Registration form

This is a registration form for Host Institutions wanting to establish a Dioscuri Centre of Scientific Excellence within Dioscuri 4 call.

Registration form for Polish research institution

1. Research institution data (name and address): Jagiellonian University in Kraków, ul. Gołębia 24, 31-007 Kraków, Faculty of Physics, Astronomy and Applied Computer Science, ul. Prof. S. Łojasiewicza 11, 30-348 Kraków
2. Type of research institution[1] (select one from the 9 listed options):
   1) higher education institution
3. Head of the institution: **Prof. dr hab. Piotr Kuśtrowski, Vice-rector for Research of the Jagiellonian University in Kraków Poland**.
4. Contact information of designated person(s) for applicants and the NCN: first and last name, position, e-mail address, phone number, correspondence address: **dr hab. Szymon Pustelny, associated professor, Institute of Physics, Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, email: szymon.pustelny@uj.edu.pl, phone: +48 12 664 4691.**
5. Research discipline in which the strong international position of the institution ensures establishing a Dioscuri Centre (select one from the 25 listed disciplines):

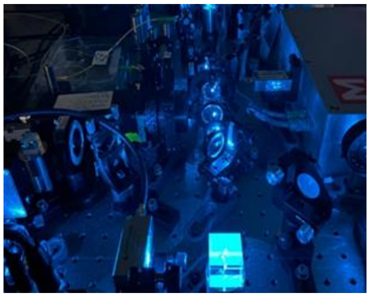
Natural Sciences and Technology

☐ **Fundamental constituents of matter**

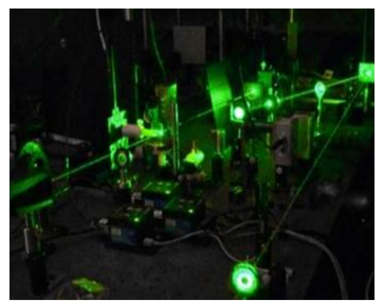
1 As specified in "Addressees of the call"

6. Description of important research achievements from the selected discipline

The Faculty's activity in the field of atomic, molecular and optical (AMO) physics involves both **experimental and theoretical investigations**. The employees tackle problems ranging from **ultracold gases**, through **spectroscopy of gases and color centers in diamonds**, **ultra-fast spectroscopy**, to **quantum metrology** and **quantum information theory**. Among all these, three (**analysis and applications of nonlinear magneto-optical phenomena**, **studies on color centers in diamonds**, and **investigations of time crystals**) are particularly interesting.



Analysis of properties of light, propagating through a dilute gas, allows for **ultra-sensitive magnetic-field measurements**, but also **enables extremely precise searches for nonmagnetic spin interactions**. If exotic fields or particles exhibit spin-dependent couplings, the latter enables **look for physics beyond the Standard Model**. In this scope, a couple of years ago, we proposed to **construct the network** of optical sensors separated by hundreds or even thousands of kilometers. Any correlation in readouts of the network's sensors, arising due to nonmagnetic origin, would **herald exotic physics**. We have also developed models, which investigate feasible theoretical scenarios which would lead to an appearance of such interactions.[1] In particular, the network allows us to **search for specific dark-matter candidates** (axion-like particles) and **test scenarios not explored to date**. In this manner the network, being the **first dedicated network seeking for exotic physics signals on the global scale**, is **a unique 'exotic' physics telescope**.



Another example of our research are nitrogen-vacancy (NV) color centers in diamonds. The research aims at **practical applications of nanodiamonds** for detection of magnetic fields and temperature measurements. We use NV-rich nanodiamonds to perform **high spatial resolution magnetometric study**.[2] Our goal is to **develop methods for measuring/imaging magnetic fields on a micro-scale**, e.g., those created by electronic integrated circuits or biological cells. We also develop techniques for **measuring the temperature inside living biological cells**, which will shed new light on biophysical processes occurring in vivo during normal cell functioning. By combining several technologies such as optical fibers, waveguides, microfluidic chambers, and nanodiamonds with biotechnological expertise of our partners, we strive to improve the existing biomedical sensors and develop novel diagnostic methods for medicine.

The most important aspect of AMO theoretical research at the Faculty concerns **time crystals**.[3] The time crystals are the **equivalents of ordinary space crystals**, that are characterized by a **temporal order arising as a result of spontaneous breaking of time translation symmetry**. The seminal work of our Faculty members has opened the field for **pioneering research on this new type of matter**. Our research includes studies of the ability to **generate and observed many different condensed-matter phases in time dimension** and **combine together crystalline structures in time and space**. Is the time-space electronics around the corner? – this is the question we are currently tackling.

<u>References</u>

[1] C. Dailey *et al.*, *Quantum sensor networks as exotic field telescopes for multi-messenger astronomy*, Nat. Astron. Nov. (2020).

[2] A. M. Wojciechowski et al., *Optical Magnetometry Based on Nanodiamonds with Nitrogen-Vacancy Color Centers*, Materials **12**, 2951 (2019).

[3] K. Sacha, *Time crystals*, Springer Nature Switzerland AG, 2020.

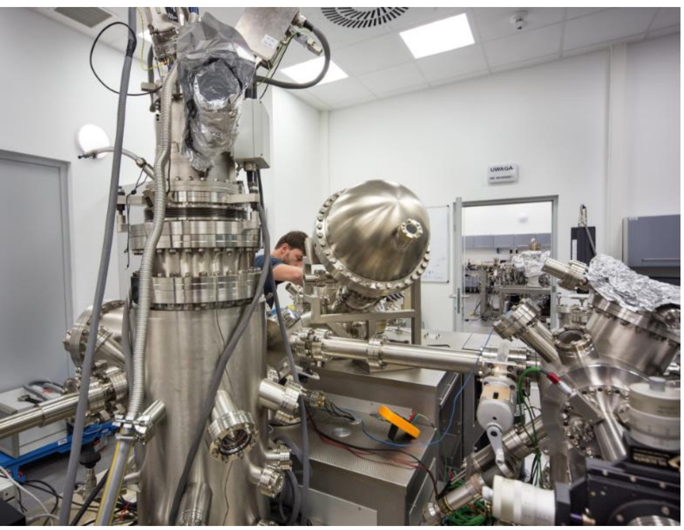
7. List of no more than 3 important research projects

ATOMIN 2.0 – Centrum badań materiałowych w skali ATOMowej dla INowacyjnej gospodarki, F. Krok, 79 981 297,17 PLN (20 856 999,3 PLN for Faculty of Physics, Astronomy and Applied Computer Science)

Zero and Ultra-Low Field NMR, S. Pustelny, Innovative Training Network – Horizon 2020, 2 769 371,28 EUR (448 274,88 EUR for Faculty of Physics, Astronomy and Applied Computer Science)

Nanosensoryka i obrazowanie z wykorzystaniem efektów kwantowych – synergia szkła i diamentu dla zastosowań w biodiagnostyce nowej generacji, R. Buczyński, FNP TEAM-NET, 18 647 075 PLN (4 665 000 PLN for Faculty of Physics, Astronomy and Applied Computer Science)

8. Description of the available laboratory and office space for the Dioscuri Centre



The Dioscuri Center will be located in the **building of the Faculty of Physics, Astronomy and Applied Computer Science (WFAIS) of the Jagiellonian University in Kraków**. The **building was commissioned in 2014 and its total area is over 26,000 m^2**, including classrooms, offices, laboratories, workshops, and a library. They are all arranged on three floors and they are accessible, among other, with freight elevators. The building and its facilities are fully adapted to the needs of disabled persons.

More than 90 high-class laboratory rooms are available in the WFAIS building. Each of these laboratories is connected to a central air conditioning system, and many have additional systems for precise temperature and humidity control. All laboratories are equipped with the most modern electrical and IT infrastructure as well as connections to the central water cooling and exhaust gas extraction systems. Among laboratories, a large part are those with higher cleanliness - **clean labs and shielded ones - Faraday cages**. On the lowest floor, there are a number of laboratories with **enhanced reduction of mechanical vibrations**. What is important and unique, there is also a **helium liquefaction station on site** that allows the recovery of gaseous helium and its condensation for re-use in laboratories for research at ultra-low temperatures.

Basically, in every Department there is an **electronic lab** where **various electronic systems and devices** are designed and built for the purpose of research

In the building there are **over 200 offices** and a dozen **15-20 person conference rooms** with fiber-optic network infrastructure and WiFi access to the internet. Office spaces vary in size and are designed for one to a maximum of four people.

There is also a **mechanical workshop** on the premises of WFAIS, where prototype test equipment is designed and manufactured, and many devices and measuring systems are repaired.

In the immediate vicinity (800 m) of the WFAIS there is the National Center of Synchrotron Radiation SOLARIS operated by the Faculty which offers research on several beamlines and end-stations.

9. List of the available research equipment for the Dioscuri Centre

No.	Device name	Company	Basic operating parameters
	LASERS AND LASER SYSTEMS		
1.	Continuous-wave Ti:sapphire laser	Tekhnoscan	Tunability within 690-1100 nm range (exchangeable optics), power up to 1.5 W
2.	Continous-wave Ti:sapphire laser	M-Squared	700-1000 nm, >2 W peak power, frequency doubling cavity w/ crystal for 470-480 nm light.
3.	Systems of contionous-wave diode lasers	Toptica, Moglabs, Sacher	Single-mode, tunable diode laser with a central frequencies 766 nm, 780 nm, 795 nm, 894 nm, power at the level of 100 mW (over 2 W in the case of 1 laser)
4.	Nanosecond single-mode Nd:YAG laser with SHG and THG	EKSPLA	3 ns pulse duration, 10 Hz repetition rate, 250 mJ @ 1064 nm, <0.01 cm^{-1} FWHM
5.	Nanosecond pulsed alexandrite laser with harmonic generator seeded by DFB diode laser.	Light Age	Pulse duration 100ns, repetition rate ~25Hz, FWHM: 30MHz. Tuning range 720-800nm (fundamental), SH: 360-400, TH: 240-266
6.	Nanosecond optical parametric oscillator (OPO)	EKSPLA	450 nm – 2400 nm, <2cm^{-1} FWHM, 1-20 mJ per pulse
7.	Nanosecond tunable dye laser Q-Scan	Quantel	FWHM <0.06cm^{-1} Fundamental range:355-740, Harmonics range: 200-320nm
8.	Nanosecond tunable dye lasers TDL90	Quantel	200-750nm tuning range, 10ns pulse duration, FWHM <0.1cm^{-1}
9.	Femtosecond Ti:sapphire laser Ti-Light with amplifier ODIN II with diagnostic tools	Quantronix (Spectra Physics)	750-850 nm, 25 fs pulse duration, 1 kHz repetition rate, 6 mJ energy
10.	CO2 laser	Synrad	10.6 mm, 100 W, CW
	DETECTORS AND SPECTROMETERS		
11.	High Speed Image Intensified CCD cameras, PI-MAX	Princeton Instruments	<500 psec gating, 1 MHz sustained intensifier gating repetition rate, UV-NIR spectral range
12.	SpectraPro HRS 750 spectrometer with PI-MAX4 1024f-SR Intensified CCD Camera	Princeton Instruments	Focal plane size: 14 mm x 30 mm Scan range: 0-1500 nm

No.	Device name	Company	Basic operating parameters
13.	Czerny-Turner spectrometer, Acton 2750	Princeton Instruments	180-900 nm spectral range, 750 mm focal length, <0.03 nm resolution
14.	Lock-in camera	Heliotis	Frame rate 4 kHz, demondulation frequency 2 – 250 kHz, Total number of pixels 90,000
15.	Time to Digital Converter, P7887 with MCDWIN software	FAST ComTec GmbH	<180 ps temporal resolution
	IMAGING SYSTEMS		
16.	Confocal microscope	TBA, Q2 2021	commercial confocal microscope w/ 4-lasers, galvo-galvo scanner, FLIM capability using ext. 520 nm laser
17.	Wide-field and confocal NV-diamond spectroscopy setup	home-made	Sprout-G 10 W, 532 nm laser, high-NA optics, modulators, MW sources, etc.
18.	LSM 710 Laser Scanning Confocal Microscope	Zeiss	4 laser light sources, fast scanning capabilities, FLIM system based on 405 nm pulsed laser.
19.	Atomic Force Microscope Agilent 5500	Agilent	All SPM modes of operation two scanners 10 and 100 micrometres
20.	Atomic Force Microscope Flex mounted on inverted optical microscope (Olympus IX50)	Nanosurf	100 micrometre scaner
21.	Near-field Scanning Optical Microscope, MV-1000	Nanonics Imaging Ltd.	100micrometer scanner, transmission, reflection and collection modes, tuning fork and beam bounce detection system
22.	Palm MicroTweezers – optical tweezers system	Zeiss	Infrared laser 1064 nm
	VARIA		
23.	Systems of magnetic shields	Various, e.g., Magnetic Shields	Numerous magnetic shields with passive shielding factor at the level better than 10-5, including man-sized shield
24.	Systems of optical magnetometers sensors	Quspin	Sensitivity at a level of 10 fT/Hz1/2, bandwidth of ~200 Hz, and dynamic range ±5 nT
25.	System for detection zero- and ultra-low field nuclear magnetic resonance	Homemade	Thermal and hyperpolarization (PHIP) of the sample, operation field (up to 100 μT)

No.	Device name	Company	Basic operating parameters
26.	Parahydrogen generator		Operation at liquid nitrogen, parahydrogen polarization (~50%)
27.	Rb magneto-optical trap system	home-made	2d+ & 3d MOT + optical dipole trap (50 W, 1070 nm)
28.	Spectroscopic ellipsometer SE 800	Sentech GmbH	350-800nm spectral range
29.	White Light Reflectance Spectrometer	Thetametrisis	Non-destructive film characterization (thickness, optical properties), equiped with fluid cell and heating stage
30.	Secondary Ion Mass Spectrometer ToF-SIMS V	IONTOF GmbH	Static and dynamic operation modes, surface chemical characterization, depth profiling, 2D and 3D chemical imaging
31.	The source of supersonic molecular beam containing Zn2 and ZnRg molecules	Measline	Max. operation temperature 1200K, Max. gas pressure: 6 bar
32.	The pulsed source of supersonic molecular beam containing Cd2 and CdRg molecules	Prevac/Measline	Max. operation temperature 900K, Max. gas pressure: 10 bar
33.	Empyrean Multi-Purpose Research X-Ray Diffractometer XRD	Malvern Panalytical	
34.	Rb magneto-optical trap, various configurations	home-made	either 85 or 87 isotope

10. List of the additional benefits

The Jagiellonian University in Kraków (UJ) is the **oldest** (almost 660 years old) and **second largest (35,000 students) university in Poland**. The students are educated at 16 faculties, covering fields ranging from mathematical and natural science, through humanities, to medical and biological sciences.

The **Faculty of Physics, Astronomy and Applied Computer Science (WFAIS)** currently educates over 1,000 students in **physics**, **astronomy, biophysics**, and **applied computer science** in **BSc**, **MSc** and **PhD programs**. The quality of the research at the Faculty is recognized by **scientific category A+**, which is the highest rank granted to a scientific institution in Poland. This is confirmed with 130 research grants (investment grants not included) currently realized at the Faculty at a total amount of over 260 million PLN.

In 2019, the University was awarded the title of **Research University**, which, besides a prestige, ensures **additional research funding** (10% in addition to a regular level). The additional funds are being distributed within the framework of the **Strategic Program Excellence Initiative**. The Faculty is directly involved in realization of 3 out of 8 so-called Priority Research Areas: Antropocene, SciMat, and DigiWorld. The programs, tackling different areas of science, offer numerous **funding opportunities**. In particulars there are **calls for research projects** up to 200,000 PLN, **maintenance and repair of scientific equipment funds**, **students scholarships**, t**ravel grants**, etc. All these programs aim at embracing research conducted at the Faculty and triggering applications for European and domestic grants. In this last context particularly important is the help of the **UJ Project Support Centre**, a dedicated administrative unit aiming at **support of researchers at a stage of preparation of grant proposals and successive management of the grants**. The experienced staff offers various trainings for researchers (hard and soft skills), as well as concrete help in preparation of research and investment applications.

Another important asset of the Faculty is the **National Synchrotron Radiation Centre SOLARIS** situated in a walking distance from the Faculty building. The Centre provides an access to two beam lines, providing soft X-rays radiation of controllable wavelength, polarization, and intensity. The Faculty is also cofounder and partner in **Facility for Antiproton and Ion Research**. The facility, currently under construction (commission planned in 2025), will enable research in nuclear, particle, atomic, anti-matter, and plasma physics with numerous applications for bio-sciences. The Faculty's staff is also involved in research at CERN, aiming at generation of extremely bright, ultra-high energy electromagnetic radiation based on the LHC infrastructure (**Gamma Factory**). If successful, this will provide a revolutionizing tool for research in particle, atomic, and nuclear physics both at fundamental and utilitarian level.

Centre for Technology Transfer is a dedicated unit focusing on helping in **commercialization of research** performed at the University. The Centre portfolio includes **promotion of the results among industry and business**, legal help in **know-how and intellectual property transfer**, and **coordination of the contact between the researchers and business and investors**.

The Jagiellonian University, being the largest employee at Małopolska region, provides **benefits to the current and retired staff members**, as well as, their **family members**. These include but is not limited to **summer and winter holiday benefit**, **holiday benefit for children and teenagers**, **crèche and kindergarten allowance**, **childcare subsidy**, **cash equivalent of Christmas presents for kids**, **home loans**, and **sport and leisure activities**.

11. Other information about internationalization of the institution

Being one of the largest university in Poland, the Jagiellonian University continuously **attracts students from various parts of the world**. A large group of foreigners currently studying at the University are representatives of **Eastern countries** (about 500 people). The students, out of which most comes from Ukraine and Belarus, are relatively uniformly distributed among the Faculties, but due to their Slavic origin, they study mostly in Polish. A different group of permanent international students attend the **School of Medicine in English** at the Faculty of Medicine. The School currently runs two programs (medicine and dentistry), which educates about 700 students from over twenty countries (mostly from the United States, Canada, and Norway). Besides the School, many faculties run programs in English (19 programs). Particularly, the Faculty of Physics, Astronomy and Applied Computer Science runs two such programs: **Theoretical physics** and **Advanced materials and nanotechnology**. The first studies (Theoretical physics) provides MSc candidates with a complete program (lectures, exercises and seminars) taught exclusively in English. The second English MSc program (Advanced materials and nanotechnology) aims at educating experts in technology and materials. The program provides the students with the opportunity to gain knowledge in the fields of physics, chemistry, materials science, and the basics of nanotechnology and develop skills applicable for nanomaterials, biomaterials, and photonics. In both programs, all classes (lectures, exercises, seminars) are exclusively taught in English, which offers the opportunity to both students and employees. Moreover, the students are graduating by preparing and defending their MSc thesis in English.

Another group of foreigners at the University are the **PhD students**. About **150 foreigner students** are currently working at the University, out of which **27 attend the Doctoral Schools**. Among them, many is based at the Faculty of Physics, Astronomy and Applied Computer Science and their number increases for many years. The newest students, who attend the Doctoral School of Exact and Natural Sciences, are being regularly trained through **series of lectures and seminars given in English**. The PhD students, being members of scientific communities, also transform dynamics of many groups and departments. Particularly, **many seminars in the Faculty are only given in English**, independently from the speaker's origin. English also becomes the **language of many research groups**.

Finally, the group of foreign employees at the university also increases. A prime example of such internationalization is the Małopolska Centre of Biotechnology, the University affiliated institution focused at innovative research in biological and medical sciences. About **1/3 of the total employees and students** associated with the Centre are foreigners. While staff-wise the number is significantly smaller at other Faculties, the situation is also changing. Particularly, in 2019, the University hosted **46 foreign professors** for at least one semester, who were both teaching and conducting research. The number of talks or shorter series of lectures is incomparably larger.

The internationalisation of the University successively increases and the process will continue in the future. This provides new opportunities for both teaching and studying, as well as conducting state-of-the-art research. This process will be particularly enhanced by domestic and international grants aiming at larger diversity. In this scope, the foundation of the Dioscuri Excellence Centre at the Jagiellonian University will be yet another step in the process.