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Proposal for a new COST Action

COST Action 299
Optical Fibres for New Challenges Facing the Information Society – “FIDES”

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DRAFT

MEMORANDUM OF UNDERSTANDING

for the implementation of a European Concerted Research Action

designated as

COST Action 299

OPTICAL FIBRES FOR NEW CHALLENGES FACING THE INFORMATION SOCIETY

"FIDES"

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 400/01 "Rules and Procedures for Implementing COST Actions", the contents of which the Signatories are fully aware of.

2. The purpose of this Action is to find novel and disruptive applications of fibre optics, to define guidelines for standardisation of optical fibre applications and to combine the transdisciplinary expertise of key-players in this field to promote the invention of new optical fibre based information providing tools.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at Euro 30 million in 2005 prices.

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

5. The Memorandum of Understanding will remain in force for a period of four 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 299

OPTICAL FIBRES FOR NEW CHALLENGES FACING THE INFORMATION SOCIETY "FIDES"

Abstract

Developed societies require more and more information for their safety and for their economic development. Optical technologies are an essential actor owing to their tremendous capability to transmit and process a high density of information. Optical fibres are a key component for these technologies and their potential for optical processing and for collecting information as sensing probe is still widely unexplored. The FIDES Action fills this gap by bringing solutions for processing information and sensing using specific linear or nonlinear effects in standard, doped and micro-structured fibres.

A. BACKGROUND

"Information" is recognized as the key to sustained economic development and to the protection of our society against all kinds of threats such as natural disasters, diseases and terrorism. As a result, the need for information acquisition, processing and transmission equipment has never been as acute as today. In this respect, optical fibre technology has played a central role in the development of high density telecommunication. Its introduction led to a multiplication by many orders of magnitude of the data rate capability and has drastically improved the efficiency of information distribution.

The ever increasing demand for bandwidth calls for even more developed transmission links and consequently optical fibre technology faces new challenges to increase the data rate capabilities. In particular new classes of optical fibres are being developed to broaden the transmission spectral band and to reduce the distortions induced by optical nonlinearities for hundreds of dense wavelength-multiplexed channels to be transmitted in a single fibre. The development of these new fibres requires intense and transdisciplinary collaboration between academic and industrial partners, since it needs to address a wide field of scientific expertise. Many different solutions are being proposed to cope with the challenge such as new fibre geometries, improved manufacturing processes and photonic bandgap waveguides.

The transmission of information is only one aspect of the new challenges that the information society is facing. The increased amount of data requires advanced processing techniques to extract and interpret the essence of the information flux and it clearly appears that photonic processing will play a key role to achieve this goal. Optical fibres turn out to have a very important impact on optical signal processing for the following reasons.

a) They offer unmatched amplification in actively doped waveguides.
b) They allow for lossless delay and total control of dispersion.
c) Enhanced nonlinearities can be exploited in novel micro-structured (photonic crystal) fibres and by introducing novel dopants such as metal nanoparticles.

Another aspect that used to be considered only for niche applications but for which the interest is widening involves the ability of optical fibres to collect or sense information. They are indeed sensitive to many physical quantities and they can encode and transmit an optical carrier as a function of these quantities. Optical fibres may thus be used as sensing probe and offer a very effective solution for remote sensing: the fibre acts as a probe for the physical quantity by transducing the information to a modified characteristic of the optical signal (power, phase, frequency, polarisation) and, at the same time, as a link to transmit the information to the relevant place. In addition the fibre offers the unique possibility to perform distributed measurements, since every point along the fibre length can act as a sensing element. This way the fibre may substitute for thousands of point sensors and enable the surveillance of wide and sometimes intricately accessible areas with a drastic saving of resources. Such sensors are now required in many new installations as a result of new regulations for preserving the environment and for public safety.

In conclusion optical fibres have an essential role as physical information provider due to their ability to perform the 3 functions described above: transmission, processing and sensing of information. Research is very vivid in Europe in these fields and takes place in dispersed research units (Universities, small and medium size companies) present in most countries. These groups need a flexible structure on which they can build a “House of Knowledge” or community that would foster the coordination of the research work of scientists and engineers in disruptive applications of optical fibres.

The purpose of this Action is therefore to use the transdisciplinary expertise of the different key-players in the field to support the invention of new optical fibre based information providing tools. Some participants are active in other COST Actions and will report on topics of mutual interest during meetings, so that any possibilities of collaborations can be identified. This may result in common Study Groups or even in a common Workshop organised to address a common topic of interest. These COST Actions are clearly identified (270, 288, P11) and common participants will receive the special status of liaison officer with the formal duty to report to members of this Action. Several participants are also active in FP6 projects and NoE's, namely NEMO (especially WP10 chaired by a FIDES participant) and EPIXNET. The purpose of FIDES is to promote cooperative research between different teams on exploratory topics and through studies without material deliverables (devices). This is clearly a different approach compared to FP6 projects, with less technology and more exploratory studies. FIDES is dedicated to feeding future FP7 or existing FP6 projects and NoE's and there is a commitment to efficiently managing the available funds.

In addition to this, the Action will establish contacts with the European Photonic Industry Consortium (EPIC). EPIC members put pre-competitive components and systems in the hands of research programmes in order to train students on future and promising technologies. Many participants are experts for standardization bodies, such as IEC (SC 86A, B and C) and ITU-T (SG.6 and 15) and make an efficient liaison by providing FIDES with the concerns of the standardization bodies and by issuing recommendations to them resulting from the outputs of FIDES.

This collaboration can be most effectively initiated within a COST framework because:

- Active research groups are small and scattered over the full geographical Europe from Atlantic to Ural Mountains and need a flexible structure to effectively build up a community. The COST framework based on a voluntary participation with a limited administrative overhead perfectly fulfils the conditions for a successful start.

- Partners with different fields of expertise are involved in the different working groups, some with a theoretical and modelling approach, and others with an experimental background. This requires free discussions with open views using a common professional jargon and such an environment is proper to the COST spirit.

- Partners from different kinds of organisations (Universities, Bureau of Standards, Small and Medium Companies) have to interact, to provide samples and equipments and to perform measurements through round-robin inter-comparisons.

- This Action is the core of an expert group for issuing recommendations to standardisation bodies in the field of optical fibres and for supporting and organizing future or existing conferences and workshops (OFMC: Optical Fibre Measurement Conference, EWOFS: European Workshop on Optical Fibre Sensors, OFS: Optical Fibre Sensor conference, SPIE Photonics Europe, ECOC, …).

B. OBJECTIVES AND BENEFITS

The purpose of this Action is to find novel and disruptive applications of fibre optics, to define guidelines for standardisation of optical fibre applications and to combine the transdisciplinary expertise of key-players in this field to promote the invention of new optical fibre based information providing tools.

The applications of optical fibres are no longer limited to telecommunications and partners in all fields must interact to increase the knowledge and to share experience. Some techniques developed for telecommunications are of great potential interests for setting up efficient sensors and vice-versa. The definition of adapted fibre devices for a class of applications is a benefit that such an interaction can trigger.

Knowledge is currently scattered among many small research units and small & medium companies, each of them defining their own standard that results in poor compatibilities between active partners. A concern that is repeatedly expressed in recent forums and conferences is the need of standardization in application fields different to telecoms. Such a COST Action is expected to initiate a think tank about this issue and to result in a frame of propositions for standardization.

Another objective is to trigger an interaction between complementary partners in the field of fibre optics: fibre manufacturers, modelling specialists and theorists, system designers, metrologists and end users. Converging solutions must emerge from such an interaction, that is an essential benefit of a COST Action: manufacturers can provide samples that are on one hand modelled and compared to theoretical predictions and are on the other hand measured and characterized in round-robin exercises carried out by experimental teams.

An important benefit is the organisation of a scientific core group in the field of fibre optics that can plan and manage a wide range of scientific activities in the European hemisphere, such as conferences, workshops, standardization procedures and EU-supported projects such as coordinated actions, integrated projects or specifically targeted research projects. The Action supports the participation to collective and cooperative research to valorise the know-how generated in the Action, to find possible funding sources for specific research activities, to assist the SMEs present in the Action, to contribute to the visibility of the Action and to actively participate to the ERA.

C. SCIENTIFIC PROGRAMME

The scientific aim of the project is to investigate and validate advanced and novel techniques using optical fibres as signal processors. The impact of optical fibres as transmission links has been widely proved and now constitutes the preferred long haul transmission medium. But the potential use of fibres for other photonic applications is still a vivid research topic and novel techniques are regularly reported in the domains of optical processing and sensing. A clear trend today is to achieve a substantial part of signal processing in the optical domain.

The types of properties that are investigated in this Action are steered by the positive evaluation of feasibility, societal concerns, and industrial needs. A recurrent observation of active partners ranging from researchers to end-users is the absence of coordination and standardization is this multi-interest field. A clear objective of this Action is to find and define guidelines for standardisation, in connection with standardization bodies such as ETSI, CECC, IEC and ITU-T.

Recently, novel types of fibres have been proposed to potential users offering unprecedented possibilities in the domain of sensing and processing: fibres doped with new type of doping, micro-structured fibres, air guiding fibres, etc… Moreover, the ever growing power and spectral quality of semiconductor sources result in a more efficient use of nonlinear effects in fibres, offering unprecedented possibilities for distributed sensing along optical fibres.

The Action mainly focuses on the passive properties of fibres, namely their intrinsic sensitivity to external quantities and their nonlinear response for optical processing. Nevertheless, some active configurations are addressed if they bring a major advantage to the target response.

These aspects form the scientific framework of the Action that can be divided in 3 main directions of study.

1. Photonic crystal fibres

Photonic crystal fibres (PCF), also known as micro-structured fibres or holey fibres, constitute a new class of optical fibres offering significant new possibilities and functionality within a diverse range of applications including optical communications, fibre lasers and amplifiers, nonlinear fibre devices, fibres for high power transmission and new types of fibre-based sensor devices. There are two types of PCFs: in index-guided PCFs the core area is solid and the light is confined to a central core by a modified form of total internal reflection. In bandgap-guided PCFs the core is hollow, and light is guided by the photonic bandgap (PBG) effect. Index-guided PCFs have already proven their capability for specific telecom applications, while PBG

PCFs show extremely promising features, such as the possibility to propagate with a linear attenuation below the Rayleigh limit owing to air guiding, together with much reduced nonlinearities. In addition filling the hollow core with specific gasses can give PBG-MOFs a decisive advantage for sensing purposes.

The scope of WG1 encompasses characterisation of PCFs and PCF-based components through measurement and modelling of their linear and nonlinear properties and experimental investigations and numerical simulations of light propagation in PCFs. WG1 focus on fibres showing an interest for optical processing (highly nonlinear) and for sensing (hollow core). Topics of particular interest for this WG are:

- Measurement of linear parameters of PCFs: attenuation, bending loss, mode field diameter, cut-off wavelength, chromatic dispersion, birefringence, polarisation mode dispersion.
- Measurement of nonlinear properties of MOFs: nonlinear coefficient, 4-wave mixing, modulational instability, Raman scattering, Brillouin scattering, $\chi(2)$ properties.
- Theoretical analysis (modelling) of index-guided PCFs.
- Experimental studies and numerical simulations of nonlinear propagation in PCFs.
- Experiments on spectroscopy using gas-filled hollow core fibres.
- Characterisation of specialty PCFs: i.e. rare earth ion-doped fibres, multicore fibres, fibre gratings etc.

The main method of working is through performing round robin measurement inter-comparisons and joint studies by participants, together with exchange of results and information.

2. Characterisation and applications of rare-earth highly-doped fibres

The main goal of this study in this Action is the development and testing of measurement techniques for highly doped fibres. Also, efforts are made to study the design and characteristics of amplifiers and lasers made by highly doped fibres. The focus is on Er^{3+}, Yb^{3+} and Er/Yb doped fibres but any other dopant is considered.

The characterisation of highly doped fibres is very challenging when compared with low concentration fibres. Effects like clustering and up-conversion are not yet fully understood and their measurement is still under debate in the scientific arena. Developing more accurate models for clustering and up-conversion effects is a target of this working group and will provide better tools to simulate amplifiers and lasers made by highly doped fibres.

The study of non-linear effects in highly doped fibres has a two-fold importance. First, non-linear effects like four-wave mixing are a major problem in WDM applications. Secondly, non-linear effects can be used for distributed measurements of other fibre parameters.

Other measurements like PMD and polarisation-dependent losses are less reliable and difficult to perform due to the high losses and fluorescence produced at the signal wavelength. The standard measurement techniques must be tested in these conditions and, if necessary, new techniques developed.

Splicing highly doped fibres to SMF or other speciality fibres is also a very important topic for development of efficient amplifiers and lasers.

Highly Er doped fibres have already proved exceptional performances in EDFA applications (very short doped fibre lead to very high bit-rate due to low PMD and low non-linear effects). This Action has activities on designing, characterisation and modelling of fibre amplifiers aiming to the optimisation of gain, gain flatness and conversion efficiency.

The activities within this Action are carried out by round-robins, personal contributions, and joint publications. Several highly doped fibres are circulated among the participants and various measurement techniques are compared. Also, modelling and simulation comparisons are conducted in order to tune the software tools of the participants. The technical sessions of the bi-annual meetings provide the floor for proposals and debates on different issues regarding highly doped fibres.

3. Distributed measurements and the use of nonlinear effects for sensing and metrology

The use of distributed measurement techniques has become more and more important in sensing and optical telecommunication systems. They make possible to measure the distribution of a parameter along the length of a fibre which can be important for fibre manufacturers and network operators, and decisive for sensing applications. First of all, when upgrading a network, it is essential to be able to characterize the optical links by, for example, measuring the attenuation, the chromatic and polarization mode dispersions. These two last parameters limit the maximum bit rate that can be used on the network and their measurements are therefore essential when upgrading the bit rate. The use of a distributed measurement technique would enable measuring a dispersion map along an optical link and therefore to localize the fibre trunks presenting high dispersion values. For the fibre manufacturer, distributed measurement techniques will allow to evaluate the uniformity of their products. For sensing applications the fibre can substitute for thousands of point sensors and informs decisively on the structure or area under control.

Distributed sensing requires a position-dependent response and this is only possible through 2 types of optical interactions with the fibre material: scatterings (Rayleigh, Brillouin, Raman) and non-linearities (Kerr-based effects, stimulated scatterings). Scatterings cause a partial redirection of the light in the backward direction (change of the wavevector direction), while the nonlinearities make possible the transfer of light between 2 distinct lightwaves (light sensitive to the presence of light). Such interactions are very dependent on the power of the stimulating light and show a better response for an increased power. Therefore new optical sources based on doped fibres or semiconductor materials are of particular importance owing to their higher power and better spectral properties.

In the frame of this Action, the implementation of distributed measurement techniques is studied in order to characterise several important fibre parameters and to evaluate many external quantities for sensing purpose:

- Spot size, mode field diameter, core doping concentration.
- Chromatic dispersion: waveguide and material dispersions
- Polarization properties: beat length, coupling length and polarization mode dispersion (PMD)
- Sensing of temperature, strain, nuclear radiation and hydrogen.

The discussions and studies are divided along two main directions. The first one studies OTDR-based techniques for measuring the spatial distribution of the parameters. OTDR (Optical Time Domain Reflectometry) is an already well known technique for distributed measurement of losses in optical fibres. Recent papers have shown that it is also a potential technique for measuring other parameters as mode field diameter, chromatic dispersion and polarization mode dispersion (Polarization-OTDR). This study direction examines new OTDR-based set-up and focuses on the improvement of the existing OTDR techniques by, for example, improving the signal processing.

The second study direction focuses on the use of nonlinear effects for distributed measurements.

Recently published papers have shown that these effects have a potential interest for the measurement of chromatic dispersion, effective mode area and beat length, together with quantitative information on external quantities such as temperature and strain. In this study group, three nonlinear effects are addressed:

- Brillouin scattering
- Raman scattering
- Four Wave Mixing (FWM).

Of course novel techniques proposed by participants are studied as well and existing set-ups can be compared and dynamically improved.

It is important to mention that the members of the WG focus on a reduced set of parameters and quantities to measure, for instance temperature and chromatic dispersion, or hydrogen sensitivity and polarization mode dispersion. The final choice is settled according to the propositions of the participants. Separate Working Groups and Study Groups are established to investigate the topics identified above and must map the different study directions as described.

D. ORGANISATION

The management of the Action and its organisation structure are planned to create a discussion space between scientists specialised in the different disciplines presented in Section C, so as to achieve the objectives.

A Working Group (WG) will be created for each direction presented in Section C, so that the Action starts immediately with 3 active Working Groups, namely:

- WG1: Photonic crystal fibres,
- WG2: Characterization and applications of rare-earth highly-doped fibres,
- WG3: Distributed measurements and the use of nonlinear effects for sensing and metrology.

These WGs are divided into 2-3 Study Groups (SG) reflecting the diverse interests of the participants. Additional WGs may be created if the participants show a decisive interest in a general topic within the objective of the Action.

The consortium is coordinated by the Management Committee (MC) composed of the national delegates under the lead of the Chair and Vice-Chair, and supported by the Secretariat, as usually done in COST Actions.

Short-term scientific missions (STSMs) are a unique opportunity to acquire new knowledge in other prestigious institutions and to develop long-lasting collaboration with other laboratories, by merging different types of knowledge and creating transdisciplinary teams. Special attention is paid to ensure that all active partners schedule such a scientific mission during the Action: this can be used to extend the scope of the research of a PhD student or to enable key personnel to bridge technology and know-how gap of collaborating labs during short stays. This merging of expertise normally leads to increased scientific outputs and to original scientific publications for the benefit of COST visibility.

There is also a clear drive among interested participants to actively support the organisation of Workshops and Conferences on a world-wide basis, by initiating an Organizing Committee and a Programme Committee involving Action participants and extending them to key persons not involved in this Action, namely extra-Europeans. Furthermore, Members of the Management Committee are involved in large symposia, such as Photonics Europe. The COST Action 299 will be promoted by means of oral presentations, participation in the steering committees, and advertising, in the following major events: Optical Fibre Sensor Conference (OFS'05, OFS'06), European Conference on Optical Communications (ECOC'05,ECOC'06), Optical Fibre Measurement Conference (OFMC'05), Symposium on Optical Fibre Measurements (SOFM'06), SPIE Photonics Europe'06. In the next stage, the Action will support and promote the European Workshop on Optical Fibre Sensor, will organise specialised workshops and training, as well as one large international conference. There is a strong will to include the findings/information for educational material that will be available through a FIDES web portal.

E. <u>TIMETABLE</u>

The duration of the Action is **four years**, the timetable foreseen to accomplish the scientific program described in Section C along with the consortium organisation specified in Section D, is shown in the table below.

Activities	**YEAR 1**		**YEAR 2**		**YEAR 3**		**YEAR 4**	
WG Meetings	X	X	X	X	X	X	X	X
MC Meetings	X	X	X	X	X	X	X	X
Conference, Workshop			X					X

Short-Term Scientific Missions will take place over the course of the Action, as it evolves.

F. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: Belgium, Czech Republic, Denmark, Finland, France, Germany, Israel, Italy, Poland, Romania, Slovakia, Spain, Sweden, Switzerland, and UK.

On the basis of national estimates provided by the representatives of these countries, the economic dimension of the activities to be carried out under the Action has been estimated, in 2005 prices, at roughly Euro 30 million. This estimate is valid under the assumption that all the countries mentioned above but no other countries participate in the Action. Any departure from this will change the total cost accordingly.

G. DISSEMINATION PLAN

The dissemination of the scientific results mainly occurs through:

- Presentation of the results at seminars, workshops, and conferences;
- Publication of the results in international journals;
- Publication of book chapters;
- Technology transfer to spin-off companies, many of the interested Universities having direct connections with start-up companies or even being directly involved in some of them;
- Incorporation of scientific results and experience gained in academic courses and laboratory exercises;
- Maintenance of a Web site to be used for information dissemination among Action members on one hand, and with the open scientific community on the other hand.

The Web site established for the Action is composed of two access levels:

1) A public part containing at least:

- General information on this COST Action (membership, MoU, Annual Progress Reports, etc.);
- Calendar of meetings, workshops, and conferences, including contacts to get copies of the proceedings;
- Explanation of the core scientific problems investigated;
- List of publications emerged from the Action;

- On-line publication of scientific and technical reports.

2) A secured consortium-internal part (password protected) containing:

- Administrative information related to the management of this Action;
- Internal working documents;
- Scientific documentations related to the problems studied including
  - Commented bibliography;
  - Draft documents on ongoing work; preliminary reports;
  - Option: prototype software, databases and data used for experimentation.

A Workshop will be organised by members of the Action and will be open to the whole scientific community. This will stimulate mutual interest, promote quality of research through scientific confrontation of results, and contribute to identifying further challenging problems, while contributing to the visibility of COST in general and of this Action in particular. Moreover, this Action foresees to organise at least one international conference.

Additional Information (not part of the MoU)

I. HISTORY OF THE PROPOSAL

At the final stage of COST Action 265 some participants expressed the wish to launch a new Action, although with a severe renewal of the objectives and with a new leading team. COST265 suffered severely from the massive transformation of the research scene in the field of telecommunications and many partners among the most active left prematurely the Action. A group of core experts (5 persons) was designated and they decided to extend the technical scope to novel fields for fibre optics and to select a limited set of topics showing an active interest among a broad range of participants. Dr Luc Thévenaz was chosen to be the Proposer and to carry out the practical preparation of the Proposal, with significant contributions from the core experts.

This new Proposal reflects the trend among the active people in the research field of fibre optics. If telecommunication applications are still an important field for optical fibres, a significant part of the research efforts are now directed to field of sensing and information processing. In addition new types of fibres, namely the microstructured or “holey” fibres, have been developed and are now commonly available, with ever increasing performance. These new tools make possible enhanced interactions with the environment for sensing applications and extreme performance for optical processing, thanks to their susceptibility to nonlinearities and to their design flexibility.

These topics currently raise a broad interest and it was no surprise to learn that an independent team from the COST270 had shown a very similar interest and planned to propose an Action with close objectives, under the direction of Dr Francis Berghmans from SCK-CEN(BE). The two teams decided to merge their Proposals and to gather their efforts to make a Proposal reflecting a broad interest among the research community.

This Proposal should therefore not be considered as a sequel of COST265 (very oriented to telecom and standards) and COST270 (strictly oriented to reliability issues), but as a new Action reflecting the recent trends in optical fibre technology for the collection, the transmission and the processing of the information.

II. PRELIMINARY WORK PROGRAMME

The Proposer will invite all interested people who have answered to a Call during major conferences to join the Action and to participate in a first technical meeting. With the advice and support of Dr Francis Berghmans, Working and Study Groups will be proposed, together with propositions and rules for a working programme. Chairpersons for Working and Study Groups will be key research persons in the specific field of the Group, are already known to a wide extent and will be asked to present a first working programme.

There is also a clear drive among interested participants to actively support the organisation of Workshops and Conferences on a world-wide basis, by initiating an Organizing Committee and a Programme Committee involving Action participants and extending them to key persons not involved in this Action, namely extra-Europeans. Furthermore, Members of the Management Committee are involved in large symposia, such as Photonics Europe. During the next 24 months COST 299 will be promoted by means of oral presentations, participation in the steering committees, and advertising, in the following major events: Optical Fibre Sensor Conference (OFS'05, OFS'06), European Conference on Optical Communications (ECOC'05,ECOC'06), Optical Fibre Measurement Conference (OFMC'05), Symposium on Optical Fibre Measurements (SOFM'06), SPIE Photonics Europe'06. In the next stage, the Action will support and promote the European Workshop on Optical Fibre Sensor, will organise specialised workshops and training, as well as one large international conference. There is a strong will to include the findings/information for educational material that will be available through a FIDES web portal.

III. EXPERTS WHO HAVE INDICATED THEIR INTEREST TO BE PART OF THE MANAGEMENT COMMITTEE OF THE ACTION

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Professor Miguel Andres, University of Valence, Valencia, Spain

Dr Agustin Gonzalez-Cano, Universidad Computiense, Madrid, Spain

Dr Jacques Morel, METAS, Bern, Switzerland

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Experts

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IV. RECENT PUBLICATIONS OF CORE EXPERTS IN THE SCOPE OF PROPOSAL

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