Faculty of Science and Engineering

Profile report: *Physics of Nanodevices (Fysica van nanodevices)*

- Discipline: *Applied Physics*
- Level: Assistant professor
- Focus: Research
- Fte: 1,0 fte

1. Scientific discipline

Physics of nanodevices explores new physical phenomena that occur in electronic, magnetic, spintronic, and opto-electronic device structures with nanoscale dimensions. The dynamics of electron transport in such devices is often quantum mechanical in nature, but much richer than the dynamics of isolated atoms due to interactions with the solid-state environment. The research investigates this quantum transport and related dynamics. The research is fundamental, but with an open eye for new device functionalities, for future applications.

2. Vacancy

This position is opened by the board of the Faculty of Science and Engineering (JF/mvo/26/00679) and will be embedded in the Zernike Institute for Advanced Materials basic unit "Physics of Nanodevices". The position falls within the framework of the faculty's career system Career Paths in Science and Engineering. As the focus domain of the position is research, the criteria of the career path with a focus on research apply. Please see the link for more information.

3. Selection committee (BAC)

Prof.dr. Maria Antonietta Loi, (Chair) professor Photophysics & OptoElectronics

Prof.dr. Thomas La Cour Jansen, director education, professor Computational Spectroscopy

Prof. dr. Bert Koopmans, professor Physics of Nanostructures, TU Eindhoven

Prof.dr. Tamalika Banerjee, professor Spintronics of Functional Materials

Prof. dr. Jianting Ye, professor Device Physics of Complex Materials

Prof. dr. Steven Hoekstra, Professor Experimental Quantum Physics

student member

Advisors: Dr. J.P. Birkner-Pfaffenroth, Femke Postma (HR)

4. Area of expertise

Two-dimensional (2D) materials and their van der Waals heterostructures have become a central research direction in modern condensed-matter physics, nanoscience, and quantum materials. Since the advent of graphene, a rapidly expanding family of atomically thin materials has emerged, offering complementary electronic, optical,

magnetic, spintronic and superconducting properties. When combined into heterostructures, these materials provide unprecedented opportunities to engineer interfaces and investigate emergent phenomena—including Ising and topological superconductivity, low-dimensional magnetism, spin–orbit coupling, optoelectronics and optospintronics and spin-dependent transport—while also creating a pathway towards future nanoelectronic and quantum technologies. This area is a strategic priority within the Zernike Institute for Advanced Materials, whose Quantum Materials programme explicitly includes 2D materials and spintronics.

Important are advances in deterministic assembly, interface control, lithographic device fabrication, and reliable electrical, optical, thermal, and magnetic characterisation. The presence of specialised crystal-growth activities and companies such as HQ Graphene at the Zernike Campus further strengthens Groningen's position as an international hub for this research.

A closely connected frontier is magnonic and skyrmionic spintronics, in which spin waves, or magnons, and topological spin textures such as skyrmions are used to generate, transport, manipulate, and detect information. This direction extends conventional spintronics beyond the use of electron charge and spin and addresses the fundamental coupling between spin, charge, heat, light, and topology. In particular, spin caloritronics investigates the interaction of thermal and spin currents in magnetic materials, including insulating ferromagnets and antiferromagnets. Current developments are directed towards the controlled generation, long-range transport, conversion, and detection of (magnon) spin information in dedicated devices and hybrid heterostructures combining magnetic insulators with two-dimensional, semiconducting, insulating, or metallic materials. Groningen has established expertise in these areas, including long-range magnon transport and the development of 2D spintronic devices. The phenomenon of chirality induced spin selectivity offers a new paradigm for the coupling between electron charge, spin and optoelectronic degrees of freedom

The proposed position is therefore needed to strengthen and broaden the institute's ability to address the next generation of questions in quantum materials and nanodevices. It would contribute to research on magnon spin transport in three-dimensional and two-dimensional ferro- and antiferromagnets; electronic spin transport and spin control in graphene and related 2D materials; proximity-induced magnetism and spin–orbit coupling in van der Waals multilayers; and spin–charge coupling in nanoscale chiral materials. These themes are strongly complementary to the existing research environment and create opportunities for collaboration across materials synthesis, theory, nanofabrication, magnetism, superconductivity, optoelectronics, and quantum-device research. They also build directly on Groningen's longstanding strengths in mesoscopic physics, quantum transport, graphene, and spintronics, superconducting proximity effects, and the manipulation of electron spin.

The position responds to a clear scientific and institutional need: to maintain international leadership in a rapidly developing field while connecting fundamental discoveries to scalable materials platforms and functional devices. The required expertise spans the complete research chain—from material growth, exfoliation, heterostructure assembly, and device fabrication to dedicated measurements under ambient conditions, and/or at low temperatures, and/or in high magnetic fields. Establishing this capacity at the professorial level is essential for developing an independent research programme, attracting competitive national and international funding, training the next generation of researchers, and strengthening collaborations with academic and industrial partners. In this way, the position will consolidate Groningen's role in quantum materials and spin-based nanotechnology while positioning the institute to respond to emerging opportunities in low-power electronics, information processing, and quantum technologies.

5. Embedding: institute (and base unit)

The position is created within the base unit Physics of Nanodevices at the Zernike Institute for Advanced Materials. The mission of the Zernike Institute of Advanced Materials (https://www.rug.nl/research/zernike/) lies in focused, curiosity-driven, symbiotic studies of functional materials involving researchers from physics, chemistry and biology. Our main driving force is the desire to understand how things work at the microscopic level, also known as the atomic and molecular scale. This is the realm of nanoscience and nanotechnology. In this field, the Zernike Institute for Advanced Materials covers the whole chain from synthesizing materials, building devices, characterizing materials and devices, and investigating the theoretical foundation of their properties. The base unit Physics of Nanodevices (https://www.rug.nl/research/zernike/physics-ofnanodevices/) includes the subgroups Physics of Nanodevices (Prof. B.J. van Wees), Spintronics of Functional Materials (Prof. T. Banerjee), Optospintronics of Quantum Materials (Prof. M.H.D. Guimaraes) and Physics of Quantum Devices (Prof. C.H. van der Wal). It has currently about 30 employees. Subjects of study are: (i) spin and charge transport in graphene, 2D materials and their heterostructures and devices, (ii) quantum optics, opto-electronics and spintronics in organic, inorganic semiconductors and oxide materials, (iii) spincaloritronics, (iv) (magnon) spintronics in magnetic nanodevices and insulating ferromagnets, and (v) charge and spin dynamics in semiconductor and organic systems, including (molecular) chirality induced spin selectivity systems, (vi) Twistronics-Moiré magnetism and magnetoelectric coupling in complex-oxide nanofilm stacks, (vii) Antiferromagnetic Spintronics with complex oxides.

Several facilities are available for the research, including the nanofabrication facilities of Nanolab NL (http://www.nanolabnl.nl/)

6. Local and (inter)national position

The Physics of Nanodevices group collaborates with several groups in the Zernike Institute on the study of magnetism, spintronics, superconductivity and

optoelectronics of 2D materials and oxide materials. Groups include the Photophysics and Optoelectronics group of Prof. Loi on (opto)electronics of carbon based materials, the Device Physics of Complex Materials group of Prof. Ye on study of properties (e.g. induced superconductivity) of 2D materials, the groups of Lo Conte and Grubisic Cabo on the (surface) science and spectroscopy of (functionalized) 2D materials, the group of Feringa on chirality induced spin selectivity, the groups of Prof. Noheda on skyrmionics and ferroelectric materials. There are also strong ties with the group Theory of Condensed Matter, especially with Prof. Mostovoy (skyrmions/skyrmionics) and Prof. Slawinska and Prof. Bauer (spintronics/spin-caloritronics). On the national level collaborations are present with other experimental and theoretical groups in the Netherlands e.g. through national programs on (magnon) spintronics and skyrmion physics. These include Prof. Duine at Utrecht University, Prof. Van der Sar at Delft University. The group also interacts with other spintronics groups in the Netherlands, including Prof. Prof. Koopmans and Prof. Flipse (TU Eindhoven) and Prof. Rasing (Radboud University). The group participates in the Dutch consortium Quantum Materials QuMat. International collaborations exist with various experimental and theoretical groups from the EU Graphene Flagship on electronics and spintronics of graphene and other 2D Van der Waals materials. This research aims to push the science and technology of 2D materials and devices towards future applications. In the area of spincaloritronics international collaborations exist e.g. with the groups of Prof. E. Saitoh (University of Tokyo), prof. G.E.W. Bauer (Tohoku University) and prof. J. Barker (Leeds University) on magnon transport and dynamics in various material systems.

7. Expected contributions to education

The candidate is expected to contribute to the teaching in the bachelor and master degree programs within the School of Science and Engineering. They are expected to participate in the teaching program of specialized courses in relation to Physics of Nanodevices and other related topics. Furthermore, the candidate will be involved in supervising bachelor, master and PhD students.

8. Expected contributions to research

The candidate is expected to initiate and develop a research program in one (or more) topics mentioned above. The research should have a visibility on the national and worldwide level and lead to publications in top journals. The research is expected to cross-fertilize the existing research within the institute (e.g. Prof. T. Banerjee, Prof. C.H. van der Wal, Prof. J. Ye, Prof. M.A. Loi, Prof. J. Slawinska, Dr. R. Lo Conte, and Dr. A. Grubisic-Cabo) and should lead to a strengthening of the international reputation of the group and the institute. Obtaining substantial external funding is crucial. Supervision of PhD students is an important part of the research activities. The research is expected to strengthen the existing efforts within the Zernike Institute for Advanced Materials in the field of Physics of Nanodevices and to take an international leadership role.

9. Expected contributions to the organisation

The candidate is expected to have an active interest and to provide a positive contribution to the management and organisational tasks of the institute. The candidate will furthermore contribute to the organisation of the faculty, for example by participating in working groups and committees, in the domains of education, research and management. The candidate will contribute to relevant organisational activities on the national and international level.