

COST Action IC1101

OPTICWISE

Minutes of the 2nd MC Meeting (19th – 21st March, 2012, Istanbul).

Author: Professor Roger J. Green, University of Warwick, UK.

DAY 1: 19th March.

Initial activities.

Registrants arrived between 9 am and 9.30 am. A full agenda and information pack was available.

MC meeting (9.30 am until 10.30 am).

Dr. Murat Uysal (COST 1101 Chairman) welcomed the visitors to Ozyegin University and wished all to have a productive meeting. An outline of the University was then presented, which discussed its history, objectives, and general details. The University was founded by the Hüsnü M. Özyeğin Foundation in 2007, and is a private university.

Dr. Uysal then discussed the OPTICWISE COST project, and how it concentrates purely on Optical Wireless Communications, being awarded in May 2011. The kick-off meeting was in Brussels in November 2011. The objectives of the Action as discussed included training of students in the Optical Wireless field and the mobility of Optical Wireless researchers in Europe. The scope of the technical areas was discussed, and the Action will concentrate on the range from the UV to the Near InfraRed (NIR). The Management Committee (**MC**), Workgroups (**WG**) have been defined, and also a number of permanent, Special Interests Groups (**SIG**) including Techno-Economic areas. The organisational structure has generally been agreed (MC, SIGs, etc) and 19 COST countries are involved currently.

There will be progress monitoring, and this will also be partly via Input Documents – from which Presentations will be generated. WG chairs will collect information from WG participants, semi-annually in terms of publications and patents, etc. The next COST meeting of IC1101 will take place at Pisa, Italy, in October from the 22nd until the 23rd. Volunteers are wanted for the 4th meeting organisation and proposals for the Training School. There are Travel Grants, money for Short Term Scientific Missions (**STSMS** – 8 x 1500 Euros each, with forms from E-Cost webpages and evaluations by the Steering Committee [**SC**]).

There must be Dissemination Actions: an Actions website, and Actions leaflet, a semi-annual Action Newsletter, and a Social Networking site (to be generated by one of Dr.

Uysal's students). There will be interaction with other EU research programmes and industrial participation is needed ("invited experts").

Professor Boucouvalas then discussed progress on the Action website. The purpose of this is to store information, and to add documents arising from everyone's activities and location. There could be Skype communications, and an email address to input to the website (www.Opticwise.uop.gr). The structure of the website, including login, was discussed. The main menu is to be on the left. The website is not yet complete, but will include the MC, SIG, WG, and industrial links.

The key issue for the future is to be the WGs. Much more could be added than is currently on the website about them. It will be important to maintain communications throughout the year. The question was asked, "What do we need to make the website pages more usable?". The target for groups need to be established, that is, demonstrations, student exchanges, etc. The plea was made: "Let the web team know what the WGs are going to define as their space!". In terms of updating the website, there were discussions on permissions for this, such as the web team and also the WG chairs. **Professor Ghassemlooy (COST 11001 Vice-Chairman)** said that there should be a link on the front page to every research group. The organisation of this was then discussed by the meeting: there was the need to avoid duplication and clutter on the website. There could be pictures of people. **Professor Ghassemlooy** said that there were many activities which could be reported, and conferences such as the one in China and Globecom in the USA, and also books could be mentioned. However, **Professor Boucouvalas** said that too much information could clog the website, and so the idea could be that they could be just listed, according to **Professor Ghassemlooy**. There could be useful links in the WG pages to such items. He also said that there was a German website which listed a good number of workers in the area of Optical Wireless, and that he could supervise the list. Papers which have been submitted, accepted by journals/conferences but not yet published could be included, meaning, copyright problems could be avoided if the pre-publication versions of papers were available. There could be links to IEEE Xplore. **Professor Boucouvalas** suggested that the COST members should have documents in PDF format and use *Skype* for communications.

(There was an intermission for coffee).

MC meeting talks (11 am until 12.30 am).

Professor Ciaramella (Convenor, Pisa meeting) then introduced the Pisa Workshop to be held later in the year. He mentioned the WG chairs, and **Professor Green (Meetings Secretary)** requested to be included, as Chair of WG4. The research topics to be discussed at the meeting include *localisation* using Optical Wireless techniques. The recommended hotel is to be the Alitalia Tower, where costs are 100 Euros per person including a shuttle service. There are IEEE and LEOS discussions to see if the papers and documents presented could be recognised in those contexts. **Professor Ghassemlooy** suggested informing the Italian chapter of the IEEE. **Professor Ciaramella** then went on to say that a website for the Pisa meeting was in hand, and the fees and copyright issues for the meeting are to be controlled by CNT (handling, badges, etc, especially for non-COST attendees). Proceedings will be produced, and it is expected that there will not be more than 50 research types of paper produced. A tentative timescale was presented (details to be on website).

MC presentations.

Dr. Beleffi introduced the SIG on “Techno-economic issues” and the objectives of the Group. Included was mention of the links which **Professor Green** has with the IrDA, and others with ETSI etc. The main focus of the Group is: “Where is Optical Wireless in the market?”. There were then short presentations by other MC participants:

- a) **Professor Aleksic** – a research group presentation was given, and intersatellite communications was stated to be the speciality. There are many funded projects, and hme ICT energy efficiency projects are ongoing, RF LAN plus FSO from the energy perspective.
- b) **Dr. Alves** represented the Insituto de Telecomunicações activities. Wireless, optics, networks and multimedia, and also basic sciences and technology. There is a specialised optics group involved in: Optical Wireless, radio over fibre, including energy-efficient methods.
- c) **Dr. Angelakis** introduced the work at Linkoping and Lund universities. There is a networking group, with interests in protocols, routing, and performance analysis. There, they are moving into Optical Wireless communications, in respect of optimisation of wireless-optical mesh networks, and various types of node network.
- d) **Professor Baycal** of Çankaya University, Turkey, are working on turbulence, turbulence spectra, and oceanic applications. Of particular interest is coherence and

scintillation index. Technical details of the work were presented, and current and future plans for the research.

- e) **Dr. Belmonte** described research undertaken in FSO digital coherent communications, direct detection, Space Lasercom, laser remote sensing, experimental studies, modeling, analysis, and signal theory. There was also work on fading mitigation techniques.
- f) **Dr. Marzano** described channel modeling work and high speed FSO link research. There was a test bed of 800 metres range, with a SONA beam FSO link (SONA beam 1250-E-1.25 Gbps link). Included was a visibilimeter at 850 nm for measuring fog aspects including density and visibility. There was also work on channel modelling in theory and practice. The research team is interested in WG1, WG3, and WG4.
- g) **Professor Boucouvalas** then returned to the subject of web pages, and a short personal history stretching back 35 years. He has been involved in the original IrDA standard work, including eye safety specifications. Other work included throughput, delays in the IrDA communications systems, and the evolution of standards. There had been much work on protocols, and also IEEE 802.11, Bluetooth, IrDA OBEX, payment methods using the IrDA systems, and the Gigabit IrDA standard of recent times. Currently he and a colleague are working mainly on the modeling of protocols.
- h) **Professor Ciaramella** and his team are working on optical communications, and there is a Centre of Excellence set up. Ericssons, CNIT, CEIRC and other universities are involved. There are around 6 systems people. Work covers 1.28 Terabits per second (32 x 40 channels) FSO over 210 metres. The one-way loss over the link is around 7.5 dB – in a configuration of : { fibre > FSO > fibre } for WDM over free space. There is also work on radio over fibre and VLC (Visible Light Communications) with 25 MHz of RF bandwidth/50 Mbps. More recently work has begun on localisation methods using adaptive OFDM and WDM. There is also work on interfaces to FSO.
- i) **Professor Frigyes** described FSO activity, and work on a hybrid RF/FSP system. Space diversity/MIMO in FSO were of interest. Propagation modeling and testing were undertaken (for fog, rain; also turbulence) over a 930 metre link. Fog tests were done from 2009 onwards. Fog particles were characterised by reflection tests (with collaboration between the University of Graz and Prague). Also, an E-band hybrid system (70 – 90 GHz) was described. Important aspects were capacity, coding, and

hop length being investigated for IM/DD and coherent BPSK, and QPSK. It was stated that intense fog situations require back-up for FSO. AN FSO link using BPSK gives 2.6 Km at 10^{-5} BER, and a QPSK link gives 2.4 Km at 10^{-5} BER. A 10^{-4} BER was obtained for a 4.6 Km link employing BPSK. MIMO work was also being undertaken.

- j) **Professor Fracasso** of the Institut Telecom, France described picocellular work employing Optical Wireless for home networks and home access. A very high bitrate was employed: 10 – 20 Gbps. The links were effectively fibre-to-FSO in a NLOS (Narrow Line of Sight) configuration. OAPs (Optical Access Points) were being investigated (2 – 4 per room) operating at 1.55 μm wavelength. The downlink model includes an optical concentrator and filter (like the Warwick Optical Antenna). Simulation of the hybrid link is being done, and polymer fibre is employed.
- k) **Dr. Udvary** described an optical and microwave laboratory. Involved are two professors, two associate professors, and PhD students. In the optical aspects, SOAs, EAMs, and VCSELs were being investigated. Both analogue- and digital work was being done (radio over fibre and CATV). A VPI transmission maker was employed. The team's interests are in WG4 – optical wireless subsystems, and to use a testbed at visible wavelengths. The objectives include the target of high data rates using visible light LEDs. Modulation schemes and driver circuits were of particular interest.
- l) **Professor Ghassemlooy** discussed his team of 4 academics and 2 research assistants, plus 15 PhD students. Interests in the team included propagation, channel modeling, and software/hardware systems. Both 110 metre- and 1 Km links had been set up in Newcastle, and there is a fog machine for indoor work. An RF/FSO hybrid system is being investigated, and there is a sand chamber. In the FSO work, polarisation shift keying is being done, and measurements are under computer control. VLC, using OLEDs up to 1 Mbps are being considered and investigated. OFDM links of 1 Mbps are being implemented. Also, cellular Optical Wireless is being investigated in an indoor optical house, and £1M of funding for the lab has been obtained from Agilent.
- m) **Professor Green** described work at Warwick University in the UK. This research included the optimisation of receiver amplifier configurations, and the use of Optical Antennas, hybrid RF/optical receivers, and applications in vehicles and underwater were also mentioned. There is new work on rapid manufacture of optics for FSO and

other applications as well. The team consists of around 20 PhD students and two Research Assistants, and 3 Professors.

- n) **Professor Kandus** discussed EU projects in his group, of which there were many under way. There were wireless projects concerning 4G in pico base stations. There was work on channel simulators for the atmosphere taking distortions into account. Interests also included modulation and coding, and MIMO systems. In FSO work, included were OOK, PPM, and advanced coding.
- o) **Professor Katz** discussed CWC (Centre for Wireless Communications) at Oulu, Finland. The Centre is involved with the WWRF (Wireless World Research Forum) with interests in mobile clouds and broadband wireless. In VLC, dual air interfaces are assumed. The team is developing a framework for RF and FSO integration in a “Dynamic Air Interface Management Technique”. They are hoping to promote the optical interface as a standard.
- p) **Dr. Khalighi** described work on FSO to and from aircraft, and also between buildings, with channel characterisation and modeling being the main focus of the work. Codes, noise reduction, underwater systems, and sensor network design were all within the remit of his team.

At this point there was a lunch break until 1.30 pm or a little later, and the main MC groups broke up afterwards into the WG1 and WG3 meetings, with later meetings involving the SIG TESEO, and then WG2 and WG4 meetings.

WG4 meeting.

In attendance were: Roger Green, Eszter Udvary, Tony Boucouvalas, Marcos Katz, Bruno Fracasso, Frank Deike, Jürgen Van Erps, Michael Connelly, Mike Wolf, Luis Alves, and Ernesto Ciaramella.

The meeting was relatively informal, and under discussion was how members were going to organise themselves in terms of interests and documentation. The meeting was chaired by **Professor Green**. It was generally agreed that the next day meeting for this WG would include presentations of interests by those who had not presented at the main MC meeting. Two presentations were actually made at this meeting, being:-

- a) **Dr. Van Erps** who described interests of his team. The included micro-optical components, deep proton writing, and interfacing PC boards with optical

components. Also backplanes were being investigated with optical interconnects. A 45° micromirror was described and pictures shown. There was modeling work concerned with the MSL (MicroStereoLithography) and proton writing, plus work on diamond tooling. There is a Powerpoint presentation on the team's website.

- b) **Dr. Wolf** talked about the EU Omega project, where IR links operating at 1 Gbps had been set up at Ilmenau University. Commercially-available components had been employed, and the FOV (Field of View) was quite small ~ around 8° for a unit with 25 transmitters/receivers. Eye safety aspects were considered. Indium Gallium Arsenide devices were used with 60 pF/mm² as detectors. APDs were found to be better than PIN diodes as photodetectors in the experiments. A “fovean” image array was used, in which multiple concentrators were involved. A cheap version of the optics and hardware was needed.

A target data rate of 1 Gbps was set by the WG for operations of the systems the group could develop in collaboration. Two-dimensional beam steering was thought also to be a target capability.

DAY 2: 20th March.

MC meeting talks (9.30 am until 10.30 am).

Presentations by invited speakers were given, as follows:-

- a) **Dr. Loeschnigg** talked about research at the University of Graz. Work continues on FSO and plastic fibre systems, to cover “last mile” applications. Of interest are modulation and coding methods, and research areas include space applications. Adaptive optics work was ongoing, in 3 types of configuration, being (i) standard components, with no tracking, (ii) space grade components, with a narrow FOV (field of view) and (iii) systems using telescope optics. The channel parameters include fog and smog. Typically near Graz attenuations can reach 30 dB per Km, whereas near Nice they can reach 300 dB/Km in dense fog conditions. The Graz group is also involved in COST action IC0802, and has other collaborations.
- b) **Dr. Marzano**, of the Politecnico di Milano, discussed research involving links up to 100 GHz RF plus using two optical wavelengths, with fog, rain, snow, and clouds in the links, and mixtures of them. Channels models were being developed, and there is collaboration with Graz University, and the University of Prague.

- c) **Dr. Moll**, of the Institute of Communications and Navigation (Germany), represented a group working on moving aircraft communications, satellite-, and to- and from ground station communications. Satellite links are operating on a “fly-by” basis at 847 nm, 1064 nm, and 1550 nm. A project, entitled Free-Space Experimental Laser terminal (FELT 2) on aircraft to ground links, was described. A ground station with dome has been set up and a telescope is to be installed in a transportable unit. Adaptive optics are being used with an interferometric wavefront sensor. There is a master clock in space, sending signals to satellites for synchronisation.
- d) **Dr. Murat Uysal**, Ozyegin University, described the team of researchers at that university to be 6 MSc and 2 PhD students, plus three PhD students in conjunction with the University of Waterloo, Canada. Interests include space-time coding and MIMO (1998 – 2006), and Cooperative Wireless (2004 onwards). From October 2003 research on Optical Wireless began, in terrestrial links and also fading mitigation thereof. In Optical Wireless, now the research has focussed on space diversity and MIMO in FSO, using low complexity detectors/receivers. Cooperative relay-assisted transmission work is ongoing. All optical relays are now being investigated. Issues of importance include power, modulation, coding, wavelengths, beam divergence and shape. There is an FSO testbed, and VLC/OFDM work on MIMO for IM/DD. Multiple access and user scheduling work is also being undertaken. There is a project with the Turkish government on ground-to-air and air-to-ground FSO.
- e) **Dr. Van Erps** discussed a group of 50 people at his establishment, in B-Phot. Work is ongoing on optical interconnects on PCBs, optical fibre connectors, and micromirrors. A multichip module, and integrated microlenses are also being investigated and developed. Further work covers micro-optical waveguides, microgrooves, and micro-channels. €3M have been obtained in the previous year for extension of the facilities. Prototyping, replication, and post processing is being undertaken in clean rooms designed for the micro-optical fabrication.
- f) **Dr. Poliak**, Brno University of Technology, and his team have been working on wireless communications for 16 years, covering optical-, satellite communications, and EM waves. At their facility, they have a fog chamber, excellent optical equipment, spectrometers covering from 0.36 μm to 1.5 μm . They have FSO links operating at 1550 nm for 60 metres range, 950 metre links, and 750 metre links at Donnersberg, Brno, and Prague respectively. At Brno, there is a constant wind of 5 –

8 metres/s apart from just 8 days a year. There is near field diffraction work going on, involving PhD students. There are hybrid RF/FSO links at 850 nm/1550 nm and 122 GHz. FSO beam propagation is being modelled. Coding for such hybrid links is being investigated.

- g) **Dr. Wolf**, University of Ilmenau, and his team have a Communications Research Laboratory investigating infrared, and modulation methods in bandwidth-restricted channels. OFDM is used, and single carrier schemes are being investigated (OOK, PAM, etc). The last major project of relevance to this COST action was the Omega (EU) project. Of particular interest in the group is consideration of angular aspects in transmitters and receivers, and beam steering approaches.
- h) **Professor Yashchyshyn**, University of Warsaw, said that there were 30 titled Professors at his institution in his department, with 67 professors of all ranks overall. There are 6 institutes in the Faculty (including Electro-acoustics, Nuclear and Mechanical Engineering, Radiocommunications, etc). Work in communications extends up to 500 GHz, with structures including “photonic antennas” being investigated. Some work on power line to LED illumination was also being undertaken.
- i) **Professor Zranovec**, from Prague University Department of Electromagnetic Fields, and his team have 7 COST involvements (297, IC0803, IC0603, OC08018, IC0802, etc.). FSO links include Lightpointe and Plaintree equipments, and an MRV telescope, all operating at 850 nm. There are links involving RF and FSO with a microwave radiometer, operating from 10.95 – 12.75 GHz. There are new laboratories for beam optics and nonlinear fibre optics. Work is ongoing on rain measurements with colleagues at the Atmospheric Physics Institute at Prague University.
- j) **Dr. Connelly**, University of Limerick, Ireland, discussed Semiconductor Optical Amplifiers (SOA). Modulation methods included QAM and there was also microwave work, with fibre links using the SOAs in a PON (Passive Optical Network) configuration. The group, although new to FSO, is interested in collaborating and contributing. There is also work on the use of an RSCA as a simultaneous transmitter and receiver. There is interest in WG4 of the COST action (i.e. IC1101).

(There was an intermission for coffee).

Invited speaker talks (11 am until 12.30 pm).

- a) **Dr. Deike**, Fraunhofer Institute, discussed the LiFi Consortium, which has been set up to deal with the lack of conventional RF spectrum expected to become very noticeable by 2013/14. RF announcements include mention of a bridge to cover data rates in excess of 20 Billion bps using 200 GHz systems. This RF outreach is successful, so why is Optical Wireless not as successful? There are optical wireless standards, including IrDA, VLCC, IEEE 802.15, ISO, and ITU. “Light Fidelity is the next Wireless Fidelity” – in the broader vision. LiFi includes the superset, such as Optical Wireless Communications, Positioning, Light Imaging, and Natural User Interfaces. The LiFi configurations include simplex, duplex, and use LEDs, laser diodes, OLEDs for visible, and infrared devices also. Subsystems being considered include transceivers, optics, protocol controllers, SOC adaptation, software, and wire-free charging using Optical Wireless. The LiFi Consortium began in October 2011, and the web page link is: www.lificonsortium.com . Transmission distances of importance in the Consortium are around 40 metres. Walter Kraus is the Chairman, and further information can be obtained via: info@lificonsortium.com . The Consortium is interested in collaborating with the IrDA.
- b) **Professor Chatzimisios** discussed standardisation, and mentioned IC0906 – “**Wireless Networking for Moving Objects**” (WiNeMO), and involvements in the IEEE Communications Society. Connections are also with the IrDA, WWRF, ITU, IEEE more widely, ETSI, and ISO. Some details of IEEE standards work was described, including IEEE and ITU collaboration for (ITU-R, ITU-T, and ITU-D). The “802” work was quite broad in scope. New working groups can be set up via these connections, and details were given about how to check if standards work already existed in a particular area, by contacting the appropriate Technical Committee on Optical Networking, as a way in. Optical Wireless work involved the IrDA (100 – 1000 Mbps), IEEE 802.11 IR (1997, 2 Mbps), and IEEE 802.15.7 (2011) (96 Mbps).

Frame structures were then discussed. Interframe spacing was similar to 802.11 and the IrDA frames. The group is involved with COST IC1003, IC1004, IC0703, and IC0298. Professor Chatzimisios’ group had job vacancies, scholarships and fellowships, Ph.D. positions advertised on the website. The plea was made that 2 COST meetings per year was not enough! WG leaders, and WG members should have some form of frequent meetings, and there could be TC meetings. Groups

should active all year, and there could be online meetings. Cooperation should be in the form of dissemination events, and there could be special issues of peer reviewed journals, and workshops. A presence at main communications events is essential (**Professor Green** mentioned his attendance at Globecom to that effect). The maxim should be “Cooperation, cooperation, and cooperation!”. Training schools can be set up in due course: tutorials at conferences, liaison with other standardisation bodies, and collaborative research projects.

- c) **Dr. Muammer Uysal** then went on to discuss fibre laying costs – typically \$250 per metre, showing FSO to be very cheap in comparison. 850 nm, and 1550 nm are typically used for 1 – 10 Km FSO links, point-to-point at up to 1.25 Gbps, up to 6 Km range at that data rate. Reliability at this range is quite well proven. In his group’s work, an Omnitek module was used, with a laser source and fibre optic connections to the emitting optics. Ethernet and EU standard protocols were used. The hardware had a beam divergence of 0.2 – 1 mradians, equivalent to 0.2 to 1 metre beam spreading at 1 Km distance, and automatic tracking was employed. An Omnilaser had 2 – 10 mradians of beam divergence, which translates to a 2 – 10 metre spread at 1 Km. A Turkish company modifies Canadian hardware and manages to obtain more range from it than it was originally designed for. RF is used as a back-up, and overall “Five nines” availability ($BER = 10^{-5}$) was achieved. Links are between “Turkcell” base stations. There is an FSO City Security Management System as well, which provides real-time video, and avoids the network costs of the fibre- or RF alternatives. The system operates in a 100 Mbps FDX-FSO plus RF backup configuration. There is a secure communications link in the east of Turkey not using RF but using FSO as a trial system (military). There is also work at airports. An interesting configuration involving multi-hops goes across Istanbul, providing the world’s first “backbone” FSO system – the first between two continents! The ITU has referred to it in correspondence. In fog and/or rain, an E-band RF link takes over the multihop system in part or wholly. There are some new topology issues in this approach.

This talk finished the second day’s activities in terms of MC meetings. The remainder of the day was concerned with WG meetings for which separate reporting will take place.

DAY 3: 21st March.

MC meeting – SIG propositions (9 am until 10.30 am).

The meeting was opened by **Dr. Uysal** who discussed progress monitoring of the COST action, and requested any comments about how the members could improve this activity. In particular, he suggested that Input Documents to WG Chairs should be sent prior to the WG meetings so that the Chairs could draw up the agenda properly. These input documents could include: specifications, achievements, and future directions. Two weeks at least before a WG meeting would be very helpful. Participants at a WG should have a Powerpoint presentation to facilitate communications at WG meetings, based on the Input Documents. The topic of Future Directions, though, could be in the form of journal papers accompanying the Powerpoint slides (as documentary backup). **Professor Ghassemlooy** said that research papers which resulted from COST actions should have an acknowledgement to that effect contained within them. **Professor Boucouvalas** reminded members that attendance at conferences could be covered by the COST budget if a COST meeting took place at those conferences. There were various general rules discussed by **Dr. Uysal**, and **Professor Ghassemlooy** said that sharing resources and outreach were very important. A volunteer was requested to set up a data bank for the project, and **Dr. Poliak** came forward for this.

Dr. Uysal said that the 4th meeting of the group must soon take place. Volunteers for the organisation of this meeting are being sought. **Dr. Loeschnigg** said that he would be happy to be involved, and it was discussed that a Training School could be set up alongside the 4th meeting. The deadline for the arrangement of the latter has to be mid-April. **Professor Ghassemlooy** said that he had a few workshop opportunities which could contribute to this idea. The IrDA could also be involved, but timing could be an issue if things took too long to be agreed. In terms of dissemination activities, **Dr. Moll** said that he would like to be involved in that.

Dr. Uysal said that there should be an **OPTICWISE** logo used in presentations, and younger persons such as research students could be encouraged to come up with ideas for the logo itself, in exchange for free meeting attendance. Liaisons should be set up between this COST action and related FP7 projects, the LiFi Consortium, and other groups, with more industrial participation as well.

SIG proposals made.

In collaboration with **Professor Green**, **Dr. Alves**, Aveiro, Portugal, made a joint presentation for an SIG concerned with “*VLC in Public Lighting Systems*”. This was because of the advances in efficiency of LED light sources, and their introduction for public lighting. The idea is to provide services as well as lighting from these facilities. Lighting accounts for 2% of the worldwide energy consumption, but 25% - 60% of the municipality global budget. Also, LEDs have a higher cost per lumen than current lighting systems. There are EU projects in this area. VLC can be considered to be a value added service, and as an alternative communications interface, using existing

LEDs, and power constraints are not relevant as for IR Optical Wireless. VLC can offer low, medium, and high data rate services, such as traffic information, interactive advertising, and video surveillance, respectively, as examples of each. VLC lighting can be regarded as an ad-hoc sensor network. There are several emerging standards, and ruling data exchange protocols can be used. Issues in VLC include the effect of dimming circuits and whether or not the illumination is actually "ON". Traditional dimming techniques are slow to react, and stroboscopic effects when carrying data are not well investigated.

The jointly proposed SIG, "VLC in Public Lighting Systems", was approved.

Another proposal by **Professor Baykel**, was for an SIG in "*Underwater Systems*". Of interest include the medium characteristics, turbulence, and Gaussian beam propagation in turbulent conditions. Effects on refractive index have to be considered. Activities will be proposed in order to discover more favourable beam types and other parameters. **Professor Boucouvalas** suggested at this point that people (rather than just the proposer) should choose what the SIG was all about and contain. **Professor Ghassemlooy** suggested that there should be lunch time meetings "to test the water!". **Dr. Uysal** responded by saying that MC meetings would be responsible for endorsing such proposals and meetings for SIGs.

The SIG in "*Underwater Systems*" was approved.

Professor Ghassemlooy pointed out that we are all optical fibre communications and Optical Wireless communications in background, so that we should have some RF speakers at our various meetings. **Dr. Uysal** also said that we should submit papers to RF communications journals to keep mainstream, as we are complementary areas of communications. **Professor Ghassemlooy** said that mobility was an issue for us compared to RF, so hybrid systems ought to be considered. In a general discussion subsequently, it was agreed that in reality RF and optical communications are the same area, so the question arose about whether or not the level of description was the same across the board in the different communications cultures (mathematics, signal processing, etc). We should all have the same vocabulary.

Around this discussion the meetings came to an end, and **Dr. Uysal** closed the event, to be followed by the workshop in Pisa in August 2012.