KTH International RAE 2008

REPORT PANEL 6: ELECTRONICS and PHOTONICS

GENERAL ASSESSMENT OF THE RESEARCH FIELD

Electronics and Photonics at KTH is patently of high international standing. Overall leadership by Prof. Mikael Östling is excellent, the panel was also impressed by the leadership in the various UoAs (see there). UoA themes (Semiconductor Components, Embedded Electronics and Computer Systems, Optics and Photonics, and MEMS – microelectromechnical systems) are all relevant to the field. Each UoA contains well-known researchers with an undisputed international reputation. Teams are well formulated, with a strong leader well supported by team members. The range of interests within each UoA shows significant breadth and depth. Collaboration between the UoAs is limited and could certainly be increased (except for the joint use of the central facility by most groups and many outside). We also encountered an impressive young and very enthusiastic staff, some of whom succeeded in getting prestigious awards, even though shortage of PhD students and junior faculty positions appears to be a serious threat faced by most UoAs.

Grouping around a central facility (Electrum laboratory) which is also a national facility, is sensible for three of the UoAs (all except Embedded Electronics). Electrum lab is modern, well equipped with state-of-the-art device fabrication tools, and is adequately staffed. It provides good access for companies and the presence of the companies is beneficial to KTH researchers. Equipment is generously financed by the Wallenberg Foundation, but the consequence is over-reliance on one funding source. Most UoAs seem fairly happy with their location, although there is an on-going discussion concerning the relative merits of Kista and main campus. There is also discussion concerning the scattering of some research interests (optics) throughout KTH. One serious problem with the lab facilities in the UoA is the lack of technical personnel; technical work is generally done by PhD students, which is a waste of resources to some extent.

Standards of publication are very high, with a good balance between original research papers and textbooks aimed at translating new work rapidly into the mainstream curriculum. Work is generally published in international journals with high impact factor or in the leading conferences. The volume of publication (i.e. papers per researcher) is comparable to many competitor research groups in Europe.

All Units are very active in generating new funds to support their activities, in some cases even reaching 80% of their income. Most of them are also active spinning off research results; in one case the spin off company has become very successful. Highly commendable also is the attention the Swedish paper and pulp industry gets from two Units; the panel believes that there is a bright future laying in the area of ‘intelligent paper’ or ‘intelligent wallpaper’ etc. There are a number of other gems in their field, we found them in every UoA (e.g. work on SiC, the drug delivery patch, digital enhanced RF IC’s).

There is a major structural problem with the whole-cost funding model. Undergraduate and postgraduate teaching (especially for foreign students) is accounted for in a way that appears strange to panel members from outside Sweden, and seemingly contribute little to the balance sheet. Costs for personnel, accommodation etc... are punitive. The model has in some cases distorted the emphasis away from long term research. The relatively small and declining number of Swedish students was also a considerable concern. It is difficult to secure five-year funding for PhD students. More attention has to be devoted to hiring female students and staff, in some Units there are (almost) no women.

At the critical side, the panel found that the 'value chain' reaching from devices and process technology, over circuit design to embedded systems and architectures is not completely covered, with the result that the distance between devices and systems is not well bridged. It would be much easier to bring results 'to the market' if fully integrated solutions to problems could be provided. Another critical comment that has been made is the groups' need to develop new application fields for their technology (e.g. in Sensor Networks). They are excellent at what they do, but they also have to push their ideas into new fields.

Very commendable are the major efforts the groups are doing to spin off their activities. Given the extra burden this puts on the senior staff, the panel was very impressed with the scope and the level of the companies they created.

Those students interviewed seemed happy with KTH. All seemed mature and supportive of their teachers. The panel's student guide (Ann-Sophie Ahn) was extremely helpful and should be congratulated.

In conclusion: the Micro-electronics and Photonic groups at KTH have an excellent international reputation and the visit confirmed this.

UoA: MEMS

General Assessment

This UoA is smaller than others within the research field, having only one full professor. Despite this, it is well known and successful in Europe. It is certainly not the largest activity of this type, being considerably smaller than other major National Institutes such as IMEC, LETI and the Karlsruhe Helmholtz Laboratory. Its closest competitor in terms of size of effort compared with size of national economy is probably MIC Lyngby. The UoA is well led and well organized. It has made very effective use of the Electrum Laboratory for device fabrication. As a result, it has for around one decade out-performed some larger European efforts both in terms of impact on MEMS and value for money. In fact, its performance is more comparable to a US MEMS centre such as UC Berkeley, U Michigan or MIT.

Performance Against Evaluation Criteria

Scientific Quality (basic research)

Part of the UoA currently performs at a world-leading standard with the main part performing at an internationally high standard. This is reflected in the large number of papers published in the leading journals in the field (JMEMS; JMM; Sensors and Actuators). The main research themes (Biomedical MEMS, Micro, nano and bio fluidics, RF MEMS and 3D MEMS) are all extremely current. The group has developed a deep understanding of fluidics, mechanics,

(bio-) chemistry and electrical physics at the micro-level over many years. More recently there is a concerted effort in studying fluidic phenomena at the nano-scale.

Applied Research Quality

It is clear that the majority of the UoA currently performs at a world-leading standard. The MEMS group has clearly applied MEMS in very novel ways in many application domains. The application in medical diagnostics is pioneering. The development of new wafer attachment and machining methods is also world leading and allows the group to explore many new application areas. New MEMS structures for application in RF systems are also impressive. In addition, this UoA has been responsible for the generation of significant IP and for spinning out several successful MEMS companies. There has been a definite contribution to the Swedish economy though e.g. creation of Silex Microsystems (120 employees). Research funding through European consortium projects (FP6, FP7) is likely to emphasize applied research.

Scholarship

Scholarship is outstanding across the majority of the UoA. Prestige within the UoA is mainly concentrated in Prof. Stemme, however, who has been recognized by the award of Associate Editorship of the leading journal, IEEE/ASME JMEMS, and Fellowship of IEEE. He is a leading and respected scholar in this subject at the international level, as evidenced by invited and plenary talks.

Vitality and Potential

The UoA is led very enthusiastically, and this has resulted in the development of a new generation of extremely able associate professors, some of whom clearly deserve promotion to full professor. The average age of staff is low, and the number of PhD students is rising. Thus, vitality and potential within this UoA is excellent.

Strategy

The strategy at the moment is excellent but challenging to achieve as it appears to focus on income generation. While this is currently very successful probably the emphasis should be altered somewhat to long-term research. A vision for a long term programme designed to nurture a world leading position is somewhat lacking. Some longer term investment by the university to allow new areas to be pursued which will in time be revenue generating is clearly much needed. Also, a conscious effort at engaging more women in this field would be beneficial (there is a good collection of internationally well known women working in it).

Strengths

- Leading university group on MEMS in Europe. The group found new paths of MEMS technology different from others.
- Excellent understanding of Material Physics and MEMS fabrication processes.
- High creativity in finding new application areas.
- Stable funding base leading to a natural expansion of the technology base.
- Good users of the Electrum facility.
- Many patents, great attractor for students.
- Excellent spin off activities.

Weaknesses

- Some junior staff should move to senior positions.
- Medium to long term strategy not so clear.

- Given the strength of the group more leadership at the national and international level desirable (the group could set the tune in Europe!)
- Gender strategy needed. In the MEMS area there is a good choice of excellent female researchers!

Actions for Development

Taking into account the already great standing of the UoA MEMS, we would underwrite the following strategic actions:

- Develop a long term strategy, building on strengths.
- Promote the associate professors with a strong track record.
- Enhance and streamline the collaboration with the other groups in this area through better proximity and joint programmes.
- Enhance university-wide visibility since much needed technology for a variety of fields is provided.
- Pursue new areas.
- Engage more women.

Additional Information

The group has to divide its activities between the central Stockholm campus and Kista. The same is true for some other groups. Proximity at the research level can be a factor in providing for a complete design chain and enhancing cooperation towards new applications, e.g. fluidics and bio-medical systems.

UoA: Embedded Electronics and Computer Systems

General Assessment

This UoA is quite large and divided into a number of sub-themes: Electronic Systems Design, Media Electronics, Radio Electronics, Circuit Theory and IT Systems. The overall effort is led by Axel Jantsch. Some efforts are clearly larger than others (particularly, Electronic Systems Design). It was hard to judge all the themes since not all themes (e.g. Radio Electronics) were given the opportunity to present. Good masters programme. Collaboration with Fudan University but rationale for this is not obvious.

Performance Against Evaluation Criteria

Scientific Quality (basic research)

Scientific research quality is excellent and the majority of the UoA currently performs at a world-leading standard. This is mainly due to the efforts of several leading researchers. Significant impact has been created by work in System-on-chip. An excellent group in Radio and Mixed Signals has created the programme RaMSiS. Large scale collaborations are very visible throughout Europe. Some excellent publications and textbooks have been produced. The group has been leading in Europe in setting scientific foundations for System on a Chip and Networks on a Chips design, and some of their insights have been largely applied in industry. A strong balance has been achieved between new concepts, industrial relevance (implementation as industry standard ECAD tools) and dissemination of ideas through landmark papers and books. Also the activity in the areas of RF and Mixed-Signal design appears to be very strong, again with a good mix of research, implementation and dissemination. There is also an excellent balance between in-depth research and broader approaches on new topics such as the iPack.

Applied Research Quality

Part of the UoA currently performs at a world-leading standard with the main part performing at an internationally high standard. The group appeared to have less of a connection to industry, although the situation is changing with the formation of a large Centre of Excellence in intelligent packaging, the new area of using paper as a base for 'ubiquitous electronics' holds much potential for applications.

Scholarship

Scholarship was outstanding across the majority of the UoA. Significant contribution is visible through the organization of a large numbers of conferences and through a strong presence on conference TPCs. The group members participate in many editorial boards.

Vitality and Potential

Vitality and potential was excellent across the majority of the UoA and the average age of professors is low with good new researchers emerging. Funding appears to be entirely strong at the moment and is allowing the growth of group. The team Jantsch-Tenhunen provides strong leadership in the area SoC-NoC, while Ismail is providing strong leadership on Mixed-Signal, but the leadership picture is possibly too scattered, with some groups hardly participating.

Strategy

Long-term strategy was good, with real potential to achieve, but was somewhat confused. Neither the future membership nor the future location of the UoA was clearly stated. There seems to be a lack of communication between some group members. The groups should decide more clearly on where to go (e.g. 3D, medical...). Strong focus is needed.

Strengths

- Strong leadership and excellent division of tasks between the leaders.
- Great European and international visibility.
- Excellent balance between in-depth research and broad interest in modern topics.
- Strong initiatives in development of ties with industry (e.g. Ipack).

Weaknesses

- Major effort still needed in 'proving oneself' through related publications, patents, spin offs etc...
- Long term vision on the future of electronic design somewhat fuzzy.
- Stronger focus on new applications needed.

Actions for Development

Even though this area at KTH is very strong, the following may strengthen it even more:

- Consolidate locations.
- Develop long term vision better.
- Create a matrix to check coverage of domains.
- Provide for a stronger 'chain-management' going from devices, over circuits to systems, by stronger cooperation with the other UoA in the overall theme.
- Strengthen collaboration with industry in the new relevant fields.

Additional Information

Participating groups are scattered over different locations

UoA: Optics and Photonics

General Assessment

This is a well-established group and a leading effort in several areas of photonics research in Sweden. Scientific international competitiveness is to be found across the UoA.

Strong emphasis is put on the enabling nature of photonics technologies for a variety of industries and applications.

A long history and broad knowledge base is patent, ranging from classical optics to integrated optics, optical networking, optical signal processing, photonic crystals and quantum optics. The highly-competitive Linné grant "Advanced Optics and Photonics" was recently secured.

There is a good span of interest, ranging from theoretical research in quantum optics and near field optics to fundamental effects such as laser-induced transparency and applied research in high speed and integrated devices for optical telecommunications. Some use of the Electrum laboratory for device fabrication has been reported on, but devices are also fabricated in their own facilities, that are mostly operated by PhD students. Strong collaboration has been institutionalized with ACREO. Collaboration with Zhejiang University (very strong in optics in China) has been set up but it is not obvious that the present model of funding is sustainable.

Performance Against Evaluation Criteria

Scientific Quality (basic research)

A leading position in high-speed modulation, III-V devices and strong position in integrated photonics and quantum topics is very visible and is one of the reasons by the Panel felt that the majority of the UoA currently performs at a world-leading standard. Excellent new developments in nano-waveguides have been achieved. Many high-quality publications are listed and an excellent publication record has been reported on (publications in top journals, Phys Rev Lett, Optics Letters, Nature Photonics, etc). There is a large number of papers with high quality and impact.

The groups have secured a number of competitive national and international grants e.g. QuComm, SECOQC, QUIPROCONE, QPhoton, QAP; MOSEL, ePIX, PCIC, HECTO, IPHOBAC, MANGO, BONE). There is an active collaboration with international universities and many major optics centres in Europe.

Applied Research Quality

The long history of supporting Ericsson with trained personnel and research in telecoms optics is a good demonstration of how part of the UoA currently performs at a world-leading standard with the main part performing at an internationally high standard. More recently, good performance and active entrepreneurial attitude is evidenced by the generation of spin-out companies, e.g. Syntune, Phoxtal based on III-V technology such as tuneable lasers (12 patents in last 5 years). About half the students still go to industry. The UoA builds on a very solid tradition, world-leading in applied research in some areas. Part of the UoA (Photonics) had strong relations with industry (Ericsson, ACREO, Proximion, etc), some of them surviving the downsize of the telecom industry. Participation in important industry-orientated projects grants (e.g., MOSEL, ePIX, PCIC, HECTO, IPHOBAC, MANGO, BONE). Unique experience and programmes in Sweden in several applied areas (e.g., optical networking).

Scholarship

Good representation on international boards and editorial boards means that scholarship in this UoA is excellent in some parts/individuals: faculty with high international status across the UoA; co-recipients of the European Descartes award 2004 for QuComm ("Long Distance Photonics Quantum Communication") for scientific excellence.

Vitality and Potential

Vitality/potential is excellent in some parts of the UoA, good in the remainder. The groups show a reasonable age distribution and there is a good number (18) of enthusiastic PhD students. Problems in funding PhD students, especially Swedish students have been reported on. The group leaders in the UoA have top international status and serve in major international Boards (e.g., President of the Quantum Electronics and Optics Board of the European Physical Society; President International Commission for Optics). Presence in major international conferences and organizations is visible (e.g., the European Photonics Platform Photonics 21). There are several editorial board memberships. Impressive are some major achievements: e.g. being co-recipients of the European Descartes award 2004 for QuComm ("Long Distance Photonics Quantum Communication").

Strategy

The groups exhibit a proven, old tradition in optics for telecommunications, but they also show a successful diversification after the telecoms downturn in 1999-2000. They are now active over a range of areas including telecoms, interconnects, medical optics, quantum cryptography, and more. New areas the groups have engaged in are plasmonics and metamaterials. They have been able to acquire some good large and prestigious grants (SFRC, Linné) that allow a long term perspective on staff and an emphasis on fundamental research. Strategy was judged to be excellent but challenging to achieve in this Unit.

Strengths:

- Clear structure and organization.
- Experience and clarity of resource management.
- Internationalization plans.
- Clear assessment and identification of challenges for the UoA.

Weaknesses:

- Heterogeneity across the UoA.
- Location at Kista is to be debated, as there may be more affinity with groups elsewhere.
- Financial model, in particular the support for technical facilities.
- Need to develop new application areas and industrial contacts.

Actions for Development

Here again we are faced with a group of true international excellence that is facing a number of challenges, which may be summarized as follows:

- The future development and choice of topics needs careful consideration, but as the group has a leading position it should be able to take care of that in a strong way.
- Some of the leading scientists are approaching retirement age, nurturing of a new generation of similar quality very much desired, including care for gender issues.
- More synergy with the other groups (mems, electronics, systems) would be profitable to cover the complete chain.
- Consolidation of locations necessary.

- Additional technical set up needed in the experimental facilities and additional technical support should be arranged.
- Strengthen and enhance industrial contacts in some parts of the UoA.

Additional Information
The old industrial base for this activity has been decimated (it might come back!) and the group has been diversifying its contacts successfully, but more will be needed.

UoA: Semiconductor Components

General Assessment
This is an excellent research group covering a wide range of research topics, with diversification away from classical capital-intensive CMOS and work ranging from materials deposition to fabrication processes to device structures. The groups exhibit a significant use of the Electrum laboratory for device fabrication. The panel has observed a general switch from supporting conventional semiconductor industry to supporting SMEs, for which substantive efforts have been engaged in. Good links with MEMS and Embedded Electronics (I-Pack centre) have been established. However, relatively poor links with Optics and Photonics are shown where there should be natural synergy.

Performance Against Evaluation Criteria

Scientific Quality (basic research)
Some parts of the UoA currently performs at a world-leading standard, and the main part performs at an internationally high standard. This is evidenced by the excellent work on nanoelectronics, sidewall lithography, wide bandgap semiconductors for high voltage transistors on SiC, PLD deposition of novel materials such as ferroelectrics, magneto-optic material, and associated micromachined devices. Some fundamental results in solid state physics have been obtained. There is a significant production of high quality publications in leading IEEE journals, and some important textbooks. The ratio (PhD students)/(Senior Staff) in some of the groups is too low.

Applied Research Quality
The majority of the UoA currently performs at a world-leading standard as evidenced by the demonstrably good support for the Swedish economy (indicated by the recent foundation of spin-off companies Replisaurus, Scint-X, TransIC). Foundation of Somark (cattle ID tattoo) shows diversity. Also a good level of Swedish patents (and also 38 Russian patents!). The group has also pioneered the set up of the Electrum facility in a major altruistic effort from which the other groups largely profit.

Scholarship
Scholarship is excellent in some parts/individuals of the UoA. For example, the scholarship reputation of Östling is excellent, both in the area of publications and in the area of influential textbooks. Also, a good past record of graduating PhD students (27 in period) is visible.

Vitality and Potential
A good staff age distribution is present. However, it is a relatively small group lacking mass by comparison with similar efforts elsewhere in Europe, especially given the availability of modern expensive facilities. Also, a good input of quality students for the masters programme is visible, attracted by the Electrum lab, but there are substantial difficulties with funding

resulting in a relatively low numbers of PhD students, sub-critical in some areas (solid state physics). In general, vitality and potential is good across the majority of the UoA.

Strategy

The UoA seems to function well together despite a wide range of interests. Diversification of research themes is clearly good but, as a result, efforts may be spread too thinly. Lack of personnel especially PhD students is a significant weakness. One staff member (solid state physics) apparently has no PhD students or RAs. There seems to be no plan to overcome this problem. Overall, then, the strategy was excellent but challenging to achieve.

Strengths

- Groups feel most responsibility for making Electrum running, a great facility allowing Swedish research groups to experiment with great new ideas.
- A large number of PhD students have graduated in the past.
- Strong and responsible leadership, also covering the other units in Micro-Electronics.
- Strong efforts in creating spin-offs.

Weaknesses

- PhD students/senior staff ratio too low generally.
- Financial basis of Electrum not diversified.
- Poor female/male ratio.

Actions for Development

Given the past strengths of the UoA, strong measures for the future are needed, e.g.:

- Broaden the support basis for Electrum at the international level to make it less dependent on ‘charity funds’.
- Major effort in fund raising is necessary, especially to allow for funding more PhD students.
- Search for female senior staff.
- Enhance activities in the circuit area to cover the whole chain from devices to systems and, in so doing, be more appealing to potential appliers.

Additional Information

The Panel considers the Electrum facility as a major asset to KTH that deserves a much broader support base than is presently available. The ability to create new devices integrating sensing and measuring systems, calibration electronics, signal processing, communication and actuating is absolutely essential for the future position of technology at KTH and in Swedish society in general. The UoA should be credited with providing a leadership role in achieving this and in view of its quality it deserves the unmitigated support of Swedish university and central authorities.

Further General Recommendations Concerning the Research Field

It should be clear from the above assessments that the Panel values the general field Micro-Electronics and Photonics very highly and considers it as belonging in general at the top in Europe and certainly comparable and/or competitive with the main European groups in the area. However, the general outlay is somewhat limited and it may be argued that the groups, although excellent, are generally smaller than their siblings elsewhere. Since the area is of key importance to future technology in many other areas (in particular bio-medical

instrumentation and consumer products) and needs extensive experimental facilities, its development deserves the utmost attention from university and national authorities. Although the Panel was generally extremely satisfied with the state of achievement of the field at KTH, it is of the opinion that the following items deserve special attention:

- Contacts between the research groups and industry could be intensified in several directions. A working group to explore new areas of development could be set up as well as an industry-orientated phd programme, partially financed by industry with governmental support**.**
- In a similar vein, the already existing cooperation between the research units and developmental labs such as acreo could be intensified, e.g. Through the creation of a lab forum for contacts.
- The field as a whole may benefit from more structuring and a more intense collaboration between the groups. The responsibility for making electrum a success should be a responsibility more evenly borne by the several units (and outside agencies).
- One very obvious weakness in the set up is the lack of coverage of the entire 'value chain' ranging from devices all the way up to systems and catering for major application domains. Especially circuit design expertise seems to be somewhat weak so that the integration of devices into systems is not really covered.
- Application domains have to be broadened. This is hard to do given the limited number of scientists and the many contracts the staff and students are already working on. The panel appreciates the efforts going in this direction, yet also believes that more is needed.
- It is evident that the groups deserve more visibility given their evident quality.
- Some groups are truly leading in Europe, but need also to develop that position.
- It is clear that some of the idiosyncrasies of the Swedish funding system is hampering much needed developments of some of the groups.