Brussels, 14 May 1998

COST 237/98

[DRAFT]

Memorandum of Understanding

for the implementation of a European Concerted Research Action designated as COST Action 268

"Wavelength scale photonic components for telecommunications"

The Signatories to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the Technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 400/94 "Rules and Procedures for Implementing COST Actions", the contents of which are fully known to the Signatories.

2. The main objective of the Action is to investigate the potential and to promote the use of wavelength scale photonics in telecommunications, thereby enabling a faster transition from research prototypes to commercial devices in systems. To this end a cooperative effort involving universities as well as telecommunications R&D establishments and industries is required.

3. The overall cost of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at ECU 12,7 million at 1998 prices.

4. The Memorandum of Understanding will take effect on being signed by at least 5 Signatories.

5. The Memorandum of Understanding will remain in force for a period of 4 years, unless the duration of the Action is modified according to the provisions of Chapter 6 of the document referred to in Point 1 above.

COST Action 268

Wavelength scale photonic components for telecommunications

A. BACKGROUND

A.1. Introduction

Photonics is a key enabling technology in telecommunications. In the last decade, the technology to fabricate structures on an optical to sub-optical wavelength scale has matured, and opened for a new generation of photonic devices, which once inserted in the telecom fabric is expected to increase systems performance significantly. To give a few examples of already implemented, or near implemented technologies: Quantum well heterostructure active layers are used in almost all commercial laser diodes for telecom applications. Vertical cavity surface-emitting lasers (VCSELs), requiring advanced epitaxial growth, are close to a full commercial breakthrough; already Honeywell, MITEL Semiconductors, Hewlett Packard and Motorola are selling data and telecom solutions based on VCSELs. Indeed, wavelength scale photonic components such as VCSELs may become the key solution in telecommunications to the interconnection "bottleneck", as well as the key provider of low-cost optical solutions for high capacity data traffic to the homes.

There is at present a strong world-wide research effort to fully harness the potential of wavelength scale photonic components. In Europe, several national or international projects are investigating various aspects of wavelength scale photonics. Still, many European groups agree that there lacks a broad forum to catalyse the deployment of these components in telecommunications, and that such an effort would strengthen the European competitiveness in exploiting advanced photonics in telecom applications.

This is the background and rationale of the proposed COST Action, which has the objective to investigate the potential, and to promote use of wavelength scale photonic components in telecommunications. The Action will act as a catalyst for research by improved collaboration and networking, and a proactive collaboration on identified strategic research topics. Already, as detailed by the appendix, many of the leading European groups have been involved in discussing the proposal and declared their interest to participate in the Action.

A.2. State of the art

The state of the art in wavelength scale photonics (as at January 1998) is best illustrated by a few representative examples. On the theory side there are predictions on:

- High-efficiency devices, for instance diode lasers with an ultra-low lasing threshold, even to the point of thresholdless operation ([1]). Another example is light-emitting diodes (LEDs), with an extraction efficiency above 50%, even up to and above 90% if fully optimized ([2]).

([1]) See for example "Spontaneous emission and laser oscillation in microcavities", edited by H. Yokoyama and K. Ujihara, CRC Press, London, 1995.

([2]) S. Fan, P. Villeneuve, J. Joannapoulos, E.F. Schubert, Phys. Rev. Lett. vol. 78, pp. 3295-3297 (1997).

- Complete control of light propagation in so-called "photonic bandgap" periodic structures in two dimensions (2D and 3D), abbreviated as PBGs, also denoted as photonic crystals ([1]) (a one-dimensional equivalent would be a Bragg grating). Such structures have applications in lasers and light-emitting diodes (LEDs), in integrated optics for compact high-Q filters, waveguides, and sharp 90-degree waveguide bends. PBGs are directly scalable in frequency by a scaling of the periodicity, making the PBG concept generic. Therefore, the first application of photonic bandgap structures may be in the microwave region for e.g. novel antennas.

- Control of material gain properties by quantum size confinement, e.g. carrier confinement in the scale of tens of nm modifying the gain and light-emission properties ([2]). The great majority of commercial diodes have quantum wells as active material. The next step is quantum wire structures (2D confinement), to be followed by quantum box, or dot structures (3D confinement).

The state of the art in terms of experimental demonstrations can be illustrated by:

- A few microampere threshold vertical cavity lasers using lateral oxidation techniques, demonstrated by SANDIA National Laboratories, USA ([3]) and high-power surface-emitting lasers with a pulsed output power above 1,5 W demonstrated by University of Ulm, Germany ([4]).

([1]) J.D. Joannopoulos, R.D. Meade and J.N. Winn, "Photonic Crystals", Princeton University Press, Princeton, New Jersey, USA, 1995, with many references.
([2]) For an excellent introduction, see C. Weisbuch and B. Winter "Quantum semiconductor structures – fundamentals and applications", Academic Press, San Diego, USA, 1991.
([3]) K. Lear et al, 1996 Conference on Lasers and Electro-Optics, IEEE Technical Digest Series, 9, 205 (1996).
([4]) R. Michalzik, K.J. Ebeling, M. Grabber, D. Wiedenmann, R. Jager, C. Jung and B. Weigl, "High Power and High Efficiency GaAs based VCSELs". Invited talk ThI1, LEOS 97 annual meeting, San Francisco, 10-13 November (1997).

- Resonant cavity light emitting diodes with an extraction efficiency above 20%, demonstrated by IMEC, Belgium ([1]), within the ESPRIT 3 SMILES project (followed up by ESPRIT 4 SMILED).

- 2D Photonic bandgap filters and cavities, the smallest with a cavity mode volume = 0,055 μm^3 demonstrated by Glasgow University ([2]) and Massachusetts Institute of Technology ([3]).

- Full 3D Photonic bandgap at optical frequencies demonstrated by UCLA and CalTech in collaboration ([4]).

- Photonic crystal fibres, optical fibres with lateral periodic perturbation featuring single-mode operation from 800-1 600 nm demonstrated by University of Bath and Southampton University ([5]).

([1]) H. De Neve, J. Blondelle, R. Baets, P. Demeester, P. Van Daele and G. Borghs, IEEE Phot. Tech. Lett., vol. 7, pp. 287-289 (1995).

([2]) T. Krauss, Y.P. Song, S. Thoms, C.D. Wilkinsson and R.M. DeLaRue, Elec. Lett., Vol. 30, pp. 1444-1445 (1994).

([3]) J.S. Foresi, P.R. Villeneuve, J. Ferrara, E.R. Thoen, G. Steinmeyer, S. Fan, J.D. Joannapoulos, L.C. Kimberling, H.I. Smith, E.P. Ippen, Nature, Vol. 390, pp. 143-145 (1997).

([4]) C.C. Cheng, A. Scherer, V.A. Engels and E. Yablonovitch, J. Vac. Sci. Technol. B, Vol. 14, p. 1410 (1996).

([5]) T.A. Birks, J.C. Knight and P. St.J. Russel, Opt. Lett. Vol. 22, pp. 961-963 (1997).

- Quantum dot VCSELs with a low threshold have been demonstrated by University of Texas, Austin ([1]), and Ioffe Institute, US Air Force Inst. of Techn. and Tech. University Berlin ([2]), the latter with as low a threshold as 68 µA, already in the same range as the best quantum well VCSELs.

The common feature of all these devices is the optical or sub-optical wavelength scale (roughly < µm) feature size, and the direct need to consider the full device optimization including the active material, cf. the Quantum dot VCSELs mentioned above. Hence, the generic interest in telecom to scale down device sizes, reduce power consumption and enable small to large-scale integration is at the heart of the present Action.

B. OBJECTIVES AND BENEFITS

B.1. Objectives of the Action

The main objective of the COST Action is to investigate the potential and to promote the use of wavelength scale photonics in telecommunications, thereby enabling a faster transition from research prototypes to commercial devices in systems. A coordinated effort on wavelength scale photonics in telecommunications is expected to enable an increased system performance. This is due to a higher level of hardware integration being possible, the devices being compact with low power consumption, and an increased device functionality due to a more optimal use of optical waveguiding/mode and material gain properties of devices.

([1]) D. Huffaker, O. Baklenov, L. Graham, B. Streetman and D.G. Deppe, Appl. Phys. Lett., 70 (17), pp. 2356-2358 (1997).

([2]) M.N. Ledentsov, V.M. Ustinov, J.A. Lott, A.Y. Egorov, A.E. Zukov, M.N. Maximov, P.S. Kopev, Z.I. Alferov and D. Bimberg "Vertical cavity surface-emitting lasers based on vertically-coupled quantum dots", LEOS annual meeting, Paper ThY6, San Francisco, 9-13 November (1997).

At present, many university and industrial labs are conducting research in national or European projects, e.g. ACTS and ESPRIT. However, the fabrication and process technology for wavelength scale photonics still require a large research infrastructure, and not all university labs in Europe have the possibility to conduct experimental research in the field. In particular this is true for laboratories having no close industrial partner within the country doing research on optoelectronics. A secondary objective of the Action, therefore, is to provide resources for a pan-European effort, so that small laboratories lacking facilities are able to collaborate with other groups to realize novel prototype devices that can be tested in an application context. This effort will therefore also serve to spread the technology know-how in the field to all participating areas in Europe.

B.2. Benefits of Action

The COST Action will bring together experts covering the full technology spectrum of wavelength scale photonic components, and promote an open collaboration between groups already in the field, as well as groups getting into the field. This will lead to a faster identification and solution to problems and possibilities, thus increasing the competitiveness, of European telecom industry. Furthermore, the fabrication technology is generic. For instance, for research on nano-structured materials (such as COST Action 523, which does not address the telecom and semiconductor aspects specifically addressed here), there will be a mutual benefit in terms of the know-how in fabrication technology.

Hence, the benefit of the Action can be summarized as follows:

- The ability for a larger research community to identify and give a fast reply to industrial needs, e.g. the early-on identification and development of applications, e.g. in optical interconnects and data communication (conventional glass optical fibre, plastic optical fibre (POF), wireless) optical data storage, sensor, displays, etc.

- The provision of a broad engineering forum in a field of generic importance for photonics, a forum beyond that already provided by existing projects bringing together scientists, manufacturers and potential users.

- Facilitate human resource exchange and discussions. In particular, this is true for young researchers, who, by the Action, get an excellent contact network and a forum to test novel ideas.

C. TECHNICAL PROGRAMME

C.1. Platform of research and development effort

The COST Action will build on the existing research effort in Europe, strengthen and supplement this effort by a collaborative Action, an added value being that many groups are not yet working with each other in projects. The present Action will also benefit from previous Actions, such as COST Action 240 on "Techniques for modelling and measuring advanced photonic telecommunications components". The method of work is to catalyse research on wavelength scale photonics for telecom applications by improved collaboration and networking, in a manner
similar to the US-Japan JOP collaboration (Internet address: www.OIDA.org/JOP/index.html).

The work of the Action will aim at:

- The exchange of information and human resources, to organize joint work by groups in between meetings, short-term missions, and by organizing workshops on key issues for the Action.

- Act as an information channel on accessibility of advanced technologies and characterization facilities needed to make and evaluate components so that groups lacking this capability can easily find their way to collaboratively realize a new component.

- Act as a platform for distribution of non-commercial prototype components for laboratories to experiment with them in an application context.

- Interact with potential manufacturers and system users so as to identify possible applications as well as critical specifications at an early stage and to speed up the transition from research labs to applications.

The technical program will be split between initially three Working Groups, with joint meetings to promote the information exchange. During the Action, the work will be continuously revised and if needed the structure of the Working Groups may be rearranged.

The overall joint effort of all three Working Groups is to provide technology input for the insertion of wavelength scale photonic components in telecom systems, this facilitated by the collaboration between industrial and university groups. The Action will also be open to external interests and experts from e.g. ACTS, ESPRIT and other COST Actions are invited to participate.

C.2. Working Groups

C.2.1. Working Group 1: Microcavity devices

Working Group 1 will focus on the design, modelling, characterization and fabrication of microcavity telecom devices, such as microlasers and vertical cavity surface-emitting lasers (VCSELs), resonant cavity light-emitting diodes (RCLEDs), resonant cavity detectors and vertical cavity amplifying photonic switches. In particular the work will study:

- Establishment of common model tools for microcavity resonators, notably VCSELs, and modelling tool comparisons, e.g. in the form of modelling exercises.

- Establishment of an optical constant database.

- Fabrication technology evaluation and procedures for access to fabrication facilities for Action usage.

- Comparison and development of characterization, notably VCSEL characterization (static and dynamic properties, noise ...).

- Round-robin measurements of prototype components.

C.2.2. Working Group 2: (Quasi) periodic structures

Working Group 2 will address the design, modelling and fabrication of quasi-periodic structures for telecom applications such as photonic bandgaps and resonant surface gratings, the structures fabricated in semiconductors or inorganic and organic dielectrics. In particular the work will study:

- Studies of diffraction by or waveguiding in strong grating structures and photonic bandgap structures for applications in telecom (e.g. such as compact WDM filters), both in semiconductor structures and in other inorganic or organic materials. Establishment of common modelling tools for vectorial analysis of such structures.

- Modelling of fabrication of devices, with the target of finding processes suitable for cheap mass production.

- Fabrication technology evaluation and identification of, and procedures for access to, fabrication facilities tor Action usage.

C.2.3. Working Group 3: Quantum confined gain materials for photonic telecom devices

Working Group 3 will work on the design, modelling and fabrication of the optoelectronic properties of quantum well, quantum wire and quantum dot gain materials to be used in photonic telecom devices. Specifically, the work will establish:

- A joint material parameter database.

- Development and comparison of modelling tools for the optimization of optical properties, notably gain of quantum confined structures.

- Establishment of standard measurement procedures and comparisons.

- Work on the joint characterization of materials.

- Work on the assessment and optimization of quantum confined materials in devices.

D. ORGANIZATION AND TIMETABLE

D.1. Management

The Action will be administered by one of the proposing groups with a management committee (MC) composed of participants from each signatory. The MC will elect at the kick-off meeting a Chairperson and Vice-Chairperson from among the MC members of the countries that have signed the MoU. The duration of the Chairperson appointment and Vice-Chairperson appointment is one year, re-election being possible. Chairpersons and Vice-Chairpersons who are elected once a year by the MC will head the Working Groups.

Management Committee meetings will be held in conjunction with regular meetings. The Chairperson will handle the external contacts with the commission, e.g. status report, financial and administrative questions, if needed with support of the Working Group leaders.

The communication in between meetings will preferentially be done by electronic means.

D.2. Information exchange

D.2.1. Electronic forum

The Action will use electronic information forums (e-mail, Internet) as the primary means for information exchange. An Internet site will be set up, which will contain all background material and administrative material of the Action, results from the work in the three Working Groups, and software and data in the form of a database for use by the Action.

D.2.2. Meetings and workshops

Annually, 2-3 combined management and Working Group meetings will be arranged. In conjunction with some meetings, typically one per year, a workshop on a selected theme of the Action will be organized.

D.2.3. Technical visits

In conjunction with meetings, the Action will seek to organize technical visits to either university or industrial facilities. These visits constitute an important starting point to enable the further in-depth collaboration between groups.

D.2.4. Short-term missions

The Action will provide funding for short-term technical missions. The objective of the missions is to promote joint work between groups, with key personnel bridging the technology and know-how gap of collaborating labs during the short research stays.

Each mission must be applied for and approved by the Management Committee.

D.3. Dissemination of results

To assure the scientific quality of the Action and that the results will be available for the research community in academia and industry, the Action will report the results in the normal channels, e.g. at conferences and in peer-review scientific journals, as well as providing information through electronic media.

The incorporation of telecom industry will assure that the Action is focused on relevant technological issues, as well as assuring that applications are identified in an early stage. The Action, being focused on application issues, will proceed within the Technical Committee Telecommunications. However, special liaisons are envisaged to relevant Actions in "Materials", "Nano-science" and in "Physics".

D. 4. Intermediate reviews and final report

The Action will be subject to annual reviews by the TCT. Finally, besides the periodic dissemination of results, a final report will be written, including an executive summary, final financial statement, and a summary of the results achieved in comparison to initial and updated Action plans.

D.5. Duration and timetable of Action

D.5.1. Duration of Action

The Action will proceed over four years.

D.5.2. Tentative timetable of Action

This is a tentative timetable of the Action. Due to the nature of a COST collaboration, the specific topics of work may be shifted with time in order to react to specific needs identified by the Action.

Time	WG1	WG2	WG3	Common WG1, 2 and 3
T0 + 6 months	Optical constant database	Modelling tools surveyed	Material constant database	Internet site ready 1st model exercise 1st MCM (Management Committee Meeting)
T0 + 12 months	Results of 1st model exercise VCSEL characterization evaluated Round-robin meas.	Results of 1st model exercise 2D PBG structure proposed for fabrication Strong grating structure fabricated	Results of 1st model exercise	1st workshop+MCM tentative "VCSELs and microlasers in applications"
T0 + 18 months	VCSEL and microcavity emitter characterization	PBG and strong grating structure characterization	Optimized gain material inserted in device structure	MCM
T0 + 24 months	Recommendations (= a report) for microcavity emitter characterization	2D PBG structures fabr. and evaluated 2nd modelling exercise	Modelling tools compared and made use of within Action	2nd workshop and MCM, tentative "Quantum dot lasers, status and perspectives"

T0 + 30 months	VCSEL dynamics and quantum noise characterization, performed and optimized	Results of model exercise Round-robin meas.	Gain material evaluation	MCM
T0 + 36 months	High-speed, low-noise microcavity/VCSEL light emitter evaluated	Recommendations for optimized PBG and strong grating devices	Optimized gain material used by WG1 and 2	2rd workshop and MCM, tentative "Photonic bandgap components, from theory to devices"
T0 + 42 months	Results on systems test on VCSEL/microcavity light emitter		Recommendations/ summary of optimized quantum confined gain material	MCM
T0 + 48 months		Optimized 2D and 3D PBG structure with emitter evaluated		Final report and MCM, possibly a book

E. ECONOMIC DIMENSION

Estimated number of signatories: 14

Cost (KECU) per signatory per year:

Estimated person/year: Engineer, Researcher involved in Action	
3 person/year: average of engineer/student (this would include Lab. overhead, etc.)	KECU 120
Equipment and material costs, consumables	KECU 60
Travel	KECU 10
Short-term missions, additional costs	KECU 10
Total per signatory per year	KECU 200

Economic dimension:

Total over 4 years for all signatories (1 decimal)	MECU 11,2
+ 10% overhead for running/operational costs	MECU 1,1
Total cost to national funds	MECU 12,3
EU overhead (over 4 years) KECU 90	MECU 0,4
Total economic dimension	MECU 12,7