

Annual Report
2010 - 2011

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Chairpersons' review

The rapid progress of globalisation and technological development has altered the operational environments of companies and organisations at an unforeseen rate. Competition is becoming fiercer and the population more centralised in all sectors of society. Such developments force businesses and training and research organisations to focus on their strengths while simultaneously restructuring their operations. Kainuu has already experienced the impacts of structural redevelopment: some existing structures and operations have been relinquished but nevertheless new, compensatory activities have also been created. This indicates that Kainuu's main operators are able to recognise and exploit future opportunities.

Change is never easy, but it generates opportunities. A fitting example of such success is CEMIS where it has been possible to functionally unite university level measurement and information system research, training and innovation operations forming a single umbrella organisation. The results of the first year of operations, evaluated with different impact indicators, have been excellent. For this we thank all those involved in starting up CEMIS for their work, support and shared enthusiasm in building something new and genuinely impressive!

CEMIS indicates how a university of applied sciences, two universities and two state research institutions with their open-minded *modus operandi*, can produce genuine added value for the region and parent organisations. Higher education, business and commercial and regional policy related objectives have successfully been united in CEMIS. Each brings their own strengths creating a strong and comprehensive competence hub in se-

lected fields. Kainuu has now advanced to the new type of innovative regional cooperation through structural and operational change, which the state will require throughout Finland in the future.

All things considered, CEMIS cooperation is a question of a shared, powerful state of willingness to confront future challenges. Each has their own role and all are strongly committed to cooperation. The operations have clear objectives. Necessary structural reforms have been implemented to achieve these objectives. We believe in CEMIS' powerful and successful future although undoubtedly the austerity of the state economy will also be felt.

CEMIS is systematically becoming a creative training and research environment offering a perfect arena for university students to complete theses and conduct a variety of research and development projects. The central objective is to integrate students nearing the end of their studies into the commercial and business life of Kainuu, thus guaranteeing the availability of a competent labour force. Such work requires the efforts of us all.

Our work goes on, together and in cooperation!

Lauri Lajunen

Rector

University of Oulu

Turo Kumpulainen

President

Kajaani University of Applied
Sciences

CEMIS (the Centre for Measurement and Information Systems)

CEMIS (the Centre for Measurement and Information Systems) is a contract-based joint measurement and information system research and training centre involving two universities (the Universities of Oulu and Jyväskylä), two research institutions MIKES (the Centre for Metrology and Accreditation) and VTT (Technical Research Centre of Finland) and Kajaani University of Applied Sciences. CEMIS consists of Oulu University's Metrology Unit, Kajaani University of Applied Sciences' Information Systems competence area, the Kajaani sites of MIKES and VTT and the measurement technology development operations of Jyväskylä University's Sports Technology Unit.

The Metrology Unit includes all of the Oulu University technological research units situated in the Kajaani district. The Information systems competence area comprises Kajaani University of Applied Sciences' information technology teaching and R&D functions. The MIKES Kajaani site was established to develop industrial metrology and to maintain selected national measurement standards. VTT's Kajaani office specialises in the development of vehicle sensor and data transfer solutions. Jyväskylä University's Units provide training and implement R&D in the field of sports technology. The aforementioned five organisations as well as the City of Kajaani and the Municipality of Sotkamo are committed to CEMIS' operations. CEMIS is one of Oulu University's innovation centres and the only one outside the City of Oulu. Oulu University has concentrated its Kainuu based technology related research and development operations in CEMIS. Where Kajaani University of Applied Sciences is concerned, CEMIS is its most significant form of inter-university and research institution cooperation and focus of development. For Jyväskylä University, MIKES and VTT, CEMIS is a form of regional cooperation. The structure of CEMIS is presented in figure 1.

CEMIS focuses on nationally significant fields of application such as the extractive industry, the renewable chemical and mechanical forest industry, vehicle information systems, sports and wellbeing, and the develop-

ment of game and simulation technology measurement and information system competence. CEMIS' goal is to be Finland's leading research and education centre specialising in measurement and information systems within selected cutting-edge fields by 2015. With the aid of such comprehensive cooperation-based research and development services and higher education offered by the competence and innovation hub located in Kainuu, CEMIS is aiming to create internationally significant expertise as well as new technology and commercial activities.

The aim of establishing the centre is to increase the attraction, competitive edge and impact of measurement and information system research and training provided by the parties to the contract. Establishing the centre has enabled the coordination of operations, cooperation and division of labour between the parties involved, the use of shared resources and the visibility of operations.

The centre is aiming for a responsible position in the research, training and innovation operations of its parties and within cutting edge fields, a leading national and powerful international position. In order to achieve these aims, CEMIS has set quantitative operational targets for R&D, education and innovation activities covering the centre as a whole and each participating organisation. The main tool used during the start-up of CEMIS has been the CEMIS Development Programme, which defines actions to increase the coordination of activities, to increase cooperation and division of labour between parties, as well as the use of shared resources and the visibility of operations. The growth of quality, attraction, competitive edge, and impact is monitored using CEMIS' participant organisations' own national indicators.

At the beginning of 2011, a two-year € 4.9 million development programme commenced that was mainly funded by the East Finland ESF and ERDF programmes and the Kainuu Development Fund. CEMIS' total funding is over € 10 million and it comprises self-financing from the participant organisations, regional development

funding (e.g. the CEMIS development programme) and competitive external funding. Almost 120 measurement and information system experts are employed by CEMIS.

Measurement and information systems are the cutting edge of technological expertise in the Kajaani district. In addition to CEMIS, a company owned by the City of Kajaani specialising in measurement and information systems business development, Measurepolis Development Oy and about 15 other companies operate within the same field.



Figure 1 The structure of CEMIS – the Centre for Measurement and Information Systems



CEMIS' joint activities, as stated in the action plan, consist of a shared leadership system, a joint development programme, R&D cooperation, education cooperation, developing joint R&D environments and facilities, cooperation within device development and chemical laboratory operations, joint marketing and communication and the joint commercial exploitation and promotion of R&D outcomes. The following briefly describes how joint operations within different areas have developed during the years 2010 – 2011.



CEMIS Leadership System

The CEMIS leadership system consists of a Strategy Group, management group and groups of experts appointed to CEMIS' three fields of focus. The group members and their position are presented in figure 2. The Strategy Group, comprising the top management of CEMIS' participant organisations, monitors and directs CEMIS' operations and secures appropriate resources from each member organisation. The members of the CEMIS Strategy Group are Lauri Lajunen, Rector and Vesa Virtanen, Director of Kajaani University Consortium from the University of Oulu, Turo Kilpeläinen, president and Merja Mäkinen, Director of Administration and Finance from Kajaani University of Applied Sciences (KUAS), Timo Hirvi, Director General of MIKES, Professor Jussi Paakkari, Vice President, R&D, ICT from VTT, Professor Janne Avela from the University of Jyväskylä, Jari Tolonen, City Manager of Kajaani and Petri Kauppinen, Municipal Manager of Sotkamo. Rector Lajunen and President Kilpeläinen take turns to chair Strategy Group meetings.



CEMIS Strategy Group

Lauri Lajunen/Oulu University, Vesa Virtanen/Oulu University, Turo Kilpeläinen/KUAS, Merja Mäkinen/KUAS, Timo Hirvi/MIKES Jussi Paakkari/VTT, Janne Avela/Jyväskylä University, Jari Tolonen/Kajaani, Petri Kauppinen/Sotkamo

Director of CEMIS, Risto Oikari

Management group

Heikki Isotalo/MIKES, Vesa Linnamo/Jyväskylä University, Vesa Virtanen/Oulu University, Jari Kähkönen/KUAS, Timo Lehtikainen/VTT



Figure 2 CEMIS Leadership System



Director's review

Risto Oikari, Director, CEMIS

CEMIS' operations started officially with the signing of the CEMIS Co-determination Agreement on 17.9.2010. Operations commenced at the beginning of 2011 when the organisations participating in CEMIS started their work within the structurally and legally renewed organisation. At this point the two-year CEMIS development programme also started.

The start-up of CEMIS' has been extremely successful although it has required significant operational and structural changes in the units involved. The basis of CEMIS' operations is the strong commitment demonstrated by all five organisations involved from top management level, a jointly compiled and approved action plan and a comprehensive joint development programme.

During the first one and a half years, all of CEMIS' target forms of operation have started-up successfully. Work at MIKES' Kajaani Unit has fully begun and produced results. The organisation of the Information Systems competence area of Kajaani University of Applied Sciences and Oulu University's Metrology Unit CEMIS Oulu is now complete. Jyväskylä University has been able to take charge of sports technology measurement research and development operations within CEMIS. VTT has widened its responsibilities as a developer of wireless measurements and information systems. CEMIS' joint operations, such as the Strategy and Management Groups, the work of the field of focus expert groups, cooperation in R&D operations, project coordination, joint marketing and communication, business development, the development of shared facilities and environments and training cooperation have all progressed according to plan.

CEMIS' development programme, which has a central role in reinforcing the aforementioned forms of cooperation, has progressed as planned albeit with a delay of several months in some parts. The main cause of delay was the need for resources to complete previously

commenced development projects and for resources to start new schemes implemented with external research funding. However, by the end of 2012, the CEMIS Development Programme is expected to reach all set targets although with slightly less resources than originally planned.

In addition to the development programme, CEMIS has **almost 20 continually ongoing technological development projects implemented with the aid of national and international public funding as well as business financing**. New technological projects are continually being prepared with national and international and business partners in cooperation. In 2011, CEMIS prepared almost 50 project proposals, implemented 37 different projects and additionally, completed a number of direct business commissions. The project areas comprehensively covered CEMIS' fields of focus including the renewable **chemical forest industry** (particularly the production of liquid biofuels and biochemicals), **mechanical wood processing, mining process management and environmental impact monitoring measurements, and vehicle and work machine measurement and information systems, game and simulation solution and sports and well-being measurement development**. 300 businesses were involved in CEMIS projects and used CEMIS' services.

The implementation and development of training in the field of metrology and information systems has been a part of CEMIS' operations. Training leading to a university of applied sciences Bachelors degree in Business Administration and a Bachelors degree in Engineering as well as a higher university of applied sciences degree qualification (Masters) in Engineering has been carried out within the information systems competence area of Kajaani University of Applied Sciences, studies leading to a Masters and Doctoral degrees in Sports Sciences have been implemented at the

Vuokatti Unit of Jyväskylä University's Department of Biology of Physical Activity, and education leading to a Masters degree in Foodstuff Biotechnology in Oulu University's Metrology Unit, CEMIS Oulu. Training developed in Kajaani University of Applied Sciences with the setting up of engineering studies specialising in game technology, and game-oriented BBA studies taught in English, as well as with the development of game and simulation training and R&D environments.

CEMIS operates as part of the metrology and information system scientific community, producing scientific knowledge and participating in scientific activities. In 2011, a total of **25 international scientific**, peer reviewed publications and **45 conference publications** were published in CEMIS. Additionally, **one engineering doctoral thesis, 8 MSc in engineering/technology project theses, 6 University of Applied Sciences Masters theses, 33 engineering Bachelors theses and 5 Business Administration Bachelors theses** were produced in CEMIS.

CEMIS' total funding for 2011 was almost **12 million euros**. In 2011, there were approx. **114 (person work years)** metrology and information experts in CEMIS. CEMIS has participated in the implementation of two national competence hub programmes: renewable forest industry and smart machines. CEMIS has had projects in three strategic expertise hub competence cluster programmes, Cleen Oy, Metsäklusteri Oy and FIMECC Oy. CEMIS' experts have actively taken part in the Finnish Government appointed Metrology Consultative Committee (such as participating in preliminary inquiries concerning the development of measurement standard and comparative laboratory work, and a national survey concerning metrology training).

CEMIS has started or continued cooperation with several foreign research institutions, educational institutions and companies e.g., in Canada, the USA, Russia, China, South Korea, Thailand, Spain, Poland, Romania, Italy, Austria, Great Britain, the Czech Republic, France, Germany and Sweden.

To summarise CEMIS' results for 2011, CEMIS received a record amount of

- national R&D funding and
- business funding as well as
- submitting a record amount of funding applications during national applications.

In addition, CEMIS exceeded set targets in the

amount of

- first choice study place applications
- scientific publications and
- theses produced
- commercialised technologies and
- R&D based businesses established.

CEMIS' qualitative targets are to increase attraction, competitiveness and impact. CEMIS has attracted students, employees and customers. In 2011, CEMIS' had a record amount of first choice applications for study places, with three applicants per available study place, mainly within Kajaani University of Applied Sciences' Information Systems competence area. CEMIS' expert posts, particularly MIKES' vacancies have attracted several tens of applicants per available post. Interest in CEMIS amongst customers has also continued to grow. In 2011, CEMIS customers comprised over 300 companies and other operators with a record amount of financing and direct commissions from businesses. CEMIS' competitiveness amongst research and training institutions increased in 2011. CEMIS received a record amount of national external funding and financing from businesses. The main reasons for such a growth in competitiveness are the activation of operations, an increase in efficiency and focus as well as in visibility. In the first instance CEMIS' impact is measured by the amount of commercialised technologies produced and the amount of businesses established. In 2011, 13 commercially viable inventions were developed and two new enterprises were established. CEMIS has also enabled the following:

- Kajaani has maintained and strengthened its position as a metrology expertise cluster.
- Vuokatti has developed as an international skiing training, coaching and research centre.
- Kajaani's role as a training and new business centre in the field of games has strengthened.
- The competence of metrology companies has been updated to include fields of growth such as biofuels, bioenergy and mining.
- Metrology companies have been able to further develop their products and business operations.
- Mines in Kainuu have acquired analysis competence and measurement devices to develop their processes.
- Companies operating in the field of metrology in Kainuu have gained new experts whose efforts have given rise to new products.
- The operations of measurement and information systems field research and training organisations have become more efficient and cooperation has increased.



Vesa Virtanen, Director,
CEMIS-Oulu

The Operations of Oulu University

At the beginning of 2011 Oulu University established a Metrology Unit, CEMIS Oulu by combining research conducted at the Biotechnology Laboratory, the Kainuu operations of the Centre for Wireless Communications CWC, the Measurement and Sensor Laboratory and the Kajaani Unit of Information Processing Science. The organisation's new structure enabled a more efficient shared use of equipment and research environments. The unit was formed from four research groups: analytical and bioanalytical chemistry, optical spectroscopy, image-based measurements, and information systems and sensor networks. The research groups operate in facilities located in Kajaani and Sotkamo. The main fields of application in research are the **mining industry, environmental monitoring, well-being applications** (exercise and health), **the mechanical wood processing industry, the electronics, pulp and paper industry** and the **food industry**.

2011 was a significant year for CEMIS, the Centre for Measurement and Information Systems, as its operations started. Simultaneously the projects of the CEMIS Development Programme also commenced. The start-up of CEMIS has seen the significant strengthening of cooperation between the Universities of Oulu and Jyväskylä and MIKES. The Director, Vesa Virtanen, has participated in the work of the Strategy and Management Groups. CEMIS Oulu is clearly the largest operator within the CEMIS Development Programme.

The image-based measurement group, being Professor-lead, has the special task of participating in teaching by producing theses in CEMIS Oulu. Throughout its existence, it has produced many MSc (technology/engineering) graduates and their MSc theses as well as post-graduate students aiming for a doctoral qualifica-

tion supporting the economic life of the Kainuu region. The Professorship is temporary (2 years) and funded partly by the Ministry of Education and Culture through CEMIS start-up funds. There are also post-graduate students in other research groups.

The Foodstuff Biotechnology Masters Degree ESF project (2008 – 2012) continued in Sotkamo in cooperation with the University of East Finland/Kuopio campus. On 1.1.2011 there was a supplementary intake of 10 students, with a total of 30 students undergoing training. The aim is to create a permanent Masters programme managed by the University of East Finland.

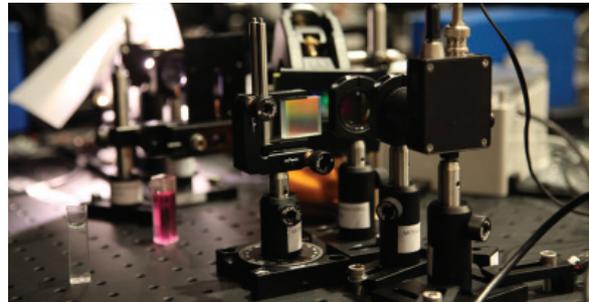
The previous units' comprehensive development programmes continued into 2011. The KETO projects continued in Kajaani until April 2011 and the Biokeho projects continued in Sotkamo until the end of 2011. The development of an expertise service for cell culture and anti-microbiological research, the MIKROSOLU project continued in 2011. The Service and Innovation Development Project, PALI, continued in 2011 and successfully focussed on developing service business operations. Business cooperation increased both in the Kainuu area and nationally.

Between the period 9.2010 – 2011 there were more than ten projects financed by TEKES.

1. **Minewater** (Tekes Water Programme): development of online monitoring of mine waters for the purposes of measuring low metal content (complete).
2. **RACE** (Tekes Water Programme): development of methods for measuring toxic compounds for the chemical process industry
3. **Cleen/MMEA** programme: development of

sensor contamination control and assessing the applicability of biosensors.

4. **Biomecon:** development of measurement technologies for paper industry water circulation control and bio-processors.
5. **Pulpvision:** development of imaging and machine vision systems for use in the manufacture of paper and pulp.
6. **NAMI:** Development of methods for measuring small particles.
7. **Nutrisense:** Development of a biosensor for nutrition nutrigenomics
8. **Bio-BLG-Flavo:** Developing uses of berry production by-products (complete)
9. **LULU:** Development of ski condition and equipment measurement methods
10. **NONIT:** Laser measurement technology for examining the functionality of biomembranes
11. **Tammi:** Image-based measurement methods for the quality control of industrial particle populations and transparent materials (complete)
12. **PUNOS:** Development of sawn timber quality control measurement methods based on wood radiocopy
13. **Timteko:** development of measurements for uses in further processing in sawmills and the timber industry
14. **2B-identification:** the application of capillary electrophoresis and flow cytometry in the identification of bacteria in sample matrices of the environment and mining industry (complete)
15. **MOSA:** development of biosensors and surface plasma resonance methods for cycle analysis (complete)



Additionally a project linked with the diagnostics of intoxicant and medicinal substances (**InToxSign**) conducted in CEMIS Oulu with the aid of international funding, finished at the end of 2010. During 2010 – 2011 two joint projects concerning berry and vegetable cultivation were conducted with MTT and the Sotkamo Unit. In addition, cooperation took place in relation to bioreactor operations and products. **The Creavehicle** project focussing on vehicle simulator research and development and funded mainly by the Kainuu Joint Municipal Authority, continued. The vehicle simulator planned and built during the Creavehicle project, was moved into facilities at Kajaani University of Applied Sciences as a part of CEMIS cooperation.

The Unit's project for the development of low nickel content measurement for the mining industry (**Nick**) was accepted as part of Tekes' Green Mining programme at the end of the year, when the final funding decision arrived at the beginning of 2012.

The Unit has participated in the strategic expertise cluster CLEEN Oy's Measurement, Monitoring and Environmental Assessment (MMEA) research programme. In addition, the unit's staff participated in implementing the **CreaBase** and **CreaLearn** projects managed by the Kajaani Unit of Information Processing Science in 2011. The aim of these projects was to create a permanent innovation environment where different operators could meet, share and create new knowledge and awareness in the sub-areas of usability and process research and also to support dispersed project work thus enabling businesses to operate in a geographically dispersed environment.

The Unit took on the coordination of a bioenergy theme programme to develop rural Kainuu when it was transferred from the Lönnrot Institute. The cross-provincial **Wenet Centre** project has been integrated into the implementation of the bioenergy theme programme. The aim the Wenet Centre programme is to promote export amongst companies operating in the bioenergy field. The international **Robinhood plus** project (Interreg IV C programme) promotes the versatile use of forests e.g. through bioenergy.

The amount of international researcher exchanges increased as planned to 38 person months. There was active cooperation with more than 10 research institutions e.g. in Italy, Russia, the USA and the UK. The number

of scientific articles produced was good: 10 referenced international scientific articles and 22 conference publications. The unit's employees participated in international and national assessment tasks (scientific magazines, preliminary reading of doctoral theses, opposing speaker during a doctoral presentation, assessment of international project applications). There were two notifications of inventions. In 2011, one doctoral thesis, one MSc (technology/engineering) and 4 Masters theses were completed in the unit. In addition one researcher established a company.

The unit reached its operational targets well. The unit's budget was approx. € 6 million. During the year, there were 89 members of staff incurring 66 person work years. The unit employed 21 PhD level employees. Kajaani City provided € 255 000 in funds, Sotkamo municipality contributed € 70 000 and Oulu University € 630 000 including separate funding from the Ministry of Education and Culture of € 150 000 to start up CEMIS' operations.

Outlook for 2012

The unit will continue to focus its research in line with CEMIS' strategy. The information systems and sensor network research group stopped operating as an independent group from 1.1.2012 and their operations were merged with other groups. The unit is aiming to raise the standard of research and to reinforce international relations. At the beginning of 2012 the unit received funding from the Tekes Green Mining programme for a research project concerned with the development of low nickel content measurement for the mining industry (NICK). The estimated budget for 2012 is approx. € 4 million and the number of person work years is estimated to be 55.



Arto Karjalainen, Principal Lecturer, Kajaani University of Applied Sciences

The operations of Kajaani University of Applied Sciences

CEMIS' operations within Kajaani University of Applied Sciences have focussed upon the development of the **Information Systems** competence area, as stipulated in the CEMIS co-determination agreement. 32 people worked in this area in 2011, with 20 people involved in education and training activities. Such development activities have been set in motion to strengthen training and R&D operations.

The main education related actions have been to develop game studies taught in English within the Business Information Technology degree programme and international relations, to develop studies in the field of games within engineering (game technology), to develop game and simulation training and R&D environments (METIS) and to strengthen practical training and these related activities within the universities, research institutions and companies involved in CEMIS.

As regards R&D, the Information Systems competence area model has been systematically developed within CEMIS in terms of scheme preparation and implementation, technological expertise has been developed to serve cooperation, which in turn has required development in itself and the development of regional, national and international networks. The CEMIS model is in full swing with the start-up of the CEMIS development programme. Various forms of cooperation with different operators are ongoing, such as expert exchanges, jointly implemented projects, student trainee and thesis related activities, joint project proposals to various funding bodies and closer and more efficient overall joint operations.

The CEMIS development programme has developed training within the Information Systems competence area at Kajaani University of Applied Sciences. The programme includes the planning of a **new Game Tech-**

nology Option within the Information Technology (engineering) degree programme. The new syllabus emphasises the UAS' "Finland's most proactive university" strategy. For example, project studies are conducted as separate courses, where students conduct hands-on schemes linked to other ongoing courses.

Students who select the Game Technology option will graduate as programming professionals specialised in serious games or simulator engineering to serve the requirements of the game and other industries. Another area of development has been the internationalisation of business information technology game studies, implemented through the game (Bachelor of Business Administration) syllabus where courses are delivered in English during the second year of studies. This form of training has also been marketed through the CEMIS development programme, which has enabled comprehensive cooperation with businesses and other educational institutions. The training option has been presented at regional, national and international events, for example at an event aimed at military service conscripts at Kainuu Brigade, at the Students' Kajaani event at Kajaani University of Applied Sciences, at the Assembly, Demowall and AltParty game events, at the Studia student recruitment fair in Helsinki and at desired cooperation partner educational institutions in Sweden, China, South Korea and Thailand.

The aim of the CEMIS development programme's METIS project has been to bring its members' (Kajaani University of Applied Sciences, Oulu University and Jyväskylä University) simulator-related competence, research equipment and environments together to form CEMIS' joint simulator research and education environment. At the end of 2011 new facilities for the CSE (CEMIS Simulation Environment) laboratory were

completed in the Taito 1 building at Kajaani University of Applied Sciences.

The new simulator **training and R&D environment** is comprehensively equipped with state-of-the-art 3D projector technology, a moving platform providing a genuine feeling of movement, and devices for measuring the driver's reactions and behaviour. Purchases have been made using not only CEMIS development programme funding, but also the university of applied sciences' own financing with some of the devices acquired during previous projects lead by Oulu University. The Kajak3D game engine in the simulator environment has also been developed through the programme as well as creating versatile software for the interfaces of the simulator, moving platform and vehicle. Towards the end of the year, CSE's operations were reinforced with the recruitment of two persons with substantial expertise and experience not only in simulator development but also in psycho-physiological measurements conducted in the simulators.

The CEMIS programme has also enabled Kajaani University of Applied Sciences to be involved in the implementation of a smart measurement and information system solution for the work machine environment (ÄTYLI project), in the development of a measurement system for skiing (LIKE project) and in the development of new liquid flow measurement devices (TUNES project). Kajaani University of Applied Sciences' role in the above projects has been the development of fault diagnosis methods, planning and implementing measuring modules as well as testing the developed measuring devices. In order to support the implementation of the projects Kajaani University of Applied Sciences has provided teachers from its own development funds.

Part of CEMIS' operations included one Tekes project (**MeWex**) conducted in Kajaani University of Applied Sciences until the end of January 2011. In 2011, one new Tekes project (TARRA) began and three other Tekes schemes were prepared (**Pelitys**, **DEVICO** and **WintEVE**), with two of them still waiting for a positive funding decision in spring, 2012. These projects involve developing new measurement and testing methods to evaluate and limit exposure to vibration in work machines (TARRA), a production integrated condition based maintenance model for the mining industry (DEVICO), winter testing technology for electric vehicles (WintEVE) and a game testing services model

(pelitys). Additionally, Kajaani University of Applied Sciences participated in the preparation of four international R&D projects (**TWIRL**, **EgoDi**, **COMPRES** and **DAREC**), with one project funding decision expected during 2012. The development focuses in these projects are vehicle information systems, computer games, an all-encompassing measurement and monitoring system for the mining industry, and an environmentally efficient machine hall (datacenter). The university of applied sciences' own development fund has been used to finance Datacenter and game related activities. The main focus of development within Datacenter activities has been to introduce the accomplishment of certificates required by different systems in the field of information system maintenance. The demand for courses leading to certification is growing worldwide and Kajaani University of Applied Sciences is the first university of applied sciences to provide such training.

Many visitors from domestic companies and educational institutions are now familiar with Kajaani University of Applied Sciences thanks to such projects. The most significant international visitors comprise Turkey's Akdeniz University, Howest University and Rangsit University because working international exchanges with these organisations are in place. New international exchange agreements have been made with China's Xi'an University and South Korea's Youngsan University. Foreign travel has mainly headed for larger game events such as the Game Developers Conference in Germany and Shanghai, to desired foreign partner educational institutions and mining research and training institutions such as the Colorado School of Mines in the USA, Toronto University in Canada and the Technical University of Silesia, Poland. Students have obtained new practical training places through company visits and contacts at Wooga (Germany) and DigitalChocolate. Good contacts have enabled university of applied sciences students to participate in Nokia's and Microsoft's game competitions, bringing wider and positive visibility.

14 students from the Business Information Technology and Information Technology degree programmes participated in an international exchange. Exchange destinations were China, Thailand, Canada, the UK and Germany, amongst others. There were international exchange students from Thailand at Kajaani University of Applied Sciences in spring 2011 and from China in autumn 2011. An Indian game expert has worked as a project engineer in the METIS project from March 2011.

33 university of applied sciences Bachelors theses have been completed within the Information Systems competence area and 6 university of applied sciences Masters theses in 2011. Additionally 5 Bachelor of Business Administration theses have been completed in relation to CEMIS operations. In 2011, Kajaani University of Applied Sciences published one scientific newspaper article and three professional magazine or conference publications.

The field of games at Kajaani University of Applied Sciences has been especially visible in the media.

From the beginning of 2011, Kajaani University of Applied Sciences joined the **Älykkäät koneet (Smart machines)** expertise hub programme together with Measurepolis Development Oy.

There has been active cooperation with companies over the year. Datacenter, vehicle information system and game companies have visited and delivered lectures and a number of domestic and international companies in these fields have also been visited with the objective of developing teaching through cooperation, gaining permanent working life partners and contacts and for the main part, planning different Tekes projects.

In addition to the Information Systems competence area, CEMIS has had a significant effect on competence areas in other universities of applied sciences. Experts and students within the **Business and Innovations** competence area are promoting the commercial exploitation of research results for the benefit of all CEMIS operators. The operations are headed by the university of applied sciences' Senior Lecturer in R&D together with a teacher with a background in marketing and mainly students from the English-taught BBA programme, due to the internationality of the measurement and information system field. In 2011, approx. 50 students participated and five Bachelors theses were completed. The operations are expanding and being reinforced due to Tekes' new funding model where specific models (from research ideas to new knowledge and business) require significant actions to advance not only technological development but also commercial activity. This enables the university of applied sciences to strengthen its role in business development tasks within CEMIS. CEMIS' business development operations have been carried out with CEMIS development programme funding.



The mechanical and mining engineering competence area has worked in close cooperation with CEMIS. The field of mechanical engineering and mining prepared a project proposal together with other CEMIS operators for the Tekes Green Mining Programme that began in 2011. The project involves developing a measuring maintenance model and solution for mines in cooperation with Oulu University and Kemi-Tornio University of Applied Sciences. The project is to start at the beginning of 2012.

Within the CEMIS development programme, cooperation also exists with Oulu University's CEMIS Oulu Unit, to develop the measurement technology of the mineral processing training and R&D environment owned by the university of applied sciences. Close cooperation in the field of mechanical engineering and mining will continue.

CEMIS has commenced cooperation with the **Health-care** competence area in setting up lectures by experts on new methods of measuring human physiology and in developing new measuring technology linked with a care simulator. To support such activities, two project researchers whose expertise and available research equipment strongly support the development and implementation of physiological measurements, started work at Kajaani University of Applied Sciences at the beginning of 2012.

In terms of the **Activity Tourism** competence area the CEMIS development programme will use sports instruction students to test a new measuring system as originally planned in autumn 2012.

CEMIS' management, general administration and administration of the development programme is the task of the staff at Kajaani University of Applied Sciences. Experts from the university of applied sciences are involved in leading CEMIS, marketing and communication operations, project planning and in development programme project management.

Outlook for 2012

The new programme period 2013 – 2014 will be challenging particularly because of the negative developments in regional financing. All operators must continue to develop their activities within shared, selected themes in order to attain impact and credibility in an extremely competitive external funding arena.

The strategy of the Kainuu University Consortium creates opportunities for harnessing the operations of all the universities in the region. The aim is to create profiled cooperation so that the functions of all involved receive real added benefits that cannot be exploited on their own campuses. This is not only an opportunity, but also a definite challenge because the operators involved must also indicate that they have sufficient resources to continue the joint development operations.





Timo Lehtikainen, Site Manager, VTT

The operations of VTT Technical Research Centre of Finland

VTT's Kajaani office continued technology development activities with the theme of vehicle sensor and data transfer solutions. In 2011, VTT had four people in Kajaani. During the year one person was on in exchange was in Belgium as an exchange researcher and in June 2011, a Mexican researcher began work in Kajaani. VTT prepared the ÄTYLI (smart supplementary devices for work machines) project within the CEMIS development programme, in addition to preparing six other project proposals mainly within EU and other international applications. The projects that began were **ProComSen** (Professional Mobile Communications, Localized Sensing in Hazardous Environments) and **VAMMA** (Measuring network for harsh environments). One project application to the EU 7th framework programme was still being processed at the beginning of 2012.

In addition, VTT continued with the **FAMOUS** (wireless vehicle positioning research and development) project that is part of strategic competence cluster, **FIMECC** Oy's programme. VTT has actively worked in cooperation with businesses. Businesses have participated in the implementation and funding of all the aforementioned projects.

Two MSc (engineering/technology) theses were completed at VTT during 2010 – 2011. One concerned the application of UWB (Ultra Wide Band) technology in 3D positioning (indoors/in work machines) and the other creating energy needed by sensors (energy harvesting) in heavy machinery environments.

Outlook for 2012

VTT's activities will continue in Kajaani in 2012 with the aim of increasing the number of staff by one or two people. The developments of the coming years will be strongly influenced both by ongoing projects and projects within the application process. VTT Kajaani

will continue to develop competence within selected fields of focus. Important targets of focus are short-range relative positioning, energy harvesting and the development of sensor network solutions for work machines and vehicles. Despite the clear emphasis on vehicles and work machines, activities will expand to include other sectors mainly when the developed technology can also be applied directly to them. The demands of work machines and vehicles are so stringent that solutions applicable to them can also generally be applied to industry either directly or with minor modification.





Petri Koponen, Group Manager, MIKES

The operations of MIKES, Centre for Metrology and Accreditation

MIKES decided to establish an office in Kajaani in June 2010. The Kajaani office is responsible for **measurement standards for force, torque, mass and flow** measurements and carries out related **research, development and training**. In the autumn of 2011 facilities were renovated for MIKES in the area of the closed-down UPM factory in the Renfors Riverbank Business Park. During autumn 2010, MIKES also recruited and trained its first Kajaani employees and started to transfer its measurement equipment. From the beginning of 2011 MIKES has been in charge of measurement standards of the aforementioned fields in Finland. All the measuring devices had been installed and were in use in Kajaani by October 2011.

During 2011, 12 employees, of whom 6 were full-time, worked at MIKES Kajaani. Most of the employees have been recruited from the Kajaani area. All vacant posts have attracted many good applicants. Additionally, a large number of employees were also involved in laboratory construction work and moving equipment from Lahti, Tampere, and Espoo to Kajaani.

Petri Koponen, Dphil, was appointed Manager of MIKES Kajaani Office on 1.10.2011. Koponen previously worked as a researcher in Oulu University's CEMIS Oulu unit. Aimo Pusa, who was the previous Manager and responsible for establishing MIKES' office in Kajaani continued to work as a full-time expert until the end of 2011 and then part-time from the beginning of 2012.

One member of Kajaani University of Applied Sciences' teaching staff accomplished a work placement at MIKES and helped to plan and implement a liquid flow system. Towards the end of the year an expert exchange was

planned with Kajaani University of Applied Sciences involving one member of the university's teaching staff would come and carry out R&D work at MIKES during 2012 and one person from MIKES would come to Kajaani UAS to teach. There were three UAS trainees at MIKES: two completed their engineering Bachelors thesis and one was a German exchange student. Additionally one member of staff and one student from Kainuu Vocational College as well as one student from Central Ostrobothnia Vocational Institute completed their practical training at MIKES Kajaani. MIKES has also commenced cooperation with the German Metrology Institute, PTB and with Tampere Technical University in the development of liquid flow measurement standards.

MIKES has actively participated in the implementation of joint schemes within the CEMIS development programme such as TUNES Liquid Flow Measurements of the future, ÄTYLI Smart Supplementary Devices for Work Machines, and LIIKE Sports and Wellbeing Measurements as a provider and developer of reliable measuring services.

MIKES prepared and received funding 9/2010-2011 for six projects (**Painevesi, LUMO, Analytical Photonics, Cleen/MMEA, TARRA** and **NICK**). In the Painevesi project, whose main financier is the Centre for Economic Development, Transport and the Environment, MIKES is developing a national liquid flow measurement standard. The Tekes-funded LUMO project is being implemented in cooperation with Oulu University's CEMIS Oulu Unit. The LUMO project is developing new optical sensors for the online monitoring of different types of liquids. The Academy of Finland awarded **Toni Laurila** (D.Eng.), Project Manager at MIKES Ka-

jaani, a five-year post as a researcher of the academy. During 2010-2011, MIKES also continued in energy and environment cluster CLEEN Oy's MMEA programme (Measurements, monitoring and environmental assessment) developing measurement quality control. In the TARRA project, MIKES is developing vibration control systems in cooperation with Kajaani University of Applied Sciences, Jyväskylä University and the Finnish Institute of Occupational Health. MIKES was involved in the preparation of the NICK project that will receive funding via the Tekes Green Mining Programme.

At the end of 2011, MIKES started expert group 'Voimaklubi' (Force Club) activities comprising bodies interested in force and torque measurements. The first meeting took place on 17.1.2012. There were 39 participants and positive feedback was received and also indicated that there was a need for future similar events. An article concerning Kajaani's liquid measurement activities was published in *Automaatioväylä* professional magazine, 6/2011. Two articles on MIKES Kajaani's operations have been published in the local newspaper. Two news items concerning MIKES Kajaani have been published in social media (FB).

During the first year of operations MIKES Kajaani has had 200 customers of whom 90 % were from outside Kainuu. There have been more foreign than local customers, thus the location has not prevented demand.

Outlook for 2012

The outlook for 2012 is positive. Operations in CEMIS' shared projects will increase as other partners' projects progress. MIKES' aim is to bring its expertise in measurement reliability control to the projects.

The objective is that MIKES Kajaani will be one of the leading force and torque measurement standard laboratories in Europe. As regards liquid flow measurements, the goal is to create a usable liquid flow measurement standard and to start up commercial liquid flow meter calibration services in 2012. Additionally, MIKES aims to get one Tekes funded project and one EMRP project off the ground during 2012.





Vesa Linnamo, Professor, Jyväskylä University

The operations of Jyväskylä University

Jyväskylä University's Department of Biology of Physical Activity has delivered Masters training in Sports Technology since 2004 and Doctoral studies since 2005. Its third EU-funded Masters programme project has been operating since December 2010 and will be continued until 2013. The Head of the Sports Technology Unit is Professor **Vesa Linnamo**.

Those selected for the Masters programme are required to have a background in engineering or information technology at a university or university of applied sciences. The subjects of study are biomechanics, sports and exercise physiology and coaching and testing theory. In 2011, 23 students were selected and by the end of December there were 32 Masters in Sports Technology in Vuokatti. The subjects of those completing their doctoral studies are aging and balance control, the physical stress of soldiers, and cross-country skiing. The first person to defend their doctoral dissertation from Vuokatti may well be ready to do so in 2012.

The Vuokatti Sports Technology Unit with its focus on researching forms of skiing has achieved close cooperation with regional operators over the years, particularly with the University of Oulu. 2011 was significant due to CEMIS operations and the start of the CEMIS development programme. The aim of activities that started in January 2011 has been to develop the measurement technology competence of the Vuokatti Unit on behalf of Jyväskylä University. Vuokatti as a region and the environs of the Sports Institute have provided the perfect arena, e.g. with the ski tunnel and athletes, for conducting research on forms of skiing.

The Unit's research projects are often linked with the use of technology as a wellbeing and sports tool. In 2011 there were two ongoing Tekes-funded research projects: **Automatic Game Analysis for Team Sports** (completed 2011), where the use of machine vision technology to analyse games was examined, and a joint project with the University of Oulu and CEMIS Oulu that began in 2011, called **Mobile Sports and Snow Research** which focuses on developing ski condition and ski equipment testing measurement methods.

The Finnish Olympic Committee and Hiihtoliitto (Finland's Skiing Association) are involved in the latter project, coordinated by Jyväskylä University. There has also been intensive international cooperation in skiing research, e.g. with the Universities of Salzburg and (Mid Sweden) Östersund. Over the years studies commissioned by businesses have also formed a major part of Vuokatti's operations and in August 2011 force and radar measurements for the ski manufacturer salomon were carried out in Vuokatti ski tunnel.

The unit also participated in a joint project with the Municipality of Sotkamo and Jyväskylä University's Department of Sports Sciences called "**Exercise: a skill for all citizens**" and where the press power, body composition and balance of a test group of 120 secondary school pupils, were measured and the results analysed. In 2011, the unit submitted a total of four research project applications: "Mobile Sports and Snow research" (Tekes) in cooperation with CEMIS Oulu, the Unit's own project "Automatic Game Analysis for Ice Hockey" (Tekes), "**Evaluating and Limiting Exposure to Vibration**" in cooperation with Kajaani University of Applied Sci-

ences and “**Coaching Feedback System for Biathlon Research and Classification**” (Tekes), in cooperation with CEMIS Oulu. The “**Mobile Sports and Snow Research**” project received a positive funding decision on 1.4.2011 and the “Evaluating and Limiting Exposure to Vibration” project, on 2.12.2011.

The research has been actively presented at seminars and congresses organised in Vuokatti. In April 2011 Jyväskylä University’s Departments of Biology of Physical Activity and Sports Sciences organised an international congress “**International Congress on the Enhancement of Physical Activity of Children and Youth**”. 2011 saw the planning of a new congress “**2nd International Congress on Sciences and Nordic Skiing**” begin in cooperation with Jyväskylä University’s Department of Biology of Physical Activity, Salzburg University, Vuokatti Sports Institute, the Municipality of Sotkamo and CEMIS and where 160 participants are expected in may 2012.

International scientific publications in 2011: 6 original referenced scientific articles, 1 book or chapters of a book, 7 invited lectures, 14 congress abstracts. Additionally representatives of the Unit were invited to lecture at domestic and international events 6 times during 2011.

The unit operates in close international cooperation. In 2011 the main international partner universities were **Ljubljana University** (neuromuscular system research cooperation), **Maastricht University** (physical stress of soldiers research), **Mid-Sweden University** (skiing research), **Osaka University** (skiing research), **Potsdam University** (neuromuscular system research cooperation), **Salzburg University** (skiing research) and **Tubingen University** (skiing research).

A German researcher from Tübingen University, Doctor **Walter Rapp** worked at Vuokatti for a month in November 2011 to research the measurement of ski pole force in skiing. In addition, a research group from Salzburg University, lead by Professor **Stefan Lindinger** visited Vuokatti for a week in November to pilot a skiing movement analysis system (VICON) in Vuokatti ski tunnel. In January 2011 the Unit’s operations were presented to the International Paralympic Committee’s (IPC) Medical and Scientific Director **Peter Van de Vliet**. The IPC invited Professor Vesa Linnamo to the IPC Nordic Skiing Classification Expert Meeting in June 2011. The

IPC also committed itself to funding the “**Coaching Feedback System for Biathlon Research and Classification**” research project, for which an application was submitted in cooperation with CEMIS Oulu and is still awaiting an answer from Tekes. Research cooperation also began with the Tekes project “Mobile Sports and Snow Research” at the lead of Doctor **Hansueli Rhyner** of the Federal Institute for Snow and Avalanche Research research group within the competence area of ski and friction research.

Jyväskylä University has participated in the implementation of the CEMIS development programme with the aim of reinforcing measurement technology competence at the Vuokatti Unit. The programme has provided resources for a laboratory engineer and project coordinator. The project coordinator has generally coordinated the Unit’s projects and helped the Unit’s director in project planning, applying for project funding, implementation, reporting and ending the projects. The project coordinator has also worked within the CEMIS joint project “Measurement Systems for Sports and Wellbeing Technology (LIIKE)” as a project manager and in the METIS project as an expert. The aim of the LIIKE project is to develop measurement methods that can be used not only in both individual sports and wellbeing measurement but also in demanding measurement technologies used by industry. The project will demonstrate a developed skiing measurement system, non-invasive methods of measuring cortisol and IL-6 as well as a method of measuring snow structure and properties. The laboratory engineer has worked as an expert in the LIIKE and METIS projects, and has been responsible for the maintenance, development (SW & HW), and use of Jyväskylä University’s measuring equipment and in charge of measuring equipment and systems at Vuokatti Ski Tunnel and Ski Ramp.

In 2011, 11 people worked at the Sports Technology Unit located in Snowpolis Oy’s facilities: a professor, three lecturers, a laboratory engineer, a project researcher, a project coordinator and two research assistants.

Outlook for 2012

It is the intention of Jyväskylä University to operate within CEMIS as an active developer and applications expert in sports and wellbeing measurement technology. Cooperation with CEMIS and the CEMIS joint development project will continue to be considered as significant forms of operation by Jyväskylä University. Jyväskylä University will aim to keep a laboratory engineer and project coordinator involved in the operations in the future. It is intended that the joint development programme could cover 75% of the costs of the aforementioned employees with the university's own financing and other projects covering remaining expenses. The laboratory engineer could also work in other technical support tasks within CEMIS according to the CEMIS' joint technical support and chemical laboratory operations model. From 2014, Jyväskylä University is planning to include some of the expenses incurred by a project secretary and renting facilities within a joint development programme.



International relations

CEMIS has an expansive and continually expanding and deepening international cooperation network consisting of universities, research institutions and companies.

In 2011, representatives from a large number of bodies visited CEMIS and representatives from CEMIS presented CEMIS elsewhere. Below are some of the most significant visits:

- MIKES' Board visit
- Vaasa University of Applied Sciences' management visit
- Rovaniemi University of Applied Sciences' management visit
- Diaconia University of Applied Sciences' visit
- The Federation of Finnish Technology Industries, Director of Innovation Activities visit
- Moscow State Technical University STANKIN
- Smart machines competence cluster, management visit
- TestLabGate project, steering group visit
- Colorado School of Mines, Denver, U.S.A.
- Lassonde Institute of Mining, Toronto University, Toronto, Canada
- EMAG- Institute of Innovative Technologies, Poland
- Katowice Mining Fair, Poland
- Silesia Technical University, Poland
- Grenoble Innovation Fair, France
- Geological Survey of Finland, Director General's visit
- BusinessOulu visit

CEMIS organised many expertise related events, seminars and conferences. The most significant of them in 2011 were:

- CEMIS seminar 31.3.
- International Congress on Enhancement of Physical Activity of Children and Youth, 7. -9.4.2011, Vuokatti
- CEMIS Business Development Seminar, 8.6.
- Digital Image Processing workshop, Tampere, 31.10.
- Online detection of metal species in industrial processes seminar, 17.11.
- CEMIS information and discussion events for the staff of CEMIS various units
- CEMIS recreation day, 16.9. Vuokatti

CEMIS was present at the following fairs organised in 2011:

- CleanTechExpo, Lahti

Publications

In 2011 CEMIS produced 25 international scientific, peer assessed publications and 45 conference publications. Additionally in 2011, CEMIS produced one doctoral thesis in engineering, 8 MSc (engineering/technology) papers, 6 university Masters theses, 6 university of applied sciences Masters theses, 33 Bachelors theses in engineering and 5 Bachelor of Business Administration theses.

Doctoral theses:

Kalliokoski Juha, Tekniikan alan väitös: "Models of filtration curve as a part of pulp drainage analyzers". Oulu university.

Kuivalainen Kalle, Fysiikan alan väitös: "Glossmeters for the measurement of gloss from flat and curved objects". Oulu university.

MSc, Masters and Bachelors theses:

Torvinen Sami, DI-työ: "*Konenäkövalaisimen optiikan toteutus*". Oulun yliopisto.

Heikkinen Aili, 06/2011, Elintarvikebiotekniikan muuntokoulutus

Tuominiemi Hilka, 08/2011, Elintarvikebiotekniikan muuntokoulutus

Kämäräinen Helena, 08/2011, Elintarvikebiotekniikan muuntokoulutus

Pahtamaa Ulla, 12/2011, Elintarvikebiotekniikan muuntokoulutus

Bundina Natalia, Smirnova Anastasia: *Evaluation of the company's competitiveness when acquiring new measurements devices*. Kajaanin ammattikorkeakoulu 2011.

Avanesova Arina, Firina Ekaterina: *Economic impact studies of the measurement technology*. Kajaanin ammattikorkeakoulu 2011.

Koskinen Toni, D-työ: *UWB in 3D indoor positioning and base station calibration*. VTT 2010.

Pellinen Marko, D-työ: *Energy harvesting methods for wireless sensor nodes in heavy-duty vehicles*. VTT 2010.

Aalto Paula: *Liikunta-aktiivisuuden yhteys autonomisen hermoston toimintaan lukioikäisillä nuorilla*. Jyväskylän yliopisto.

Inkinen Virpi: *Naisten lentopallon teknis-taktinen lajiansalyysi - vertailu*. Jyväskylän yliopisto.

Latva-Rasku Laura: *WLAN-paikannus sisätiloissa, sen soveltuvuus nopeuden analysointiin ja liikkumisnopeuden vaikutus askelpituuteen ja -tiheyteen*. Jyväskylän yliopisto.

Malinen Jukka: *Palautteenantojärjestelmä mäkikihypyssä*. Jyväskylän yliopisto.

Santala Jukka: *Hermoston lihasjärjestelmän väsyminen ja palautuminen eksentrisen ja konsentrisen polkuergometrikuormituksen jälkeen*. Jyväskylän yliopisto.

Virtanen Arto: *Reaktioaika ja lihasaktiivisuus pikajuoksun lähdössä*. Jyväskylän yliopisto.

Scientific Publications:

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Arvinte Adina, Sesay Adama Marie, Virtanen Vesa (2011): *Carbohydrates electrocatalytic oxidation using CNT-NiCo-oxide modified electrodes*. - Talanta 84 (1), 180-186

Haapalainen Mikko, Kaikkonen Ville, Kinnunen Ismo, Mäkynen Anssi (2011): *Characterizing electrokinetic mobility of microparticles using a transparent platform and in-line holographic microscopy*. - Photonics letters of Poland 3

(2), 85-87. <http://photonics.pl/PLP/index.php/letters/article/view/3-30/169>

Räty Jukka, Niskanen Ilpo, Myllylä Risto, Peiponen Kai-Erik (2011): *Light transmission model for the determination of the refractive index of solid particles in suspensions: Immersion study*. - Applied spectroscopy 65 (5), 557-560

Peiponen Kai-Erik, Räty Jukka, Niskanen Ilpo (2011): *Measurement of the refractive index of highly turbid media: comment*. - Optics Letters 35 (24), 4108

Bollström Roger, Saarinen Jarkko, Räty Jukka, Toivakka Matti (2011): *Measuring solvent barrier properties of paper*. - Measurement science & technology 23

Watanabe Koyo (2011): *Illumination method for high resolution imaging at water surface*. - Optica Applicata 41 (1), 135-144. <http://www.if.pwr.wroc.pl/~optappl/article.php?p=871>

Watanabe Koyo (2011): *Model for measurement of water layer thickness under lipid bilayers by surface plasmon resonance*. - Biomedical optics express 2 (5), 1115–1120. <http://www.opticsinfobase.org/boe/home.cfm>

Kontturi Ville, Silfsten Pertti, Räty Jukka, Peiponen Kai-Erik (2011): *On optical properties of dilute colloidal gold*. - Plasmonics 6, 345-349

Mika Porento, Veijo Sutinen, Timo Julku, and Risto Oikari (2011): *Detection of Copper in Water Using On-Line Plasma - Excited Atomic Absorption Spectroscopy (AAS)* Applied Spectroscopy, Vol. 65, Issue 6, pp. 678-683A

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