Overview on activities at Strathclyde and SCAPA – the Scottish Centre for the Application of Plasma-based Accelerators

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*presenting, also affil. w/ Uni Hamburg/CFEL, UCLA
Int'l context

ICUIL World Map of Ultrahigh Intensity Laser Capabilities
+ PWFA-capable facilities existing /upcoming
Plasma wakefield acceleration in the UK working jointly, e.g. towards novel (5th gen.?) light sources: A multi-centered approach

Many world-leading university groups w/ preparatory R&D, and larger experiments at three complementary facilities:

**CLF:** User facility, pushing the envelope of laser systems and concepts, laser development & applications, light sources

**ASTeC:** Light sources, interface to state-of-the-art accelerator science & technology and PWFA

**SCAPA:** Applications of plasma-based accelerators, lasers & light sources and industrial interface

Synergistic, complementary approach optimizes use of resources and strengthens UK profile on European and worldwide level. Naturally carved out basis to work for common goals such as new plasma-based light sources.
SUPA: Scottish Universities Physics Alliance

SUPA is the largest Physics Alliance in the UK, with 8 Scottish universities.

SUPA I: 2005-2011 £14M
SUPA II: 2009-2016 £48M

SCAPA is flagship of SUPA II
SCAPA & Glasgow Cluster

University of Strathclyde Glasgow

£350M investment

Colville Bldg.

JA Bldg.

Fraunhofer Centre for Applied Photonics
**Highlights 2002-**

**protons, ions, WDM**

- demonstration of plasma focusing of ions - QUB, Science 2006
- Narrow-band energy techniques - Strathclyde, Nature 2006
- TNSA energy scaling study at PW - Strathclyde-led, Nat. Phys. 2007

**electrons & light sources**

- 1st gen. of mono-energetic electrons (UK collaboration)
- 1st gen. of quasi-mono. electrons in self-mod. regime, PRL 2006
- 1st gen. of undulator rad. - Nat. Phys. 2008
- 1st gen. of γ-rays from resonant β-oscillations - Nat. Phys. 2011
- 1st gen. of γ-rays from resonant β-oscillations - Nat. Phys. 2011
- Trojan Horse - ε_n ~ 0.01 mm mrad PRL 2013
- ΔE/E < 1%
- ε_n ~ 1 mm mrad measured w/ pepper pot - PRL 2010
- PUFFIN – 1st plasma-compatible FEL code
- Advanced apps.: radiotherapy; nuclear waste imaging; space radiation...

**1st gen. of mono-energetic electrons**

- A-SAIL – EPSRC Program grant 2013-2019
- TNSA energy scaling study at PW - Strathclyde-led, Nat. Phys. 2007
- Narrow-band energy techniques - Strathclyde, Nature 2006

**Advanced apps.:**
- radiotherapy; nuclear waste imaging; space radiation...
- ICL_Betatron and CPL codes

**Clear scientific trajectory towards usable applications, compact advanced light sources etc.**
2008: First undulator radiation from a plasma accelerator


2 undulator sections already in lab, three more to come
Designed by ASTeC, primarily for LWFA applications,
200 periods, 1.5 cm


...into the VUV .. and beyond?
2011: Light source: $\gamma$-rays from enhanced betatron radiation

S. Cipiccia et al., “Gamma-rays from harmonically resonant betatron oscillations in a plasma wake”, Nat. Phys. 7, 867-871 (2011)

...and at laser-plasma-accelerators in hybrid setups!

Potential game-changing: may allow for the first time plasma based accelerators to produce bunches with **much better** key characteristics (such as emittance, brightness, shortness (~sub-fs-regime),) than w/ conv. accelerators!

When looking back, disruptive emittance and brightness improvements have led to next-gen. light sources...

*Hidding et al., PRL 2012 & pat. 2011; Xi et al., PRSTAB 2013, Li et al., PRL 2013; Bourgeois et al., PRL 2013, Yu et al., ArXiV 2013.*
Dedicated theory and simulation plasma wakefield acceleration group

- Currently 12 senior members (including Prof. Z.M. Sheng)
- Development of codes such as ICL, Betatron and CPL, PUFFIN; use of PIC codes such as OSIRIS, VORPAL, EPOCH, WAKE; fluid codes such as MULTI, HELIOS, etc.
- Relativistic laser-plasma based radiation sources from THz to gamma-rays, including transition radiation, mode conversion, Thomson/Compton scattering, betatron radiation, raman amplification.

Betatron radiation (Nat. Phys. 2011)
Attosecond e-bunches (PRL 2013)
Attosecond XUV pulses (NJP 2012)
Ion acceleration target design (PRST-AB 2013)
Tunable multi-bunch trains (submitted 2014)
Ultra-intense THz sources (APL2013)
Selected Applications (since 2003) & impact

- Radioisotope production
- Nuclear waste imaging with gamma rays Cipiccia et al., J. Appl. Phys. 111, 063302 (2012);
- Phase contrast imaging
- Nuclear physics applications w/ partners
- Proton therapy/Fusion
Selected Applications & impact


  ![Image of dosimetry measurement](image1)

  Dose mapping measurement
  LWFA-generated electrons in water phantom

  vs. calculation for 135 MeV

- Space radiation: Reproduction of “killer electrons“ in the lab & testing of space grade electronics

  ![Image of space grade optocouplers](image2)

  ![Image of electron radiography](image3)

  ![Graph showing CTR ratio](image4)

  Other electronics with Strathclyde per gamma rays

  funded by [Science & Technology Facilities Council](https://www.stfc.ac.uk)

  funded by [European Space Agency](https://www.esa.int)
SCAPA Glasgow Cluster and how we relate

www.supa.ac.uk

Cockroft Institute & Daresbury Laboratory
Strathclyde Associate Member of CI since 12/2013

"Northern Lights" Alliance with

CDT: Centre for Doctoral Training in next-generation accelerators

Fraunhofer Centre for Applied Photonics

TIC: Technology and Innovation Centre

Fraunhofer UK

NHS

NATIONAL NUCLEAR LABORATORY

=e=esa

Laserlab Europe

SCAPPA

University of Strathclyde Glasgow

UK Entrepreneurial University of the Year 2013/14
UK University of the Year 2012/13

The Scottish Funding Council
Promoting further and higher education

Science & Technology Facilities Council

EPSRC
Engineering and Physical Sciences Research Council

"Northern Lights" Alliance with

Virtual Institute PWFA at FLASH

Helmholtz Association
Virtual Institute
PWFA at FLASH

Central Laser Facility

CLF Nuclear Physics attosecond beamlines

Lasers

Science Scotland
Strategic team-building based and SCAPA long-term goals

Annual third party funding since 2002 shows strong trajectory (w/o facility access grants, computation grants etc.):

Prof. Dino Jaroszynski (SCAPA Director)
Prof. Paul McKenna (EPSRC Leadership Fellow, ion acc.)
Prof. Zheng-Ming Sheng (SUPA chair, theory & sim.)
Prof. Bernhard Hidding (SUPA chair, expmts. & sim.)
Prof. Ken Ledingham (Nuclear Phys./Particle Therapy)
Dr. Brian McNeil, Dr. Gordon Rob (FEL)
Dr. Mark Wiggins (Technical Manager, SCAPA)
Dr. Gregor Welsh (Head of Lasers, SCAPA)

Training and capacity building:

Centre for Doctoral Training in Next Generation Accelerators (- 2014?)

Absolute need for continuation of such training programmes: Booming field needs trained personnel, ELI alone needs hundreds of well-trained scientists over the next years!
Bunker A – Electrons, undulators, light sources, nucl. physics…

Bunker B – Ion/protons, WDM…

Bunker C – Health
Substantial Expansion of ALPHA-X facilities with new laboratories

£8M investment + additional infrastructure funds

In-depth programme of applications

Accelerator and Light Source R&D

Knowledge Exchange & Commercialization

Engagement in European and other large projects

Training: Centre for Doctoral Training in the Application of Next Generation Accelerators

3 shielded areas with 7 accelerator beam lines

High-intensity femtosecond laser systems
  a) 200-300 TW (with provision for PW) @ 5 Hz
  b) 40 TW @ 10 Hz
  c) sub-TW @ 1 kHz

High-energy electron, positron, proton, ion and neutron bunches

High-brightness fs duration X-ray & gamma-ray pulses: coherent and incoherent
Summary & Outlook

- SCAPA: critical mass (SUPA, TIC, Fraunhofer(s),..), new bldg. ready by fall 2014
- Application-centered heritage since 2003. We function via joint experiments with the community. Consolidated “business model” and long-term strategy.
- Training and capacity-building emphasized: CDT, SUPA, various partnerships. Must not lose this!
- Working towards all kinds of novel advanced light sources: FEL, Betatron, Thomson-scattering…
- As need goes, we may consider access models, e.g. having a dedicated community beamline
- Thanks to STFC/EPSRC/SFC, other RC’s and Universities for enabling the UK community to pioneer the field!
- In context of a worldwide booming field, substantial investment necessary to keep UK in leading position (CLF extension, ASTeC, Cockroft, John-Adams, SCAPA…)
- Community has shown tremendous progress and growth. Fundamental and highly multi-disciplinary impact (biology, medicine, chemistry, material science..). Highly attractive for 3rd parties
- Plasma accelerators matured, (re-)coalescing w/ state-of-the-art acc. technology. Highly cross-council relevant (RCUK/STFC/EPSRC/..)
- Naturally shaped network of plasma groups offer unique complementary approach in the UK! World-class laser facility (CLF) in conjunction w/ univ. network plus CLARA, plus SCAPA.