Abstract—The dramatic growth in Optical Communication Networks in most developed countries and also in South Africa, desperately needs skilled human resources (engineers) for design, operation and maintenance of these sophisticated networks. With only 8 ECSA accredited engineering schools in South Africa, we are faced with a huge shortage in suitably qualified engineers. Proper education in Optical Networking in South Africa is further hampered by the high cost of laboratory instrumentation and equipment, as well as the continuous drop in the value of the SA Rand. The access to educational discounts or easy access to previous generation measuring equipment for research and education, further limits the quality of Optical Network education in South Africa. Creative solutions to address these problems have to be found. A SWOT analysis of the South African academic situation reveals some unique opportunities: creative curriculum development, co-operative research and teaching opportunities with other universities in South Africa and abroad, student projects to develop laboratory equipment, co-operation with the Optical Networking Industry and the sharing of expensive equipment and instrumentation amongst tertiary institutions, suppliers and the operators of optical networks.

Index Terms—Optical network education, optical network laboratory, optical network curriculum, optical fibre training equipment.

I. INTRODUCTION

With the integration of voice, data and video communications over the Information Super Highway, we are combining three historically separated educational and research fields into one. These are Telecommunications, Computer Systems and Photonics. The new field is called Optical Communication Networks. To introduce such a new field into any academic institution takes courage, negotiation skills, office and laboratory space, human and capital resources and a team effort. With very limited information in the literature on similar efforts, one has to rely on experience and intuition [1].

Developing a suitable curriculum for Optical Communication Networks has to address all the following topics:

- ECSA (Engineering Council of South Africa) requirements
- Module prerequisites
- Laboratory facilities
- Computer and software capabilities
- Complementary courses from Telecommunications and Computer systems
- Final year projects
- Postgraduate courses

- Masters and Doctoral studies
- Library and other reference sources

To comply with this list of requirements it has become clear that an Optical Network research and teaching group has to be established in the Department of Electrical, Electronic and Computer Engineering (DEECE) at the University of Pretoria (UP). This group currently consist of two full-time and one part-time lecturer, as well as a number of postgraduate students.

To establish a viable and growing programme in Optical Networking, links and cooperation have to be established with the following role-players:

- Other educational institutions working in this field (in South Africa and abroad)
- Research institutions such as the CSIR
- Network Operators such as Telkom
- System, sub-system and component manufacturers and suppliers; including suppliers of computer software
- Government departments such as DoC
- Professional societies such as IEEE, SPIE and OSA
- Research support organisations such as the NRF

As a result of limited trained optical networking professionals in industry as well as the academic environment in South Africa, universities are faced with a serious bootstrapping exercise: The required optical network engineers cannot be trained because of the lack in teaching staff in this field, this lack resulting to a great extent from too few PhD students in the field. These human resource shortages in the academic institutions are further aggrevated by the high cost of optical communication networking laboratory equipment (instrumentation, components, training/educational “kits” and simulation software). The high cost of equipment has three components: (a.) The high cost of importing equipment from abroad, (b.) The weak and weakening Rand and (c.) the absence of significant educational discounts for universities in South Africa.

Despite these restrictive factors, there are also certain strengths in the Optical Communication Engineering community in South Africa. By exploiting these strengths South Africa can become the Optical Networking Hub for Africa and even address niche markets for exporting knowledge, skills and equipment (hardware and software) to Europe, USA, Asia and others. These opportunities include:

- The relative low cost of skilled labour in South Africa (especially engineers)
- The excellent quality of engineers and postgraduate
students (broadminded)

- Government incentives for export
- The experience of some of the high-tech companies in the RSA
- The good relationships amongst the mentioned role players
- The Innovation Hub in Pretoria.

II. OPTICAL COMMUNICATION NETWORK CURRICULUM DEVELOPMENT

After many years of teaching introductory courses in Photonics at the undergraduate level (first called Optoelectronics in the 1970’s and 1980’s) at the University of Pretoria, the emphasis gradually shifted from broad Photonics to Fibre Optics and since 2000 to Optical Communication Networks. The postgraduate courses in Optical Signal Processing and Infrared Technologies were also replaced by Optical Network related courses. The current package of courses presented at the University of Pretoria include:

- Introduction to Optical Communication Networks for postgraduate students with no background in this field at undergraduate level. Textbook by Ramaswami [2].
- Advanced Optical Communication Networks. Textbook by Stern and Bala [4].
- Optical Network Laboratory. Textbook by Derickson [5].

All the relevant ITU-T Recommendations are also referred to.

The first introductory course in optical networking consists of basic topics such as fibre optic principles, types and components; light sources and detectors; modulation and receiver electronics; optical amplifiers; switching components such as multiplexers and wavelength converters; optical network principles; protocols; network simulation, protection and restoration and finally instrumentation and measurements. Such an introductory course builds on principles such as physics, optics, semiconductor theory, electronics, telecommunications, computer communications and mathematics.

The curriculum for the undergraduate course at UP includes a number of laboratory experiments and computer network simulations, including:

- 125 Mbaud HP plastic optic fibre communication links (analogue and digital communications)
- OptSci Communication kits for characterising a LED, LD, pin photodiode and different optical fibre lengths (including components such as connectors, splices etc.)
- OptSci Optical Network kits with OTDR’s for analysing emulated 1310nm and 1550nm optical networks (including couplers, WDM’s, different fibres, etc.)
- VPI optical network simulation package (e.g. PTDS Lite)

With the rapid growth in Optical Network development and implementation, similar growth is experienced in the number of new publications appearing day by day, such as:

- Textbooks
- Journal publications from professional institutes (e.g. IEEE, SPIE, OSA)
- Industry Journals (e.g. Lightwave, Laser Focus World, WDM solutions, FiberSytems)
- Manufacturer magazines (e.g. Anritsu News)
- Information guides from suppliers of systems (e.g. Siemens, EXFO)

The rapid change in the Optical Networking field is however creating a rapid change and increase in the sophistication of the equipment available. New measuring and laboratory equipment appear on the market at an increasing rate. This creates a high per unit cost and even higher Rand cost for South African universities. In a research laboratory or postgraduate course it is sufficient to equip laboratories with one or two pieces of expensive measuring instruments such as spectrum analysers, OTDR’s, and even equipment such as EDFA’s, optical cross-connect (OXC’s), WDM’s, etc. Only a few manufacturers produce training kits for Optical Network training and these fairly simple units are frequently the same price (South African Rands) as much more sophisticated measuring instruments. These training kits do however have the advantage of well-prepared training manuals that accompany the kits. For training large groups of undergraduate students (150 or more), it is however essential to have numerous training “stations”, consisting of equipment and measuring instruments. It also turns into a very challenging time and space multiplexing exercise for the lecturers and instructors. The DEECE at UP introduced 24-hour laboratories a number of years ago. These laboratories are equipped with entrance and exit control as well as surveillance equipment, so that they can be used any time of the day or night. Time multiplexing and laboratory assignments are therefore much easier to be scheduled.

At the UP extensive final year projects by Electronic and Computer Engineering students can be selected from the different research fields in the Department. It is therefore essential to prepare approximately 6 to 12 project proposals in Optical Networking every year. To broaden the scope of these projects the University has negotiated with the Technical University of Eindhoven (TU/e) (under the official agreement between the two universities) to send a small number (2 or 3) of these students to TUE for part of their project research. This is an important stimulus for recruiting students into the postgraduate programme in Optical Networking.
III. POST GRADUATE STUDIES AND RESEARCH

Master’s degree studies at the University of Pretoria require at least four compulsory semester modules as well as a comprehensive research project and dissertation; or seven modules and a mini-research project (called a course-work Master’s degree). All modules are presented as Telematic (Web-based) courses, which require only two visits to the campus for 2.5 days each (per module). During these mini-blocks specific problems are discussed, extensive laboratory work (including simulations) is done and a test is written at the end of the session. All three of the Optical Networking postgraduate modules are presented in this way. These modules prepare the students for the advanced research projects of the Master’s degree. The PhD degree in engineering is based on research only (in most cases). For both the Master’s and PhD degrees expensive laboratory equipment and/or computer simulation software is essential. Educational institutions have a limited number of support mechanisms for such advanced research:

- Limited support from the institution itself
- Support through centres of expertise/excellence (such as those sponsored by Telkom)
- Support by research funding organisations such as the National Research Foundation (NRF)
- Support/sponsorship from Industry (and possibly co-sponsored by the NRF through the THRIP)
- Research co-operation with universities and research establishments in North America, Europe, Asia, Far East and other countries.

For many years advanced postgraduate studies (PhD) in South Africa has been viewed as something destined for academics and of no real value for engineers in Industry. Through Industry-based research at Master’s and PhD level, the UP has been able to gradually change this view and PhD student numbers are gradually increasing.

The UP has found that short (e.g. three month) visits by lecturers to co-operative research universities are essential and very attractive to the interns.

IV. STAFF (LECTURER) RECRUITMENT, TRAINING AND RETENTION

As a result of the short history of Optical Network education at South African universities and the small scale at which it happens, the source of academics in this field is very limited. Combine this with the needs of the Industry for Optical Network engineers and the salary difference from Industry to academic institutions, it is clear that only a small number of dedicated educationists will join and stay with universities. Young graduates frequently join the university to use the opportunity for “full-time” postgraduate studies up to the level of PhD. Thereafter they leave the university for better remuneration, practical experience, entrepreneurial opportunities and interesting work environments. Combinations of these, combined with the week Rand and the current high levels of crime in South Africa, cause many young engineers to leave the country.

The challenge that faces South African universities is to come up with creative plans and programmes to create as many opportunities as possible for lecturers to:

- Exercise their educational (teaching) skills and desires
- Be active in the specific research environment; including conference participation and research visits
- Practice their engineering skills through consulting work to stay in contact with real engineering projects and earn extra income
- Participate in research and teaching exchange programmes with universities abroad
- Present short courses
- Develop their innovative and entrepreneurial skills through patenting and product development.

Academic institutions frequently face stiff competition from Industry (and recently even government departments, parastatals and local governments) for the services of young engineers. Because of fixed salary scales at universities for academics, there is very little room for matching offers made to these lecturers. Academic institutions however also carry out this process of “head-hunting”, as most universities do not have a bursary scheme for attracting scholars into university studies with the aim of becoming lecturers. Better cooperative programmes for staff development between universities and the Industry have to be developed.

V. OPPORTUNITIES IN OPTICAL NETWORKING FOR UNIVERSITIES IN SOUTH AFRICA

The challenge is to change the weaknesses and threats facing South African universities (as listed above) into strengths and opportunities. The proposals can be summarised as follows:

(i) Closer cooperation amongst educational institutions, equipment suppliers and network operators
(ii) Improved opportunities for internships at research facilities abroad
(iii) Opportunities for innovation and entrepreneurship in developing educational optical network equipment (for the local market, but more so for the export market)

To evaluate the benefits of any such cooperation, we have to consider what each participant can offer and require:

Universities
Offer – Expert knowledge on the state of the art research from all over the world; student projects (undergraduate and postgraduate); Continuing Professional Development (CPD)
Require – Access to state of the art equipment and instruments; participation in real world problems; training equipment

Equipment suppliers
Offer – Subsidised equipment; information on equipment and instrumentation developments; internships for students and lecturers
Require – Equipment sales; product promotion and evaluation; product research

Network operators
Offer – Access to state of the art installations; internships; consultancy possibilities
Require – Good and well prepared human resources; access to technology forecasting; specialist consulting.

By combining the efforts of these three groups, funding from others (such as the NRF, government support programmes and venture capitalists) can be leveraged. This can even lead to new initiatives for import replacement and export ventures (especially in educational training equipment and software).

A project on developing Optical Networking Training kits for educational institutions in South Africa, the rest of Africa and abroad, can be started from within the Technology Incubator system at the University of Pretoria and the Incubator at the Innovation Hub (operated by the Southern Education and Research Alliance – SERA).

The imminent introduction of CPD for all registered professional engineers (with ECSA) will require a certain number of hours per year of course attendance. These courses will take the form of refresher courses, as well the introduction to new technologies, products and systems. Universities will play a major role in presenting some of these courses. It is the opinion of the authors that organisations will benefit from two types of CPD courses:

- Discipline and field specific courses that deal with the latest trends in the technology
- Overview courses for managers and engineers working in related (but not the same) field

These courses can even be presented as in-house courses and may include laboratory experiments and techniques. This will limit the costs

VI. CONCLUSION

The tremendous speed and bandwidth capabilities of fibre optic communication networks for voice, data and video communications make them essential components of the Information Super Highway. The training of engineers for the design and management of optical networks is a challenge for especially South African universities with their unique problems. These are mainly the high cost of imported measuring and training equipment, the lack of postgraduate students and the difficulties in recruiting and retaining suitably qualified lecturers. Novel solutions to address these problems can actually create opportunities for developing products (hardware and software), skills and services for the export market. These solutions could also assist the universities in obtaining funding for the purchase of expensive measuring equipment.

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