

Nano Meets Spectroscopy

National Physical Laboratory, Teddington, UK
September 15th -16th, 2011

Summary

This multidisciplinary two-day Nano Meets Spectroscopy (NMS) event was planned from the outset to be at the interface of several areas – in particular spectroscopy and nanoscience, and bring together topics and people with common goals in biomolecular science. Hence the meeting cut across traditional boundaries and brought together researchers from diverse areas such as fluorescence and Raman spectroscopy, which, despite addressing common problems, are frequently seen as mutually exclusive with the two communities rarely meeting at conferences. The meeting achieved its goals in good measure and was undoubtedly very successful. It attracted the maximum capacity of ~ 120 participants, including 22 distinguished speakers (9 from outside the UK), over 50 posters and a vibrant exhibition comprising 10 leading instrument companies and the Institute of Physics. The organisers were Prof. David Birch (Chair), Dr Karen Faulds and Prof. Duncan Graham of the University of Strathclyde, Prof. Cait MacPhee of the University of Edinburgh and Dr Alex Knight of NPL.

The modern facilities and infrastructure support at the National Physical Laboratory (NPL) in Teddington greatly helped towards making the event a success. Promotion of the event was supported by the event's own website <http://sensor.phys.strath.ac.uk/nms/> and NPL's website. Sponsorship by ESF and others was acknowledged on the website. A conference dinner held at the Park Hotel on the evening of the 15th September, five poster sessions combined with coffee/lunch and an instrument exhibition greatly helped interaction between the delegates.

Feedback from the participants on the NPL feedback sheet after the meeting was excellent:

96% of delegates said that they will use the information learned in their organization
100% of delegates said the event exceeded or fulfilled their expectations

Typical quotes from delegates:

“Great event, hope you organize it again”

“The scientific quality was very high and the talks were very stimulating”

“Interesting mix of talks and subjects, and top speakers gathered together”

Delegates have been invited to submit papers arising from the meeting to a special issue of the Institute of Physics journal Measurement Science and Technology. All papers being refereed according to the journals usual procedures. It promises to be a landmark issue at the interface of several disciplines that will document NMS for use by others for years to come.

The event seemed to fill a real need for bringing together complementary approaches to solving common problems in nano-bioscience and technology and the organisers are actively considering repeating the event in two years time.

Scientific content and discussion

The meeting commenced with Registration, which was combined with a welcoming lunch on September 15th in order to help foster initial interactions before the formal sessions got underway.

The sessions for the meeting were chosen to be on common themes in order to bring together the different spectroscopic approaches to the solution of common problems. The sessions were Plasmonics, Nanoparticles, Single Molecules, Nanomedicine and Biomolecules and Imaging and selected in this sequence in order to increment from the more fundamental to the applied as the meeting progressed. Chairing the first session Professor David Birch welcomed everyone and set the scene before NPL as hosts were given the opening talk linking Nano and Spectroscopy. Dr Debdulal Roy of NPL gave this talk entitled “*Tip-enhanced Raman spectroscopy- opportunities and challenges for nanoscale analysis.*” Following some historical perspectives the talk described combined scanning probe microscopy (SPM) with optical spectroscopy e.g. Raman and fluorescence spectroscopy that allow near-field measurements below the diffraction limit of the microscope, with the spatial resolution only limited by the size of the tip. Development and progress of near-field techniques including scanning near-field optical microscopy (SNOM), tip-enhanced Raman spectroscopy (TERS) and tip-enhanced fluorescence imaging were reviewed. Examples of measurements on single wall carbon nanotubes and phase separated polymer blends were given in order to demonstrate chemical speciation and spatial resolution. Metrology aspects of the techniques were addressed.

The next invited talk to start the session on Plasmonics was given by Professor Joseph Lakowicz, of the University of Maryland School of Medicine entitled “*Plasmon-Controlled Fluorescence: Principles and Applications to Biomedical Research.*” Professor Lakowicz is one of the best known researchers in fluorescence in the World and his book “Principles of fluorescence spectroscopy” is the definitive text for fluorescence in the biosciences. In recent years he has pioneered research and application of metal enhanced fluorescence. After describing the basic plasmonic phenomena influencing fluorescence Professor Lakowicz highlighted the many complexities and results that are not so well-understood. He also outlined the potential for new opportunities in novel probes, devices, high-throughput biology, diagnostics and molecular imaging. Not a regular visitor to Europe the organizers were particularly pleased to have Professor Lakowicz present his work, which prompted numerous questions and much discussion.

Continuing the plasmonics theme, our next speaker, Professor Stefan Maier of the Department of Physics, Imperial College, is a past winner of the IoP Paterson Medal. Among his successes is the first demonstration of plasmonic waveguides below the diffraction limit in chains of metallic nanoparticles. His talk “*Plasmonics for nanometrology, nanocavities, and sensing*” reviewed work on new design concepts for optical and near-infrared nanocavities, control of nanoemitters, and applied work in nanometrology, nanobiosensing, and photovoltaics.

There then followed two contributed talks that further demonstrated the wide-ranging application of plasmonics in spectroscopy. Dr Sumeet Mahajan of the Cavendish Laboratory of the University of Cambridge presented his group’s recent work entitled “*Molecular imaging with surface-enhanced CARS on nanostructures*” on the

development of surface-enhanced coherent anti-Stokes Raman scattering (SECARS) on nanostructured surfaces and its application in bio-molecular imaging. SECARS showed an enhancement of $>10^5$ over conventional CARS and an additional enhancement of $>10^3$ in SECARS over surface enhanced Raman scattering (SERS). SECARS was employed in molecular imaging and studying interaction of lipid layers with biomolecules on plasmonic nanostructures and is leading to reliable single molecule spectroscopy and fast biomolecular imaging on plasmonic surfaces. Dr Malcolm Kadodwala of the Department of Chemistry of the University of Glasgow then presented "*Super chiral light for ultrasensitive characterization of biomaterials*" describing the use of chiral light generated in nanostructures as a new approach to studying molecular structures at a 10^6 higher sensitivity than conventional circular dichroism. This was followed by a coffee break that included both the poster session and instrument exhibition in the same hall and a representative of the Institute of Physics was on hand at their exhibition stand in order to advise on publication of papers from the meeting in Measurement Science and Technology. The posters remained on display for all the meeting.

The meeting then moved into a session on nanoparticles Chaired by Dr Karen Faulds and started with an invited presentation by Dr Jeff Fagan of the National Institute of Standards, Gaithersburg, Maryland. The major topic addressed in "*Characterizing the Carbon Nanotube-Solution Interface with Spectroscopy*" was the solvation and dispersion of single wall carbon nanotubes, a problem that holds the key to applying these novel structures. Using absorbance and fluorescence spectroscopies, as well as Raman scattering, it was shown to be possible to characterize the interface of the nanotubes with the environment, including the isolation of individual nanotubes, the surface coverage of the dispersant, and the local effective dielectric environment.

Professor Sebastian Schlücker of the Molecular Biophotonics Group, Department of Physics, University of Osnabrück, then presented an invited lecture "*SERS Microscopy: Nanoparticle Probes and Biomedical Applications*" on a core topic of the meeting, namely surface enhanced Raman. Impressive images were shown of the novel structures and encapsulations developed to date that included the development of gold nanosphere dimers for rapid tissue imaging experiments with single particle sensitivity as well as the first results on two-color immuno-SERS microscopy. Finally, potential future directions for tumour diagnostics were discussed.

Dr Ewan W. Blanch of the University of Manchester Interdisciplinary Biocentre then gave a contributed talk "*SERS and ROA: Arranged Marriage or Love Story?*" on combining SERS with circularly polarized light. The final talk in this session "*Nanoparticle Tracking Analysis; Multiparameter nanoparticle characterisation in real time*" concerned the measurement of nanoparticle size down to 10 nm using microscopic video monitoring of the light scattered from nanoparticles. It was presented by Dr Bob Carr of Nanosight Ltd, the UK company who manufacture products based on this technique and some impressive video clips were enjoyed by the meeting. The technique was compared to the alternative of dynamic light scattering and found to offer advantages in the measurement of size distributions.

The meeting then closed its first day of talks by opening a new session on single molecules Chaired by Dr Alex Knight. Professor David Klenerman of the Department of Chemistry of the University of Cambridge presented "*Single Molecule Studies of Protein Aggregation*" wherein he demonstrated the detection of the early oligomers

thought to be precursors to Alzheimer's disease using labelled beta amyloid single peptide. Although still difficult to implement, and restricted in application, single molecule methods of detection are one of the most promising areas of nanotechnologies to be combined with spectroscopy and might lead to deeper understanding of key biomolecular processes of medical bearing such as protein misfolding.

A poster session with a wine reception then closed the first day's scientific programme followed by the conference dinner at the Park Hotel, Teddington.

The second day continued the session on single molecules with an invited talk by Professor Enzo Di Fabrizio of the Italian Institute of Technology, Genoa, entitled "*Nanostructures for spectroscopy and biophotonics applications*" This presentation concentrated on the fabrication of a novel plasmonic nanostructure for Surface Enhanced Raman Scattering for single molecule detection. Using nanolithography some spectacular structures were presented and detection sensitivity down to a few molecules demonstrated.

Two contributed talks then followed. Professor David Millar, of the Scripps Research Institute, La Jolla, then took the meeting back to fluorescence in "*Single-Molecule FRET Studies of DNA Polymerase*." Using single-molecule Förster resonance energy transfer (FRET) to observe dynamic conformational changes of proteins and nucleic acid molecules during essential cellular processes such as DNA replication. The final talk of this session was given by Professor Jacob Piehler of the Faculty of Biology, University of Osnabrück entitled "*Self-controlled monofunctionalization of quantum dots and their superresolution imaging applications in live cells*." This work nicely covered the application of quantum dots in imaging for probing the dynamics of signalling complexes in live cells by combining single molecule tracking with localization beyond the diffraction limit.

The next session, Chaired by Professor Cait McPhee, then moved into Nanomedicine in order to further demonstrate the pull-through into medical application of some of the techniques already covered in the meeting. Professor John Pickup, of Kings College London School of Medicine, Guy's Hospital presented "*Fluorescence, Nanomedicine and Diabetes*." This invited talk laid out the importance of glucose sensing as one of the grand challenges in medical sensing and how there was a need for a new technology for non-invasive and continuous glucose sensing. The potential of a new approach combining fluorescence lifetimes and an engineered mutant of a glucose binding protein was illustrated. The second invited talk in the Nanomedicine session was presented by Professor Nick Stone, of the Biophotonics Research Unit, Gloucestershire Hospitals NHS Foundation Trust and Cranfield University, titled "*SESORS – deep probing molecular specific signals in tissues*." This talk explored SESORS (surface enhanced spatially offset Raman spectroscopy), as a novel combination of surface enhanced Raman spectroscopy and deep Raman techniques for non-invasively detecting small, deeply buried lesions using encapsulated-SERS active gold nanoparticles. The method opens prospects for in vivo, non-invasive, specific detection of molecular changes associated with disease up to depths of several cm representing significant improvement over traditionally detected Raman signals in tissue by two orders of magnitude.

Following the morning Poster and Instrument exhibition we then had two contributed talks. Professor Roger Bisby of the School of Environment and Life Sciences, University of Salford presented "*Multiphoton fluorescence lifetime microscopy: imaging of intracellular drug uptake, activation and induction of oxidative stress.*" This talk used intra-cellular multi-photon excited fluorescence lifetime imaging as its primary tool and hence was able to cover this important technique for the benefit of the meeting. The second contributed talk "*Imaging of Fibrinogen Binding to Erythrocytes,*" was presented by Professor Carlota Saldanha, of the Institute of Molecular Medicine, University of Lisbon, and described the use of conventional fluorescence microscopy in imaging for the first time the fibrinogen interaction with human red blood cells.

The final session, Chaired by Professor Duncan Graham, focused on Biomolecules and Imaging and started with an invited talk "*Super-resolution imaging of cellular structure and organization with standard fluorescent probes*" by Professor Markus Sauer, of the Department of Biotechnology and Biophysics, University of Wuerzburg. After reviewing recent methods for overcoming the diffraction limit in microscopy down to 20 nm resolution the speaker focused on dSTORM in combination with standard chemical tags and conventional synthetic organic fluorophores to provide a simple method for live-cell super-resolution imaging.

The final Poster Session and Instrument Exhibition was followed by Professor Joseph Lakowicz presenting the three student Best Poster Prizes of £50 Amazon vouchers to Linden Webster of Kings College London, Ingeberg Iping Petterson of the University of Amsterdam and Alison McLintock of the University of Strathclyde.

There then followed two contributed talks. Professor David Richards of the Department of Physics, King's College London, presented "*Super-resolution axial sensitivity in plasmonic fluorescence cellular assays of protein internalisation*" describing a novel fluorescence lifetime imaging technique using a plasmonic substrate with super-resolution intra-cellular axial sensitivity. Dr Steven Bell, of the School of Chemistry and Chemical Engineering, Queen's University, Belfast then presented "*Taking Surface Enhanced Raman Spectroscopy from Simple Nucleobases to Single Base Mismatches in DNA*" which explored label-free SERS.

The meeting closed on a strong note with two further invited talks. Professor Kishan Dholakia, School of Physics and Astronomy, University of St Andrews presented "*Advanced methods in Raman spectroscopy: fluorescence removal and wavelength confined Raman analysis on chip.*" While describing relevant aspects of quantum physics this talk covered applications to bladder cancer and microfluidic Raman. Professor Volker Deckert, of the Institute of Physical Chemistry, University of Jena then presented "*Nanoscale surface investigations - from cell membranes to single bio molecules.*" This included not only membrane structures and specific structural properties of distinct membrane proteins, but also single structures like protein crystals that demonstrated even a lateral discrimination of amino acids is feasible.

The meeting ended with the closing remarks of Professor Duncan Graham to the same excellent attendance as throughout the whole meeting.

Further scientific details, including the Invited Speakers' abstracts and photographs of the event, are available on the NMS website at <http://sensor.phys.strath.ac.uk/nms/>

Results and future impact of the event

The programme we arranged was quite ambitious in terms of the breadth and depth of its scope. Not only in bringing spectroscopy and nanoscience together, but in terms of the variety of spectroscopy and application that we were able to cover by inviting leaders in various fields and by attracting others through contributed talks and posters.

Fluorescence and Raman were the core spectroscopies, but the meeting had little repetition and also attracted more specialist aspects such as CARS and chiral techniques. In terms of application the event managed to bridge as far as medical application of nanotechnologies. It could have turned out that such a hotchpotch would have produced an incoherent event that lacked direction and focus, but in truth, as the feedback showed, the delegates revelled in the diversity and depth of quality. The common application of biomolecules and common language of spectroscopy were probably the main planning reasons why things worked out so well.

It is highly possible that meetings that are outward looking such as NMS, rather than inward-looking and sole-topic meetings, will start to gain a place more generally. It is interesting that the format of NMS has already been replicated, almost identically, by the Institute of Physics in its “Topical Research Meetings”. Although the first such IoP meeting was on a specialist topic, Graphene, the guidelines highlight the interface of physics with other disciplines. Like NMS the IoP meetings are of two-day duration, comprised of a mixture of invited and short oral contributions and capable of attracting 100 leading scientists. In the case of NMS we placed a high importance on attracting research students and achieved this goal with 34 research students attending.

We very much like the interdisciplinary and synergistic concept of “*X meets Y*”. There can be no doubt that cross-fertilisation between different fields is often a source of progress. So for example, if the knowledge and awareness of the techniques needed to fabricate the bespoke architectures of plasmonic structures and their performance, passes between Raman and fluorescence then much will have been achieved by NMS. Other cross-benefits are also possible. For example in respect of microscopic resolution, discrimination against unwanted signals, plasmonic optimization and preservation of signals. There is to a large extent competition between fluorescence and Raman techniques and this can be quite creative. The relative shortcomings as well as the strengths of the two techniques can also stimulate improvement and having so many of the top-proponents of each together at one meeting can only serve to advance this cause.

Reinforcement of the “Nano Meets Spectroscopy” message will undoubtedly be needed to achieve a lasting impact and we should be cautious to expect too much from just one meeting. The publication of papers from the meeting in *Measurement Science and Technology* will undoubtedly help and a repeat of the meeting in two years time would also help sustain the message of NMS. The meeting was tightly packed over essentially the equivalent of 1½ days and if we run it again we may well add another half day such that it runs from lunch time to lunch time, giving the equivalent of 2 days spread over 3 in order to give more time for discussion, posters and contributed talks. The NMS website will be maintained as it continues to attract hits and thereby contribute to sustaining the impact of the meeting.

DJS Birch

4th November 2011

Nano Meets Spectroscopy (NMS) DAY 1

Thursday 15th September 2011, NPL, London

11:30- 12:45	Registration, buffet lunch & Instrument Exhibition
12:45- 12:50	Welcome & Introduction (Auditorium)

Nano & Spectroscopy

Chair David Birch

12:50–13:20	Debdulal Roy, National Physical Laboratory, London <i>“Tip-enhanced Raman spectroscopy- opportunities and challenges for nanoscale analysis”</i>
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Plasmonics

13:20-13:50	Joseph Lakowicz, University of Maryland <i>“Plasmon-Controlled Fluorescence: Principles and Applications to Biomedical Research”</i>
13:50–14:20	Stefan Maier, Imperial College London <i>“Plasmonics for nanometrology, nanocavities, and sensing”</i>
14:20- 14:40	Sumeet Mahajan, University of Cambridge <i>“Molecular imaging with surface-enhanced CARS on nanostructures”</i>
14:40–15:00	Malcolm Kadodwala, University of Glasgow <i>“Super chiral light for ultrasensitive characterisation of biomaterials”</i>
15:00–15:30	Poster Session, coffee, Instrument Exhibition

Nanoparticles

Chair Karen Faulds

15:30–16:00	Jeffrey Fagan, National Institute of Standards & Technology, Gaithersburg <i>“Characterizing the Carbon Nanotube-Solution Interface with Spectroscopy”</i>
16:00–16:30	Sebastian Schlücker, University of Osnabrück <i>“SERS Microscopy: Nanoparticle Probes and Biomedical Applications”</i>
16:30–16:50	Ewan Blanch, University of Manchester <i>“SERS and ROA: Arranged Marriage or Love Story?”</i>
16:50- 17:10	Bob Carr, NanoSight Ltd <i>“Nanoparticle Tracking Analysis; Multiparameter nanoparticle characterisation in real time”</i>

Single Molecules

Chair Alex Knight

17:10-17:40	David Klenerman, University of Cambridge <i>“Single Molecule Studies of Protein Aggregation”</i>
17:40–18:40	Poster Session with Wine Reception & Instrument Exhibition
19:00- 22:00	Conference Dinner at the Park Hotel, Teddington

Nano Meets Spectroscopy (NMS) DAY 2

Friday 16th September 2011, NPL, London

Single Molecules

Chair Alex Knight

09:00–09:30	Enzo Di Fabrizio, Italian Institute of Technology, Genoa <i>“Nanostructures for spectroscopy and biophotonics applications”</i>
09:30–09:50	David Millar, The Scripps Research Institute, La Jolla <i>“Single-Molecule FRET Studies of DNA Polymerase”</i>
09:50-10:10	Jacob Piehler, University of Osnabrück <i>“Self-controlled monofunctionalization of quantum dots and their superresolution imaging applications in live cells”</i>

Nanomedicine

Chair Cait MacPhee

10:10-10:40	John Pickup, Kings College London <i>“Fluorescence, Nanomedicine and Diabetes”</i>
10:40-11:10	Nick Stone, Cranfield University <i>“SESORS – deep probing molecular specific signals in tissues”</i>
11:10-11:40	Poster Session, coffee, Instrument Exhibition
11:40-12:00	Roger Bisby, University of Salford <i>“Multiphoton fluorescence lifetime microscopy: imaging of intracellular drug uptake, activation and induction of oxidative stress”</i>
12.00-12.20	Carlota Saldanha, University of Lisbon <i>“Imaging of Fibrinogen Binding to Erythrocytes”</i>

Biomolecules and Imaging

Chair Duncan Graham

12:20-12:50	Markus Sauer, University of Wuerzburg <i>“Super-resolution imaging of cellular structure and organization with standard fluorescent probes”</i>
12:50-13:50	Poster Session, buffet lunch & Instrument Exhibition
13:50-14:10	David Richards, King’s College London <i>“Super-resolution axial sensitivity in plasmonic fluorescence cellular assays of protein internalisation”</i>
14:10-14:30	Steven Bell, Queen’s University, Belfast <i>“Taking Surface Enhanced Raman Spectroscopy from Simple Nucleobases to Single Base Mismatches in DNA”</i>
14:30-15:00	Kishan Dholakia, University of St Andrews <i>“Advanced methods in Raman spectroscopy: fluorescence removal and wavelength confined Raman analysis on chip.”</i>
15:00-15:30	Volker Deckert, University of Jena <i>“Nanoscale surface investigations - from cell membranes to single bio molecules”</i>
15:30-	Close & Tea

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