Thematic Network for Ultraviolet Measurements

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Partners

Helsinki University of Technology (Co-ordinator); STUK, Radiation and Nuclear Safety Authority; Finnish Institute of Occupational Health; Finnish Meteorological Institute; Leopold-Franzens-Universität Innsbruck; Danish Institute of Fundamental Metrology; Danish Meteorological Institute; Delta Danish Electronics, Light & Acoustics; Physikalisch-Technische Bundesanstalt; Alfred-Wegener-Institut für Polar- und Meeresforschung; Bundesamt für Strahlenschutz; BioSense; Laboratory for Biosensory Systems GbR; Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, Dortmund; Dr. Gröbel UV-Elektronik GmbH; Fraunhofer Gesellschaft zur Förderung der angewandten Forshung e.V.; Gigahertz-Optik Vertriebsgesellschaft für Technische Optik mbH; GSF-Forschungszentrum für Umwelt und Gesundheit GmbH; Instrument Systems GmbH; Universität Karlsruhe; OMTec Gesellschaft für optische Messsysteme GmbH; Osram GmbH Berlin - München; PRC Krochmann GmbH; Scintec Atmosphärenmesstechnik GmbH; Aristotle University of Thessaloniki; Instituto Elettrotecnico Nazionale Galileo Ferraris; Nederlands Meetinstituut B.V.; National Institute of Public Health and the Environmental protection; Philips Lighting B.V.; Norwegian Metrology and Accreditation Service; Agricultural University of Norway; National Institute of Public Health; Norwegian Institute for Air Research; Norwegian Polar Institute; Norwegian Radiation Protection Authority; CETO-Centro de Ciências e Technologias Opticas; Instituto De Fisica Aplicada (C.S.I.C.); Swedish National Testing and Research Institute LTD; Swedish Radiation Protection Institute (Statens strålskyddsinstitut); Swedish Meteorological and Hydrological Institute; NPL Management LTD; ABLE Instrument + Controls Ltd.; Bentham Instruments ltd.; Cathodeon ltd.; Regional Medical Physics Dept.; Hanovia Limited; Applied Scintillation Technologies Ltd; The Nottingham Trent University; Unicam Instruments; University of Dundee; Macam Photometrics ltd.; Laboratoire National D'Essais

Final report
January 2001

HELSINKI UNIVERSITY OF TECHNOLOGY

Summary

Background

The commercial, scientific, and industrial applications of ultraviolet (UV) radiation in many new areas, and the consequent need for UV measurements, have increased enormously over the last decades. Concerns of the environmental and health effects of solar UV radiation have also greatly emphasised the urge for accurate and reliable UV radiometry. Many of the problems associated with UV measurements are common to all areas. The Thematic Network was therefore set up to bring together the wide range of user groups from industry and academia to discuss these common problems and themes.

Objectives

The main objectives of the Thematic Network were to enhance exchange of results and ideas between the research laboratories and industry, and to obtain a better understanding of the problems associated with the calibration and testing work.

Within the Network, there are four Working Groups (WG), with their own specific objectives. WG 1, "Guidance for UV power meter classification for particular applications," WG 2, "Improvement of measurement and calibration methods for spectrally resolved UV measurements," WG 3, "Improvement of measurement and calibration methods for spectrally weighted UV measurements," and WG 4, "UV Measurements related to health and safety."

Work programme

During its 3 years of operation, the Network arranged 4 Workshops in: 1. Finland (March 2-3, 1998), 2. Germany (November 9-10, 1998), 3. UK (September 8-10, 1999), and 4. Sweden, (September 6-8, 2000). The Workshops included scientific presentations on agreed themes, parallel sessions of the Working Groups, presentations on the progress of the Working Groups, and presentations on plans and results of UV related research projects. In addition, two Training Courses were arranged in years 1999 and 2000. The Network published a Newsletter, *UVNews* (6 issues during years 1998 – 2000) to exchange knowledge between the participants of the Network and to disseminate information on the forthcoming and past activities of the Network.

Results and achievements

The Network arranged four Workshops, published six *UVNews* Newsletters, arranged two Training Courses, and implemented web pages. The web pages include an action spectrum database. The Workshops have served as a platform to exchange knowledge about on-going EU and other projects related to UV metrology; 43 Oral presentations and 53 posters were presented. The WG's found solutions to many of the problems they were set to solve. The results of the WG's were published in *UVNews* **6**.

Table of contents

1. Definitions

HUT – Helsinki University of Technology

NPL – National Physical Laboratory

PTB – Physikalisch-Technische Bundesanstallt

SP – Swedish National Testing and Research Institute LTD

TC – Training Course

UV – Ultraviolet

WG – Working Group

WS – Workshop

2. Description of the project

2.1. Background

The commercial, scientific, and industrial applications of UV radiation and the consequent need for UV measurements have increased enormously over the last 25 years. UV radiation has found application in semiconductor photolithography, material curing, non-destructive testing, acceleration of chemical processes, water purification, sterilisation, phototherapy and solarium appliances.

Accurate calibration of the UV irradiation is essential in some photolithography processes of semiconductor manufacture to guarantee high yield of production. In non-destructive testing cracks are revealed by fluorescent liquid under UV irradiation. For reasons of occupational health, determination of UV irradiance is of high interest when using certain light sources, such as new metal-halide lamps. These lamps are used for indoor lightning in, e.g., television industry because of their good colour-rendering index. Quartz halogen lamps may produce significant UV doses when not properly shielded.

Selecting the correct standards for optical measurements is one of the most important tasks in making accurate radiometric measurements. One can choose from a number of primary and secondary UV standards such as high temperature blackbodies, cryogenic radiometers, synchrotron radiation, quartz halogen lamps, deuterium lamps, argon and hydrogen arcs, various kind of detectors, etc. There is a variety of working UV standards to choose from as well. According to the quality assurance standards, the UV measurements should be traceable to national standards. At present, a direct traceability chain is not widely available. In many cases the instrument calibration is arranged via non-European manufacturers in a form which does not meet the requirements of quality assurance systems.

Some instruments are provided with accuracy specifications in the UV which are almost an order of magnitude better than the level of agreement reached in comparison measurements between national standards laboratories. Realistic uncertainty estimation thus requires basic knowledge of radiometry in the UV.

In industrial applications UV irradiance is usually monitored with filtered silicon photodiodes. Unfortunately, the spectral responsivity of the detector is often not specified. In addition, the sensitivity of many of the detectors is so low that measurement of the spectral responsivity with ordinary monochromator systems is not easy. With an unspecified spectral responsivity, two different detectors meant for measurements in the same wavelength band can display different irradiance results for the same source. From the point of view of quality assurance systems, this is more than a theoretical problem.

An important UV measurement application is the precision determination of solar UV radiation, which is needed for the assessment of health and environmental effects associated with the depletion of stratospheric ozone. Skin erythema and photo

conjunctivitis of the eye are reversible health effects of UV while skin cancer, ageing of skin, cataracts and the suppression of the immune system are more serious effects. Ecological consequences of increasing UV radiation may be widespread including direct damage to marine organisms living within a few meters from the surface and damage to many plants resulting in decreasing productivity in agriculture and forestry.

The possibility of large ozone depletions over Europe combined with the relatively high UV sensitivity of the population are reasons justifying increased efforts on solar UV measurements. In recent years, society has become aware of the deleterious effects of UV radiation. As a result, public education campaigns have been started and individuals are seeking products for their personal protection. Manufacturing laboratories around the world are using spectrophotometers to measure products such as sunscreen lotions, sunglasses and fabrics to determine the level of protection they provide against UV radiation.

UV radiation is also used for treatment of skin diseases such as psoriasis. At hospitals numerous patients are treated every year with UV radiation. It is essential to have reliable calibration of the equipment for optimal dose evaluation and for safety reasons.

In recent years, radiometry at visible wavelengths has experienced significant progress. Improvement of primary and transfer standards has enabled more reliable measurements throughout the traceability chain. However, the progress of measurements at UV wavelengths has been slower. Part of the problems is associated with the standards since both sources and detectors tend to be unstable in the UV. Especially, there is lack of reliable easy-to-use calibration methods for needs of industry.

The thematic Network for UV measurements was aimed to enhance exchange of results and ideas between the research laboratories and industry and also to obtain a better understanding of the problems associated with the calibration and testing work. The Network helps to improve the competitive position of European industry by promoting better measurements. It also contributes to the increased awareness of the effects of UV radiation on public health and occupational safety at workplaces.

2.2. Objectives

The objectives of the project were set as:

1. To bring together the wide range of user groups from industry and academia to discuss common problems and themes. National standards laboratories will provide their specialist knowledge on UV measurement and calibration techniques, and standards to achieve common solutions to problems. The user community and industry will provide their views on which kind of developments in standards and methods are needed.

2. To give European industry a view on the needs of the user community of the equipment for UV measurements and processes. This information helps in targeting the efforts into areas with significant markets.

3. To assist national standards laboratories and other research institutes aiming their research work to better meet the needs of industry and other users of calibration services. This results in considerable savings of research resources.

4. To improve exchange of knowledge, which will reduce the amount of overlapping research among participating organisations. In the long run this will be the benefit of all participants.

3. Roles of the partners

Table 1. Role of the major participants in the project. The other 37 participants acted as technical specialists in their own fields.

Participant	Role in the Project
Helsinki University of Technology, Finland	Co-ordination, Overall scientific, financial and administrative management of the project, practical arrangements of WS 1, National co-ordination in Finland, Editing of UVNews, Implementation and maintenance of the web-pages
University Innsbruck, Austria	National co-ordination in Austria, practical arrangements of TC 2
Danish Institute of Fundamental Metrology, Denmark	National co-ordination in Denmark
Physikalisch-Technische Bundesanstalt, Germany	National co-ordination in Germany, leader of WG 2, practical arrangements of WS 2
Gigahertz-Optic, Germany	Leader of WG 1
Aristotle University of Thessaloniki, Greece	National co-ordination in Greece
Instituto Elettrotecnico Nazionale Galileo Ferraris, Italy	National co-ordination in Italy
Nederlands Meetinstitute B.V., The Netherlands	National co-ordination in the Netherlands
Norwegian Metrology and Accreditation Service, Norway	National co-ordination in Norway
CETO-Centro de Ciências e Technologias Opticas, Portugal	National co-ordination in Portugal
Instituto De Fisica Aplicada (C.S.I.C.), Spain	National co-ordination in Spain
Swedish National Testing and Research Institute LTD, Sweden	National co-ordination in Sweden, practical arrangements of WS 4
NPL Management LTD, United Kingdom	National co-ordination in United Kingdom, leader of WG 3, practical arrangements of WS 3, Arrangement of the 2 Training Courses
University of Dundee	Leader of WG 4

4. Description of all the work carried out

4.1. Workshops

During the project, four Workshops were arranged according to the following schedule:

Workshop 1: Espoo, Finland, March 2-3, 1998 (Arranged by HUT)

Workshop 2: Braunschweig, Germany, Nov 9-11,1998 (Arranged by PTB)

Workshop 3: Teddington, UK, Sep 8-10, 1999 (Arranged by NPL)

Workshop 4: Borås, Sweden, September 6-8, 2000 (Arranged by SP)

The participation in the first Workshop was restricted to the participants only. The number of attendants was 69. The participation in the remaining three Workshops was not restricted, which increased the number of people involved with the Network significantly. The number of participants in the 2nd Workshop was 88, the number of participants in the 3rd Workshop was 51, and the number of participants of the 4th Workshop was 47.

The contents of the Workshops consisted mainly on scientific presentations (oral and poster) and meetings of the Working Groups.

4.2. Working Groups

In the first Workshop, four Working Groups (WG) were formed to study some key issues within the UV measurement problems. The subjects and leaders of the Working Groups are presented below.

WG 1: Guidance for UV power meter classification for particular applications (Director Anton Gugg-Helminger, Gigahertz-Optik, Germany)

WG 2: Improvement of measurement and calibration methods for spectrally resolved UV measurements (Prof. Dr. Jürgen Metzdorf, PTB, Germany)

WG 3: Improvement of measurement and calibration methods for spectrally weighted UV measurements (Dr. Nigel Fox, NPL, UK)

WG 4: UV Measurements related to health and safety (Dr. Harry Moseley, University of Dundee, Scotland)

Working Group 1 was set to carry out preparatory work to establish a standard on classification of broadband UV meters used in industry. Working Groups 2 and 3 were set to carry out surveys on the problems that the participants encounter in making spectrally resolved and spectrally weighted UV measurements. Working Group 4 was set to prepare guidelines for applying European Standards for type-testing of sun tanning devices.

Between the Workshops, the Working Groups were operating mainly by exchanging E-mail. The results and progress of the Working Groups were presented in the Workshops.

4.3. Training Courses

The Network arranged a Training Course on UV measurements. The Course was aimed at technicians and scientists relatively new to the field, who are making UV measurements, or who need to use and understand such measurements (such as safety or quality assurance officers) regardless of their particular area of application. The Course arranged by NPL was held twice.

The first Course was held at the National Physical Laboratory, Teddington, on September 6 – 7, 1999. A total of 24 people applied to attend the Course, although two people were forced to cancel immediately prior to the date.

The second Course was held at the Alpotel, Innsbruck, Austria on May 4 – 5, 2000. It was organised by the National Physical Laboratory (NPL) with assistance from Innsbruck University. Only 7 people attended the Course.

The Course consisted of a series of twelve lectures spread over two days, followed by visits to relevant labs at the NPL and Innsbruck University. The broad content of the Course had been determined to a considerable extent during discussions at the First Workshop in 1998, while the content of individual lectures was decided by each speaker, with guidance from NPL. The first lectures covered the basics of measurement: concepts, definitions, detectors, sources, materials, broad band and spectrally resolved measurements, the treatment of uncertainty in measurement, and traceability and quality assurance. There was then a series of lectures on particular application areas: solar UV, health, high power measurement, and finally a lecture on new developments.

4.4. Newsletter

The Network published its activities in a special Newsletter, *UVNews*. During the project, 6 issues were published. The total number of pages was 340.

The contents of the *UVNews* consisted of information on the past and coming activities of the Network, extended abstracts of Workshop presentations, scientific and technical articles, and a news-section, publishing all kinds of information on activities related with UV measurement.

UVNews was sent not only to the participants of the Network, but to all people interested in UV measurements, who had registered to the mailing lists. The circulation of *UVNews* **6** was 194. This reflects well the interest that various parties expressed for the Network.

4.5. Internet resources

The WWW-pages of the thematic Network were established in March 1999. The pages may be found in

http://metrology.hut.fi/uvnet/index.html

The pages contain all documents produced throughout the project, including minutes of Workshops and meetings, reports to the Commission, and Newsletters. The four Working Groups have their own pages, containing e.g. mailing lists and lists of participants. A database for UV action spectra is also included in the pages.

4.6. Milestones

Title of action	Estimated time (Elapsed months from the beginning)	Date of completion
Start of the contract	0	Nov 15, 1997
Invitations for the first Workshop	1	Dec 1997
Agenda for the first Workshop	3	Feb 1998
Workshop I	4	March 2-3, 1998
First report and delivery of the detailed workplan to Commission	6	May 1998
Newsletter No. 1	10	Sep 1998
Workshop II	11	Nov 9-11,1998
First annual report to Commission	12	Jan 1999
Network WWW pages opened	14	March 4, 1999
Newsletter No. 2	16	March 31,1999
Second report to Commission	18	June 15,1999
Newsletter No. 3	20	July 1999
Training course No. 1	23	Sep 6-8, 1999
Workshop III	23	Sep 8-10, 1999
Second annual report to Commission	24	Jan 2000
Newsletter No. 4	26	March 2000
Training course No. 2	30	May 4-5, 2000
Third report to Commission	30	June 15, 2000
Newsletter No. 5	34	Oct 2000
Workshop IV	35	Sep 6-8, 2000
Final report to Commission	36	Jan 2001

5. Results of all the work carried out

5.1. Evaluation of the Network

The main objectives of the project (Chapter 2.2) were related to transferring knowledge between the participants of the Network. Meeting the objectives can best be judged by measuring whether the participants considered the events of the Network important and well organised.

The success of the project was evaluated during Workshop 3 in September 1999, with a questionnaire distributed to all participants of Training Course 1 and Workshop 3. A total of 49 questionnaires were filled in and returned. Questions were asked on both the importance and the quality of the actions arranged by the Network. A summary of the replies is given in the tables below. The rating extends from 1 (poor) to 5 (excellent).

In Table 2, we can see how important the participants considered the activities of the Network. The average (4,0) is rather high, and the standard deviation (0,8) is low, which suggests that all participants considered the actions of the project important in general. Two items were considered slightly more important than the others – Workshops (4,5) and the Working Groups (4,4). These are the two actions where people have been personally in contact and working with other participants, which supports an idea that the objectives of improving the exchange of knowledge were met and welcomed. This is also supported by the fact that the Workshops were considered more important than their contents.

Table 2. Results of the Network evaluation questionnaire – Questions on importance of the Network actions.

Importance of actions		
Action	**Average**	**Standard deviation**
Workshops	4,5	0,6
Oral presentations	3,8	0,9
Poster presentations	3,4	0,8
Equipment exhibitions	3,3	0,8
Working Groups	4,4	0,7
Training Course	3,9	0,9
Newsletter	4,1	0,8
WWW-Pages	4,2	0,7
Project as whole	4,1	0,7
Continuation of the Network after year 2000	4,1	0,9
Average	**4,0**	**0,8**

Table 3 presents figures on the quality of the arrangements as ranked by the participants. In general, the average is high (3,9) and none of the actions was considered significantly better or worse than the others.

Table 3. Results of the Network evaluation questionnaire – Questions on quality of the Network actions.

Quality of actions		
Action	**Average**	**Standard deviation**
Workshop 1 (Espoo)	3,8	0,9
Workshop 2 (Braunschweig)	3,8	0,7
Workshop 3 (Teddington)	3,8	0,8
Working Groups		
WG 1	4,2	0,8
WG 2	3,5	0,8
WG 3	3,8	0,8
WG 4	4,0	0,8
Training Course	3,9	0,7
Content	3,8	0,7
Administration	4,0	0,6
Oral presentations	3,9	0,6
Course notes	3,8	0,9
Newsletter	4,1	0,7
Contents	3,9	0,6
Appearance	4,0	0,7
WWW-Pages	4,1	0,7
Contents	3,9	0,7
Appearance	4,1	0,7
Co-ordination	4,1	0,7
Average	**3,9**	**0,7**

Based on the results, it may be concluded that the project can be considered a success. The actions were considered both important and well organised.

5.2. Workshops

The four Workshops arranged formed a platform for exchanging knowledge between the participants. Formal oral and poster presentations were given in order to find out the state of art and problems in the field of UV measurements. A list of titles and authors of the presentations is given in Appendix B: Scientific presentations. The total number of oral presentations given was 43 and the number of posters presented was 53.

The contents of the presentations included e.g. the following key areas in the field of UV measurement:

1) Measurement of intense UV radiation

2) Industrial UV measurements

3) New developments and devices

4) Non-destructive testing

5) Facilities in national standards laboratories

6) Solar UV measurement

7) Medical UV applications

8) Cosmetic UV applications

9) Intercomparisons

10) Standardisation

11) Uncertainty evaluation

12) On-going and past EU- and other projects

13) Quality assurance and control

14) Material science

The Thematic Network was tightly linked with a EU research project "Improving the accuracy of ultraviolet radiation measurement" co-ordinated by Dr. Neil Harrison of NPL. The results of this project were widely presented in WS 4.

The abstracts and extended abstracts of the presentations have been published in *UVNews* and in the web pages of the Network.

In the Workshops, people from the National Metrology Institutes (NMI) got together with participants from small industrial companies. Also user groups of the UV measurement devices were present. Lots of time was allocated for presentations of the industrial participants to give NMI's a view on the problems encountered and to set guidelines on the directions where research should be targeted. On the other hand, time was also allocated for speakers from NMI's to give industrial participants a view on calibration services that are available, and what they should take into account when ordering services.

5.3. Working Groups

The four Working Groups were established in the first Workshop. In the remaining Workshops, lots of time was reserved for the meeting of the Groups and presentation of the progress achieved. Between the Workshops, the Groups operated mainly by exchanging E-mail. The final outcome of the Working Groups was published in a special issue of *UVNews* (Appendix C: *UVNews* **6**).

WG 1 was initiated by needs of European industry. Manufacturers of UV radiometers have no agreed ways of characterising and classifying the properties of their UV radiometers. During the project, WG 1 developed a recommendation "Characterisation of integral measuring UV-meters" which is the first attempt to define common methodologies for characterising and classifying UV meters. The recommendation has

been distributed widely to manufacturers and users of UV meters for trial and comments. The WG will continue its operation on the basis that if comments on the recommendation are initiated, the WG will discuss them and update the recommendation if necessary. The up-to-date version of the document will be maintained in the web-pages of the Network.

The final document has also been delivered to CIE TC2-47. This technical committee is preparing a similar document as a CIE standard. It has been agreed with Dr. Xu Gan, the chairman of TC2-47, that the produced WG 1 document will be used as input for the future work within CIE. Some members of WG 1 have joined in TC2-47 to continue the work of WG 1. This way, parts of the produced document may eventually get a status of standard in the near future.

WG 2 defined its objectives as 1) to determine the most important user requirements for spectrally resolved calibrations of standards and characterisations of instruments and components in the field of non-coherent UV radiometry and spectrometry, 2) to stimulate and promote the improvement and development of measurement techniques and exchange of experiences based on the respective needs and problems as well as on the state-of-the-art methods, devices and instruments identified before, and 3) to prepare and publish examples of the expression of the uncertainty of measurement in UV radiometric calibrations based on the documents EAL-R2 and EAL-R2-S1 and in compliance with the recommendations of the ISO Guide to the Expression of Uncertainty in Measurement.

Five specific subjects were selected in order to produce reports describing current status and improvements of

- Equivalent and consistent radiometric scales,
- Pulsed UV source spectroradiometry,
- Total UV spectral radiant power measurement,
- Calibration of outdoor UV spectroradiometers,
- Examples of a work instruction and best practice instruction for the calibration and operation of radiometric UV standards.

In addition, there seemed to be lack of examples of appropriate uncertainty evaluation and uncertainty budgets for calibration of lamps and detectors.

All these aspects are handled in the series of reports “Improvement of measurement and calibration methods for spectrally resolved UV measurements” published in *UVNews* **6**. In the final report and the appendix, the current status and recent improvements of spectral irradiance and spectral responsivity measurements mostly made by Working Group members are described and discussed concentrating on the above-mentioned five specific subjects within the main area of calibration problems. In addition, common

sources of uncertainty contributions and examples of uncertainty evaluation agreed on and prepared by Working Group members are presented and discussed.

It was decided during the last WG2 meeting in September 2000 to continue WG2 work after 2000 as a platform where to exchange information and agree upon co-operation and mutual assistance.

WG 3 had three objectives:

1. To make use of the user requirements developed in WG1,

2. To determine the current best practise, and

3. To develop/recommend best techniques for the calibration of spectrally weighted UV measurements as a function of accuracy/application.

The work of WG 3 was overlapping with the scope of WG 1. WG 3 therefore did not make its own final report, but instead contributed their outcome to the recommendation produced within WG 1. The calibration procedures written will help those making measurements, or suppliers of equipment, to identify sources of uncertainty relevant to their application and appropriate methods to assess their levels.

The aim of **WG 4** has been to provide practical advice on suitable measurement techniques in health and safety aspects of UV radiation with respect to artificial tanning units. The Working Group achieved its aim and has produced a report "UV measurements related to artificial tanning units" in *UVNews* **6**, which contains a consensus view on the following topics:

- Typetesting of sunbeds according to EN 60335-2-27

- Replacement and labelling of tube lamps in sunbeds

- List of acceptable replacement lamps for UV-Type 3 sunbeds

- Specification of field measurement device for sunbeds

- Sunbed database

The WG members will continue to communicate by e-mail as an informal special interest group. A meeting is being planned to be held in two-years time.

5.4. Training Courses

The two Training Courses were very well received, although the number of attendants was lower than expected. There are probably several reasons for the poor attendance. First, wider publicity would certainly have helped. Whereas NPL has had success in recruiting participants from the UK for its own courses over many years, mechanisms are not yet in place for doing this at a pan-European level. Future organisers of such courses should bear in mind the need for adequate resourcing of publicity activities. A

second reason may well be cost. Such international courses are inevitably expensive to organise, and this was reflected in the registration fee of €600, which was a significant barrier to participation for some organisations, judging from feedback received. Travel costs were also prohibitively high for many people.

All returned Course Evaluation Forms indicated a consistently high level of satisfaction with the Course content, presentation, organisation and usefulness. The Innsbruck Course received even higher ratings than the NPL Course (Chapter 5.1), indicating that the changes to the Course content after the first run were beneficial.

Consideration has been given to the future of the Course. It seems unlikely that the Course can continue without the support of the European Commission, at least in its present form. In the absence of future runs of the Course, it has been agreed within the Network to make the Course notes publicly available, subject to the authors' permission. The price charged for the notes would only be such as to cover any copying and binding costs. Participants at both Courses have suggested that these notes could provide a valuable resource for future Courses, in particular those aimed at more specialist audiences, for instance hospital technicians, and perhaps organised at a national rather than European level.

The produced Course material is attached in this report as Appendix D.

5.5. Newsletter

The Newsletter *UVNews* appeared a useful means of disseminating information. Practically all data produced within the project is documented in the 6 printed issues. The published abstracts and extended abstracts of presentations form a review of state of the art in UV measurements, in both achievements and problems.

The Newsletter has given publicity for the project also outside the European Union and European Economic Area. Of the 194 receivers of *UVNews* **6**, 19 were in countries outside the European Union. 13 issues were sent outside Europe to China, USA (6), Russia (2), St. Lucia, Singapore (2), and Egypt.

The News-section of the Newsletter appeared to be surprisingly popular. There appears to be no other forum for publishing information on new developments and events that would reach such a wide audience of people interested in UV measurement.

5.6. Internet resources

All data produced during the project have been published in the Internet pages. HUT has volunteered to maintain the pages also after the formal EU-funded part of the project. The pages will be used to serve the Working Groups, and to disseminate information on the possible forthcoming events.

6. Conclusions

In general, the project may be concluded as a success. The objectives were met to a large extent. The participants were satisfied with the quality of the actions and considered participating in the Thematic Network important.

The arranged Workshops served as a useful platform for exchanging knowledge. They collected together an extremely wide range of user groups from industry and academia. The formal presentations formed a clear picture on the state of art within the area.

While progressing, the Network was growing remarkably. In the three workshops, where participation was not restricted, a significant amount of participants were from organisations outside the actual project. Most of them attended the workshops at their own expense. This emphasises further the importance of the project.

The Network has improved the situation of standardisation in UV measurements. The recommendation produced within WG 1, if adopted widely enough by manufacturers and end-users, makes it possible to compare measurements with UV-meters of different manufacturers. In future, this recommendation may receive a status of standard within CIE. The document produced within WG 4 improves safety issues, as it clarifies ambiguous points in existing standards.

Probably the most useful output of the project is the personal contacts between different user groups within the project. The industrial participants have now personal contacts towards many European NMI's that they may use when encountering calibration problems. These contacts also work the other way around; when considering needs for development projects, NMI's may ask opinions on usefulness from the industrial participants. Meeting of the solar UV measurement community and the NMI's has also been fruitful. Collaboration between NMI's and solar UV researchers may finally solve the fundamental problems in solar UV measurements. In creating all these contacts, the broad work within WG's 2 and 3 have played an essential role.

The Network has decided to continue most of its activities also after the official part of the project. HUT will maintain the web pages, and the working groups will continue their operation more or less as consultative groups within their fields. A fifth workshop has been agreed to be arranged in Greece in year 2002.

7. List of publications

1. P. Kärhä (Editor), *UVNEWS* **1**, Newsletter of the thematic network for ultraviolet measurements, ISSN 1456-2537, HUT, Espoo, September 1998, 32 p.

2. P. Kärhä (Editor), *UVNEWS* **2**, Newsletter of the thematic network for ultraviolet measurements, ISSN 1456-2537, HUT, Espoo, March 1999, 60 p.

3. P. Kärhä (Editor), *UVNEWS* **3**, Newsletter of the thematic network for ultraviolet measurements, ISSN 1456-2537, HUT, Espoo, July 1999, 28 p.

4. P. Kärhä (Editor), *UVNEWS* **4**, Newsletter of the thematic network for ultraviolet measurements, ISSN 1456-2537, HUT, Espoo, March 2000, 44 p.

5. P. Kärhä (Editor), *UVNEWS* **5**, Newsletter of the thematic network for ultraviolet measurements, ISSN 1456-2537, HUT, Espoo, October 2000, 28 p.

6. P. Kärhä (Editor), *UVNEWS* **6**, Newsletter of the thematic network for ultraviolet measurements, ISSN 1456-2537, HUT, Espoo, November 2000, 148 p.

7. P. Kärhä, *Thematic Network for Ultraviolet Measurements*, a poster in the 25th BCR-Anniversary Conference, Brussels, 3-4 November 1998.

8. A. Corrons, *Thematic Network for Ultraviolet Measurements*, an oral presentation in "From the Fifth Framework Programme to Competitivenes." Measurement and Testing Seminar, Paterna (Valencia), Spain, 3-4 June 1999.

9. E. Ikonen, *The European Union Thematic Network for UV Radiation Measurement*, an invited talk on the Second International Workshop on Detector-Based UV Radiometry, Madrid, Spain, 28 October, 1999.

Espoo January 10, 2001

Erkki Ikonen

Co-ordinator

Appendix A: Details of the partners

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Appendix B: Scientific presentations

Workshop 1

Oral presentations

1) Measurement of Intense UV-C radiation (Wolfgang Heering, Lichttechnisches Institut, Universität Karlsruhe, Germany)

2) Proposal for Industrial UV-Radiometry (Anton Gugg-Helminger, Gigahertz-Optik, Germany)

3) The SPECTRO320D-A Fast Scanning Spectroradiometer Based on a Novel Double Monochromator Design (Erich Obermeyer and Richard Distl, Instrument Systems, Germany)

4) UV Radiometry and Calibration in Non-Destructive Testing (Stuart Quinn, Paul Hutchins, Iain A. Gray, and Glenn C. Tyrrell, Levy Hill Laboratories Ltd., UK)

5) New Developments in Ultraviolet Measurement at NPL (Bill Hartree and Nigel P. Fox, National Physical Laboratory, UK)

6) Radiometric Standards of the PTB (Werner Möller, Klaus Stock, and Jürgen Metzdorf, Physikalisch-Technische Bundesanstalt, Germany)

7) Monochromator-based cryogenic radiometry at NMi-VSL (Charles A. Schrama, Nederlands Meetinstitut - van Swinden Laboratorium, The Netherlands)

8) Establishment of a facility for the absolute calibration of broadband detectors (Alkiviadis Bais, Aristotle University of Thessaloniki, Greece)

9) Stability and quantum efficiency of a novel type of a-Si:H/a-SiC:H Based UV Detector (Pietro Mandracci and Maria Luisa Rastello, Instituto Elettrotecnico Nazionale Galileo Ferraris, Italy)

10) A Portable Lamp Unit for UV-Instrument Inter-comparisons (Ulf Wester, Swedish Radiation Protection Institute, Sweden)

11) Detector Based Calibration of Solar UV Radiometers (Kari Jokela, Radiation and Nuclear Safety Authority, STUK, Finland)

12) Current Needs for Solar UV Spectroradiometry (Günther Seckmeyer, Fraunhofer Institute for Environmental Atmospheric Research, Germany)

13) Solar UV Monitoring by BfS/UBA, Improved QA/QC With Newly Developed Calibration Units (Manfred Steinmetz, H. Sandmann, M. Wallasch, and O. Scheel, Bundesamt für Strahlenschutz, Institut für Strahlenhygiene, Germany)

14) A Multi-channel UV-B Spectrometer (Christian Groß, Thomas Hanken, and Helmut Tüg, Alfred-Wegener-Institut Bremerhaven, Germany)

15) An Improved Diffuser for Global UV Irradiance Measurements (Mario Blumthaler and Josef Schreder, University Innsbruck, Institute of Medical Physics, Austria)

16) Sensors for Measurements of Atmospheric UV Radiation (Volker Thiermann, Scintec Atmosphärenmesstechnik, Germany)

17) Ultraviolet Radiation Measurement in Medicine (Harry Moseley, University of Dundee, Photobiology & Medical Physics, UK)

18) Type-testing of sun tanning devices (Merete Hannevik and Bjørn Johnsen, National Radiation Protection Authority, Norway)

19) Measurement of The Erythemal Effective Dose caused by UV-B and UV-A with a Detection film (biochip VioSpor®) (Hans Holtschmidt, BioSense, Laboratory for Biosensory Systems, Germany)

Poster presentations

1) UV Radiometry and Calibration in Non-Destructive Testing (Stuart Quinn, Paul Hutchins, Iain A. Gray, and Glenn C. Tyrrell, Levy Hill Laboratories Ltd., UK)

2) Cosine Correction of UV Measurements (Wolfgang Heering, Lichttechnisches Institut, Universität Karlsruhe, Germany)

3) A Stabilised Transfer Standard System for Spectral Irradiance (V. Bentlage and A. Sperling, OMTec Gesellschaft für optische Messsysteme, Germany)

4) Developments in Deuterium Discharge Lamps (Andrew J. Page, Cathodeon, UK)

5) UV Measurement Standards for Spectral Irradiance and Spectral Responsivity and Their Uncertainties (Anton Gugg-Helminger, Tran Quok Khanh, and Stephan Fenk, Gigahertz-Optik, Germany)

6) Generation of Blue and UV Radiation by Frequency Doubling of Diode Lasers (A. Seppänen, H. Talvitie, A. Äijälä, and E. Ikonen, Helsinki University of Technology, Finland)

7) Filter Radiometry Based on Direct Utilisation of trap detectors (P. Kärhä, Pasi Toivanen, Atte Haapalinna, Farshid Manoochehri, and Erkki Ikonen, Helsinki University of Technology, Finland)

8) A Multi-channel UV-B Spectrometer (C. Groß*, T. Hanken†, and H. Tüg*, *Alfred-Wegener-Institut Bremerhaven, Germany, †iSiTEC Ingenieurbüro Bremerhaven, Germany)

9) Solar UV Metrology: Activity Report of the PTB (J. Metzdorf and W. Möller, Physikalisch-Technische Bundesanstalt, Germany)

10) Artificial UV for Biological Experiments (H. K. Seidlitz, A. Kuttenberger, and S. Thiel, GSF Forschungszentrum für Umwelt und Gesundheit, Expositionskammern, Germany)

11) Cosine correction of global spectral measurements obtained by Brewer spectroradiometers (Alkiviadis Bais, Aristotle University of Thessaloniki, Greece)

12) Measurements of Spectral and Broadband Ultraviolet Radiation Performed by the Norwegian Polar Institute in Ny-Ålesund, Svalbard, Norway. Instruments and Applications (Jan Børre Ørbæk, Norwegian Polar Institute, Norway)

13) Solar UV Measurements at the Agricultural University of Norway (Cecilia Futsæther and Arne Auen Grimnes, Agricultural University of Norway, Dept. of Agricultural Engineering, Norway)

14) The Nordic Intercomparison of Ultraviolet and Total Ozone Instruments at Izaña, October 1996 (Berit Kjeldstad*, Bjørn Johnsen†, and Tapani Koskela‡, *Norwegian University of Science and Technology Norway, †National Radiation Protection Authority, Norway, ‡Finnish Meteorological Institute, Finland)

15) Type-testing of sun tanning devices (Merete Hannevik and Bjørn Johnsen, National Radiation Protection Authority, Norway)

16) UV-health Hazard Assessment-Guidelines, Measuring Methods and Equipment (Anton Gugg-Helminger and Tran Quoc Khanh, Gigahertz-Optik, Germany)

17) An Electrical Dosimeter (ELUV-14) for Personal-Related Outdoor UV-B-Dosimetry (Saad El Naggar* and Robby Rochlitzer†, *Alfred-Wegener-Institut, Germany, †ESYS GmbH, Germany)

18) MED Measurement and Spectral Characterisations of Various UV Radiation Sources Using the biochip VioSpor®-a New UV-Detection film System (Hans Holtschmidt, BioSense, Laboratory for Biosensory Systems, Germany)

19) UV-Biological irradiance measurements in BNM-LNE (Jean Gaudemer, Martin Lièvre, and Jean-Rémy Filtz, Laboratoire National d'Essais, France)

20) Monitoring UV irradiances; measurements, quality control and cosine correction (Henk Reinen, Harry Slaper, Peter den Outer, and Rick Tax, National Institute of Public Health and the Environment, The Netherlands)

21) A Review of Solar UV Measurements and Modelling at SMHI (Swedish Meteorological and Hydrological Institute) (Weine Josefsson, Swedish Meteorological and Hydrological Institute, Sweden)

Workshop 2

Oral presentations

1) Intercomparison of biological UV dosimetry and spectroradiometric data (P. Rettberg, G. Horneck, A. Bais, N. Munakata, and G. Ronto, DLR Institut für Luft- und Raumfahrtmedizin, Germany)

2) Characterising the performance of integral measuring UV-meters (E. Krochmann, PRC Krochmann GmbH, Germany)

3) On the measurement of actinic radiation - methods and equipment (A. Gugg-Helminger and Tran Quoc Khanh, Gigahertz-Optik, Germany)

4) Evaluation of the radiometric performance of UV photodetectors (H. Rabus, PTB, Berlin, Germany)

5) UV measurements at an industrial calibration and measurement laboratory (Werner Halbritter and Werner Jordan, OSRAM GmbH, Germany)

6) Uncertainty estimate for the spectral measurement of solar UV radiation (Ann R. Webb, UMIST Ltd., UK)

7) Absolute calibration of erythemally weighted broadband radiometers (Mario Blumthaler, University Innsbruck, Institute of Medical Physics, Austria)

8) Calibration of broadband UV radiometers for solar UV monitoring (Kari Jokela, Kirsti Leszczynski, Lasse Ylianttila, and Reijo Visuri, Radiation and Nuclear Safety Authority, STUK, Finland)

9) Calibration of broadband UV radiometers at NPL (Bill Hartree, NPL, UK)

10) Irradiance measurements with UV spectroradiometers : limits of working (Jean Gaudemer, Jean-Rémy Filtz, and Martin Lievre, BNM, France)

11) Control measurements in old / used sunbeds (Hans Holtschmidt and Lothar Quintern, BioSense, Laboratory for Biosensory Systems, Germany)

12) Harmonising methods and standards for typetesting of sunbeds (B. Johnsen and M. Hannevik, Norwegian Radiation Protection Authority)

13) Improving the accuracy of UV radiation measurements (Neil Harrison, NPL, UK)

Poster presentations

1) Indirect intercomparison of the spectral irradiance scales of HUT and NIST in the UV region (Petri Kärhä, Toomas Kübarsepp, Farshid Manoochehri, Pasi Toivanen, Erkki Ikonen, HUT, Reijo Visuri, Lasse Ylianttila, and Kari Jokela, Radiation and Nuclear Safety Authority, STUK, Finland)

2) A proposal characterising the performance of integral actinic measuring equipment (A. Gugg-Helminger and T. Q. Khanh, Gigahertz-Optik, Germany)

3) Photocurrent stabilisation of deuterium lamps at user-defined wavelengths (Armin Sperling and Volker Bentlage, OMTec Gesellschaft für optische Messsysteme, Germany)

4) UV-reflectance measurement device (H. König and E. Aden, PTB, Berlin, Germany)

5) On the stability of an irradiance calibration lamp (Tapani Koskela, Finish Meteorological Institute, Finland)

6) Fast calibration of photodiodes in the near IR, visible and UV using a Fourier-transform spectrometer (Lutz Werner, J. Fischer, and K. Grützmacher, PTB, Berlin, Germany)

7) Determination of erythema effective solar radiation with a spore monolayer film optimised for the detection of UVB and UVA - results of a field campaign (Hans Holtschmidt, Yoshiya Furusawa, Lothar E. Quintern, Peter Koepke, and Mizuho Saito, BioSense, Laboratory for Biosensory Systems, Germany)

8) Large-size high-sensitive thermopile as a radiometric standard (J. Müller, E. Kessler, U. Dillner, P. Ratz, M. Pawlak, H.-C. Holstenberg, K. D. Stock, and J. Metzdorf, PTB, Braunschweig, Germany)

9) QA/QC of BfS/UBA UV monitoring network in practise (H. Sandmann, O. Scheel, M. Steinmetz, and M. Wallasch, Bundesamt für Strahlenschutz, Germany)

10) Realisation of the spectral irradiance scale in the air UV using thermal radiators (W. Möller, P. Sperfeld, B. Nawo, K. Hube, and J. Metzdorf, PTB, Braunschweig, Germany)

11) A fast multichannel UV-B spectroradiometer for field measurements (C. Groß*, H. Tüg*, and T. Hanken†, *Alfred-Wegener-Institut Bremerhaven, Germany, †iSiTEC Ingenieurbüro Bremerhaven, Germany)

12) Daylight (UV) - simulation for applications in photobiology and photochemistry (H. Tüg, Alfred-Wegener-Institut Bremerhaven, Germany)

13) Thematic network for ultraviolet measurements (Petri Kärhä, HUT, Finland)

Workshop 3

Oral presentations

1) Uncertainty and confidence in measurements (John Hurll, UKAS, UK)

2) Measurement of actinic radiation (Wolfgang Heering, Lichttechnisches Institut, Universität Karlsruhe, Germany)

3) High power UV-lasers and UV-measurement techniques for excimer lasers (157 nm - 351 nm) - state of the art and future developments (Michael Fiebig, Lambda Physik GmbH, Germany)

4) UV measurements in artificial weathering of polymeric materials (Bo Carlsson, SP, Sweden)

5) Integral UV-Meters - Physical principles - States of the art - Problems of applications (Anton Gugg-Helminger, Gigahertz-Optik, Germany)

6) International Ultraviolet Association (Petra Rettberg, DLR Institut für Luft- und Raumfahrtmedizin, Germany)

Poster presentations

1) Measurements of Intense UV-Radiation in the Coating, Lacquer and Semiconductor Industry (Tran Quoc Khanh, Wolfgang Dähn, and Anton Gugg-Helminger, Gigahertz-Optik, Germany)

2) Indication of Dangerous Levels of Ultraviolet Radiation of the Sun with Coloured Crystals (S. I. Anevskiy, A. V Demin, and A. F. Zerrouk, VNIIOFI, Russia)

3) Measurements of Spectral UV-Reflectance of Arctic Snow and Ice (J. B. Ørbæk, Boris Ivanov, and Stefan Claes, Norwegian Polar Institute)

4) Biologically Weighted Measurement of UV Radiation in Space and on Earth with the Biofilm Technique (P. Rettberg and G. Horneck, DLR Institut für Luft- und Raumfahrtmedizin, Germany)

5) On the Uncertainty of the UV Irradiance Scales (Tapani Koskela, Finish Meteorological Institute)

6) The Responsivity of UV Meters used in Broadband, Extended Sources: A Comparison of Two Different Approaches (A. J. Coleman, St Thomas' Hospital, UK)

7) Measurements of Erythemal Doses and Spectral Characterisations of Various UV Radiation Sources Using the Biochip Viospor - the New UV-Detection Film System (H. Holtschmidt and L. Quintern, BioSense, Laboratory for Biosensory Systems, Germany)

8) UVB and Ozone Distributions between Cape Town and Bremerhaven from 27.05.98 to 21.06.98 (Saad El Naggar, Otto Schrems, Thaddaeus Bluszcz, and T. Hanken, Alfred-Wegener-Institut Bremerhaven, Germany)

9) Simulation of Solar UV Radiation at Ground for Biological Effects on the Marine Ecosystem (H. Tüg, Ch. Groß, and T. Hanken, Alfred-Wegener-Institut Bremerhaven, Germany)

10) Interpretation of UV-Effects on the Internal Quantum Efficiency of Silicon Photodetectors (T. Kübarsepp, P. Kärhä, and E. Ikonen, HUT, Finland)

11) Rare earth doped Sol-gel Materials as Potential Absorbance Standards (Séverine Aubonnet and Carole C. Perry, The Nottingham Trent University, UK)

Workshop 4

Oral presentations

1) Progress of the EU-project "Improving the accuracy of ultraviolet radiation measurement" (Chair: Neil Harrison, NPL, UK)
   - WP 1: Filter radiometers (Petri Kärhä, HUT, Finland)
   - WP 2: Comparison of techniques to establish high accuracy ultraviolet radiometric scales (Hans Rabus, PTB, Berlin, Germany)
   - WP 3: Improving industrial measurements (Charles Schrama, NMi-VSL, Netherlands)
   - WP 4: Development of a portable lamp calibrator for field calibration (Lasse Ylianttila, STUK, Finland)
2) Intercomparisons and equivalence (Rainer Köhler, BIPM)
3) The use of photometric and UV transfer standards in lighting industry (Anton Bouman, Philips, Netherlands)
4) The solar UV-instrument Intercomparison NOGIC2000 and preliminary results (Ulf Wester, SSI, Sweden)
5) State of art in technologies (Nigel Fox, NPL, UK)

Poster presentations

1) Test-Burn of DXW-Lamps (Lasse Ylianttila, STUK, Finland)
2) Problems with the Classification of UV-Detectors (Anton Gugg-Helminger, Gigahertz-Optik, Germany)
3) The Development of National Standards on UV-radiometry (S.I. Anevsky, V.S. Ivanov, O.A. Minaeva, O.Yu. Morozov, V.I. Sapritsky, Yu.M. Zolotarevsky, and A.E. Vernyi, All-Russian Research Institute for Optical and Physical Measurements (VNIIOFI), National Technical Committee on Ultraviolet Measurements (TK 386) of Gosstandard, Russia)
4) International Instrument Intercomparison of The Viospor® - UV-Detection Film System Versus High Sofisticated Spectroradiometers (S. Kazadzis[1], A. Bais[1], L. Quintern[2], H. Holtschmidt[2], [1]Aristotle University of Thessaloniki, Laboratory of Atmospheric Physics, Greece, [2]BioSense, Laboratory for Biosensory Systems, Germany)

5) A Multichannel UV-A/B Spectroradiometer with High Time Resolution (Ch. Groß, T. Hanken[1], H. Tüg, and O. Schrems, Alfred-Wegener-Institut Bremerhaven, [1]iSiTEC Ingenieurbüro Bremerhaven, Germany)

6) Survey Of Tanning Studios in Norway (Eva G. Bjørklund, Bjørn Johnsen, Merete Hannevik and Lill Tove Norvang, Norwegian Radiation Protection Authority, Norway)

7) Preliminary Results of a Comparison of Silicon Quantum Yield Values in the Near Ultraviolet (T. Kübarsepp[1], H. Rabus[2] and C. A. Schrama[3], [1]Metrology Research Institute, Helsinki University of Technology (HUT), Finland, [2]Physikalisch-Technische Bundesanstalt (PTB), Germany, [3]Nederlands Meetinstituut/Van Swinden Laboratorium B. V. (NMi-VSL), Netherlands)

8) First Results of Long Term Measurements of Solar UV Radiation in Germany (M.Steinmetz, R.Matthes, and P.Hofmann, BfS, Germany)