Welcome
to the NLS Workshop on Advanced Photon Sources

3rd-4th June 2008, Daresbury Laboratory

Richard Walker, Diamond Light Source,
NLS Source Design Manager

Jon Marangos, Imperial College London,
NLS Project Manager

Welcome also from Swapan Chattopadyhay, Director of the Cockcroft Institute

The Cockcroft Institute
of Accelerator Science and Technology

Daresbury Science and Innovation Campus,
Keckwick Lane, Daresbury, Warrington,
WA4 4AD, Cheshire UK

Office of the
Director
Prof. Dr. Swapan Chattopadhyay, *PhD. (Berkley)*
F InstP, FAPS, FAAAS
SIR JOHN COCKCROFT CHAIR OF PHYSICS
UNIVERSITIES OF LIVERPOOL, MANCHESTER AND LANCASTER

June 3, 2008

Dear Colleagues,

Welcome to Daresbury – home of the Cockcroft Institute, the Daresbury Laboratory and the Daresbury Science and Innovation Centre. I am aware that many of my friends and colleagues are present at this meeting. I regret that due to family travel commitment, I will miss saying hello and welcome you all personally, especially those of you traveling from around the world.

The workshop that you are a part of is a significant milestone for the researchers in the photon sciences throughout the UK and the world. Particularly, it is a major opportunity for accelerator and laser scientists to conceive something bold and yet responsibly so, within technical and fiscal reach associated with a high level of confidence. It will also have to be differentiated from existing facilities worldwide.

I have personally pledged my full support of the Cockcroft Institute and its stake-holding affiliated partners to the NLS project. Specifically, the Cockcroft Institute will fully support Jon Marangos (NLS Project Director), Justin Wark (Chief Scientist of the Photon Research Institute), Frances Quinn (NLS Project Manager), Richard Walker (Manager of the Photon Source Design) and Mike Dunne (Director of the Photon Sciences of STFC) in bringing about the best value in photon sciences in UK and globally, complementing the existing DIAMOND Light Source in areas where novel and exotic light pulses will show the way to new frontiers of science.

It is increasingly clear that for frontier science of the day, such a source will have to provide: a level of 'coherence' significantly higher than the existing low-emittance, high brightness synchrotron radiation sources both temporally and spatially; a reach into probing ultra-fast processes approaching femto- to atto-seconds by a combination of novel techniques; the most ambitious and brightest beam of electrons possible right from the source; suitable radio-frequency, linear accelerator, laser-plasma and undulator technologies with more than sufficient reach in the necessary energy, flexibility in pulse structure /shapes and peak/average fluxes; and highest attainable resolution in pulse synchronization schemes.

I wish the workshop leaders Richard, Jon and all of you the very best in a successful workshop that will get us started in the right direction. We have the advantage of standing on the able shoulders of many of you frontier designers who already have conceived the likes of LUX, BESSY-II, Arc-en-Ciel, 4 GLS, Laser-Plasma schemes, etc. Please enjoy the workshop and your brief but intense scientific interaction in this important venture.

With my best regards,

Tel: +44 (0) 1925 603242 +44 (0) 1925 603820 (PA) Fax: +44 (0) 1925 864303 Mobile: +44 (0) 7796 993898
Email: swapan@cockcroft.ac.uk Website: www.cockcroft.ac.uk

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5th in a Series of Workshops to Establish Key Science Drivers and Outline Specifications for a possible New Light Source

- Electron Dynamics / Attosecond Science
  - May 13th 2008, Imperial College London
  - Meeting convenor – Jon Marangos
- High Energy Density Science
  - May 20th 2008, Rutherford Appleton Laboratory
  - Meeting convenor – Justin Wark
- Condensed Matter
  - May 21st 2008, Rutherford Appleton Laboratory
  - Meeting convenor – Andrea Cavalleri
- Chemical Science
  - May 22-23rd 2008, Daresbury Laboratory
  - Meeting convenors – Jonathan Underwood and Wendy Flavell
- **Advanced Photon Sources**
  - **June 3rd-4th 2008, Daresbury Laboratory**
  - **Meeting convenor – Richard Walker**
- Life Sciences
  - June 19th, Diamond Light Source
  - Meeting convenors – Dame Louise Johnson and Peter Weightman

Scope of the Workshop

- to provide input, expert advice, suggestions and opinions, to the preliminary design phase of the UK New Light Source project

- to examine the technological capabilities and limitations of both the conventional laser and accelerator based light sources on which a New Light Source may be based

- not about particular projects as a whole but (some of) the key underlying technology, and schemes

Some key questions (i)

What can and can't be achieved with laser sources ?

- photon energy range, ease of tunability, pulse energy, rep. rate, stability, etc.
- under what circumstances do accelerator sources out-perform lasers ?
- what improvements are likely in the next few years and what R&D is needed to achieve this ?

What are the relative advantages and disadvantages, potential and challenges, of normal and superconducting linac technologies ?

- achievable gradient, and effective gradient, vs. rep. rate/time structure
- what can be considered mature technology and what requires R&D ?
- availability of power sources
- relative impact of wakefields for different accelerating structures
- relative stability (LLRF) aspects etc.

What are the advantages, and disadvantages, of the different FEL seeding schemes ?

- photon energy range, laser requirements (where applicable), tunability, contrast ratio, stability aspects, layout implications etc.
- R&D needs

Some key questions (ii)

What are the relative merits of the various proposed attosecond pulse generation schemes ?

- photon energy range, laser requirements (where applicable), tunability, contrast ratio, stability aspects, layout implications etc.
- R&D needs

Are Compton backscattering and laser-plasma accelerator based light sources relevant in the context of NLS ?

- will they be competitive in terms of output ?
- what are the required laser parameters etc. ?
- stability/reliability ..
- R&D needs

Can fs and sub-fs pulse lengths be maintained through optical elements ?

What are the limitations of synchronisation systems ?

- what are the advantages/disadvantages of the different schemes and what improvements can be foreseen ?
- what is the influence of different pulse lengths and time structures ?
- will we ever be able to practically use "attosecond" pulses in an experiment ?

Workshop Programme

Tuesday June 3rd

09:15 – 09:45	Registration and Coffee
09:45 – 10:15	Welcome and NLS Overview – R..P. Walker (DLS) and J. Marangos (Imperial)
10:15 – 10:45	**High power, high rep. rate lasers - J. Collier (CLF)**
10:45 – 11:15	**HHG in gases - J. Tisch (Imperial)**
11:15 – 11:35	*Coffee*
11:35 – 12:05	**HHG on surfaces - M. Zepf (Queens, Belfast)**
12:05 – 12:45	**Discussion**
12:45 – 13:45	*Lunch*
13:45 – 14:15	**Potential and challenges of normal-conducting Linac-based FELs - P. Emma (SLAC)**
14:15 – 14:45	**Potential and challenges of super-conducting Linac-based FELs - R.A. Rimmer (JLAB)**
14:45 – 15:15	**HHG seeding - M.E. Couprie (SOLEIL)**
15:15 – 15:45	**Cascaded HGHG - B. Kuske (BESSY)**
15:45 – 16:05	*Coffee*
16:05 – 16:35	**Self-Seeding - J. Feldhaus (DESY)**
16:35 – 17:05	**Generation of attosecond X-ray pulses using free electron lasers - A. Zholents (LBL)**
17:05 – 17:35	**Single-spike SASE - S. Reiche (UCLA)**
17:35 – 18:30	**Discussion**

Workshop Programme

Wednesday June 4th

09:00 – 09:30	**Compton scattering photon sources - G. Priebe (STFC)**
09:30 – 10:00	**Laser-plasma accelerator based photon sources - D. Jaroszynski (Strathclyde)**
10:00 – 10:30	*Coffee*
10:30 – 11:00	**Managing of ultrashort pulses by time-preserving optical configurations - L. Poletto (LUXOR)**
11:00 – 11:30	**Mode-locked FELs and attosecond pulse trains - B. McNeil (Strathclyde)**
11:30 – 12:00	**Femtosecond synchronization for Free Electron Lasers - H. Schlarb (DESY)**
12:00 – 13:00	**Discussion**
13:00	Close of Meeting

Introduction to the NLS Project

Jon Marangos, Imperial College
Project Leader

NLS (New Light Source) is a working title for the first phase

What is NLS ?

- The STFC seeks to examine the case for a New Light Source Facility in the UK
- The NLS activity is jointly supported by STFC and Diamond Light Source Ltd, coupled to strong University/Accelerator Institute involvement
- A science driven project
  - *First*: define the key science drivers
  - *Next*: assess the technical solution
  - *Only Then*: assess funding and location

Science Consultation

- The first phase of the NLS project will determine, through wide consultation, the key long term scientific objectives that are likely to be relevant for decades
  - *"What is the compelling science?"*
- NLS will examine the balance between objectives which can be achieved by exploiting the array of international next generation light sources that are under construction and those which will require a new UK capability
  - *"Do we need a new UK source?"*
  - *"What is the specification for a new UK source?"*

NLS Timescales

- Phase 1 April – October 2008 (Consultation)
- *Science Review*[*]
- Phase 2 October 2008 – October 2009 (Facility Conceptual Design)
- *Full review*
  - Large Facility Capital Fund
  - Proposal to be considered for funding 2010-

[*] **Approval at this early point is essential and should not be assumed!**

The NLS Science Challenges Include

- Measuring structural dynamics in matter of all kinds
- Structural and dynamical imaging of bio-molecules not accessible to conventional methods
- Understanding high energy density matter
- Using light to control, rather than simply observe, complex matter
- Studying matter far from equilibrium and tracking phase changes in real time
- Measuring electron dynamics in real time: attosecond science

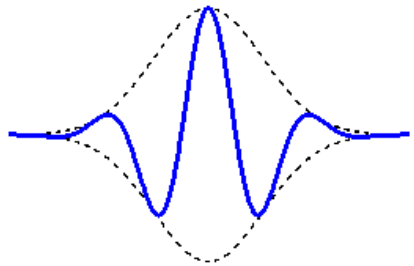
To meet these challenges we need to measure **structure and dynamics**
to understand, control and fabricate at the sub-nm scale
where dynamics are typically ultra-fast

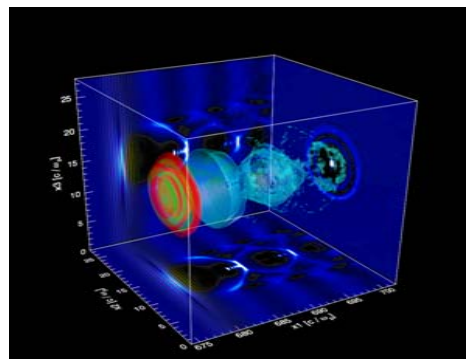
What is NLS likely to be ?

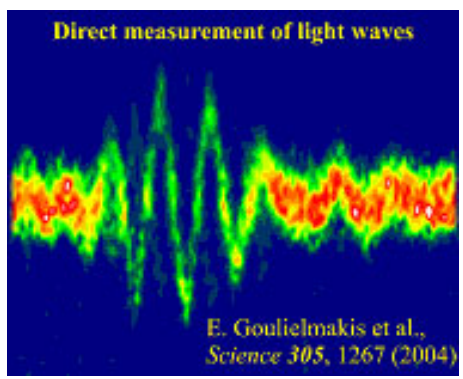
- The NLS facility, if built, will probably adopt an integrated approach e.g.
  - incorporating advanced conventional lasers alongside FEL(s) to achieve the science objectives, possibly in combination with
  - long wavelength sources
  - electron beam sources
- The facility should have unique capabilities compared to other projects under construction around the world

Key Capabilities of Conventional Advanced Lasers

- High field / ultra-fast lasers are now available in the visible and IR with pulse durations of only a few optical cycles
- These can drive electrons in new ways:
  - plasma wakefield accelerators,
  - surface harmonics,
  - gas phase harmonics
- **Attosecond duration events** are now accessible to measurement because of these developments
- Multi-colour **fully synchronised** ultra-short pulses in range from 0.3-100eV







Projected key capabilities of Next generation free electron lasers

- X-ray wavelength (down to 0.1 nm):
  - enabling atom scale structure determination
- Tuneability (>> 10nm – 0.1 nm)
- Ultra-short pulses (< 10 fs to ~100 as):
  - enabling measurement of structural dynamics at extreme timescales
- Highly Intense (up to 10^{12} photons/pulse):
  - enabling single molecule structure determination and multi-photon X-ray science
- Polarization control
- Flexible/high repetition frequency (Hz to MHz)
- Access to synchronised IR/THz radiation and relativistic electron beam

Science Drivers will Determine the Facility Specification

- **Ability to upgrade** will be a key objective
  - Budget likely to prohibit us from having all of the above specifications (at least not straightaway)
  - Also need to be open to emerging new technologies and science priorities
- **Staged project** delivering some capabilities sooner and others later is a viable approach
- We need to identify the most exciting and far reaching science to set the target specification

NLS in Context

- There are some powerful and expensive light sources being developed around the world
  - Significant UK access to these is anticipated to be part of our strategy
- NLS must be a powerful facility with unique capabilities
  - It must complement these international light sources (not be a duplicate of what we can use elsewhere)
  - It should provide the UK and partners with sufficient capacity and advanced capability to yield a significant volume of world leading science and technology in key fields not possible otherwise



Unique Capabilities

This uniqueness might be achieved through the provision of, for example, a combination of:

(a) New ranges of photon energy and combinations of photon energy

(a) A superior short pulse capability and coherence and better temporal synchronisation than any machine yet available

(b) An infrastructure that provides **simultaneous access to a wider range of laser sources** and other facilities

Phase 1: Establishing Key Science Drivers and Outline Specifications

- Workshops held and Working Groups formed
  - May / June 2008
- Working Groups report to Project Leader
  - Mid July 2008
- Science drivers case presented to Science Community for comment
  - September 2008
- Revised case submitted to STFC for consideration
  - October 2008

The NLS Vision

We need to be thinking in the long term.

The science and technology objectives we identify must be those that will remain important for several decades to come.

The NLS vision is to ensure a strong and versatile capability that enables these objectives, and new ones as yet not imagined, that will maintain UK science at the forefront into the middle of the century.

Discussion essential to this process – we need to hear your views

- Please e-mail directly to me (j.marangos@imperial.ac.uk) or Richard (richard.walker@diamond.ac.uk) or up-load to website www.lightsource.org your views and ideas
- Input welcome anytime up to end August (draft case will be released early September), but most valuable if received by July 15th.
- If you do raise any points during today's discussions we will note them – but it would help us if you would also e-mail these later to ensure they are accurately captured