

PHOTONICS AND MODERN IMAGING TECHNIQUES

RESEARCH PROGRAMME
ACADEMY OF FINLAND

2010–2013

Programme memorandum
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FOREWORD

At its meeting on 3 October 2006 to discuss the Academy's action plan and budget for 2008–2011, the Board of the Academy of Finland granted a negotiation mandate for preparations of a research programme under the heading of "Photonics and Modern Imaging Techniques".

A working group of experts who were to take charge of preparations was appointed in July 2007. The preparatory group was chaired by Professor Timo Jääskeläinen (University of Joensuu, Department of Physics, Academy of Finland Research Council for Natural Sciences and Engineering), and vice chair was Professor Tatu Juvonen (University of Oulu, Faculty of Medicine, Research Council for Health). The other members of the group were Professor Reijo Lahti (University of Turku, Institute of Biomedicine, Research Council for Biosciences and Environment), Professor Tuula Salo (University of Oulu, Faculty of Medicine, Research Council for Health) and Professor Kaisa Sere (Åbo Akademi University, Department of Computer Science, Research Council for Natural Sciences and Engineering). In addition, the following experts were invited to contribute to the preparatory group: Professor John Eriksson (Åbo Akademi University), Professor Ari T. Friberg (Helsinki University of Technology), Professor Pekka Hänninen (University of Turku), Professor Elina Ikonen (University of Helsinki), Professor Matti Kaivola (Helsinki University of Technology), Professor Risto Myllylä (University of Oulu), Senior Research Fellow Tapio Niemi (Tampere University of Technology), Professor Markus Pessa (Tampere University of Technology) and Professor Matti Pietikäinen (University of Oulu).

The preparatory group convened on three occasions and in addition communicated and coordinated their work via electronic media.

The Board of the Academy of Finland has allocated 9 million euros for the research programme to be used for project funding in 2010–2013. Three of the Academy's four Research Councils will be contributing to the programme, viz. the Research Council for Natural Sciences and Engineering, the Research Council for Biosciences and Environment, and the Research Council for Health. The programme is scheduled to run for four years.

1. BACKGROUND

Optics and optoelectronics are nowadays commonly grouped together under the generic heading of photonics. Photonics is the study of the generation and detection of light and the control of light propagation. Photonics research, then, is primarily geared to achieving maximum efficiency in the use of light both in industry and in people's everyday life.

As is evident from the definition above, practical application is an important element of photonics. In other words photonics is not just about signal detection, but also about the conversion of signals into a format in which the image data contained by the signal can be interpreted and used by the application in question. One of the biggest areas of applied photonics is imaging.

The field of imaging has grown out of multidisciplinary cooperation, but its roots lie firmly in physics. A whole range of professions are now involved in this field, including physicists, engineers, chemists, IT experts, physicians, life scientists and even psychologists. On the other hand most ordinary people also have everyday contact with photonics products, without which our society today would be very different.

Science and technology projects in the fields of photonics and imaging have and will continue to gain ever greater significance in society – they represent one of the fastest growing sectors of industry not only in Finland but around the world. In connection with the Finnsight 2015 foresight project in 2005–2006 by the Academy of Finland and the Finnish Funding Agency for Technology and Innovation Tekes, leading international experts in different fields set out to survey the change factors impacting Finnish society and Finnish business and industry, to identify future challenges in the fields of innovation and research, and to analyse key areas of competence related to science, technology, business and industry, and society. Among the areas singled out by these experts, several were related to the area of photonics and imaging. Similarly, many of the themes identified by the Government as core areas of interest for Strategic Centres for Science, Technology and Innovation (CSTIs), including ICTs, energy, forestry and health and welfare issues, are closely related to photonics and imaging.

New kinds of imaging needs are emerging all the time with increasing electronics integration, with the development of short range radio communications and with advancing manufacturing methods based on micro and nanotechnologies. Indeed, coupled with computational techniques and new methods for the interpretation of image data, it seems there is real potential now for the development of environmentally integrated image detection systems. These kinds of applications have previously been pursued using traditional techniques, but those techniques have precluded mass-produced applications at extremely low power consumption levels. The introduction of new methods in the manufacture of imaging detectors will also require major computational breakthroughs and innovations, which inevitably will have a bearing on the development of interpretation methods. The technologies pursued may have very wide ranging application potential.

Europe has played a pioneering role in the field of photonics and is determined to remain in that role. To coordinate development efforts a European Technology Platform called Photonics 21 has recently been founded to establish Europe as a leader in areas of research where photonics plays a prominent role:¹

- Information and Communication
- Lighting and Displays
- Industrial Production / Manufacturing and Quality

¹ Photonics21 - European Technology Platform "Towards a Bright Future for Europe, Strategic Research Agenda in Photonics"

- Life Sciences and Health
- Security, Metrology and Sensors

There is, inevitably, much overlap between these areas. The aim of Photonics21 is to coordinate research and development activities across Europe, covering all aspects from education and training and basic and applied research through to manufacturing and applications.

Under FP7, photonics research is carried out in two programmes, viz. Information and communication technologies (ICT) and Nanosciences, nanotechnologies, materials & new production technologies (NMP). The main driving forces in these fields are the major European countries as well as Japan and the United States. Finland has a relatively strong position in basic research, indeed in some areas it competes at the international cutting edge.

Photonics research, therefore, has high relevance and currency, and the Research Programme launched by the Academy comes at an opportune time to boost the development of Finnish research and its international competitiveness.

2. AIMS OF THE RESEARCH PROGRAMME

The themes for the Research Programme have been selected with a view to providing as comprehensive coverage as possible of the imaging process, from the generation of the optical signal through to the interaction between light and materials and its use in practical applications. A special area of interest lies in photonics applications in life sciences and medicine. The themes of the programme are described in Chapter 3 below.

Apart from aiming to deliver high quality scientific knowledge, another objective of this programme is to facilitate and enhance dialogue between industry and academia with a view to supporting and strengthening basic research. At the same time, this will help to create mechanisms for the fast and effective application of new knowledge. The programme will support graduate students in doctoral training and more advanced researchers, promote the international networking of researchers and support national multidisciplinary cooperation.

The principal aims of the Research Programme are to:

- generate internationally significant research knowledge in different areas of photonics
- steer Finnish research towards the development of innovative photonics and imaging methods and solutions
- improve scientific skills and knowledge and research environments in areas that contribute to the development of photonics research in Finland

Other programme objectives are to:

- facilitate the creation of new multidisciplinary research teams and national and international research networks
- increase the mobility of doctoral students and researchers
- strengthen the international competitiveness of Finnish research and industry
- establish Finnish research at the cutting edge in some areas of research

3. THEMES OF THE RESEARCH PROGRAMME

The Research Programme covers a broad range of photonics research areas from the interaction between electromagnetic radiation and materials through lighting and display technologies, signal detection technologies and new imaging techniques to the study of photonics applications. In the field of detector technologies, one promising area of research and development is offered by new optically sensitive materials and interaction processes. New imaging techniques may have application in connection with the detection, storage or analysis of image data, possibly coupled with the use of modelling techniques. Special

areas of application in the programme include the use of photonics techniques in life sciences and medicine. Applicants are encouraged to submit proposals for interdisciplinary research projects.

The programme themes break down into three main categories:

- Optical materials and interaction processes
- New imaging techniques
- Photonics in life sciences and medicine

3.1 Optical materials and interaction processes

Optical materials research is here understood as comprising basic research as well as work aimed at developing the materials that are needed for photonics applications.

The phenomena investigated may be either linear or non-linear. They can be either nano or microscale phenomena, or phenomena occurring within material that can be used to generate and process light. The materials can be either biological, inorganic or organic. The internal and surface properties of materials are modifiable so that they direct light in the desired direction, or so that they generate light. Another possible area of research is shaping the characteristics of light sensitive material.

Examples of relevant research subjects under this heading include:

- Research on optically active materials, e.g. metamaterials and optically sensitive biomaterials
- New imaging techniques based on coherence, polarization and quantum effects
- Lighting and display technologies
- Functional materials

3.2 New imaging techniques

New imaging techniques refer to methods that make use of spectroscopy, coherence, polarization or other additional data sources which require that processing of the information has to be multidimensional (as distinct from two-dimensional image material). Improving the spatial and temporal resolution in known imaging methods is also important in applications designed for real-time imaging of cellular and molecular level phenomena. Because of the large volumes of image data involved, it may be necessary to develop new methods of signal processing, data packing and data transfer. The same applies to methods for the interpretation and classification of image data.

New imaging techniques are not necessarily confined to optical domain signals, but the generic nature of these methods means that they can be applied to other signals that are processed in a corresponding manner.

Relevant research themes under this heading include

- development of methods using new measurements and near field effects
- packing, storage, classification and recognition of image data
- addressing imaging needs arising from biologically relevant applications in life sciences and medicine
- new imaging methods emerging from ubiquitous technologies

3.3 *Photonics in life sciences and medicine*

Biophotonics is understood as referring to the use of photon techniques in life sciences and medicine. A multidisciplinary approach to addressing a given problem fits in well with this line of inquiry aimed at specific applications.

Examples of research subjects

- photon diagnostics and therapy
- optical manipulators (optical tweezers, generation and destruction of objects)
- new approaches to real-time imaging of living objects and monitoring moving objects (organ imaging, tracking and imaging individual molecules)
- new methods in medical diagnostics and cell biology applications

4. *IMPLEMENTATION OF THE RESEARCH PROGRAMME*

4.1 *Programme funding*

The Research Programme on Photonics and Modern Imaging Techniques is funded by the Academy of Finland and coordinated by a Programme Manager based at the Academy. The programme is scheduled to run for a period of four years, with funding made available from 2010 to 2013. The Board of the Academy of Finland has earmarked 9 million euros for allocation to the programme.

4.2 *National cooperation*

The Research Programme is linked with the Tekes-funded Functional Materials research programme and with the imaging themes under the Pharma programme. Practical cooperation will be facilitated by the Programme Steering Group.

The Research Programme also has points of contact with the Academy's ongoing research programmes in the fields of nanoscience (FinNano, 2007–2010) and sustainable energy (SusEn, 2008–2011), as well as with the Computational Science Research Programme that is starting up simultaneously with this programme.

4.3 *International cooperation*

The Academy will seek opportunities for international funding cooperation in order to improve the foreign contacts of Finnish research. Over the next few years the Academy's major partners in cooperation will include India, Japan, China and Russia as well as Canada, the United States, Brazil and Chile, where steps will be taken to further intensify cooperation among the bodies funding this research. The Academy's Research Councils have submitted proposals for cooperation in the field of photonics with Brazil, India, Japan, China and Russia.

Joint calls with Brazil, Japan and China are planned for 2009. Additionally, the ERA-NET (ERA-Neuron) call scheduled for 2009 will probably be integrated with the Research Programme. Preliminary talks have been held with Russia on joint projects and a possible joint call for applications in 2010. Cooperation with other countries is also possible and encouraged.

4.4 *Timetable*

Projects involved in the Research Programme will be funded during 2010–2013. Funding terms will start no later than 1 January 2010 and end no later than 31 December 2013. The evaluation of the Research Programme will be carried out in 2014.

Applications to the Research Programme will be processed in two stages. Letters of intent for the first stage shall be submitted to the Academy no later than 30 January 2009 by 16:15. The evaluation criteria for letters of intent are scientific quality and how well the proposed projects ties in with the topic of the research programme, and its contribution to realisation of the programme objectives; based on these, the Programme Steering Group will select the applicants that are invited to submit a full application by 15 May 2009 at 16:15. Funding for the selected projects will be available from 1 January 2010.

The preliminary timetable for joint international calls is as follows. In 2009 bilateral calls will be opened if and as possible with Brazil (micro and optoelectronics), China (signal processing) and Japan (functional materials) and with ERA-Neuron (neuroscience imaging). Preparations are under way for a joint call with Russia in 2010. The final themes and timetables for these calls will be issued later and posted on the programme website at www.aka.fi/fotoniikka

4.5 Programme steering group

The programme steering group is composed of Academy Research Council members, representatives of other funding bodies participating in the programme and expert members. Other experts may also be invited to contribute to the steering group's meetings. The composition of the programme steering group will be available in January 2009 on the programme website at www.aka.fi/fotoniikka.

The duties of the programme steering group are:

- to steer and monitor the programme,
- to prepare the process for evaluating applications,
- to submit a proposal to the responsible funding bodies concerning the projects to be funded,
- to submit proposals for supplementary calls for applications and/or additional funding to the Research Councils and other funding bodies if necessary,
- to submit proposals for projects to be added to the programme at a later date,
- to plan and organise the final evaluation of the programme,
- to steer and support programme coordination,
- to promote the utilisation of research results.

4.6 Programme coordination

The aim of the programme is to help the research projects involved develop into a coherent and cohesive structure through active exchange of information and collaboration. The leaders of the projects selected to take part will therefore be required to commit themselves to the goals of the programme and to cooperate actively throughout the programme and during the programme evaluation.

The responsible leaders of the projects taking part in the programme shall:

- assume responsibility for and report on the scientific progress of the project and the use of funds according to the instructions of the programme manager and relevant funding bodies (including annual reports and final reports);
- ensure that the responsible leader and the whole research team attend all meetings, seminars and workshops organised by the programme, and facilitate exchange of information and cooperation between the research teams in the programme;
- take part in producing reviews, syntheses and information material on the research programme; and
- actively disseminate information about the programme's progress and results on public and scientific forums.

In cooperation with the projects involved, the programme manager of the research programme seeks to promote the implementation of the aims set for the programme. The programme manager coordinates the flow of information and promotes researcher cooperation between the projects. Key means of communication include joint seminars, workshops, researcher training events and electronic media.

The Programme is coordinated by the Academy of Finland and Programme Manager Anssi Mälkki.

4.7 Final evaluation

The implementation and results of the research programme will be evaluated upon completion of the programme. The aspects to be considered in the final evaluation include:

- Attainment of the programme's objectives
- Implementation of the research programme (coordination, role of steering group, programme activities)
- Scientific quality of the programme output
- Results and impact, integration of results and synthesis on the programme level
- Scientific, social and economic impacts of the programme
- Researcher training and the advancement of research careers
- National and international cooperation
- Communications.

The research teams receiving funding from the programme are required to report on the progress of their projects on an annual basis or in accordance with the steering group's decision, and submit a final report to the Academy of Finland upon the completion of the projects. The reports shall include information on, for example, scientific publications produced as well as theses and doctoral dissertations completed within the programme.

5. APPLICATION PROCEDURE AND PROJECT EVALUATION CRITERIA

The research programme has a two-stage call. Letters of intent shall be submitted via the Academy's online service no later than 30 January 2009 by 16:15. The application deadline is strict.

The application and its appendices shall be drafted in English via the online services at www.aka.fi > For researchers > Log in to online services. Then select *New application* > Photonics and modern imaging techniques.

The Academy will select the applicants that are invited to submit a full application on the basis of the letters of intent by the beginning of March 2009. Applicants that have been invited to submit a full application will be able to do so via the Academy's online services on 20 April 2009 at the earliest. The application deadline for full applications to the research programme ends on 15 May 2009 at 16:15. The application deadline is strict.

The call for applications is open both to individual research teams and to consortia made up of several research teams. This is a two-stage call. Funding applications submitted to the Academy are required to comply with:

1. The general guidelines applicable to all calls that will be given in the Academy of Finland's January 2009 call
2. The detailed guidelines on submitting an application that are available under www.aka.fi/eng > For researchers > How to apply > Guidelines

3. The detailed information on the format and length of appendices that is available under www.aka.fi/eng > For researchers > How to apply > Appendices
4. This research programme memorandum

5.1 Letters of intent

The Academy's online service will open for applications on 5 January 2009 and letters of intent shall be submitted via the online service no later than 30 January 2009 by 16:15. Only the requested appendices are appended to the application. The appendices shall be drafted in accordance with the Academy's guidelines.

The evaluation criteria for letters of intent are how well the project ties in with the topic of the research programme, its contribution to realisation of the programme objectives and the project proposal's innovative value and applicability. The Academy will select the applicants that are invited to submit a full application by the beginning of March 2009. The Academy will post information on the selection on its website and notify applicants of its decision in writing.

5.1.1 Letter of intent by one research team

- Online application form

Appendices to the application:

- a plan of intent, no more than four pages in length
- the CV of the responsible project leader, no more than four pages
- the list of publications of the responsible project leader, with the ten most important publications in terms of the research plan clearly indicated.

5.1.2 Letter of intent by a consortium

Only the consortium leader submits a letter of intent.

- Online application form

Appendices to the application:

- the consortium's plan of intent, no more than six pages in length
- curricula vitae for the consortium leader and the responsible leaders of the sub-projects, combined as one document, no more than four pages for each researcher
- lists of publications of the consortium leader and the responsible leaders of the sub-projects, combined as one document, with the ten most important publications in terms of the research plan clearly indicated for each leader of a sub-project

5.2 Full applications

The Academy's online service will open for the projects invited to the second round of application on 20 April 2009 and the deadline for applications is 15 May 2009 at 16:15. The application deadline is strict.

Only the requested appendices are appended to the application. The appendices shall be drafted in accordance with the Academy's guidelines.

5.2.1 Full application by one research team

- Online application form

Appendices to the application:

- an abstract, no more than one page in length
- a research plan, no more than 12 pages
- the CV of the responsible project leader, no more than four pages
- the list of publications of the responsible project leader, with the ten most important publications in terms of the research plan clearly indicated
- statement by an ethics committee or the Committee on Animal Experimentation, if relevant
- a progress report for any research projects with Academy funding that the responsible project leader is involved in and for which no final report has yet been submitted
- an invitation from a foreign university or research institute if the research is conducted abroad.

5.2.2 Full application by a consortium leader

- Online application with which funding is applied for only for the consortium leader's own research team.

Appendices to the application:

- an abstract drafted in accordance with the consortium guidelines, no more than one page
- a research plan drafted in accordance with the consortium guidelines, no more than 15 pages
- curricula vitae for the consortium leader and the responsible leaders of the sub-projects, combined as one document, no more than four pages for each researcher
- lists of publications of the consortium leader and the responsible leaders of the sub-projects, combined as one document, with the ten most important publications in terms of the research plan clearly indicated for each leader of a sub-project
- statement by an ethics committee or the Committee on Animal Experimentation, if relevant
- a progress report by the consortium leader and the responsible leaders of the sub-projects on their Academy-funded research projects for which no final reports have been submitted, combined as one document
- invitation by a foreign university or research institute, in case the research is conducted abroad

5.2.3 Application by responsible leader of a sub-project of the consortium

- Online application with which funding is applied for only for the research team of the responsible leader of the sub-project
- No appendices are to be appended to the application of a sub-project. The consortium leader collects and combines all appendices of the consortium as part of his/her application.

5.3 Evaluation criteria

The scientific quality of the applications will be reviewed by an international panel of experts. The criteria applied include:

- project compatibility with the research programme,
- scientific quality and innovativeness of the research plan,
- feasibility of the research plan,
- national and international contact network of the applicant/research team/consortium,
- researcher training and advancement of the research environment,
- competence and expertise of the applicant/research team/consortium, and
- in the case of a consortium application, the added value generated by the consortium.

The detailed instructions for how to evaluate applications that are given to the experts on the panels are available on the Academy website at www.aka.fi > For researchers > Reviewing applications? It is useful to read these before submitting an application.

6. MORE INFORMATION

This programme memorandum is available both on the Academy of Finland website at www.aka.fi and from the Academy Registrar's Office.

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