Report of the SR Forum's Low Energy Workshop held at Daresbury Laboratory on 5-6th March 1999

Executive Summary

The following is the proceedings of a two-day workshop organised through the SR Forum at Daresbury Laboratory to discuss the future of low energy radiation sources. The workshop attracted over 60 attendees from diverse areas of science ranging from Atomic and Molecular Physics to the Life Sciences.

Low energy radiation is defined here as photon beam energies less than 100 eV or wavelength greater than 12 nm.

The workshop came to the following conclusions:

- There is a large body of exciting and important science that requires access to Low Energy Sources.
- Laser and Free Electron Lasers do not replace synchrotron radiation but are complementary to it.
- Most importantly, there is a strong requirement for a dedicated low energy synchrotron radiation source with a Free Electron Laser and planning should start immediately.
- There is an urgent need to plan low energy beamlines on DIAMOND, moving existing SRS stations to DIAMOND as an interim measure to maintain the UK's requirement for low energy radiation to carry out world-class research until the Low Energy Source is available. Any dark period is undesirable.
- Users who require radiation in the infra-red region will require bending magnet radiation on DIAMOND and the Low Energy Source. At least five beamlines required in the short term.
- The technical requirements for the Low Energy Community are summarised on page 12.

A new state-of-the-art 3rd generation low energy synchrotron radiation source would not only be very important in maintaining the UK's front-rank in curiosity driven scientific research but would also play a crucial part in the UK's economic competitiveness in, for example:

Structural genomics	Magnetic recording sensors
Semi conductor industry	Catalysis & corrosion
Superconductors/insulator	Sensors
The Environment	Organic absorbates & new structures (eg clusters C_{60})
Alloys	Protein folding & design
Cell biology & health	Medical
Environmental biology	Pharmaceuticals & agrichemicals
Smart materials	Bioenergy

Action: Working groups derived from this workshop will now assemble detailed scientific arguments to go to funding bodies that will draw their attention to the plight of the UK synchrotron low energy users and the potential future dearth of such facilities.

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DAY 1

Prof Norris, Chairman of the Synchrotron Radiation Forum, welcomed everyone to second consultation meeting. This workshop was aimed at identifying the future low energy requirements of the SR community. The physical sciences consultation had previously been held at Daresbury Laboratory on 22-23 January 1999. There concern was expressed that the present low energy users of the SRS would not be catered for as the DIAMOND machine energy of 3GeV or more would not provide optimised vacuum ultraviolet (VUV) radiation from insertion device at energies much below 100 eV. The implication of this would be that the UK science that required low energy SR would not remain competitive into the next century. Low energies were therefore defined as light of energy less than 100eV or wavelengths greater than 12 nm. This open workshop had drawn more than sixty attendees with many more who couldn't attend at such short notice expressing concern over future access to low energy SR (attendee list at Annex I).

The Woolfson Report on Synchrotron Radiation (1992) had recommended a 'three source scenario' to replace the SRS. Here high energy X-ray radiation would be provided by the UK's share in the ESRF, the bulk of X-rays for the UK being provided for by a home-based medium energy source (DIAMOND), and VUV being provided by a home-based Low Energy Source (LES). The first two of these recommendations had now found funding, but the VUV had not been catered for.

The form of the 2 day meeting (programme at Annex II) would on the first day attempt to capture the future science that a future low energy SR would enable, taking into account the availability of conventional source such as lasers and also the emergence of free electron lasers (FELs). On the second day the technical requirement of the community would be drawn together for all sources. The first part of day one was used to provide tutorial style information on present capabilities and future possibilities with radiation sources such as SR (Mr Mike Poole, DL), lasers (Dr Graeme Hirst, RAL), FELs (Dr Laurent Nahon, LURE and Dr Guido Knippels, FELIX), and SR beamlines (Dr Frances Quinn, DL). Notes and copies of overheads from these can be found at Annex III. This was followed by three parallel syndicate sessions covering the scientific areas of atomic/molecular science, surface/condensed matter, and the biological sciences, detailed notes of which are at Annex IV. A chairmans' summary session and notes of the ensuing discussions are presented below.

Reports of Chairs of Syndicate Sessions on Future Science

(5th March, 17:00, Chair: Prof Colin Norris, Leicester)

Prof Norris opened the session and said that the emphasis in this instance was to be on science rather than technical requirements. The meeting agreed that the syndicate sessions should address the following:

1. What are the established areas of science that currently require light sources that will continue to be at the forefront in the next ten years?

2. What new areas of science may be predicted to be important and what sources would be required for these areas?

3. What particular characteristics of the above sources would be required?

4. Give examples of experiments that would benefit from a low energy source/DIAMOND, and would these require bending magnets or insertion device sources?

5. What present and future areas of science will require a particular temporal structure to be accommodated on DIAMOND/a low energy machine (ie single bunch, hybrid mode)?

6. Assess experiments that would benefit from source characteristics unlikely to be present in a third generation light source. Can these be satisfied by:
   a) FELs?
   b) Lasers?

7. Assess the complementarity between storage ring light sources, FELs and lasers for your scientific programme.

8. If there were to be a "Dark Period" for SR in the UK, how would this impact on low energy research programmes?

9. Are you satisfied with the present access mechanisms to the SRS? If not how could they be improved?

Prof Norris then invited Prof Colin Latimer (Queens, Belfast) to report on the meeting of the atomic and molecular science syndicate.

Prof Latimer reported that, for gas phase experiments, 100% of the users work at energies below 1000 eV, 90% below 100 eV, and 60-70% below 25 eV. This was a consequence of the binding energies and ionization potentials of virtually all molecules being around 10 eV.

The syndicate had first addressed new science that could be done on DIAMOND. This would be at energies above 100 eV. The science would include core ionization/excitation and dynamics of fragmentation, and non-dipole relativistic effects. To carry out these experiments, current state-of-the-art beamlines such as 5D, Phoenix, and 3.2 should be moved to DIAMOND to give an interim presence for the atomic & molecular community. This would a) keep the community alive and b) keep world class work going. It was felt that the costs of transferring the beamlines should be included in the costs of DIAMOND at the planning stage. A high energy (>100 eV) beamline would accommodate some work, but not all users could be accommodated (there are currently 12 VUV and longer wavelength beamlines on the SRS). DIAMOND could not satisfy all needs but could keep the best science alive.

The syndicate had then discussed future atomic & molecular VUV science (>6 eV). They had identified a number of important features:

a) High Flux

b) High Resolution

c) Polarization (switchable)

d) Time Structure (≥10 psec, with the possibility of few-bunch operation)

e) Free Electron Lasers

They had then identified areas of science with their particular requirements:

Dynamic processes (pump/probe)	(a) (d) + (b) (c) (e)
Dilute species (ions, LVP, clusters, Van der Waals molecules)	(a) (c) (b) + (d)
*Unstable species	(a) (d) (c) (b)
*Spin polarization in photoelectron spectroscopy	(c) + (a)
*Chiral effects in the gas phase	(a) (c)
Dispersed fluorescence	(a) (b) (c)
*Multiple ionization (ne$^-$, hollow atoms)	(a) (c) (e)
*Multiphoton processes	(d) + (a)
State-selected photoions and reactions	(b) (d) (c)
Very high resolution spectroscopies	(b) (d) (a)
*Oriented molecules	(c) (b)

Areas of science identified as new are marked with an asterisk. Prof Latimer concluded that all the user community required insertion devices, including crossed helical undulators. Most of the experiments were flux-hungry.

FELs and lasers were not considered competitive for the vast majority of the work, and should be considered as complementary, rather than replacing SR beamlines.

The user community felt that any ‘dark period’ would be undesirable. There was the possibility of two dark periods (SRS-DIAMOND, and DIAMOND-LES) and both of these should be avoided.

Finally, current methods of access to SR were unsatisfactory. More direct access was essential, and the introduction of tickets had caused considerable problems. It was felt that the EPSRC should consult with users, and possibly a working group consisting of EPSRC staff and SR users should be set up to discuss the access problem. One particular difficulty with the ticket system was that new lecturers, with their start-up grants of less than £50K, were precluded from using SR.

Prof Latimer concluded with the remark that a dedicated Low Energy Source was essential to maintain world class science for the atomic & molecular community.

Prof Norris then invited Prof Wendy Flavell (UMIST) to report on the meeting of the syndicate for surface & condensed matter science.

Prof Flavell reported that their meeting had concentrated on the first two questions, concerning established and new science. Established areas of science were as follows:

- High resolution band mapping of new materials:
  - Highly correlated materials showing exotic phenomena, e.g. giant magnetoresistance (applications in magnetic recording and sensors), superconductivity, Kondo insulators.
  - Novel intermetallic compounds and thin films.
  - Binary and ternary III-V semiconductors (applications in metal/semiconductor interface formation).
- Resonant and high resolution photoemission of complex oxide catalysis – exploration of unusual redox properties.
- Resonant enhancement of dilute band gap chemical states induced by doping (applications for gas sensors).
- Electronic effects of adsorption (applications in catalysis and corrosion).
- Spin polarised photoemission
  - Depth profiling using hysteresis loops; circular dichroism at 3p-3d resonances in magnetic multilayers. Amorphous and granular magnetic alloys (applications in permanent magnets, sensors, and recording).
- High resolution soft X-ray photoelectron spectroscopy (SXPS)
  - Core level studies with combined resolution $\cong$ 50 meV. Surface and interface bonding, e.g. metal/semiconductor interfaces, growth processes, nanoparticles at surfaces, especially at C 1s level – organic adsorbates, catalysis, C_{60}/semiconductor heterostructures.
- X-ray excited optical luminescence (XEOL)
  - Chemical and structural information particularly suited to nanoscale systems, buried interfaces, e.g. amorphous Si.
- Near edge X-ray absorption fine structure (NEXAFS), especially at C 1s K-edge
  - Catalysis, corrosion inhibition, structural studies of liquids, liquid/solid interfaces.

Of all these areas, only the last three were possible on DIAMOND. Another area was science using infra-red radiation. This would theoretically be possible on DIAMOND but it was essential that the requirement for a very large aperture be incorporated at the design stage.

The meeting had then discussed potential new areas of science, and the following had been identified:

- Resonant spin-polarised photoemission

- For Fe overlayers/alloys. Energy down to 15 eV for the study of 3p-3d resonances.

- SR ARPES with circularly polarised light
  - Very flux-hungry – would require 10^4-10^5 times more flux than the SRS.
- Spectromicroscopy of magnetic materials
  - e.g. to focus on particular domains. Focus and raster over sample.
- Time-resolved studies
  - Surface and bulk magnetisation flipping at different rates on the nanosecond timescale.
- Cluster photoemission
  - 20 eV, high flux (small cross-section).
- Measurements of saturation magnetisation
  - From the work function (a few eV) up. This would require the LES for tunability.
- Si ULSI technology. Si/O layers of a few tens of angstroms:
  - Photoemission at the Si L edge and below. This would require high resolution and very high flux.
  - Combined SR/FEL work – FEL excitation, SR spectroscopy. Links to terahertz science.
- Optical materials:
  - Band gaps are getting larger. In future 3-10 eV sources will be required to probe semiconductor bandgap excitations. Confocal microscopy could have applications for this. An FEL or SR driven FEL would be required for this.
- Surface Photochemistry:
  - Clusters on supports, effect of support on desorption rate, 2 photospectroscopies simultaneously (2 x VUV), VUV photolithography. Would need SR and FEL, short pulses, 10^{16}-10^{18} photons/sec.
- Total measurement of nanoscale systems
  - e.g. combined HR photoemission (‘snapshot capability’), SXPS and NEXAFS/XEOL.
  - Spectramicroscopy on single metal clusters (SEXAFS/NEXAFS), XES, high resolution PEEM.

The syndicate had then discussed the source characteristics required for the work. Time structure in at least the picosecond range was necessary. There had been some discussion about the femtosecond range, but it was still unclear whether this would be necessary. A spatial resolution of 1 micron or less was required, with focussing for individual clusters. Fluxes of 10^4 to 10^5 times more than the SRS were necessary, particularly for the spin-polarised PES work. Tunability between 10 and 100 eV was required (excluding the IR work). It was felt that FELs may be suitable for sub-10 eV work, provided that they were sufficiently tunable. Lifetimes of greater than 24 hours would be ideal for IR experiments, but 12 hours would be adequate for the other techniques. There was some discussion about the most suitable source for IR experiments with the community concluding that they would require a presence on both DIAMOND and the low energy machines. IR experiments on a LES would however require high beam stability and longer lifetimes than presently envisaged. Lasers were not tunable enough for this work. The most exciting developments would require a combination of FELs and SR. It was pointed out that the IR community on the SRS is large and growing rapidly. This is mirrored world-wide.

Prof Flavell then continued with the technical requirements discussed by the syndicate. Both circular and linear polarizations were necessary, and polarisation should be switchable. Relatively slow switching would be acceptable. Coherence was generally considered to be useful, but not enough was known about it at this stage. She summed up the requirements by saying that lasers were not useful for this community. FELs might be suitable for some IR and VUV work, and the ideal situation would be a combination of SR and FELs.

They had considered the possibility of a dark period, and the conclusion was reached that a dark period of a year, although undesirable, would be acceptable. Any longer than this was not. Travel to overseas sources was difficult because of the large and complex specialised equipment required for many of the experiments.

On the question of access, the tickets system was seen to be unacceptable, and the clampdown on direct access had already been disastrous for the community.

Prof Norris then invited Bonnie Wallace (Birkbeck) to report on the meeting of the biology syndicate.

Dr Bonnie Wallace said that, in answer to question 1, the syndicate had identified a number of existing areas of science that would be important:

- Live cell biology (time-resolved)
- Molecular basis of signal transduction (molecular assemblies)
- Protein folding and design
- Dynamic molecular mechanisms
- Biotechnology of materials (self-assembly in solution and on surfaces)
- Biomedical applications including clinical diagnosis
- Environmental biology (agricultural, waste management)

- Drug binding studies

She reported that the low-energy biology community was new, and that many of these areas were growing rapidly. Areas of new science identified were as follows:

- Interaction of biological materials with synthetics (e.g. dendrimer interactions with cells, DNA etc. interacting with smart materials).
- Biosensors/biochips
- Bio/micro-reactors
- Bioenergy using microorganisms
- Genomics based pharmaceuticals design
- Special confocal techniques (e.g. confocal circular dichroism)
- Surface CD and membrane interactions
- Combined techniques (e.g. CD and fluorescence, fluorescence and X-rays)
- Magnetic CD

They had then discussed the requirements for source characteristics. High flux was vital, especially for time-resolved experiments. Ideally, 10^6 times more flux than the SRS was required. Emittance was not so critical as it was generally diffraction-limited at the energies required. Time-resolution of at least sub-ns was necessary for some fast biological processes, e.g. early stages of protein folding. For the time structure of the source, a pulse width in the picosecond domain was desirable, with repetition rates at the MHz level, and minimum bunch-bunch separation of 100 ns. Flexible operations such as 'hybrid modes' would allow many time-resolved fluorescence experiments without compromising the machine current for multibunch users. Hybrid modes might be necessary for combined technique experiments. Dedicated beamtime in single bunch mode was required, and it was felt that the single bunch level of 10% at the SRS was not enough. Switchable circular polarisation with a frequency of at least 10 Hz would be desirable. Long lifetimes were required for experiments that monitored biological processes that may last for many hours. A top-up mode might be helpful for this. Spatial resolution at the sample should be sub micron, so good source stability was necessary. Finally, the highest photon energy would generally be less than 8 eV.

Questions 4, 6, and 7 were considered together, and a matrix was produced showing the suitability of the various proposed sources for the different scientific areas:

DIAMOND (Bending Magnet)	**LES (Insertion Device)**
CD (stopped-flow, spectra, surfaces) Time-Resolved Fluorescence with wavelength variation and anisotropy (time-resolution could be better than LES) IR Microscopy Microvolume Confocal Microscopy	LES good for flexibility of operational modes, and reduced power loading on optics CD (stopped-flow, spectra, surfaces) Time-Resolved Fluorescence with wavelength variation and anisotropy Possible problem with source size – need more information on machine parameters
FEL	**LASER**
Time-resolved CD at some wavelengths Pump-probe in IR Time-resolved fluorescence	Stopped-flow CD (Very limited) TR fluorescence (limited because of pulse-pulse stability variation, rapid wavelength tunability, not as good as SR for anisotropy) Confocal – TR microvolume, but again pulse-pulse stability problem
DIAMOND+FEL	
Possible use of DIAMOND LINAC for IR FEL Pump-Probe IR	

The group had then considered the question of the effect of a 'dark period' for SR in the UK. Possible access to other sources was considered. There were no appropriate FEL or conventional laser sources that could be used for most of the work. For CD, there were no SR stations anywhere that could be used. This was considered to be very important in the light of the recent award of funding by the BBSRC for a Structural Biology Centre at Daresbury, including the construction of a state-of-the-art station for SR CD work. IR microscopy could possibly be done at Brookhaven or LURE, but it was considered to be extremely unlikely that these facilities could accommodate the rapidly expanding community at the SRS. The relatively short time scales for the set-up and design of biology experiments meant that this community would be particularly affected by any dark period. A dark period would also be disastrous for new communities that were just becoming established, such as IR and CD.

Dr Wallace then said that the feeling was that the biology community was generally dissatisfied with mechanisms of access to SR. Particular problems were:

- Insufficient single bunch time, and insufficient reliability of SB mode.
- Poor co-ordination of committees.
- No mechanism (or extremely limited) for trial experiments and instrument development.
- Tickets could be disastrous for the single bunch community, as one user with tickets could effectively take all the allocated SB time for a complete allocation period.
- Less experienced users required a mechanism for access to expert staff after a run for help with data analysis.

Dr Wallace then concluded by saying that there was much potential for the biological community in the field of low energy SR, and it was hoped that this could be fulfilled by making appropriate facilities available.

A question was then raised concerning possible radiation damage to samples with photon fluxes 10^6 times higher than on the SRS. This could potentially be a problem with biological samples, although for fast processes it was hoped that data could be collected before any damage occurred. Wavelengths used were below the ionisation thresholds of proteins and nucleic acids so this was not an insurmountable problem. Prof Norris then asked if radiation damage might be a problem for the other communities. This was not seen to be a problem for the atomic & molecular science community, as the samples were generally very dilute. Radiation damage could occur to surfaces, involving the creation of new defects by exposure to the beam. This was really only a problem for delicate samples when exposed to white beam. Lower energy photons caused fewer problems.

Prof Norris thanked the chairs of the syndicates for their reports. He said that very interesting science had been described in all three groups, with many exciting new areas requiring a dedicated Low Energy Source. In addition, two groups had identified good science for FELs. He then opened the session for general discussion.

Minutes of the day 1 concluding discussions

Dr Knippels (FOM-Institute for Plasma Physics) said that it would be difficult to provide a UV FEL in a machine that was not specially designed for the purpose. However, it was relatively easy to make a FEL that would operate at a wavelength of 1 micron. This could then be frequency doubled/tripled/quadrupled to produce UV. Typically, a 1kW IR FEL could produce Watts of UV radiation.

Prof Latimer reported that he had heard of gas absorbers being used at the ALS to absorb excess power in undulators. Dr Quinn (Daresbury) said that these were not really absorbers, but were used as filters to remove higher harmonics. Dr West (Daresbury) added that these filters were placed after the first optical element, and so would not be helpful for reducing the power loading on the optic. Prof Latimer then asked whether helical undulators might help to solve the power-loading problem. Dr Quinn replied that this was a possibility, but not all user groups wanted the circular polarisation that they produce. Other exotic insertion devices such as ‘figure of eight’ undulators might have a role to play.

Prof Norris then said that all the syndicates had said that a dark period for SR in the UK was undesirable. Prof Flavell said that she agreed with this, but if it was necessary to have a dark period to get the finance for the new source a short period of about a year could be tolerated. Dr John West said that his impression was that there would be an overlap between SRS and DIAMOND operations. It would not be possible for most users to transfer to overseas sources because of the complexity of their experimental equipment. Prof Latimer commented that the worst dark period would be an indefinite one; if there were a shutdown, it would be important to know exactly how long it would last. Prof Norris replied that in reality the system for beamtime applications meant that dark periods of 6 months were already being handled. Prof Latimer said that the problem with a dark period was that it prevented long term planning, and also could be particularly problematic for students.

Dr West said that his impression was that there would be an overlap between SRS and DIAMOND operations. It would not be possible for most users to transfer to overseas sources because of the complexity of their experimental equipment. Prof Latimer commented that the worst dark period would be an indefinite one; if there were a shutdown, it would be important to know exactly how long it would last. Prof Norris replied that in reality the system for beamtime applications meant that dark periods of 6 months were already being handled, however, all agreed that the problem with a dark period was that it prevented long term planning, and also could be particularly problematic for students.

Prof Norris then moved on to question 9, that of access to facilities. He said that no one was happy with the ticket system. The community had been against it from the beginning, and had been proved right. The problem with access for young lecturers with limited start-up grants was particularly important. His understanding was that the EPSRC were looking at this and conferring with the community. Dr Richard Tuckett (Birmingham) said that the effect of tickets varied considerably depending on the subject committee; the impression was that the physics community was less affected by the system than the chemists were.

There was a suggestion that an important question was the degree of overlap between DIAMOND and a dedicated LES. The amount of potential “high-energy” component of low energy work presented in this workshop could not be completely accommodated on DIAMOND, and could there be a case for stretching the energy of the LES upward? It was realised that DIAMOND would be excellent in the 3-4 KeV energy region. Prof Flavell said that DIAMOND would produce good quality soft X-rays, but would be unlikely to able to cope with the volume of demand. There will be a drive to look at higher elements, and this would be underprovided for on DIAMOND. She thought that the LES should reach energies of 1.5-2 keV.

Prof Norris then concluded the session by stating that the technique syndicate sessions to be held tomorrow should address the more technical questions, and if possible be specific with numbers for flux, brightness, etc.

DAY 2

Parallel syndicate technique sessions were held under the following headings:

Title	Chair
Polarised photon spectroscopy	Prof Jim Matthew
Electron spectroscopy	Prof John Dyke
Time-resolved fluorescence spectroscopy and microscopy	Prof Sue Bayliss
Spin-polarised electron spectroscopy	Prof Denis Greig
Infra-red spectroscopy/microscopy	Dr Ras Raval
Coincidence techniques	Prof Keith Codling

Notes of these sessions and can be found at Annex V, and the following summary table lists the results.

1. LOW ENERGY WORKSHOP Summary of Technical Requirements Syndicate Groups	A Polarised Photon Spectroscopy	B Electron Spectroscopy	C Time resolved Fluorescence	D Spin Polarised Electron Spectroscopy	E Infrared Spectroscopy and Microscopy	F Coincidence Techniques
1. What are the technical requirements of research carried out with low energy photons from: a) DIAMOND b) A dedicated low energy source (LES) c) Lasers d) FELs Is there any overlap between these?	? DIAMOND could be used by some users (long period undulator). ? LES required for brightness dependent users. ? FEL/lasers are not a solution (limited	? DIAMOND could be used by some surface science users in the range 0.1-1 keV. ? LES would be required for 95% of community. ? Some requirement for commercial lasers. ? FEL desirable on LES.	? DIAMOND could be used ? LES with dedicated insertion device would be most suitable. ? Limited applications for lasers and FEL (e.g. phase locked laser on LES)	? DIAMOND could be used in range 50-500eV ? Would require low energy undulator. ? Gas phase spin polarised experiments (10-15eV) need low energy source.	? DIAMOND – 30-60mrad apertures essential, stepped field dipoles possible. Must be included in DIAMOND design. ? LES – as for DIAMOND. ? FEL (with	? DIAMOND – A long period undulator would satisfy some users. ? Dedicated LES is needed to cover the energy range and number of users. ? Lasers – limited use ? FEL – useful for future pump-probe measurements
2. Which of the following characteristics would be important to your research? a) Flux (photons per second) b) Brightness (angular & spatial collimation) c) Rapid tunability over wide energy range d) Long and short term stability e) Polarisation selectivity & variation f) Temporal characteristics g) Coherence	? Flux & Tunability. ? Brightness in some cases ? Polarisation selectability (~1Hz).	? Energy range (5-500eV) ? Flux 10^3x present source ? 12hr lifetime ? Switchable polarisation (~1Hz). ? Flexible time characteristics. ? Rapid tunability ? Coherence –in future.	? High flux ? High Brightness ? Positional stability (10% beam size) ? 20hr lifetime	? Requirements similar to group (B). ? Require 10^4-10^5x extra flux above SRS. ? Variable polarisation (from undulator)	? Flux and brightness must be at least that of SRS. ? Long and short term beam stability. ? Polarisation selectivity. ? Coherence is likely to be present in IR	? Flux (10^{14} phot/sec/0.1%/100mA) ? High brightness ? 10-100eV tunability ? User control of undulator ? 24hr lifetime ? ~5% spatial stability ? Polarisation selectability ? Quasi CW with <5% modulation. ? Spectral purity (>99%)
3. If time resolution is required in your experiment, state the range. a) Femtoseconds b) Picoseconds c) Nanoseconds d) Microseconds e) Milliseconds f) Seconds	Quasi CW beam with 100ps – 1ns detection times.	? Flexibility of single vs multi bunch. ? Pulsewidth 10-100ps ? Ability to measure µs lifetimes (bunch switching?).	? 50-100ps FWHM pulse ? >100ns between bunches	? Would require single bunch operation for time-of-flight experiments.	? ns- µs time structure may be needed for combined FEL or laser pump-probe experiments.	? 100ps max. bunch length ? 10ps possible as detectors improve.
4. Is there a technical requirement for a particular temporal structure on DIAMOND / a low energy source?		? Flexibility of bunch length and spacing.	? Flexibility of fill structure (single bunch / hybrid mode) ? Bunch purity (1:10^7) ? Pulse amplitude stability		? Single bunch required for pump probe measurements.	? Few bunch mode ?300ns minimum spacing.
5. What energy ranges are important on a future low energy source? a) <5eV (>250nm) b)5-10eV (120-250nm)	Two communities exist ? 4-10+ eV ? 30-80 eV	Two communities exist ? 5-100eV (atomic & molecular science) ? 10-500eV (surface	? <10eV	? 5-500eV	? <5eV	? 6-300eV

6. What other facilities (e.g. combined sources, off-line facilities, end station equipment etc) would be required in order to carry out low energy research at: a) DIAMOND b) A dedicated future low energy source?		? VUV laser ? Clean room ? In-situ STM ? Chemical prep. labs. ? Switchable beamlines ? FEL on LES.	? Off-line support labs. ? Phase locked laser. ? Faster detectors (>100MHz) ?Solid/liquid/biological sample handling on station.		? Combined beamlines (MicroIR + XRD, XAS, XPS). ? Flexibility of source to take minimum of 5 high aperture beamlines. ? FEL for pump probe ? Chemical labs ? Bio containment. ? Improved detectors e.g. parallel readout arrays.	? Laser for state selection ? Environmental sample control – temp. etc. ? Physical stability.

<u>Open Discussion: Strategy for Future Sources</u>
Chair: Prof C. Norris

The Chairman thanked all those present for attending what had been a very constructive meeting. He extended a special thanks to those speakers who had provided input on 'conventional' and Free Electron Lasers (FELs). In summarising the outcome of the two days, he identified the following points:

1. It had been shown that there was a large body of exciting science that required, and would continue to require, access to a low energy source.

2. Lasers were thought to have limited future applications for this user community.

3. In certain areas, such as polarised photon spectroscopy, DIAMOND could provide a suitable source of photons, but there was some doubt it could cope with the demand.

4. A long wavelength undulator in a straight section of DIAMOND could have some applications in this area, but possible problems associated with such a device had not been fully identified. Calculations demonstrated that a 1000mm period undulator would give a 4x increase in flux over a DIAMOND bending magnet in the range 30-100eV. It was pointed out by Prof Norman that polarisation properties of the beam, and not simply flux, were of importance to many sectors of this user community.

5. The general message from the meeting was that a low energy synchrotron source was the most desirable option for future research of this user community, and that the use of DIAMOND was seen primarily as an interim measure that would keep the user community alive.

6. For several areas of research, such as UV/IR pump-probe measurements, it was apparent that the combination of an FEL and lasers with a third generation low energy SR source would be extremely useful.

It was now clear that there was a demand for low energy synchrotron radiation, preferably from a dedicated Low Energy Source, and it was important that this message be conveyed to the Research Councils. The process of providing for low energy experiments on both DIAMOND and a future low energy source was discussed.

<u>DIAMOND</u> – It was not yet clear how beamlines, beyond the 'core' 15 included in the initial build costs, would be funded, and whether any of those 15 would be available for low energy experiments. It was suggested that to secure funding for additional beamlines, an appropriate path might be for consortia of researchers, including DL staff, to put forward proposals.

<u>Low Energy Source</u> – In the case of a low energy source, strong scientific and technical cases would have to be produced. Mr Poole told the meeting that it would not be possible to initiate the design study required for the production of a technical case in the near future. This was because the design group at Daresbury was heavily involved in work related to DIAMOND, and could become even more involved over the next year. In response to a suggestion that the Research Councils could be

asked to fund a design study, it was pointed out that the same design team would be required to perform the study.

Prof Flavell stressed that the drawing up of a scientific case need not wait for the technical case and should begin soon. This could be initiated by group heads from the universities concerned, a core group of whom could liaise with the low energy user community. It was stated that the scientific case would have to be more detailed than had been produced for DIAMOND, and it was estimated that it would take at least six months to draw this together.

The possibility of overseas collaboration was raised, with the sharing of a low energy source with another EU country being discussed. While this would provide a guaranteed stake in a low energy source, it was seen as an unattractive option from the point of view of users who may be required to transport experimental equipment overseas to the beamline. In an earlier discussion on the possibility of initiating a design study, it had been suggested that the SOLEIL design team could be brought in to undertake a design study more readily than those design staff heavily committed to DIAMOND work at Daresbury.

An issue discussed by many of the syndicate groups, and raised again in this concluding session, was that of the Tickets. There was particular concern over the differing consideration given by the various programme committees to grants that included ticket requests. The general opinion was that this was not a good system to carry forward to a new source, and that an alternative system would have to be suggested for managing access to any new synchrotron source.

In the concluding period of the meeting there was discussion of the best process by which EPSRC could now be made aware of the UK research community's need for low energy synchrotron radiation. Prof Norman told those present that they should encourage the EPSRC to start thinking about a low energy synchrotron now, and that this process would begin with the presentation to them of the outcome of this meeting. A summary of the proceedings of this meeting would therefore be prepared and presented to the Users' Forum, and then forwarded to the Research Council.