entfallen. Die Bewertung erfolgte im Rahmen eines Ersatzverfahrens, das der Senatsausschuss Evaluierung (SAE) in Umsetzung eines Grundsatzbeschlusses des Senats vom 31. März 2020 eingerichtet hat. Der Senat hält in diesem Grundsatzbeschluss fest, dass das Ersatzverfahren ein Notbehelf ist und ausschließlich auf Einrichtungen angewendet wird, die im Regelturnus von sieben Jahren evaluiert werden. Die Bewertungen, auf deren Grundlage der Senat Stellung nimmt, sind auf zentrale Kernfragen der Entwicklung und Perspektive einer Leibniz-Einrichtung fokussiert. Ausführliche Einschätzungen und Schlussvoten zu Teilbereichen und Planungen für „kleine strategische Sondertatbestände“ müssen regelmäßig entfallen.

Die Bewertungsgruppe erstellte den Bewertungsbericht (Anlage B). Das IFW nahm dazu Stellung (Anlage C). Der Senat der Leibniz-Gemeinschaft verabschiedete am 15. März 2022 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 **Ziel** des IFW ist es, die theoretischen und experimentellen Grundlagen für die Entwicklung von Materialien mit neuen oder verbesserten Funktionen zu erforschen und solche Materialien herzustellen. Dazu arbeiten Wissenschaftlerinnen und Wissenschaftler aus der Physik, Chemie und den Ingenieurwissenschaften zusammen. Das IFW ist in fünf Teilinstitute gegliedert, deren Zusammenarbeit über das Forschungsprogramm organisiert wird.

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

Die **Leistungen** des IFW in den zurückliegenden Jahren sind beeindruckend. Die sehr guten bis hervorragenden Forschungsergebnisse werden sehr häufig in international wahrgenommenen referierten Zeitschriften veröffentlicht. Eine wesentliche Grundlage für die Forschungen ist die Entwicklung von Infrastrukturen im Bereich Forschungstechnik. Seit der letzten Evaluierung hat das IFW den Transfer neuer Erkenntnisse in die Anwendung erfolgreich vorangetrieben, u. a. über das 2015 gegründete *SAWLab Saxony,* in dem die regionalen Forschungsaktivitäten auf dem Gebiet der Akustoelektronik gebündelt sind.

In den vergangenen sieben Jahren hat das IFW sein **Forschungsprogramm** weiter konkretisiert und umgesetzt. Dies ist auch deshalb positiv hervorzuheben, weil die Realisierung des bei der vergangenen Evaluierung positiv bewerteten Grundkonzepts seinerzeit stockte. Hintergrund war eine Managementkrise, die erst unter einem von außen berufenen Interimsdirektor überwunden wurde, wie der Senat im Juli 2016 anlässlich eines Berichts zur Umsetzung von Empfehlungen festhielt. Die Gremien des IFW kehrten im April 2018 mit der Berufung des Direktors des IFW-Instituts für Festkörperforschung (IFF) zu der vor der Führungskrise etablierten Struktur zurück, den Wissenschaftlichen Direktor aus der Mitte der Teilinstituts-Direktoren zu bestimmen. Diese Entscheidung ist schlüssig.

Zwei der fünf Teilinstitute werden derzeit **kommissarisch geleitet**. Der Direktor des IFW-Instituts für Integrative Nanowissenschaften (IIN) wechselte Mitte September 2021 vollständig an die TU Chemnitz, mit der gemeinsam berufen worden war, um sich dort am Aufbau eines neuen Forschungszentrums zu beteiligen. Die Leitung des IFW-Instituts für Komplexe Materialien (IKM) wurde bereits 2015 vakant. Nachdem ein erstes Verfahren ergebnislos blieb, wurde die Position im Juli 2021 erneut ausgeschrieben. Unter einer neuen Führung sollte das einzigartige interdisziplinäre Profil dieses IFW-Instituts weiterentwickelt werden. Für Leitung und Gremien des IFW ist es eine zentrale Herausforderung der nächsten Monate, diese beiden wichtigen Stellen gemeinsam mit den universitären Partnern zu besetzen.

Das IFW plant, ein **sechstes IFW-Institut** *Novel Quantum Technologies* einzurichten, und sieht dafür eine dauerhafte Grundausstattung von 4,95 Mio. EUR p. a. vor (davon 3,9 Mio. EUR zusätzliche Mittel der institutionellen Förderung). Die Idee für das neue Institut ist im Grundsatz nachvollziehbar, die genaue Zielsetzung und die Abgrenzung zu bereits laufenden Arbeiten am IFW aber noch wenig spezifiziert. Für eine Antragstellung in dem dafür vorgesehenen Verfahren müsste die Rolle und Funktion eines neuen IFW-Instituts auch mit Blick auf die bereits bestehenden Teilinstitute konkretisiert werden. In die Ausarbeitung eines Antrags sollten neben den drei derzeit am IFW amtierenden auch die beiden noch zu berufenden neuen Teilinstitutsleitungen einbezogen werden.

Angesichts der Größe des IFW ist es plausibel, dass die Zusammenarbeit der fünf Teilinstitute über eine **Matrix-Struktur** organisiert wird. Es ist für Außenstehende jedoch nicht klar zu erkennen, ob die derzeit 17 *research topics* die zentralen Arbeitseinheiten des IFW bilden oder ob sie eher als lose Arbeitszusammenhänge über die fünf Institute hinweg gedacht sind. Dies sollte noch besser definiert werden.

Das IFW bietet seinen Beschäftigten ein hervorragendes Forschungsumfeld für **die wissenschaftliche Qualifizierung**. Allein zwischen 2016 und 2018 wurden 13 Beschäftigte

(6 Frauen, 7 Männer) auf Professuren berufen. Auch der hohe Anteil von 58 % Wissenschaftlerinnen und Wissenschaftlern aus dem Ausland dokumentiert die hohe Attraktivität einer Tätigkeit am Institut.

26 % der wissenschaftlichen Positionen am IFW sind mit Frauen besetzt. Angesichts der Gesamtquote und des leichten Rückgangs der Zahl von Frauen beim weiteren wissenschaftlichen Personal (einschließlich der Promovierenden) muss aber nach wie vor eine deutliche Verbesserung erreicht werden. Es wird anerkannt, dass das IFW auf der mittleren Leitungsebene die Zahl der **Wissenschaftlerinnen** in den vergangenen Jahren wie empfohlen erhöht hat. Die anstehenden Berufungen von Institutsleitungen eröffnen Möglichkeiten, nun auch auf dieser Ebene erstmals Wissenschaftlerinnen zu berufen.

Die institutionelle **Förderung** des IFW ist für seine derzeitigen Aufgaben auskömmlich. Das IFW erzielt 22 % seiner Erträge für laufende Maßnahmen aus Drittmitteln, die ganz überwiegend bei der DFG und auf europäischer Ebene eingeworben wurden, hervorzuheben sind sieben *ERC Grants*. Der Drittmittelanteil aus der Industrie ist nach wie vor gering und sollte erhöht werden, vor allem auch angesichts des Ziels, den Transfer zu stärken.

Das IFW **kooperiert** seit langer Zeit intensiv mit anderen Institutionen. Mit der TU Dresden und weiteren Hochschulen in Sachsen bestehen enge Verbindungen über große Forschungsverbünde und gemeinsame Berufungen, die in den vergangenen Jahren auch auf die Ebene von Juniorprofessuren ausgeweitet wurden. Im Exzellenzcluster ct.qmat wird außerdem mit der Universität Würzburg zusammengearbeitet. Hervorzuheben ist auch die Kooperation mit anderen Leibniz-Instituten wie dem IPHT Jena, Dresdner Max-Planck-Instituten und dem Helmholtz-Zentrum für Materialien und Energie.

Das IFW ist ein international hoch anerkanntes Institut und hat in den vergangenen Jahren erneut hervorragende Leistungen erbracht. Mit der stetigen Entwicklung von Forschungstechniken, der darauf aufbauenden Forschung und seinen daran anschließenden Transferaufgaben arbeitet es in einer Weise, die in dieser Form an einer Hochschule nicht möglich ist. Eine Eingliederung des IFW in eine Hochschule wird daher nicht empfohlen. Das Institut erfüllt die Anforderungen, die an eine Einrichtung von überregionaler Bedeutung und gesamtstaatlichem wissenschaftspolitischem Interesse zu stellen sind.

2. Zur Stellungnahme des IFW

Der Senat begrüßt, dass das IFW beabsichtigt, die Empfehlungen und Hinweise aus dem Bewertungsbericht bei seiner weiteren Arbeit zu berücksichtigen.

3. Förderempfehlung

Der Senat der Leibniz-Gemeinschaft empfiehlt Bund und Ländern, das IFW als Einrichtung der Forschung und der wissenschaftlichen Infrastruktur auf der Grundlage der Ausführungsvereinbarung WGL weiter zu fördern.

17 June 2021

Annex A: Status report

Leibniz Institute for Solid State and Materials Research Dresden e. V. (IFW Dresden)

Contents

1. Key data, structure and tasks

Key data

Year established:	1969 / 1992
Admission to joint funding by Federal and *Länder* Governments:	1992
Admission to the Leibniz Association:	1992
Last statement by the Leibniz Senate:	2015

Legal form:	Registered association
Responsible department at *Länder* level:	Saxon State Ministry for Science, Culture and Tourism
Responsible department at Federal level:	Federal Ministry of Education and Research (BMBF)

Total budget (2020)

€ 32,757,000 institutional funding

€ 11,421,500 revenue from project grants

€ 11,000 revenue from services

Number of staff (2020)

in the five IFW institutes:

269 individuals in research and scientific services

69 individuals as service staff

10 secretaries

36 scholarshipholders

in further units:

35 individuals in the service unit Research Technology

49 individuals in administration

Mission and structure

Mission (according to the institute's Statutes as of 27 February 2017)

"The Association has the mission, mainly in the field of solid state and materials:

- *of pursuing fundamental research as well as application-oriented research and development,*
- *of promoting training and advanced training of scientific and technical young professionals in this field,*
- *of carrying out further tasks that are directly or indirectly related to work in the field of solid state and materials research as well as materials development,*
- *of exploiting knowledge and experience gained to the benefit of organisations of public authorities as well as business enterprises,*

- *of promoting the close cooperation with universities and other institutions of higher education as well as expert advisory service for the appropriate authorities in the Federal Republic of Germany (hereinafter referred to as Federal Government) and the Free State of Saxony (hereinafter referred to as State) and*
- *of establishing and operating installations required for realising these purposes."*

Organization

Scientific work at the IFW is structured into five IFW institutes, each headed by an institute director who is jointly appointed as full professor at a Saxon university. The IFW's Research Program consists of four research areas that are formed by contributions of all IFW institutes in a matrix-like manner: (1) Functional quantum materials, (2) Function through size, (3) Quantum effects and (4) Towards products. These research areas form the medium-term stable framework for the flexible sub-structuring into research topics. Over the last three years IFW has formed 13 subdivisions described in Chapter 7 by combining the research topics of research area 4 with the thematically appropriate topics of research areas 1-3(see appendix 1 for the organizational chart of IFW.)

2. Overall concept and core results

Overall concept and activities

IFW pursues fundamental research as well as application-oriented research and development in the field of solid-state matter and materials science. Key elements of the research activities are both experimental and theoretical studies of phenomena that take place at the level of electrons, atoms, molecules and nanostructures as well as the characterization of physical and chemical material properties. This includes also application-oriented research up to the development of new materials and devices based on investigated physical effects and on new functionalities.

IFW is primarily a research institute which is active in the whole range from fundamental to applied research. At the applied end of the spectrum, the institute promotes the transfer of knowledge and technology with validation projects, patent application and marketing activities. The proportion of transfer in this narrow sense is well below 5%, according to IFW.

The development and operation of research infrastructure is essential for the fulfilment of the institute's research mission. The Research Technology Division as service department of the IFW develops highly specialized research equipment for research tasks in IFW. Some of the developments are being offered for further use which is realized also in companies such as evico magnetics and SciDre GmbH, both spun-off from IFW.

The IFW is organized into **five IFW institutes**, each headed by an institute director jointly appointed with a Saxon university:

- IFW Institute for Solid State Research (IFF) (128 individuals)
- IFW Institute for Metallic Materials (IMW) (78 individuals)
- IFW Institute for Complex Materials (IKM) (89 individuals)

- IFW Institute for Integrative Nanoscience (IIN) (60 individuals)
- IFW Institute for Theoretical Solid State Physics (ITF) (30 individuals)

The **IFW Research Program** is organized along a triangular frame of the material classes Quantum Materials, Function Materials and Nanoscale Materials. It overarches all five IFW Institutes in a matrix-like manner and is structured into four research areas, three of them connecting two pillars of the triangular frame: (1) Functional quantum materials, (2) Function through size and (3) Quantum effects at the nanoscale. The fourth area (4) Towards products intertwines all three pillars and encloses research projects that are close to application.

For the purpose of this evaluation, IFW defined **13 subdivisions** (SDs) by combining the research topics of research area 4 to the corresponding topic of research areas 1-3, where appropriate. For a detailed description of the 13 subdivisions see Chapter 7.

- Subdivision 1 "Exotic ground states and low-energy excitations in bulk systems"
- Subdivision 2 "Unconventional superconductivity: Mechanisms, materials & applications explores"
- Subdivision 3 "Materials for Energy Storage and Conversion"
- Subdivision 4 "Engineering magnetic microtextures"
- Subdivision 5 "Solidification, non-equilibrium phases / High strength and biocompatible alloys"
- Subdivision 6 "Multifunctional inorganic nanomembranes / Flexmag covers four interdisciplinary branches"
- Subdivision 7 "Micromotors and drug delivery"
- Subdivision 8 "Thermoelectric materials"
- Subdivision 9 "Surface acoustic waves: Concepts, materials & application"
- Subdivision 10 "2D Systems / Designed interfaces and heterostructures"
- Subdivision 11 "Quantum and nano-photonics"
- Subdivision 12 "Functional molecular nanostructures and interfaces"
- Subdivision 13 "Topological states of matter"

Results

IFW pursues fundamental as well as application-oriented research. Between 2018 and 2020, work at IFW lead to 1,177 articles in peer-reviewed journals. Additionally, 16 articles in other journals, 31 individual contributions to edited volumes, 2 edited volumes with editorship, and 2 monographs were published (see appendix 2). The institute refers to the following ten most important research results since the last evaluation and underlines this with hints to publications in international journals:

Research

i) *Kitaev Materials:* Seminal contributions to iridium and ruthenium-based honeycomb Kitaev materials have been achieved, confirming for instance the j=1/2 state in in RuCl3 and presenting evidence for a field-induced quantum spin liquid, in nanoscale growth, and in the calculation of magnetic interaction strengths in a range of materials.

ii) *Identification of interactions and symmetries in iron-based superconductors*: IFW has detected a sizable spin-orbit interaction in all the main members of iron-based super-conductors (IBS) and emphasized the importance of p-orbitals in the formation of their low-energy electronic structure. Clear ways to its practical realization have been formulated.

iii) *Nanomagnetism & Skyrmions*: With the detection of anti-skyrmions in a metallic magnetic material one last elementary prediction could be demonstrated. IFW's capabilities in magnetic imaging by mapping of the three-dimensional flux density fields using electron microscopic techniques now allows to reconstruct detailed magnetization textures. In the same field, IFW theoretically developed its ability to model new effects of the topological magnetic textures.

iv) *New Ti-based alloys for implant application*: IFW's award-winning strategies on compositional design and optimal processing routes for adjustment of tailored microstructures lead to highly competitive properties.

v) *Rolled-up nanotechnology for 3D microdevices*: IFW has established rolled-up nanotechnology as a key enabler for next generation 3D microdevices with highly integrated functionalities and enhanced performance. The institute's work in this field has been awarded with the Leibniz Prize of the German Research Foundation in 2018.

vi) *Biomedical microrobots*: The institute has highlighted the opportunities and challenges of biomedical microrobots towards targeted cancer therapies and reproduction technologies. They have established a common lab with the Max-Planck Institute for Molecular Cell Biology and Genetics to carry out animal trials for particularly promising biomedical applications. Among others, research was funded with an ERC advanced grant and an ERC starting grant.

vii) *Microstructured devices for harvesting waste heat and thermal management*: In this field, IFW e.g. demonstrated a sign reversal of magnetic flux that avoids the drawbacks of previous designs: stray magnetic fields, hysteresis, and complex geometries.

viii) *Semiconductor quantum light sources*: Quantum light sources developed in this area are compatible with atom-based quantum memories and show great potential for semiconductor-based quantum communication technology.

ix) *Metallofullerene single molecule magnets (EMF-SMMs)*: IFW has e.g. established metallofullerenes as a platform for singe molecule magnetism based on the unique environment created for lanthanide atoms inside the carbon cage.

x) *Intrinsic magnetic topological insulators: the $(MnBi_2Te_4)(Bi_2Te_3)n$ (n = 0, 1, 2) family*: In this field, IFW was among the first to synthesize a material that is an antiferromagnetic topological insulator, a system predicted to exhibit a spontaneous quantum anomalous Hall effect and topological magnetoelectric effect.

Research Infrastructure and Transfer

In 2015, IFW founded SAWLab Saxony, a Competence and Application Center comprising 15 partners from industry and academia supporting transfer and commercial deployment of SAW-related research (surface acoustic waves). In terms of industrial property rights IFW has established a patent portfolio. Between 2018 and 2020, 65 patents were granted and IFW applied for 40 more. Additionally, IFW holds 1 other industrial property right and 68 exploitation licenses (see appendix 2).

A group of novel high-carbon steels has been developed and patented in IFW. Due to the institute's attractive range of properties, these sophisticated steels attracted various companies, among them Robert Bosch GmbH, BMW Group, and Siemens.

Furthermore, IFW progressed in bringing superconducting materials into technical applications.

Also, a new principle for a detector in angle-resolved photoemission spectroscopy was developed, patented and realized as a prototype. At the turn 2019/2020 the company Fermiologics was spun off to market.

3. Changes and planning

Development since the previous evaluation

Reshaping of the Research Program

Since the last evaluation, IFW modernized the scientific spectrum of topics and strengthened its interdisciplinary, cross-institute and project-oriented research by introducing a frame of three main pillars Quantum, Nano and Functional Materials (as described in Chapter 2). In the new program phenomena on an atomic, molecular and nanometer scale gained more importance. Further new aspects have been included, such as topological materials, whose importance for the IFW is documented by the institute's involvement in the cluster of excellence ct.qmat together with TU Dresden and University of Würzburg, established in 2019.

Other existing activities were modified and given new directions. For instance, biomedical applications of a new generation of microrobotic tools and systems have become a successful working direction of the IFW supported e.g. by two ERC grants. The interface to the biomedical sector has become a core activity for metallic implant materials as evidenced by the coordination of the EU network "BIOREMIA". In the field of magnetism, quantum phenomena in nanoscale structures, magnetic frustration and two-dimensional magnetism emerged to main activities of the IFW funded by two ERC grants, an Emmy-Noether project and participation in network programs. Finally, with the appointment of a new Director of the IFW Institute for Metallic Materials (IMW) in 2015, thermoelectronics became an additional topic.

Since the last evaluation, IFW conducted a large number of individual excellence projects i.e. Leibniz Prize of DFG in 2018, seven ERC grants since 2015, three Leibniz Junior Groups.

Strategic Measures

The IFW research program is supplemented by accompanying strategic measures taken by the Board of Directors in a continuous process. Since 2015 the following strategic measures have been implemented:

i) Internal IFW excellence program with annual calls and funding of three projects per year to promote unconventional ideas benefiting from cross-organizational internal co-operation.

ii) Tenure track program to promote the recruitment of excellent young researchers from outside the IFW with a long-term perspective in the institute.

iii) IFW strategic projects have been introduced in 2019/2020 to focus a critical mass of joint resources on emerging topics. Each project is driven by one institute director and brings together activities of several institutes. Until now, first four projects have a total amount of 30 PhD positions and 2 M€ investments (X-Stream TEM, Sensor devices for high temperature applications, SmartBio Stent, Machine Learning for Functional Quantum Materials).

iv) Strategic investments include the establishment of the Center for Transport & Devices of Emergent Materials (2015), the establishment of the FlexMag Development center for flexible magnetoelectronic devices (2016/2017) as well as the investment in a TEM-EELS facility (2020).

v) Enhanced technology transfer has been envisaged through a whole package of measures among them the establishment of application labs such as the SAWLab Saxony (2015) and the carbon nanotubes application lab (2020).

vi) New ways of cooperation with universities, e.g. by establishing several joint laboratories with TU Dresden and TU Bergakademie Freiberg as well as by the appointment of junior and W2 professorships combined with junior group leader positions at IFW. Cooperation with HTW Dresden (University of Applied Research) was deepened.

Personnel Changes

Since 2014 there have been several personnel changes in the Institute's management. At the time of the last evaluation an interim <u>Scientific Director</u> was in office. Since 2018, the position of Scientific Director of the IFW has again been taken over by one of the Institute Directors. After the former Administrative Director left the institute to follow an appointment as Chancellor of the HTF Stuttgart, the position was filled again in 2020.

On the level of <u>Institute Directors</u> a new director of the Institute for Metallic Materials (IMW) has been appointed in 2015. After the departure of its former director in 2016, the intended appointment of a new director of the Institute for Complex Materials (IKM) failed in 2019. Since, the denomination of this professorship was discussed anew and changed to “Materials Chemistry”. The joint procedure with TU Dresden is still ongoing. The former focus of the IKM on materials science will continue to be covered by a new W2 professorship, occupied since 2019. Another new W2 position in the field of electron optics is also closely related to former core fields of the IKM.

Strategic work planning for the coming years

According to IFW, the following activities are of particular strategic importance for the future of the institute:

- Building up a Nanomembrane lab together with ct.qmat, the Excellence Cluster "Complexity and Topology in Quantum Matter", in which IFW is broadly engaged. Ct.qmat will also co-finance improvement and expansion of IFW's measuring stations for angle-resolved photoemission (APRES) at the BESSY synchrotron source of the Helmholtz-Zentrum Berlin to develop new instrumentation for analysis of monolayers and heterostructures.
- The establishment of the Institute of Materials Chemistry is expected to have strong impact on IFW's profile. The new director is expected to establish viable bottom-up concepts for the production of large-area two-dimensional quantum materials in addition to top-down processes for individual test structures.
- The Institute enhances research on two-dimensional (2D) materials. Starting in 2021, a new Leibniz junior group will produce and investigate heterostructures from van der Waals materials. The group will use the infrastructure of the nanomembrane lab. Additionally, bottom-up processes are addressed in the new Collaborative Research Center SFB 1415 "Chemistry of Synthetic 2D Materials" at TU Dresden including two sub-projects from IFW.
- Endowed W2 professorship on Electron Optics financed by CEOS GmbH for five years is expected to be filled in 2021.The cooperation with the company includes the realization of a high-resolution electron energy loss spectroscopy (EELS) in a modern electron microscope (TEM) which will be operated in a joint laboratory with TU Dresden.
- In 2021, IFW has become a member of the Else Kröner-Fresenius-Center for Digital Health which bridges the gap between medical big data efforts and biomedical engineering. On this background, advances into device development at the interface of electronics and biomedicine are to be made in close collaboration with the TU Dresden, Dresden University Hospital and Dresden Institutes, e.g. the Max-Planck Institute for Molecular Cell Biology and Genetics.
- DRESDA: Machine learning and artificial intelligence methods for research on functional quantum materials. In the Dresden Electronic Structure Datalab (DRESDA) IFW will diversify its collaborative strategies by developing new methods based on machine learning (ML) and artificial intelligence (AI). DRESDA is a web-platform to explore the electronic properties of crystalline materials with a core database that contains side-by-side measured and calculated properties. The DRESDA consortiums comprises IFW, TU Dresden, Max Planck Institute for Chemical Physics of Solids and Helmholtz-Zentrum Dresden-Rossendorf.

Planning for additional funds deriving from institutional funding

IFW wants to implement a strongly applications-oriented research strategy. Therefore, IFW requests additional funds to establish a new IFW institute which addresses "Novel

Quantum Technologies". According to IFW, this new, sixth institute would approach significant advances towards application in the area of quantum materials and focus on new quantum technologies that are distinct from approaches already pursued. The new institute's work would be in close connection to the IFW's basic research on quantum materials. It intends to follow on from IFW's activities concerning e.g. nanomembranes, sensor technology and 2D materials. It is also planned to link to research conducted in the cluster of excellence ct.qmat.

According to IFW, promising research areas regarding future industry-related development which are to be addressed in the new institute "Novel Quantum Technologies" are: entangled photons from GaAs quantum dots; topologically protected electronic and magnetic states; topological superconductivity/majorana fermions; nanomagnetism, topological real-space textures, skyrmions; molecular magnetism: manipulation of quantum spin states and controlling complex many body states.

Until the envisioned start of the new institute in 2025, based on IFW's current work and the work emerging after the first period of ct.qmat, important additional results and knowledge will reveal the most promising paths to quantum technologies to be followed up after 2025.

According to IFW's current research scope, the existing experimental infrastructure as well as staff qualification is materials oriented. The new institute will take a new, translational approach. It will not study a broad range of materials, but will optimize manufacturing and processing for a given combination of materials that (i) has demonstrated potential for application, (ii) is compatible with industrial needs including economics, and (iii) is as controllable as possible to pave the way to technological application.

IFW claims, the new institute would benefit from the attractiveness of the Dresden site. Dresden is one of the leading places in basic research on quantum materials. At the same time, it is home to large industrial companies working in semiconductor technology. IFW's strategic extension would cover the entire spectrum from quantum materials to quantum technologies based on topological systems and thus promote this important future topic within the Leibniz Association.

The amount of staffing of the new institute will be similar to that of existing experimental IFW institutes. Its new director is planned to be jointly appointed with TU Dresden (preferably within Faculty of Electrical and Computer Engineering). For implementation, IFW envisages 29.5 positions: 1 (professor position, W3), 1 group leader position (E14/15 permanent), 3 group leader positions (E14/15 temp. innovation group), 5 PostDoc positions (E13), 5 PhD positions (E13 x 0,67), 7 Technicians/Laboratory engineers (E7-E11), 1.5 Secretary, 6 Service Employees (E6-E12). 1.26 M€ p.a. are required for consumables and 1.4 M€ p.a. for investments.

„Extraordinary item of expenditure“: summary of funds planning

	2025	2026	2027	2028	Permanently
Own funds + additional funds = „extraordinary item of expenditure“	*4.932 k€*	*4.957 k€*	*4.984 k€*	*4.953 k€*	*4.953 k€*
Own funds from existing funding by institution (at least 3 % of core budget)	*1.076 k€*	*1.076 k€*	*1.076 k€*	*1.076 k€*	*1.076 k€*
Additional funds of institutional funding	*3.856 k€*	*3.881 k€*	*3.908 k€*	*3.877 k€*	*3.877 k€*

4. Controlling and quality management

Facilities, equipment and funding

Funding

Between 2018 and 2020, the institutional funding of IFW totalled on average 32,2 M€ p.a..

In the same period, revenue for project grants totalled on average 9.1 M€ p.a.. Thereof, 2.4 M€ p.a. were raised from the EU, 4.3 M€ p.a. from the Deutsche Forschungsgemeinschaft (DFG), 1.8 M€ p.a. from Federal and Länder governments, and 172 k€ p.a.) from the Leibniz Association. In sum, between 2018 and 2020, third-party funding for project grants covered 22 % of the institute’s overall budget.

From services, IFW generated between 2018 and 2020 revenue in the amount of 14 k€ p.a. on average. For an overview of IFW’s revenue and expenses, see appendix 3.

Equipment and Infrastructure; building situation

IFW operates a large diversity of research facilities, including labs and standard equipment. The institute’s Research Technology Division is a technological infrastructure unit providing internal services and support in solving technical tasks. The Division consists of for departments (Electrical Engineering, Mechanical Engineering, IT, Building/Facility Management).

About the application for an additional building submitted in 2019 will be decided in 2021. In case of a positive decision, completion of the building is expected in 2025.

Organisational and operational structure

The IFW is organised as a registered association. The institute is lead Executive Board and supervised by the Board of Trustees. Executive Board and Board of Trustees are advised by the Scientific Advisory Board.

According to the Statutes, IFW’s Executive Board consists of a Scientific Director and an Administrative Director. The Board of Trustees appoints the members of the Executive Board for a term of five years. Re-appointment is possible. The current Scientific Director is jointly appointed with a Saxon university and also functions as head of one of IFW’s five institutes.

IFW's Scientific-Technical Council (WTR) is an internal body, which ensures appropriate participation of the scientific and technical staff in the development of the institute's scientific and technical programs.

The scientific work of the IFW is organised into five IFW institutes, each headed by an institute director who is jointly appointed as full professor at a Saxon university. The institute has three service units (Research Technology Division, Finance and Controlling, Administration Services)

The IFW Research Program consists of four research areas that are formed by contributions of all IFW institutes.

Quality Management

IFW follows the recommendations for good scientific practice as developed by the DFG and adopted by the Leibniz Association. Trainings on good scientific practice are being offered regularly. IFW has an ombudsperson.

Research at the institute is characterized by an open exchange of information among its researchers, guaranteeing intensive scientific exchange within the institute. The annual research planning involves all responsible scientists.

Scientific results are to be published in peer-reviewed journals. Before submitting a paper, an internal review process has to be followed. IFW provides its own publication database "SciPub". IFW has developed an Open Access Strategy. The institute uses the repository of LeibnizOpen to list freely accessible publications of IFW authors as full texts. Open Access is supported with an institute budget.

Research data management is pursued in the context of DRESDA (see chapter 3).

IFW's aim to make usable its knowledge for public institutions and commercial enterprises led to a "IFW Technology Transfer Program" launched in 2016.

Quality management by advisory boards and supervisory board

The Scientific Advisory Board (SAB) advises the Board of Trustees and the Executive Board on all important scientific, technical and organizational matters. The SAB consists of a minimum of six, maximum of twelve external voting members. They are appointed by the Board of Trustees with the consent of the Executive Board. The SAB elects its chairperson and its deputies from among its members. The term of office of the members of the SAB is three years. Re-election is permissible. The SAB meets annually.

IFW's internal evaluation procedures ensures that each research unit is evaluated by the SAB once in three years. Each of such evaluation cycles of three years represents the audit that is required by the Leibniz Association in the period in-between two Leibniz evaluations.

The IFW is supervised by the Board of Trustees consisting of a maximum of eight member: three representatives of the Land Sachsen and three of the Federal Government as well as up to two experts elected by the General Meeting. It is possible for the governments to delegate their votes to one or several representatives of their administrations. The Land acts as chairman, a representative from the Federal Government as deputy of the chairman.

5. Human Resources

As of 31 December 2020, IFW had 432 employees, including 108 doctoral candidates and 27 trainees. Furthermore, in 2020, IFW hosted 36 scholarship holders who came in with their own money. 80.5 % of the staff belong to the five scientific IFW institutes, 8.1 % to the service unit Research Technology, and 11.3 % to administration and support staff (for details see appendix 4).

Management

The Executive Board of the IFW consists of the Scientific Director and the Administration Director. Both are appointed by the Board of Trustees for a maximum of five years; reappointment is permissible. The Scientific Director can be recruited from among the five IFW institute directors, as is the case with the current Scientific Director, as well as after the proposal of a search committee or of a joint appointment committee with a university.

The Directors of the five IFW institutes (W3 positions) are recruited in joint appointment procedures according to cooperation agreements with several Saxon universities. The appointment procedure for the director of one of the institutes is currently ongoing.

IFW is establishing junior and W2 professorships as a new instrument for promoting young academics. Two junior-like professorships combined with junior group leader positions at IFW have been appointed in 2019. Further W2 professorships are envisaged. All joint appointment procedures on professorships with Saxon universities are based on the Saxon Higher Education Act and follow the standards for the appointments to academic management positions within in the Leibniz Association.

The procedure for filling scientific group leader positions is governed by proved internal regulations which define the obligation to publicly advertise these positions as well as the selection process and criteria.

Postdoctoral Staff

As of 31 December 2020, 45 classic postdocs were working at IFW, employed on a temporary basis. 12 of them were female and 33 came from abroad. For particularly talented postdocs, IFW provides tenure track. These scientists are appointed as junior research group leaders on the recommendation of the Board of Directors. By the end of 2020, 14 of 47 research groups and scientific departments were independent junior research groups. Of these, 5 are female and 11 have an international background.

Between 2018 and 2020, 13 IFW postdoctoral researchers received appointments to university professorships, thereof 6 by female scientists.

Doctoral Candidates

As of 31 December 2020, a total number of 143 (30 of them female) doctoral candidates worked at IFW. 108 are employed at the institute, and 14 are scholarship holders. 4 doctoral candidates are IFW scholarship holders, and 17 are supervised without contract or scholarship. In 2020, PhD students came both from Germany (57) and from 20 other states (86). Most of the international PhD students come from Asia (82%) or other EU countries (12%).

The IFW follows the "Guidelines for the working conditions and career development of pre-doctoral and post-doctoral researchers of the Leibniz Association". Participation in structured graduate programs, training courses, and first involvement in teaching are recommended and supported.

The average length of doctorates at IFW is 4.5 years from signing the doctorate agreement between candidate and supervisor to defending the thesis. Between 2018 and 2020, a total of 73 doctoral degrees have been completed.

PhD candidates who complete their thesis summa cum laude are awarded the Tschirnhaus Medal by IFW. From 2018 to 2020, the Medal has been awarded 18 times.

Science supporting staff

Vocational training is part of IFW's recruitment policy. End of December 2020, there were 27 trainees, interns and BA-students at IFW. Between 2018 and 2020, 11 apprentices completed their vocational training.

IFW has a cooperation contract with Zittau/Görlitz University of Applied Sciences for cooperative studies with an integrated apprenticeship. Once a year, all apprentices go on a three day excursion to broaden their knowledge by visiting other research institutes. Another measure for advanced professional training at IFW is the technician school being held every two years since 2006 for the institute's non-academic staff.

Equal opportunities and work-life balance

IFW promotes gender equality on the basis of recommendations by DFG and the Leibniz Association. IFW has an Equal opportunity officer and her deputy.

At the end of 2020, four of the five IFW institutes were headed by men, one of them being also the Scientific Director of IFW. One position of an IFW institute director is vacant at present. The ongoing joint appointment procedure with TU Dresden includes active recruitment measures to attract highly qualified women for this position. According to IFW, the percentage of female research group leaders is 31% which is slightly above the target value of 30%. In the area of administration and support, the gender ratio is balanced among employees with management responsibilities: 5 women and 5 men are heading the departments. On group leader level, IFW created two associated professorships on W1/W2 level, both of which could be filled by female scientists.

In 2020, four female IFW scientists received offers for university professorship.

In 2016 and 2019 IFW was certified by *berufundfamilie* GmbH.

6. Cooperation and environment

Collaboration with universities

Three IFW institute directors are jointly appointed on W3 professorships at TU Dresden, and one position is currently being advertised. One institute director holds a W3 professorship at TU Chemnitz. The currently renewed cooperation agreement with TU Dresden also provides for the possibility of establishing and filling joint professorships at W2 level for research group leaders at IFW. Presently, an appointment procedure for a W2 endowed professorship is underway. In 2019 the possibility of joint professorships has been enhanced to TU Bergakademie Freiberg, where a temporary professorship has been established for an IFW junior research group leader.

IFW cooperates very closely with TU Dresden. Together, they established the Center of Excellence – Complexity and Topology in Quantum Matter at TU Dresden and University of Würzburg (ct.qmat). A further cooperation with TU Dresden was established in 2012 with the “Center for Advancing Electronics Dresden” (cfAED). Additionally, IFW is involved in two Collaborative Research Centers (CRC/SFB) at the TU Dresden: “Correlated Magnetism: From Frustration to Topology” (SFB 1143), started in 2015, and “Chemistry of D2 Materials” (SFB 1415), started in 2020. An application for a further CRC on organic electronics will be evaluated in 2021. The very close cooperation with TU Dresden is also apparent in the operation of joint laboratories, e.g. the “Center for Transport and Devices of Emergent Materials (CTD)”.

IFW collaborates closely with TU Chemnitz in the “Center for Materials, Architectures and Integration of Nanomembranes (MAIN)”. IFW was also involved in the TU Chemnitz excellence cluster MERGE (2012-2019), and the DFG research groups “Towards Molecular Spintronics” (FG 1154, 2010-2018) and “Sensorische Mikro- und Nanosysteme” (FG 1713, 2011-2019).

With TU Bergakademie Freiberg IFW cooperate by a jointly use of infrastructure, by operation of joint laboratories, and in several externally funded projects.

Collaboration with other domestic and international institutions

IFW is part of the network “Dresden Research and Education Synergies for the Development of Excellence and Novelty” (DRESDEN-concept), an alliance of TU Dresden and 31 Dresden research and culture institutions. Since 2019, IFW started two ERC projects in the field of biomedicine in collaboration with the Max Planck Institute for Molecular Cell Biology and Genetics (MPI-CBG). IFW cooperates with other Leibniz Institutes, namely IPF Dresden, IPHT Jena and IKZ Berlin.

Furthermore, IFW cooperates with several German Universities, e.g. in joint DFG or BMBF funded projects. Among collaboration with non-university research institutes, Helmholtz-Zentrum Berlin (HZB) has to be mentioned, where two permanent end stations at the high-resolution beamline are being operated, which are partly designed and constructed by IFW team.

The institute is engaged in several EU projects and networks. Presently, the IFW is coordinating the Innovative Training Network on BIOfilm-REsistant Materials for hard tissue implant Applications (BIOREMIA), funded by the EU since 2020. Since 2019, IFW is represented in the Management Committee of the large-scale EU COST network "Nanoscale Coherent Hybrid Devices for Superconducting Quantum Technologies" (NANOCOHIBRI). Beside this, IFW cooperates with other partners worldwide.

Institution's status in the specialist environment

As internationally leading institutes in its scientific environment IFW indicates for example the Ames Laboratory (Iowa State University), the Institute of Materials Research (Tohoku University/Sendai, Japan) and the National Institute for Materials Science (NIMS, Japan). In Germany, IFW refers to other institutes which cover their mission parts of IFW's own spectrum, e.g. the MPI for Solid State Research (Stuttgart) and the MPI of Microstructure Physics (Halle) as well as Walter Meißner Institute and Walter Schottky Institute at TU Munich.

7. Subdivisions of IFW

Subdivision 1: Exotic ground states and low-energy excitations in bulk systems

[23.2 FTE, thereof 16.3 FTE Research and scientific services, 1.0 Post-doctoral scholarship recipient, 3.7 FTE employed Doctoral candidates, and 2.2 FTE Service staff]

Research activities bundled in this subdivision are devoted to fundamental experimental and theoretical studies of physical properties of complex bulk materials in which strong electron-electron correlations and entanglement of spin, charge, orbital and lattice degrees of freedom give rise to novel quantum magnetic phases and exotic excitations. The subdivision investigates novel phenomena which particularly result from low-dimensionality, magnetic frustration and spin-orbit coupling being decisive in defining the ground state and low-energy excitations. Those are often characterized by quantum fluctuations, lack of (long-range) magnetic order, a high degeneracy of states, and may bear fractionalized or even topological excitations of a type that can be relevant to topological quantum computation.

The group's strategy for obtaining new fundamental insights into the magnetism of correlated quantum matter is a combination of mutually complementary experimental, theoretical and computational methods and expertise available at the IFW spanning from synthesis and crystal growth, transport, magnetic and thermodynamic characterization, to various spectroscopic and dynamic local spin-probe techniques, electronic-structure calculations and various approaches treating effective many-body models. Research focusses on complex transition metal (3d, 4d, 5d) and rare earth compounds, mainly in form of oxides, chalcogenides and halides. These materials can be broadly classified into four main groups: (i) materials where magnetic frustration arises from competing and anisotropic magnetic interactions; (ii) materials where magnetic frustration and quantum fluctuations originate from geometric constraints; (iii) materials with a 2D layered structure and weak van der Waals (vdW) bonding between layers; (iv) magnetic vdW materials with a topological electronic structure.

Between 2018 and 2020, the subdivision published 151 articles in peer-reviewed journals. The revenue from project grants totalled approx. 1.64 M€ (Ø 545 k€ p.a.), with 1.2 M€ spent from the DFG, and 183 k€ from the EU. In addition, the subdivision applied for five patents. In the same period, 7 doctoral degrees were completed.

Subdivision 2: Unconventional superconductivity: Mechanisms, materials & applications

[22.4 FTE, thereof 11.8 FTE Research and scientific services, 3.3 Post-doctoral scholarship recipients, 2.8 FTE employed Doctoral candidates, and 4.5 FTE Service staff]

Subdivision 2 explores the mechanism of unconventional superconductivity using a broad spectrum of experimental techniques that reveal detailed information on the electronic structure, electronic instabilities and magnetic interactions and their possible relevance for superconducting pairing. Moreover, dedicated experimental techniques are developed to study electronic nematicity, spatial inhomogeneities of spins and charge, fermiology and superconducting order parameters. In this context, the subdivision highlights its novel ultra-high-resolution photoemission spectrometers and new detector systems, which are also available for external users at the synchrotron beamlines operated by IFW. Experimental studies are complemented by theoretical modeling, which include electronic-structure calculations and quantum field methods, as well as models that underlie engineering of transport, superconducting and optical properties of micro- and nanoarchitectures.

The rich class of Fe based superconductors (IBS) has remained the main focus of basic research in recent years with nematicity and topological superconductivity in particular being addressed as new aspects. Experimental investigations are performed on high quality single crystals as well as on thin films prepared in dedicated laboratories at IFW. In addition, the subdivision has initiated and intensified activities for the realization and investigation of superconducting interfaces and two-dimensional superconductors (see also subdivision 10).

Both the detailed knowledge of the physical properties of superconductors and the subdivision's materials expertise are the basis for applied research that deals with the design of small devices or demonstrator systems for industrial applications of high-temperature superconductors. This industry-related work has so far mainly been concerned with applications based on superconducting cuprates.

Between 2018 and 2020, the subdivision published 111 articles in peer-reviewed journals. The revenue from project grants totalled approx. 3 M€ (Ø 1 M€ p.a.), with 1.1 M€ spent from the DFG, and 1.4 M€ from the EU. In the same period, 8 doctoral degrees were completed.

Subdivision 3: Materials for Energy Storage and Conversion

[44.7 FTE, thereof 15.0 FTE Research and scientific services, 2.0 Post-doctoral scholarship recipients, 12.3 FTE employed Doctoral candidates, 5 FTE Doctoral candidates as scholarship recipients and 10.4 FTE Service staff]

Subdivision 3 comprises research on three different groups of materials: magnetocaloric and thermomagnetic materials, permanent magnets and materials for electrochemical energy storage and conversion, and includes the development of processing and measurement techniques for functional materials, e.g. advanced crystal growth and nuclear magnetic resonance (NMR). The scope of the research and development in this subdivision ranges from fundamental studies of properties and structure to the development of materials suitable for applications. The relevance of the work to industry and to society is demonstrated by transfer activities, which include several patents and a number of projects funded directly by industrial partners. The introduction of new classes of materials, topics and research infrastructure has enabled this subdivision to develop significantly during the current evaluation period. In the future, beyond the expansion and continuation of the work on the individual groups of materials and techniques, the group is planning to combine all of these aspects into building a working thermomagnetic generator, capable of converting waste heat into electricity and storing it in a battery. This demonstrator will comprise thermomagnetic materials, rare-earth-free permanent magnets and Li-ion battery materials all developed and produced at IFW Dresden with in-situ analysis by NMR, which will allow observation of dynamic processes within the system. Working together on building the generator will bring new insight which will act to focus the subdivision's research efforts on groups of materials which are critical for the sustainable use of energy on the global scale.

Between 2018 and 2020, the subdivision published 132 articles in peer-reviewed journals. The revenue from project grants totalled approx. 3.3 M€ (Ø 1.1 M€ p.a.), with 1.8 M€ spent from the DFG, and 1.4 M€ from Federal and *Länder* Governments. In addition, 8 patents were granted and the subdivision applied for 14 more. In the same period, 8 doctoral degrees were completed.

Subdivision 4: Engineering magnetic microtextures

[17.5 FTE, thereof 7.8 FTE Research and scientific services, 1.0 Post-doctoral scholarship recipient, 6.8 FTE employed Doctoral candidates, and 1.9 FTE Service staff]

Magnetic microtextures – most prominently represented by magnetic skyrmions – are patterns in magnetically ordered materials. They may be seen as an extension of the wide class of magnetic microstructures including magnetic domains created by depolarization as the classical example. Textures may be created by intrinsic properties or through the shape and structural modulations of the material. Subdivision 4 focuses on understanding and possibly targeted manipulation of magnetically ordered states on the meso- and nanoscale with a view on applied magnetism. Experimental research employs and develops scale-bridging microscopic methods for magnetic microstructures, ranging from magneto-optical Kerr (MOKE) microscopy, over magnetic transmission electron microscopy (TEM) to quantitative magnetic force microscopy (qMFM), and cantilever magnetometry.

For all these magnetic microscopies, the subdivision is developing advanced capabilities like magnetic vector field imaging and tomographic methods for three-dimensional analysis of magnetic texture, or fast dynamical observation methods. Theoretical research and numerical simulations address novel concepts in creating and manipulating magnetic textures. According to IFW, a recent key development is magneto-ionics, i.e., voltage control of magnetism by electrochemical approaches, combined with MOKE imaging in electrochemical environment.

Between 2018 and 2020, the subdivision published 92 articles in peer-reviewed journals. The revenue from project grants totalled approx. 1.6 M€ (Ø 524 k€ p.a.), with 780 k€ spent from the DFG, and 523 k€ from the EU. In addition, 2 patents were granted. In the same period, 2 doctoral degrees were completed.

Subdivision 5: Solidification, non-equilibrium phases / High strength and biocompatible alloys

[40.1 FTE, thereof 22.2 FTE Research and scientific services, 1.0 Post-doctoral scholarship recipient, 1.9 FTE employed Doctoral candidates, 3.0 FTE Doctoral candidates as scholarship recipients, and 12.1 FTE Service staff]

The research in this subdivision is driven by the continuously increasing demand for novel high-performance materials for engineering and medical applications. Such advanced materials with tailored mechanical, physical and (bio)chemical properties can be obtained via formation of compositionally, structurally or morphologically metastable phases and microstructures by processing under non-equilibrium conditions. Developments of novel metallic alloys and related composites, including high strength materials on Fe-, Zr-, Al-, Cu-, Ti-base for advanced structural applications as well as biocompatible materials on Ti- and Fe-base for implant applications, are in the scope of the research. Model alloys, such as high entropy alloys, metallic glasses (MGs) and complex concentrated alloys, are investigated for understanding the fundamental mechanisms of strength and plasticity. The processing techniques include i.e. casting, metal forming, powder metallurgy, additive manufacturing (AM), electrodeposition, thermoplastic shaping, thermal treatments, and chemical as well as thermomechanical surface modifications. Alloy design and processing are complemented by fundamental studies to reveal the underlying phenomena of interest. For this, new scale-bridging characterization techniques are being developed in collaboration with IFW Research Technology Department, German Synchrotron DESY and European Synchrotron Research Facility (ESRF). Such fundamental experiments are complemented by investigations in a microgravity environment. The overall goal of the subdivision is to exploit the complex development chain of material design ranging from fundamentals of physical metallurgy, materials engineering and surface functionalization to the transfer of novel advanced materials and components into industrial application.

Between 2018 and 2020, the subdivision published 206 articles in peer-reviewed journals. The revenue from project grants totalled approx. 3.3 M€ (Ø 1.1 M€ p.a.), with 1.6 M€ spent from the DFG, 653 k€ from Federal and *Länder* Governments, and 728 k€ from the EU. In addition, 11 patents were being granted and the subdivision applied for 4 more. In the same period, 16 doctoral degrees were completed.

Subdivision 6: Multifunctional inorganic nanomembranes / Flexmag

[33.6 FTE, thereof 11.5 FTE Research and scientific services, 1.0 Post-doctoral scholarship recipient, 7.1 FTE employed Doctoral candidates, 5.0 FTE Doctoral candidates as scholarship recipients, and 8.9 FTE Service staff]

Nanomembranes are thin, flexible, transferable and can be shaped into almost arbitrary 3D microarchitectures. The ability to create nanomembranes out of virtually any material and material combination with a plethora of different thin-film deposition techniques such as thermal evaporation, sputtering, chemical vapor and atomic layer deposition brings about a wealth of new functionalities and has generated worldwide impact in several application fields.

On the one hand, applications rely on nanomembranes targeting large area electronic applications, which the IFW has previously pioneered for flexible and stretchable magnetoelectronics, composite materials for microbattery applications as well as giant magnetoresistive pastes/inks for printable electronics. On the other hand, differentially strained nanomembranes are exploited for for nano- and micro-electromechanical origami structures, in particular for compact on- and off-chip 3D self-assembled microtube architectures towards which the IFW has made decisive contributions already in the very early days of this emerging research field. In this context, 3D rolled-up nanomembrane devices include components for microelectronics, biomimetic architectures, microenergy storage as well as 3D scaffolds for in-depth single cell investigations, ultrasensitive biomedical sensors and photonic and opto-plasmonic microcavities. Most of these subtopics are finely interwoven with research topics found in subdivisions two, four, seven, eleven and twelve.

Between 2018 and 2020, the subdivision published 62 articles in peer-reviewed journals. The revenue from project grants totalled approx. 1.9 M€ (Ø 638 k€ p.a.), with 817 k€ spent from the DFG, 376 k€ from the Leibniz Association, 695 k€ from the EU, and 15 k€ from Industry. In addition, 12 patents were being granted and the subdivision applied for 4 more. In the same period, 2 doctoral degrees were completed.

Subdivision 7: Micromotors and drug delivery

[9.3 FTE, thereof 4.4 FTE Research and scientific services, 2.6 FTE employed Doctoral candidates, and 2.2 FTE Service staff]

Multi-functional micromotors provide a fresh and promising strategy to perform non-invasive and efficient medical treatment in living organisms. Recent developments concentrate on two major goals: First, finding efficient ways to propel microstructures at low Reynold's numbers in relevant physiological fluids, and second, exploring biomedical functionalities such as micromanipulation, drug delivery or bioimaging. The subdivision recently highlighted the great opportunities but also formidable challenges involved in this flourishing research field (Nature 545, 406 (2017)).

The subdivision's contribution relies on the development of medical microrobots which can adapt to complex biological scenarios towards two main applications: targeted drug delivery and *in vivo* assisted fertilization. Dedicated micromotor designs (physical and biohybrid) have been developed to transport sperm cells, fertilized oocytes and molecular cargoes (e.g. drugs, enzymes, anticoagulants). Additional efforts to make these micro-robots biodegradable are being pursued, for example by processing proteins and biogenic materials at the micro- and nanoscale (e.g. microstructures extracted from plants). Those approaches have allowed the cargo-release of multiple sperm cells as well as of drugs in presence of local proteases or acidic media, respectively. Finally, initial steps have been taken to translate this technology to small animals and *ex vivo* human tissue. From one side, the subdivision has explored different bioimaging techniques which allow the tracking of such small untethered structures in real time and in deep tissue, and on the other side, the group started collaborations with clinicians to employ *ex vivo* biological material for future human therapies. The subdivision developed the first human-sperm drug carrier to treat *ex vivo* ovarian cancer tumors in collaboration with the Division of Cancer Sciences from the University of Manchester.

Between 2018 and 2020, the subdivision published 29 articles in peer-reviewed journals. The revenue from project grants totalled approx. 1.3 M€ (Ø 424 k€ p.a.), with 216 k€ spent from the DFG, and 1 M€ from the EU. In addition, 4 patents were being granted and the subdivision applied for 1 more. In the same period, 4 doctoral degrees were completed.

Subdivision 8: Thermoelectric materials

[21.3 FTE, thereof 6.7 FTE Research and scientific services, 2.0 Post-doctoral scholarship recipients, 4.1 FTE employed Doctoral candidates, 2.3 FTE Doctoral candidates as scholarship recipients, and 6.2 FTE Service staff]

Thermoelectric (TE) energy converters are attractive for application in waste heat utilization technologies. Peltier coolers are a vital part of modern thermal management systems. However, the comparatively low efficiency of state-of-the-art TE materials hinders a wide-scale expansion of high-performance thermoelectric devices. To increase the efficiency of TE materials, a deep understanding of the interlinked electron and phonon transport properties in nanostructured materials is a prerequisite for tailored engineering of TE materials. Challenges remain on how to efficiently decouple both the electrical conductivity and thermal conductivity, increase the stability of the TE material and the compatibility with environmental requirements. The fabrication of TE devices, especially micro-devices, includes further challenges. One key problem is to embed optimized high-performance TE materials into a device technology that is compatible with prospective applications.

Since January 2016 subdivision 8 has focused on three research activities: (i) The development of measurement platforms for the characterization of thermoelectric transport properties for knowledge-driven experimental studies, (ii) the development of efficient and sustainable thermoelectric bulk materials for low-to-high temperature thermoelectric energy conversion with neglectable concentrations of tellurium, and (iii) the fabrication and functional integration of micro-energy harvesting and micro-thermal management devices with long-term reliability and cycling stability.

Between 2018 and 2020, the subdivision published 55 articles in peer-reviewed journals. The revenue from project grants totalled approx. 1.8 M€ (Ø 588 k€ p.a.), with 503 k€ spent from the DFG, and 417 k€ from Federal and *Länder* Governments. In addition, 8 patents were being granted and the subdivision applied for 3 more. In the same period, 3 doctoral degrees were completed.

Subdivision 9: Surface acoustic waves: Concepts, materials & applications

[20.6 FTE, thereof 16.2 FTE Research and scientific services, 1.2 FTE employed Doctoral candidates, and 3.2 FTE Service staff]

Surface acoustic waves (SAW) and further microacoustic wave modes provide a versatile base for precise frequency filtering in wireless telecommunications as well as for emerging applications like sensors and actuators operating under harsh conditions, in fluidic environment and with small (bio-)particles, resp. The research of the IFW ranges from fundamentals to applications and is consequently focused on future-oriented microacoustic devices comprising the main areas concepts, materials and applications. A strong collaboration with local industry partners and R&D is achieved by IFW-operated network "SAWLab Saxony".

New innovative design concepts for acoustic wave-based devices are developed based on thorough physical modeling of wave excitation, propagation and wave-structure interaction effects together with their experimental verification while also considering effects of higher order.

Advanced material systems, especially those adapted to low/high temperature use and acoustofluidic applications, are investigated. These include (i) new piezoelectric crystals, (ii) thin film electrode materials for interdigital transducers (IDT) structures, polymeric materials for defined microfluidic structures, as well as (iii) strategies for interface engineering. In order to obtain complete data sets of linear and higher order material properties for more accurate device simulation and tailored design of advanced microacoustic devices such as high-temperature SAW temperature sensors, high-precision microacoustic characterization of new and efficient piezoelectric materials in a wide temperature range 4.2 - 1200 K is carried out. Regarding IDT electrodes, the IFW investigates material routes for highly stress-tolerant, long-term stable and purpose-compatible material systems on different piezoelectric substrates such as $LiNbO_3$, LGS or CTGS with properties adapted to harsh operation conditions as well as to biological environments. Furthermore, the improvement of approaches for surface and interface engineering, as well as the analysis of functional interlayers and protective coatings, is mandatory.

New microacoustic applications, including actuators for microfluidic systems, e.g. 1D and 2D acoustic tweezers and aerosol generators, for acoustically-assisted deicing as well as sensors for harsh environment and wireless interrogation are research emphases. This necessarily includes application-oriented approaches for microfluidic integration, e.g. on-chip lithographic channel definition, antennas capable of being integrated and temperature-resistant packaging.

Between 2018 and 2020, the subdivision published 37 articles in peer-reviewed journals. The revenue from project grants totalled approx. 2.1 M€ (Ø 700 k€ p.a.), with 1.1 M€ spent from the DFG, and 932 k€ from Federal and *Länder* Governments. In addition, 17 patents were being granted and the subdivision applied for 6 more. In the same period, 2 doctoral degrees were completed.

Subdivision 10: 2D Systems / Designed interfaces and heterostructures

[18.8 FTE, thereof 7.3 FTE Research and scientific services, 1.1 Post-doctoral scholarship recipients, 6.0 FTE employed Doctoral candidates, and 4.4 FTE Service staff]

The subdivisions aims to transfer IFW's long-standing experience in bulk quantum materials to novel two-dimensional (2D) while these will be realized in form of monolayers or interfaces. Thereby, the subdivision is targeting both the discovery and the exploration of new fundamental phenomena as well as first steps towards applications in quantum technology. In particular, the group adjusts and further develops methods and research strategies successfully developed for graphene, the most eminent 2D material. The midterm plan is to explore ultra-thin layers of quantum materials already showing interesting electronic or magnetic properties in their bulk form, such as superconductors, quantum magnets or topological materials. Ultra-thin systems, e.g. monolayers, as well as heterostructures and interfaces thereof are synthesized either by mechanical and chemical exfoliation of thin flakes starting from single crystals or by chemical bottom up approaches and physical growth methods such as molecular beam epitaxy (MBE). Research of quantum properties of sensitive 2D materials requires dedicated scientific infrastructure for the processing of nanoflakes up to nanodevices in oxygen free environments. The subdivision develops and utilizes electron microscopy and holography, near field optical spectroscopy, photoemission, and electron energy loss spectroscopy. Currently, facilities allowing for in-situ studies during growth, such as selenium and tellurium MBE, are set up at the angle-resolved photoemission spectroscopy synchrotron beamline. In addition, transport measurements on nanostructures of 2D materials and their heterostructures as well as quantum transport simulations and models employing quantum chemistry and density-functional theory are part of this subdivision. Starting from doped graphene, the variety of materials studied is broad, rapidly changing and with substantial overlap to other subdivisions, since famous examples of superconductors, quantum magnets or topological systems contain van der Waals bonded layers allowing for exfoliation.

Between 2018 and 2020, the subdivision published 90 articles in peer-reviewed journals. The revenue from project grants totalled approx. 964 k€ (Ø 321 k€ p.a.), with 681 k€ spent from the DFG, 172 k€ from the EU and 34.5 k€ from Industry In the same period, 5 doctoral degrees were completed.

Subdivision 11: Quantum and nano-photonics

[13.7 FTE, thereof 9.2 FTE Research and scientific services, 2.3 FTE employed Doctoral candidates, 1 FTE Doctoral candidate as scholarship recipient, and 1.2 FTE Service staff]

The subdivision’s research targets future communication, signal processing and sensing technology by emission, absorption and manipulation of light in nanostructures. The research is divided into three parts: Entangled photon sources, microtube cavity photonics and nanoplasmonics.

In the field of GaAs quantum dot-based entangled photon sources, one main focus is to optimize device performance through growth optimization, implementation of charge and frequency-tuning, optimization of far-field emission patterns and employing efficient light extraction techniques. The knowledge and capabilities gained by these efforts have led to landmark quantum communication experiments which will guide our future research towards real-world applications such as quantum repeater segments. In the field of microtube cavity photonics, the group discovered a non-Abelian evolution of the polarization of resonant light in asymmetric microtube cavities, where the occurrence of optical Berry phase and mode conversion was observed for the first time. The thin walls of the microtubes and their easy functionalization by for instance plasmonic materials have enabled to explore polarization-dependent enhanced light-matter interactions and to probe molecular dynamics on oxide surfaces. The on-chip fabrication of optical microtube ring resonators offers intriguing new options for 3D photonic integration schemes. In the field of nanoplasmonics, the subdivision explore interactions of free metal electrons on nanostructures with light for future electronic and sensing applications. We develop plasmon band engineering methods by hybridizing surface plasmon resonances in highly-ordered heterogeneous plasmonic nanoparticle arrangements such as 1D chains and 2D arrays. Surface plasmon excitation of topological insulating nanoparticle arrays reveals exceptional magnetoelectric effects. The group develops and applies high-resolution transmission electron microscopy methods such as electron holographic tomography and the spectrally resolved imaging of transient electric and magnetic fields pertaining to surface plasmon excitations.

Between 2018 and 2020, the subdivision published 50 articles in peer-reviewed journals. The revenue from project grants totalled approx. 2 M€ (Ø 660 k€ p.a.), with 443 k€ spent from the DFG, 873 k€ from Federal and *Länder* Governments, and 635 k€ from the EU. Additionally, 2 patents were being granted. In the same period, 4 doctoral degrees were completed.

Subdivision 12: Functional molecular nanostructures and interfaces

[23.1 FTE, thereof 9.5 FTE Research and scientific services, 1.0 Post-doctoral scholarship recipient, 6.2 FTE employed Doctoral candidates, 1.0 Doctoral candidate as scholarship recipient, and 5.4 FTE Service staff]

Molecules and molecular solids characterized by π-derived electronic states are in the focus of this subdivision. The research concentrates on organic semiconductors and purely carbon-based nanostructures. Main research issues are electronic properties, single-molecule magnetism and to a lesser extent mechanical characteristics.

In the field of organic semiconductors, both fundamental studies of charge transfer states and excitations, as well as fabrication of advanced devices are in the research focus. This allows to determine many relevant properties, provide a comprehensive knowledge of these issues, and pave the way for state-of-the-art applications. According to the subdivision, the combination of techniques available in the IFW Dresden is quite unique, also on an international level.

Metals atoms enclosed inside fullerene cages retain their physical properties and can be manipulated electronically or magnetically creating unconventional valence and spin states. The IFW Fullerene group is focused on the synthesis and the chemical and physical properties of endohedral metallofullerenes (EMFs). Single-molecule magnetism of lanthanide-EMFs is of particular interest during last years. Studies of the mechanisms of the relaxation of magnetization and the targeted synthesis of EMFs with improved magnetic functionalities are thus pursued in the group. Further, EMF monolayers on various conducting and semiconducting substrates are studied to unravel the relations between the charge transfer and magnetism at these interfaces.

Experimental studies in this subdivision are augmented by computational techniques of different complexity, from high-level quantum chemical (QC) calculations on small model systems to modelling of molecules and extended structures by density-functional theory (DFT). The in-house development of DFT code (FPLO) ensures a rapid implementation of new functionality for the interpretation of specific data. Microscopic model Hamiltonians with ab initio or experimentally-derived parameters are used to digest or predict experimental results.

The group implements straight on its long-term experience in carbon nanotubes (CNT) to industrial applications. Carbon nanotube yarns (CNY) are a novel carbonaceous material transferring the properties of CNTs to the micro scale.

Between 2018 and 2020, the subdivision published 136 articles in peer-reviewed journals. The revenue from project grants totalled approx. 2.6 M€ (Ø 857 k€ p.a.), with 1.4 M€ spent from the DFG, and 894 k€ from the EU. In addition, 1 patent was being granted and the subdivision applied for 1 more. In the same period, 6 doctoral degrees were completed.

Subdivision 13: Topological states of matter

[21.8 FTE, thereof 8.2 FTE Research and scientific services, 2.6 Post-doctoral scholarship recipients, 8.7 FTE employed Doctoral candidates, 0.7 Doctoral candidate as scholarship recipient, and 1.6 FTE Service staff]

According to the subdivision, probing unconventional topology is one of the fastest expanding explorative research fields of the last decade, both in experimental as well as theoretical condensed matter physics. Recently, many new directions have emerged within different topological classes of systems and materials. These include new types of phases, such as higher-order topological insulators and topological semimetals possessing multiply-degenerate band crossing points, novel platforms that can realize nontrivial topology, such as photonic, phononic, and topoelectric metamaterials, as well as new signatures associated to topological phases: charge accumulation at the corners of a crystal and nonlinear transport properties.

This diversity and richness of topological states and phases is a broad source of inspiration for the group's research. Its strategy for probing specific topological matter of electrons and photons is three-fold and entangles (i) cutting-edge theory, (ii) materials design and synthesis as well as (iii) targeted experiments. Using theoretical tools, the subdivision predicts new topological phases which can be realized in electronic matter and photonic lattices, as well as electromagnetic manifestations and implications of topology. The group actively designs and synthesizes photonic lattices, novel bulk single crystals, but also nanowires, thin films, as well as functional heterostructures. Finally, they are experimentally probing the fundamental topological nature of these systems by investigating their spectroscopic and transport properties.

Between 2018 and 2020, the subdivision published 90 articles in peer-reviewed journals. The revenue from project grants totalled approx. 2 M€ (Ø 659 k€ p.a.), with 1.3 M€ spent from the DFG, and 657 k€ from Federal and *Länder* Governments. In addition, the subdivision applied for 2 patents. In the same period, 5 doctoral degrees were completed.

8. Handling of recommendations from the previous evaluation

IFW responded as follows to the five recommendations of the last external evaluation (highlighted in italics, see also statement of the Senate of the Leibniz Association issued on 23 March 2015, pages B-3):

1) The scientific ideas and approaches for continuing IFW's development presented in the evaluation package are convincing. At present, however, it is not clear how these ideas are to be prioritized and implemented. Above all, it is not transparent which of the institute's human and financial resources are to be allocated to which research tasks and how cooperation between the subdivisions is to be organized within the ***new research program****. The evaluation group was informed that the Board of Trustees decided on the appointment of an external scientist to the position of IFW's Scientific Director, seen as the best possible way of responding to the* ***management crisis*** *at the institute. The newly appointed Scientific Director will be responsible for scientific management. Under his leadership and responsibility, it must now be decided which reforms and changes are necessary at IFW in order to be able to implement a research program supported by everyone and thus maintain IFW's high scientific capabilities. The Review Board expects all institute directors to collaborate constructively in this process. As a consequence of the intense discussions within the review board, it is also expected that the process is closely monitored by the Scientific Advisory Board as well as by the Board of Trustees.*

The situation in 2014 with a temporary scientific director has been converted into a stable management structure. After a period with the scientific director being engaged from outside IFW, the position of scientific director has again been taken over by one of the institute directors since 2018. During this process, a collegial leadership was established where the Board of Directors (comprising of the scientific and the administrative directors as well as the directors of the five IFW institutes) is much more involved. Relevant decisions are intensely discussed in the Board of Directors. This concerns important personnel issues, the distribution of budget funds, larger investments and all decisions on strategic measures. In addition, since 2018 the deputy Scientific Director participates in the meetings of the Board of Trustees as a representative of the Board of Directors.

The new research program proposed in 2014 has been very successfully implemented, including a bunch of strategic measures (see chapter 3.1 and 3.2). The Scientific Advisory Board and the Board of Trustees of IFW have accompanied this process and appreciate the positive changes very much.

2) The proportion of income for project funding deriving from industry should be increased and clear goals for industrial funding and research project participation should be formulated. In order to achieve this, the institute should optimize its strategy regarding ***collaborations with partners in industry*** *and combine it with an institute-wide patents strategy.*

Technology transfer to industry is a central concern of the IFW, which has been pursued with great effort since the last evaluation. A particular focus is the establishment of sustainable long-term industry cooperation, which besides project applications also concerns special infrastructure, which is realized and used in joint efforts. First successful examples are the partnerships with CEOS, the cooperation with the IFW spin-off ScIDre, and the SAWlabSaxony (see below). In addition, we are currently in the process of implementing a new coordinated by the IFW network in the area of tool manufacturing, which will provide dedicated R&D opportunities for Saxon SMEs. IFW refers in its evaluation package to examples.

3) It would be desirable if more IFW scientists were to spend longer periods of time at ***other institutions****.*

During the last 7 years, the IFW has considerably intensified the guest visits of Institute's members to cooperation partners at other locations. Usually about 20-25 IFW scientists go for research or measurement stays of more than 4 weeks to partner institutions abroad. IFW gives examples in detail in its evaluation package.

4) IFW must continue to significantly drive its efforts to increase the ***proportion of women*** *at all levels.*

This recommendation has taken very seriously and pursued fervently. At Board level, a 50% share of women has been achieved since the position of Administrative Director has been held by a woman since 2015. However, it has not yet been possible to compensate for the underrepresentation of women at the level of IFW institute directors. Four of the five IFW institutes are headed by men, one position of an IFW institute director is vacant at present. In 2018 we have been successful in the Leibniz Program for Women Professors and were very near to the appointment of a female professor on director's level. However, the appointment failed the following year and the vacant position has been advertised again recently. Thus, we still hope to fill this director position at IFW with a female professor in the second attempt.

At the level below the IFW institute directors, we have almost reached a proportion of women that expresses gender equality (30%), considering that this is the proportion of female students in the subjects relevant to IFW (physics, mechanical engineering, chemistry). At the end of 2020, the proportion of female group leaders in science at IFW is 31%. The share of female postdocs is 29% and that of other female scientific staff without leadership tasks is 27%. Only the proportion of women among doctoral students was significantly lower (22%). As this figure fluctuates greatly, we are optimistic that we will soon be able to increase the proportion of female doctoral students back up to the 30% mark.

Apart from this quantitative consideration, we can state some recent success of our efforts towards gender equality. 2019 two women have been appointed at W1/W2 level as IFW research group leaders. Another proof of the effectiveness of our efforts to improve gender equality in science is the fact that four female IFW scientists received offers for university professorships in 2020. However, the upcoming departure of talented female group leaders will initially lead to a reduced number of women scientists at this level of leadership, which we hope to compensate for in the near future.

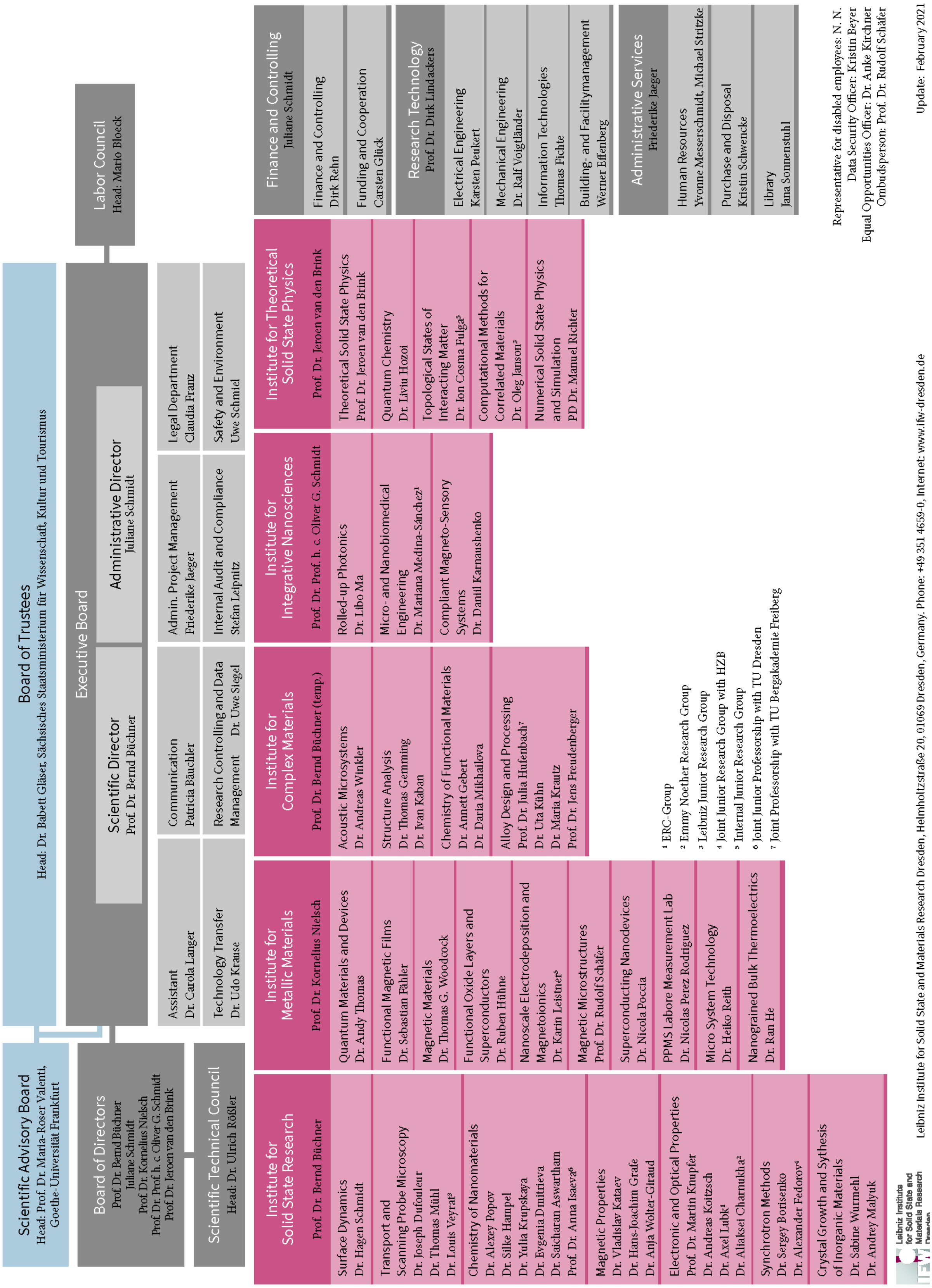
5) For some ***doctoral candidates*** *there are structured doctoral programs. It would be desirable to ensure that all doctoral candidates at IFW had the opportunity to take part in structured programs. At 4.5 years, the average length of doctoral studies is too long and should be shortened.*

In order to develop a structured doctoral qualification, the IFW has implemented formalized principles for supervision of doctoral candidates in 2017. According to this, the scientific work on the doctoral project, including the preparation of the dissertation, should be completed within a period of three years. The progress of work is monitored and fostered by continuous support and reporting. Despite all efforts to shorten the average length of doctoral studies this figure remains at 4.5 years whereas the range is as large as from 2.9 to 8.5 years. From 73 doctoral students who finished their theses from 2018 to 2020 after all 26 made it in less than 4 years.

At the far end of the scale are doctoral students who changed to other employers before the scientific work for their theses was completed. If these seven dissertations are not included, the average duration of the remaining 65 doctorate periods is 4.3 years which correspond to the average duration of doctoral studies in physics, chemistry and engineering sciences (see „Die Promotion in der Physik in Deutschland", DPG Studie 2019 and Bundesbericht Wissenschaftlicher Nachwuchs 2017).

Appendix 1

Organisational Chart



Appendix 2

Publications, patents, and expert reviews

	Period		
	2018	**2019**	**2020**[1)]
Total number of publications			
Monographs	1	0	1
Individual contributions to edited volumes	16	10	5
Articles in peer-reviewed journals	414	403	360
Articles in other journals	4	6	6
Working and discussion papers	0	0	0
Editorship of edited volumes	1	1	0

Industrial property rights [2)]	**2018**	**2019**	**2020**
Patents (granted/applied)	12/16	23/15	30/9
Other industrial property rights (granted/applied)	1/0	0/0	0/0
Exploitation rights/licences (number)	0/42	0/16	0/10

[1] Contributions that have been accepted for publication but not yet appeared are added in parenthesis.
[2] Concerning financial expenditures for revenues from patents, other industrial property rights and licences see Appendix 3.

Appendix 3 Revenue and Expenditure

	Revenue	2018 k€	2018 % [2]	2018 % [3]	2019 k€	2019 % [2]	2019 % [3]	2020 [1] k€	2020 % [2]	2020 % [3]
Total revenue (sum of I., II. and III.; excluding DFG fees)		**39.843,9**			**40.873,6**			**44.534,4**		
I.	**Revenue (sum of I.1.; I.2., and I.3.)**	**39.567,7**	100 %		**40.250,2**	100 %		**44.189,5**	100 %	
1.	Institutional Funding (excluding construction projects and acquisition of property)	31.747,0	80 %		32.075,0	80 %		32.757,0	74 %	
1.1	Institutional funding (excluding construction projects and acquisition of property) by Federal and *Länder* governments according to AV-WGL	31.747,0			32.075,0			32.757,0		
1.2	Institutional funding (excluding construction projects and acquisition of property) not received in accordance with AV-WGL	0,0			0,0			0,0		
2.	Revenue from project grants	7.805,7	20 %	100 %	8.157,9	20 %	100 %	11.421,5	26 %	100 %
2.1	DFG	3.212,8		41 %	4.653,7		57 %	5.018,9		44 %
2.2	Leibniz Association (competitive procedure)	150,4		2 %	119,8		1 %	244,7		2 %
2.3	Federal, *Länder* governments	1.155,9		15 %	1.960,4		24 %	2.224,9		19 %
2.4	EU	2.772,8		36 %	899,1		11 %	3.400,2		30 %
2.5	Industry	299,1		4 %	362,7		4 %	282,8		2 %
2.6	Foundations	161,0		2 %	72,6		1 %	100,7		1 %
2.7	*other sponsors*	53,6		1 %	89,5		1 %	149,3		1 %
3.	Revenue from services	15,0	0 %		17,3	0 %		11,0	0 %	
3.1	Revenue from commissioned work	0,0			0,0			0,0		
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.)	3,2			7,9			5,0		
3.4	Revenue from exploitation of intellectual property without industrial property rights	11,8			9,4			6,0		
3.5	*If applicable: other services*	0,0			0,0			0,0		
II.	**Miscellaneous revenue** (e. g. membership fees, donations, rental income, funds drawn from reserves)	**122,2**			**473,4**			**194,9**		
III.	**Revenue for construction projects** (institutional funding by Federal and *Länder* governments, EU structural funds, etc.)	**154,0**			**150,0**			**150,0**		

	Expenditures	2018 k€	2019 k€	2020 k€
Expenditures (excluding DFG fees)		**39.918,4**	**45.965,3**	**41.724,4**
1.	Personnel	22.792,3	24.418,4	25.923,1
2.	Material expenses	10.358,5	9.611,6	9.278,8
2.1	*Proportion of these expenditures used for registering industrial property rights (patents, utility models, etc.)*	*194,1*	*209,0*	*188,5*
3.	Equipment investments	6.613,6	11.785,4	6.372,5
4.	Construction projects, acquisition of property	154,0	150,0	150,0
5.	Other operating expenses (if applicable, please be specific)			

	2018	2019	2020
DFG fees (if paid for the institution - 2.5 % of revenue from institutional funding)	793,7	801,9	818,9

[1] Preliminary data: yes/no

[2] Figures I.1., I.2. und 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 bis I.2.7 add up to 100%. The information requested here is thus the percentage of the various sources of "Revenue from project grants".

Appendix 4

Staff

(Basic financing and third-party funding / proportion of women (as of: 31/12/2020)

	Full-time equivalents		Employees		Female employees		Foreigners
	Total	On third-party funding	Total	On temporary contracts	Total	On temporary contracts	Total
	Number	Percent	Number	Percent	Number	Percent	Number
Executive Board	**2**	0,0	**2**	0,0	1	1	0
Scientific Director included in Professors/Directors. see below	(1)	0,0	(1)	0,0	0	0	0
Administrative Director	1	0,0	1	0,0	1	1	0
Research and scientific services	**211,9**	48,2	**269**	81,8	**68**	81,6	**141**
W3 Professors / Directors	4,0	0,0	4	0,0	0	0,0	1
Research group leaders (without Junior Research group leaders)	30,1	13,3	34	23,5	10	40,0	12
Junior research group leaders	10,1	19,8	11	72,7	4	36,4	8
Scientists in non-executive positions (E13, E14)	101,9	50,7	112	85,7	30	86,7	60
Doctoral candidates (E13, E13/2 or equi.)	65,8	67,5	108	100,0	24	100,0	60
Scholarship recipients at the institution	**36,0**	77,8	**36**		**12**		**36**
Doctoral researchers	18,0	77,8	18		6		18
Post-doctoral researchers	16,0	81,3	16		5		16
other	2,0	50,0	2		1		2
Student assistants	**13,2**	25,9	**48**				
Trainees, internship, BA-students	**25,6**	15,6	**27**				
Service positions	**64,2**	5,1	**69**				
Laboratory (E9 to E13)	21,3	14,1	23				
Laboratory (E5 to E8, mid-level service)	37,9	0,7	41				
Workshops (E5 to E9)	5,0	0,0	5				
Secretaries/assistants (E4 to E8, mid-level service)	9,1	0,0	10				
Support staff	6,6	35,1	**7**				
Staff positions (from E13, senior service)	4,6	50,6	5				
Staff positions (E9 to E12, upper-mid-level service)	2,0	0,0	2				
Research Technology	**34,2**	0,0	**35**				
Head of Research Technology	1,0	0,0	1				
Information technology (E9 to E14, upper-mid-level service)	7,7	0,0	8				
Engineers (from E13)	2,7	0,0	3				
Engineers (E9 to E12, upper-mid-level service)	9,0	0,0	9				
Technical service (E5 to E8, mid-level service)	5,8	0,0	6				
Workshops (E5 to E9)	8,0	0,0	8				
Administration	**38,7**	2,6	**42**				
Head of administration	1,0	0,0	1				
Library (E9 to E12, upper-mid-level service)	0,8	0,0	1				
Library (E5 to E8, mid-level service)	2,0	0,0	2				
Internal administration (financial administration, personnel, etc.) (from E13, senior service)	1,5	0,0	2				
Internal administration (financial administration, personnel, etc.) (E9 to E12, upper-mid-level service)	12,4	0,0	14				
Internal administration (financial administration, personnel, etc.) (E5 to E8, mid-level service)	16,1	0,0	17				
Building service (E5 to E8)	5,0	20,0	5				

15 December 2021

Annex B: Evaluation Report

Leibniz Institute for Solid State and Materials Research Dresden e. V. (IFW Dresden)

Contents

1. Summary and main recommendations

The aim of the IFW is to unlock the theoretical and experimental foundations for the development of materials that may offer new or better functions. Researchers from the fields of physics, chemistry and engineering work together to achieve this aim. The structure of the IFW comprises five *institutes*. Cooperation between the *institutes* is organised via the *research programme*. An important basis of the research conducted at the IFW is the infrastructure support from the *Research Technology Division*.

At the last evaluation, in 2014, the IFW presented a new *research programme*, which focuses its mission on the development of quantum materials, functional materials and nano materials. The broad programme is implemented in three basic *research areas* and a fourth *research area* with a strong application focus ("Towards products") that builds on the first three. In view of the IFW's size, organising the collaboration between the *institutes* via the *research programme* in a matrix structure seems, in principle, adequate.

The *research areas* are subdivided into *research topics*. For this evaluation, the IFW combined the applied *research topics* with the corresponding basic *research topics*, resulting in 13 subdivisions being presented in the evaluation document (summarized in the status report). The scientific output is impressive. The very good and in many areas outstanding research results are published very frequently in internationally important peer-reviewed journals. Since the last evaluation, the IFW has successfully pursued its technology transfer activities, including the important example of *SAWLab Saxony*, which was set up in 2015. It is also appreciated that the IFW now has a patenting strategy in place, as previously recommended.

In the past seven years, the IFW has fleshed out and implemented its *research programme*. One reason this deserves a special mention is that at the time of the last evaluation, the IFW had been weakened by a serious management crisis, which was holding up implementation of the fundamental concept. The interim director, an extremely experienced scientist who was brought in from outside at the time, played a key role in overcoming the crisis, as the Leibniz Association Senate noted in July 2016 in an interim report following the evaluation of 2014/2015. In April 2018, with the appointment of the director of the *IFW Institute for Solid State Research (IFF)*, the IFW governing bodies returned to the structure established before the management crisis to appoint the Scientific Director from among the five *institute directors*. This decision proved to be reasonable.

The IFW obtains 22 % of its revenues for ongoing activities from third-party funding. The vast majority of this third-party funding is secured through highly competitive processes. A remarkably high proportion of third-party funding comes from the DFG (47 % of the IFW's third-party funding, s. status report, appendix 3, p. A-30) and the EU or ERC (26 %). Grants from the federal and *Länder* governments also play an important role (19 %). The IFW research performance is truly impressively showcased by a large number of outstanding projects, including projects of IFW scientists funded through seven *ERC grants* and three *Leibniz Junior Groups*. In addition, in 2018 the director of the *Institute for Integrative Nanoscience (IIN)* was awarded the Gottfried Wilhelm Leibniz Prize by the German Research Foundation (DFG). However, in autumn 2021 he took up a leading research position at TU Chemnitz, so he is now concentrating on his professorship there and has resigned his appointment at the IFW. The position of director of the *Institute for Complex Materials (IKM)* has been vacant since 2016. A first appointment procedure did not result in an appointment and ended in 2019. Filling these two important posts is now crucial for the future of the IFW.

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

Strategic work planning for the coming years (chapter 3: Changes and planning)

1. In July 2021, the IFW and TU Dresden readvertised internationally the position of director of the *Institute for Complex Materials (IKM)*, which has been vacant for several years. The plan now is to give the IKM, which had a broader materials science focus between 2006 and 2015, a chemistry focus in the area of scalable synthesis of functional materials. This planned focus makes sense in terms of differentiating the areas covered by the five IFW institutes. At the same time, the IKM is expected to ensure that it retains and further develops the unique interdisciplinary profile that was so successfully implemented starting in 2006.

   The departure of the director of the *Institute for Integrative Nanosciences (IIN)* means the IFW is losing an outstanding researcher this year. For the further development of the IFW, it is important to manage his succession as soon as possible and appoint a world-class scientist.

   For the leadership and governing bodies of the IFW, the main challenge in the coming months will be to fill the two vacancies in collaboration with university partners.

2. The IFW plans to set up a sixth institute, focusing on Novel Quantum Technologies, using its own and additional institutional funding (small extraordinary item of expenditure of a strategic nature, "*Sondertatbestand*") of €3.9m p.a., under the leadership of a new W3 professor. In doing so, the IFW is striving to make significant advances towards application in the area of quantum materials and new quantum technologies. The new institute's work would be closely linked to the IFW's basic research on quantum materials. It is intended to build on the IFW's activities concerning e.g. nanomembranes, sensor technology and 2D materials from a quantum technology perspective.

   While the idea behind the new institute in principle makes sense, it is currently very difficult to assess the precise aims and the distinction between this institute and the other projects already underway at the IFW. The role and function of the new institute, not least its relation to the existing institutes, would need to be fleshed out before submitting an application through the relevant process. As well as the three current IFW institute directors, the two institute directors who have yet to be appointed need to be involved in drawing up the application.

Funding (chapter 4: Controlling and quality management)

3. It is commendable that the IFW pursues a third-party funding strategy for starting new high-risk directions in basic research and to explore their potential. As recommended seven years ago, securing more funds from industry still ought to be pursued. Notably, in case of establishing a technology-oriented sixth institute an increase of funding by industry has to be achieved.

<u>Organisational and operational structure</u> (chapter 4: Controlling and quality management)

4. In view of the size of the IFW, a matrix structure is conceivable in which the five *institutes* are connected via *research areas* with sub-units called *research topics*. The IFW made use of this structuring principle at the time of the last evaluation. Its content has been modified somewhat since then, resulting, among other things, in five research areas being concentrated into four. Moving forward, the IFW needs to clarify what role the *research areas*, and especially the *research topics*, will play in future. At the moment, outsiders cannot see clearly whether the *research topics* are the central operational units of the IFW or whether they are intended rather to be loose connections linking the work across the five *institutes*. The interplay between the *institutes* and *research areas/research topics* as structural elements in the matrix should therefore be better defined.

<u>Equal opportunities</u> (chapter 5: Human resources)

5. 26 % of the scientific positions at the IFW are held by female scientists. The IFW's achievement in increasing the number of female scientists at middle management level in recent years, as previously recommended, is recognised. However, in view of the overall ratio and the slight decline in female scientists in the rest of the scientific staff (including doctoral researchers) there is still a strong need for improvement. Opportunities to make a difference are emerging especially by the upcoming appointment of two, or maybe three, new institute directors.

2. Overall concept, activities and results

Overall concept

The aim of the IFW is to unlock the theoretical and experimental foundations for the development of materials that may offer new or better functions. Researchers from the fields of physics, chemistry and engineering work together to achieve this aim. The IFW is structured into five *institutes*. An important basis of the research conducted at the IFW is the infrastructure support from the *Research Technology Division*.

The overarching IFW *research programme* provides a shared framework for the work of the *institutes*. At the last evaluation, the IFW presented a new *research programme*, which focuses its mission on the development of quantum materials, functional materials and nano materials.

The broad programme is implemented in three basic *research areas* ("Functional quantum materials", "Function through size" and "Quantum effects at the nanoscale") and a fourth *research area* with a strong application focus ("Towards products") that builds on the first three. These *research areas* form the medium-term stable framework for the flexible sub-structuring into *research topics*. For this evaluation, the IFW presented the work of its 17 current *research topics* in 13 subdivisions (four of the five *research topics* in *research area 4* ("Towards products") were integrated into the corresponding *research topics* in *research areas 1-3*. The *research topic* "Surface acoustic waves" in *research area 4* is presented as subdivision 9; see chapter 7).

In view of the IFW's size, organising the collaboration among the *institutes* via the *research programme* in a matrix structure seems, in principle, adequate (see detailed assessment in chapter 4).

Activities and results

Research

The IFW pursues both basic and applied research. Its research performance ranges from very good to outstanding. Some examples that demonstrate IFW's success include: international visibility of work on multifunctional inorganic membranes; cutting edge work on functional and molecular nanostructures and interfaces; understanding and manipulation of magnetically ordered states on the meso- and nanoscale with a view to applied magnetism; and, outstanding scientific work in the field of thermoelectrics as well as in quantum and nano-photonics.

Generally, the research at the IFW is characterised by a pronounced interdisciplinary approach and an excellent connection between theory and experiment. Scientific output at the IFW is impressive. The research results are published very frequently in internationally important peer-reviewed journals.

Infrastructure

Maintaining and upgrading research infrastructure is essential for the fulfilment of the IFW's research mission. Among other things, the central *Research Technology Division* develops highly specialised research equipment for research tasks at the IFW. It also makes available some of its developments for further use, e.g. for the two IFW spin-offs, *evico magnetics* and *SciDre GmbH*. In addition, the *Research Technology Division* also runs the IFW's IT infrastructure.

Technology Transfer

Since the last evaluation, the IFW has successfully pursued its transfer activities. It played a key role in setting up the *SAWLab Saxony competence and application centre* in 2015 which currently comprises 15 partners from industry and academia and supports transfer and commercial deployment of research related to surface acoustic waves (SAW). It is an important contribution to technology transfer in this research field (see Subdivision 9 below). It is also good to see that the IFW now has a patenting strategy in place, as previously recommended.

3. Changes and planning

Development since the previous evaluation

The IFW has fleshed out and implemented the *research programme* that it outlined at the time of the last evaluation. One reason this deserves a special mention is that at the time of the last evaluation, the IFW had been weakened by a management crisis (see chapter 4), which was holding up implementation of the fundamental concept.

The IFW's high research performance over the past few years is impressively showcased by a large number of outstanding projects, including projects of IFW scientists funded through seven *ERC grants* and three *Leibniz Junior Groups*. In addition, in 2018 the director of the *Institute for Integrative Nanoscience* was awarded the Gottfried Wilhelm Leibniz Prize by the German Research Foundation (DFG). However, in autumn 2021 he took up a leading research position at TU Chemnitz, so he is now concentrating on his professorship there and has resigned his appointment at the IFW.

A positive impact in the last few years has come from the intensive collaboration between the IFW and other high-level research institutions in Dresden (see also chapter 6). This is showcased by the IFW's participation in the Dresden Cluster of Excellence *Complexity and Topology in Quantum Matter (ct.qmat)*, in which the University of Würzburg and TU Dresden are involved, as well as two Dresden-based Max Planck institutes and the Helmholtz Centre Dresden-Rossendorf, and also by the IFW's involvement in collaborative research centres and DFG research groups.

Important decisions have been taken at leadership level in the past few years. In 2015, the position of director of the *Institute for Metallic Materials (IMW)* was filled by a scientist with an international track record in a joint W3 appointment with TU Dresden after the previous director retired. Since April 2018, the director of the *Institute for Solid State Research (IFF)* has also been the Scientific Director of the IFW as a whole (see chapter 4). A change of Administrative Director in 2020 was seamless.

Strategic work planning for the coming years

The former director of the *Institute for Complex Materials (IKM)*, a materials scientist with a strong track record, left a few years ago to take up a professorship in Austria. The position at the head of the IKM has been vacant since 2016. A first recruitment procedure did not result in an appointment and was ended in 2019. The post was provisionally filled in 2016 by a leading scientist from the IKM and then, some time ago, by the acting Scientific Director of the IFW. He is supported in this role by a female junior group leader, who has worked at the IFW since 2010 and who has held a fixed-term W2 professorship at TU Bergakademie Freiberg since 2019.

In July 2021, the IFW and TU Dresden readvertised internationally the position of director of the *Institute for Complex Materials (IKM)*, which has been vacant for several years. The plan now is to give the IKM, which had a broader materials science focus between 2006 and 2015, a chemistry focus in the area of scalable synthesis of functional materials. This planned focus makes sense in terms of differentiating the areas covered by the five IFW institutes. At the same time, the IKM is expected to ensure that it retains and further develops the unique interdisciplinary profile that was so successfully implemented starting in 2006.

The departure of the director of the *Institute for Integrative Nanosciences (IIN)* means the IFW is losing an outstanding researcher this year. For the further development of the IFW, it is important to manage his succession as soon as possible and appoint a world-class scientist.

For the leadership and governing bodies of the IFW, the main challenge in the coming months will be to fill the two vacancies in collaboration with university partners.

Planning for additional institutional funding

The IFW plans to set up a sixth institute, focusing on Novel Quantum Technologies, using its own and additional institutional funding (small extraordinary item of expenditure of a strategic nature, "*Sondertatbestand*") of €3.9m p.a., under the leadership of a new W3 professor. In doing so, the IFW is striving to make significant advances towards application in the area of quantum materials and new quantum technologies. The new institute's work would be closely linked to the IFW's basic research on quantum materials. It is intended to build on the IFW's activities concerning e.g. nanomembranes, sensor technology and 2D materials from a quantum technology perspective.

While the idea behind the new institute in principle makes sense, it is currently very difficult to assess the precise aims and the distinction between this institute and the other projects already underway at the IFW. The role and function of the new institute, not least its relation to the existing institutes, would need to be fleshed out before submitting an application through the relevant process. As well as the three current IFW institute directors, the two institute directors who have yet to be appointed need to be involved in drawing up the application.

4. Controlling and quality management

Funding

The provision of institutional funding according to the administrative agreement between the federal and *Länder* governments is sufficient to cover the IFW's current portfolio of activities. Between 2018 and 2020 the institutional funding of the IFW totalled on average €32.2m p.a.

The IFW's third-party revenues represent 22 % (average 2018–2020) of the budget, a similar level to seven years ago (average 2011–2013: 24 %). A remarkably high proportion of third-party funding comes from the DFG (47 % of IFW's third-party funding, s. status report, appendix 3, p. A-30) and the EU or ERC (26 %). Grants from the federal and *Länder* governments also play an important role (19 %). **It is commendable that the IFW pursues a third-party funding strategy for starting new high-risk directions in basic research and to explore their potential. As recommended seven years ago, securing more funds from industry still ought to be pursued. Notably, in case of establishing a technology-oriented sixth institute an increase of funding by industry has to be achieved.**

Equipment

The IFW has an impressive array of complementary state-of-the-art and sophisticated techniques for materials synthesis, experimental measurements and materials characterisation.

Organisational and operational structure

Shortly before the last evaluation, the IFW suffered a serious management crisis. The interim director, an extremely experienced scientist who was brought in from outside at the time, played a key role in overcoming the crisis, as the Leibniz Association Senate noted in July 2016 in an interim report following the evaluation of 2014/2015. In April 2018, with the appointment of the director of the *IFW Institute for Solid State Research (IFF)*, the IFW governing bodies returned to the structure established before the management crisis to appoint the Scientific Director from among the five *institute directors*. This decision proved to be reasonable.

In view of the size of the IFW, a matrix structure is conceivable in which the five *institutes* are connected via *research areas* with sub-units called *research topics*. The IFW made use of this structuring principle at the time of the last evaluation. Its content has been modified somewhat since then, resulting, among other things, in five research areas being concentrated into four. Moving forward, the IFW needs to clarify what role the *research areas*, and especially the *research topics*, will play in future. At the moment, outsiders cannot see clearly whether the *research topics* are the central operational units of the IFW or whether they are intended rather to be loose connections linking the work across the five *institutes*. The interplay between the *institutes* and *research areas/research topics* as structural elements in the matrix should therefore be better defined.

Quality Management

The IFW's quality management is well aligned with the expected standards: The IFW follows the recommendations for good scientific practice as developed by the German Research Foundation (DFG) and adopted by the Leibniz Association. Furthermore, IFW implemented an Open Access Strategy in 2016. It uses the *LeibnizOpen repository* to list freely accessible publications by IFW authors as full texts.

As part of the Germany-wide initiative to establish a national research data management system, the IFW has also launched its own project with the DRESDA (Dresden electronic structure data lab) to digitise, verify and homogenise the wide range of existing experimental and computational data on materials.

Quality management by advisory boards and supervisory board

The Scientific Advisory Board (SAB) and the Board of Trustees accompany and support the work of the IFW conscientiously and fairly. The IFW's internal evaluation procedures ensure that each research unit is evaluated by the SAB once every three years. Each evaluation cycle of three years represents the audit that is required by the Leibniz Senate between two Leibniz evaluations.

5. Human Resources

The number of people employed at the IFW is practically the same as it was seven years ago: as at December 2020, the IFW employed 434 people, 270 of them in "research and scientific services" (cp. status report, page 31 appendix 4). It also employed 36 scholarship recipients, 48 student assistants and 27 trainees. The staffing levels and structure are appropriate for the current tasks.

Management

The IFW institute directorships are jointly appointed as W3 professorships with neighbouring universities. The three directors currently in place were appointed jointly with TU Dresden. The ongoing procedure to appoint a head of the *Institute for Complex Materials (IKM)* is also being conducted with TU Dresden. The directorship of the *Institute for Integrative Nanosciences (IIN)*, which recently became vacant, was previously a joint appointment with TU Chemnitz. The directors and governing bodies of the IFW now need to decide which university to work with for the new appointment.

Postdoctoral staff and doctoral candidates

It is good to see that beside W3 professorships for leading scientists the IFW has set up jointly hired junior and W2 professorships as a new instrument to promote young academics. Candidates were appointed to two such professorships in 2019, combined with junior group leader positions at the IFW. Also worth highlighting is the fact that in the three years from 2018 to 2020 alone, 13 IFW postdoctoral researchers were appointed to university professorships, of whom 6 were female and 7 male.

The IFW is an attractive environment for doctoral candidates as seen from the high number of PhD students from abroad (60 %, 78 out of 130 individuals). In line with the recommendations in the last evaluation, the IFW revised its principles for the supervision of doctoral candidates in 2017. As recommended, it now expects doctoral candidates to take part in structured doctoral programmes.

Science support staff

The highly skilled work of the science support staff at the IFW is essential to the IFW's success. So it is very good to see that the IFW has for a long time been intensively and continuously involved in training its science support staff. Between 2018 and 2020 alone, 11 trainees completed their training at the IFW.

Equal opportunities

Of the 270 employees and 36 scholarship recipients working in research and scientific services, 68 employees and 12 scholarship recipients (26 %) were women. At the time of the last evaluation this percentage was 27.7 %. The trend varies between the different levels of the hierarchy:

- The IFW institutes are led by male directors, as they were seven years ago. Since the last evaluation, there were no recruitments on this level, so that upcoming appointments have to be seen as chance for a clear improvement (see below).
- Of the other scientific positions with leadership roles (including junior groups), 31 % (14 out of 45 posts) were occupied by female scientists, an improvement since the last evaluation, when only 23 % (7 out of 31 positions) were occupied by women. It is encouraging to see that female scientists from the IFW have been appointed to professorships (see above).

- Of the remaining scientific staff (excluding doctoral researchers), 27 % of employees and scholarship recipients were women, a slight reduction compared with seven years ago, when 28.5 % of this group were women (2020: 30 out of 112 employees and 5 out of 16 postdoc scholarships; 2013: 28 out of 103 employees and 9 out of 27 postdoc scholarships).
- Of the doctoral researchers, at 31 December 2020, 24 % (30 out of 126) were women, compared with 29 % (41 out of 141) seven years ago.

26 % of the scientific positions at the IFW are held by female scientists. The IFW's achievement in increasing the number of female scientists at middle management level in recent years, as previously recommended, is recognised. However, in view of the overall ratio and the slight decline in female scientists in the rest of the scientific staff (including doctoral researchers) there is still a strong need for improvement. Opportunities to make a difference are emerging especially by the upcoming appointment of two, or maybe three, new institute directors.

58 % of scientific staff and scholarship recipients came to Dresden from abroad (177 out of 306 individuals). This situation is evidence of the IFW's high international reputation.

6. Cooperation and environment

Cooperation with universities

The IFW's university partnerships include close collaboration with TU Dresden, and collaborations with TU Chemnitz and TU Bergakademie Freiberg. The central structural element of these partnerships is the joint appointments of the IFW *institute directors* (see chapter 5). A particularly noteworthy cooperation project is the establishment of the Cluster of Excellence *ct.qmat* at the University of Würzburg and TU Dresden in 2019.

In the last years, the IFW has continued to develop its longstanding close relationships with universities. In 2019, the possibility of joint professorships was extended to TU Bergakademie Freiberg, where a temporary professorship has been established for an IFW junior research group leader. The recently renewed cooperation agreement with TU Dresden also provides for the possibility of establishing and filling joint professorships at W2 level for research group leaders at the IFW. An appointment procedure for a W2 endowed professorship is underway.

Other collaborations

The IFW has very good connections with other institutions in the Dresden research landscape besides the university. It is part of *Dresden Research and Education Synergies for the Development of Excellence and Novelty (DRESDEN-concept)*, an alliance between TU Dresden and 31 research and culture institutions. Since 2019, the IFW has started two projects in the field of biomedicine in collaboration with the Max Planck Institute for Molecular Cell Biology and Genetics in Dresden being funded in the context of ERC grants at IFW.

The IFW cooperates with other Leibniz Institutes, namely the Leibniz Institute of Polymer Research (IPF) Dresden, the Leibniz Institute of Photonic Technology (IPHT) Jena and the Leibniz Institute for Crystal Growth (IKZ) Berlin. The Helmholtz-Zentrum Berlin für Materialien und Energie (HZB) operates two permanent end stations at the high-resolution beamline BESSY II that were partly designed and constructed by the IFW. The IFW is also engaged in several EU projects and networks.

7. Subdivisions of the IFW

Subdivision 1: Exotic ground states and low-energy excitations in bulk systems

[23.2 FTE, of whom 16.3 FTE research and scientific services staff, 1.0 post-doctoral scholarship recipients, 3.7 FTE employed doctoral candidates, and 2.2 FTE service staff]

The subdivision very successfully conducts fundamental experimental and theoretical research into complex bulk materials with strong electron–electron correlations and entanglement of spin, charge, orbital and lattice degrees of freedom, their novel quantum magnetic phases and exotic excitations. The subdivision is characterised by a particularly fruitful collaboration between theory and experiment. Examples worth highlighting are the work on thermodynamics and on thermal transport in Kitaev materials. A close eye should be kept on overlaps and demarcations between the planned projects in subdivisions 1 and 13, and also subdivision 10. Subdivision 1 is firmly embedded in the Dresden research environment, especially through its involvement in the Cluster of Excellence *ct.qmat*, and is a major strength of the IFW.

Subdivision 2: Unconventional superconductivity: Mechanisms, materials & applications

[22.4 FTE, of whom 11.8 FTE research and scientific services staff, 3.3 post-doctoral scholarship recipients, 2.8 FTE employed doctoral candidates, and 4.5 FTE service staff]

Subdivision 2 very successfully conducts research on properties of unconventional superconductors. Research towards application includes the improvement of the materials themselves and the development of devices based on these materials. A particular highlight is the research to elucidate nematic correlations and the interplay with superconductivity. Also particularly notable are the experiments which found symmetry breaking in Fe-based superconductors, as well as the high-resolution ARPES study of this material which found the role of spin-orbit coupling using the high-quality single crystals grown at the IFW. The group is doing outstanding work in this field. By contrast, the work on applied superconductivity has had less impact so far. In terms of the research that has begun on superconducting 2D materials, the subdivision should keep an eye on overlaps with subdivision 13, and also with subdivision 10. Worth highlighting is the fact that the subdivision's successful work on the market introduction of a new spectrometer in 2019 led to a new spin-off company, Fermiologics.

Subdivision 3: Materials for energy storage and conversion

[44.7 FTE, of whom 15.0 FTE research and scientific services staff, 2.0 post-doctoral scholarship recipients, 12.3 FTE employed doctoral candidates, 5 FTE doctoral candidates as scholarship recipients and 10.4 FTE service staff]

Subdivision 3 concentrates very successfully on tailoring magnetic intermetallic alloys and compounds towards energy applications, and conducts electrochemical and structural studies on materials and devices for energy storage. Since the last evaluation, the subdivision has taken up research into rare-earth-free permanent magnetics, among other things. The excellent research in this area is being intensively supported via third-party funding secured through competitive processes. Among other things, the subdivision coordinates a *DFG priority programme*. The research work is regularly published in high-level journals. It is also highly relevant in terms of application, as reflected in a high number of patents. The ambitious plans for the future in the field of battery studies, crystal growth technology, and rare-earth-free permanent magnet composites are once again very promising, both scientifically and with a view to potential practical applications.

Subdivision 4: Engineering magnetic microtextures

[17.5 FTE, of whom 7.8 FTE research and scientific services staff, 1.0 post-doctoral scholarship recipient, 6.8 FTE employed doctoral candidates, and 1.9 FTE service staff]

Subdivision 4 focuses on understanding, and possibly targeted manipulation of, magnetically ordered states on the meso- and nanoscale with a view to applied magnetism. The excellent research work is based on various magnetic imaging techniques. Kerr measurement techniques have been developed since the last evaluation. They enable new studies of magnetisation processes and will support a new collaboration to determine DMI coupling films. The support from in-house theory is excellent and facilitates rapid development of techniques as well as guiding experiment.

The subdivision has an excellent publication rate with good presence in high-impact journals in the relevant fields. This output is based on significant growth in project funding since the last evaluation, with nine DFG and EU grants running.

Theoretical work, which pioneered some of the first research projects on skyrmion, is evolving in new directions for textures in complex magnetic spin systems. This development is extremely welcome. The enhanced imaging capabilities are also impressive and will enable new projects and opportunities for new research and transfer linkage. This is seen as a major strength of the subdivision and it will likely become a state-of-the-art leading facility with potential for broad impact.

Subdivision 5: Solidification, non-equilibrium phases/High strength and biocompatible alloys

[40.1 FTE, of whom 22.2 FTE research and scientific services staff, 1.0 post-doctoral scholarship recipient, 1.9 FTE employed doctoral candidates, 3.0 FTE doctoral candidates as scholarship recipients and 12.1 FTE service staff]

Subdivision 5 completely fulfils the goal of exploiting the complex development chain of material design, ranging from the fundamentals of physical metallurgy, materials engineering and surface functionalisation to the transfer of novel advanced materials and components to industrial application. Several application-related topics have been started since the last evaluation. The transfer of high strength materials through patents and close collaborations with industry is successful and is also documented through numerous national and international collaborations. Overall, the subdivision has achieved an outstanding balance between fundamental and highly developmental funding.

This balance must also be considered in future projects. So it is good to see plans to research e.g. basic principles of metastability in materials. The research work on additive manufacturing for biomaterials, which started recently, is also promising. The available infrastructure is excellent, as is the reasoning behind the plan to acquire XRD tomography.

Both the basic and applied research is very well supported through third-party funding and publicised at a high international level. Structurally, the subdivision benefits from the new joint professorship with TU Bergakademie Freiberg, which was set up after the last evaluation and is held by the head of the subdivision, which means the subdivision should also attract a higher number of doctoral researchers in the future.

Subdivision 6: Multifunctional inorganic nanomembranes/Flexmag

[33.6 FTE, of whom 11.5 FTE research and scientific services staff, 1.0 post-doctoral scholarship recipient, 7.1 FTE employed doctoral candidates, 5.0 FTE doctoral candidates as scholarship recipients and 8.9 FTE service staff]

Subdivision 6 focuses on challenges in the areas of multifunctional inorganic membranes. The excellent science performed in this group has made an outstanding contribution to the success of the IFW. Worth mentioning, among other things, is the lab-in-a-tube development of a variety of analytical devices with integrated electronics and microfluids providing advanced functionalities for single cell and single molecule analyses.

The subdivision's excellent research results are published in internationally highly visible journals. The subdivision is led by the director of the *Institute for Integrative Nanosciences (IIN)*. He was awarded the Leibniz Prize by the DFG in 2018, which is of considerable benefit to the subdivision. This director is leaving now, so the future development of the subdivision will depend to a great extent on how quickly an excellent replacement can be found (see chapter 2).

Subdivision 7: Micromotors and drug delivery

[9.3 FTE, of whom 4.4 FTE research and scientific services staff, 2.6 FTE employed doctoral candidates, and 2.2 FTE service staff]

Subdivision 7 conducts research on biocompatible microbots to perform medical tasks at the microscale, like cell transport or targeted drug delivery. Very successful work has been conducted in this subdivision since the last evaluation. Among other achievements worth highlighting are ground-breaking developments in technologies for 3D printing and the use of new materials for untethered micromotors with optimisations for efficient mobility through non-Newtonian fluids. The subdivision is highly productive with many significant publications in high-profile journals. This productivity is based in part on the successful acquisition of competitive third-party funding. In addition to DFG projects, an ERC grant is particularly worth mentioning.

This subdivision too is led by the director of the *Institute for Integrative Nanosciences (IIN)* and is heavily influenced by him. Its future development will therefore depend to a great extent on the individual recruited to replace him (see chapter 2). The plans presented for the next few years, for which he is responsible, are excellent. For example, a number of different organic and inorganic materials are planned to be investigated as well as more sophisticated microbots based on strain engineering with integrated sensing. Also, analysis and modelling activities are planned to be strengthened.

Subdivision 8: Thermoelectric materials

[21.3 FTE, of whom 6.7 FTE research and scientific services staff, 2.0 post-doctoral scholarship recipients, 4.1 FTE employed doctoral candidates, 2.3 FTE doctoral candidates as scholarship recipients and 6.2 FTE service staff]

Subdivision 8 has a strong track record in transfer and focuses on thermoelectric materials, from methods for measurement, through development of new materials, to the fabrication of reliable devices. The outstanding scientific work in the field of thermoelectrics deserves a special mention. The subdivision is a global reference in thermoelectrics research. And the developments in the direction of topological matter research, via collaborations building on the strengths of the IFW's materials and novel characterisation methods, are also welcome.

The excellent research results are very well published and are highly visible. A scientist in the subdivision secured an *ERC consolidator grant* in 2020. She has recently moved to the University of Bielefeld. Insofar, there is still potential for further increases in third-party funding. The group is excellent at translating its research into applications. This work is undertaken with a number of industrial and governmental partners, demonstrating true technology transfer.

Subdivision 9: Surface acoustic waves: Concepts, materials & applications

[20.6 FTE, of whom 16.2 FTE research and scientific services staff, 1.2 FTE employed doctoral candidates, and 3.2 FTE service staff]

Subdivision 9 develops very successful innovative concepts for new system designs based on precise analysis and physical modelling of wave excitation, propagation and interaction effects, including ones of a higher order. The work in this subdivision builds on the IFW's expertise in the field of surface acoustic waves (SAW) and comprises cutting-edge measurements of elastic properties of the new piezoelectric materials, prepared in-house by sputtering and other thin film methods.

The group has an explicit mission of technology transfer, which it fulfils in a convincing manner on the basis of a diverse portfolio of third-party funding. It is a founding member of SAWLab Saxony and expands the network of industrial and research and development centres working in SAW. The plan to intensify this work in the fields of life science and energy applications is very welcomed.

Subdivision 10: 2D systems, designed interfaces and heterostructures

[18.8 FTE, of whom 7.3 FTE research and scientific services staff, 1.1 post-doctoral scholarship recipients, 6.0 FTE employed doctoral candidates, and 4.4 FTE service staff]

Subdivision 10 aims to transfer the IFW‘s long-standing experience in bulk quantum materials to novel two-dimensional (2D) materials, which will be realised in the form of monolayers or interfaces. The comparatively new research unit is in the build-up stage, but can already demonstrate some very strong research results. For example, the work on the antiferromagnetic topological insulator MnBi2Te4 is notable. The subdivision is to be seen as an emerging area of research at the IFW.

The group's steps towards establishing chemically diverse 2D materials platforms are promising, as well as its initial work on magnetism and superconductivity in 2D materials. This subdivision has considerable overlaps with the established subdivisions 1 and 2, so its work should be better differentiated from these units and its profile sharpened.

Subdivision 11: Quantum and nano-photonics

[13.7 FTE, of whom 9.2 FTE research and scientific services staff, 2.3 FTE employed doctoral candidates, 1 FTE doctoral candidate as scholarship recipient and 1.2 FTE service staff]

Subdivision 11 conducts excellent research in quantum and nano-photonics. Pioneering work is being done on microelectronic and biomedical robots, energy and photonics. It has made mayor breakthroughs in tuneable quantum light sources, nanoplasmonics and demonstrated control of entanglement of photon pairs. The subdivision is also successful in the relevant area of non-Hermitian Hamiltonians in topological matter. It makes important contributions to the Cluster of Excellence *ct.qmat* and to quantum (communication) technologies. A particular strength is the way it successfully combines strong semiconductor physics with a photonic background.

The world-class research results are published in top-tier journals. Research is strongly supported by an impressive third-party funding portfolio. The highly beneficial collaborations at local, national and international level also deserve a mention. And it is good to see that this is a very attractive research area for young researchers.

The plans for further development make sense. The setup and application of TEM with a unique spectrometer will enhance the basic research aspect in the subdivision even further and many exciting results are to be expected from this instrument. Implementation will depend on who is appointed to lead the subdivision following the departure of the director of the *Institute for Integrative Nanosciences (IIN)*.

Subdivision 12: Functional molecular nanostructures and interfaces

[23.1 FTE, of whom 9.5 FTE research and scientific services staff, 1.0 post-doctoral scholarship recipient, 6.2 FTE employed doctoral candidates, 1.0 doctoral candidate as scholarship recipient and 5.4 FTE service staff]

The subdivision's activities and core results in the field of functional molecular nanostructures and interfaces are cutting edge. The subdivision plays a nationally and internationally leading role in the synthesis, isolation, and characterisation of endohedral metallofullerenes. Research conducted in this area has led to milestone contributions in spintronic applications of magnetic metallofullerences. Also worth mentioning is the work on organic semiconductors, molecular magnets and carbon nanotube yarns (CNY).

The excellent research results are very well published. The subdivision obtains a high amount of third-party funding, especially from the DFG and the EU. It is good to see that the subdivision is in demand as a national and international cooperation partner because of its excellent work. The plans for the future make sense.

Subdivision 13: Topological states of matter

[21.8 FTE, of whom 8.2 FTE research and scientific services staff, 2.6 post-doctoral scholarship recipients, 8.7 FTE employed doctoral candidates, 0.7 FTE doctoral candidates as scholarship recipients and 1.6 FTE service staff]

The subdivision carries out excellent work on conventional topology, a field of research that continues to thrive. The subdivision succeeds in producing results on band calculations and high-resolution ARPES that are excellent both from a theoretical and an experimental point of view. A close eye should be kept on overlaps and demarcations between the planned projects in subdivision 13 and the work in subdivisions 1 and 2.

8. Handling of recommendations of the last external evaluation

The IFW successfully addressed the recommendations from the last evaluation (see status report, p. A-25-27). The recommendations on industrial funding (recommendation 2) and female scientists (recommendation 4) still apply.

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)

Norbert **Suttorp**	Charité – Universitätsmedizin Berlin

Reviewers

Yoichi **Ando**	Institute of Physics II, University of Cologne
Dirk Michael **Guldi**	Chair of Physical Chemistry, Department of Chemistry and Pharmacy, University of Erlangen-Nürnberg (FAU)
Bernhard **Keimer**	Max Planck Institute for Solid State Research, Stuttgart
Annie K. **Powell**	Institute of Inorganic Chemistry and Institute of Nanotechnology, Karlsruhe Institute of Technology
Christian **Rüegg**	Paul Scherrer Institute and Department of Physics, ETH Zurich, Switzerland
Robert **Stamps**	Department of Physics and Astronomy, University of Manitoba, Winnipeg, Canada
Jörg **Schmalian**	Professor of theoretical physics, Karlsruhe Institute of Technology
Clivia M. **Sotomayor Torres**	ICREA Research Professor, Catalan Institute of Nanoscience and Nanotechnology, Barcelona, Spain
Kerstin **Volz**	Material Sciences Center, Philipps-Universität Marburg

Representative of the federal government

Jochen **Schneider**	Federal Ministry of Education and Research, Bonn

Representative of the Länder *governments*

Robert **Geiger**	Bavarian Ministry of Economic Affairs, Regional Development and Energy, Munich

12 January 2022

Annex C: Statement of the Institution on the Evaluation Report

Leibniz Institute for Solid State and Materials Research Dresden e. V. (IFW Dresden)

The Leibniz Institute for Solid State and Materials Research Dresden (IFW) thanks the members of the evaluation panel and the staff of the evaluation unit for their highly dedicated work of a profound assessment, which was carried out under the limited circumstances of the pandemic and confined to a substitute procedure without an onsite visit. We are therefore all the more pleased that the overall performance of the institute continues to be rated as very successful and that the concept for the further development of IFW is strongly supported. IFW welcomes the fact that its medium-term strategic plans, in particular the **establishment of 6th IFW institute**, are judged to be a reasonable for the further development and innovative strength of the institute. We will take up the suggestion to request the strategic expansion once the two director vacancies are filled and the new directors can be involved in the planning of the 6th Institute. Both **appointment procedures** are already underway, one of them being well advanced already. We firmly intent to fill at least one of the two director positions with a female scientist to take the overdue step to appoint a woman at the director level. The recommendation to **increase the share of women** also among doctoral researchers is taken very seriously and will be pursued rigorously.

The IFW agrees that **more funds from industry** still ought to be pursued and has already implemented further measures towards reaching this goal, e.g. the launch of a strategic partnership with the CEOS company including the financing of an endowed professorship on electron optics from 2022 on. An extra boost of industrial funding is pursued by establishing the 6th institute with a strong focus on application of quantum materials.

As far as the **matrix structure of our research program** is concerned, we will strive to make it even clearer in the future that internal cross-organizational networking is not only a matter of presentation but a lived practice that is fundamental to IFW's high performance. We are sure that this would have become even clearer during an on-site visit of the panel.