University of Birmingham

Dr Mark Laver BSc, MASt, PhD, MInstP

Lecturer
Birmingham Fellow

School of Metallurgy and Materials (/schools/metallurgy-materials/index.aspx)

Contact details

Telephone +44 (0) 121 414 5218 (tel:+44 121 414 5218)

Telephone (2) +44 (0) 121 414 7468 (tel:+44 121 414 7468)

Email m.laver@bham.ac.uk (mailto:m.laver@bham.ac.uk)

School of Metallurgy and Materials
University of Birmingham
Edgbaston
Birmingham
B15 2TT
UK

About

Mark Laver is a Birmingham Fellow in the School of Metallurgy and Materials.His research explores the nature and development of functional materials, namely magnetostrictive and multiferroic materials, thermoelectrics and superconductors. These investigations frequently employ and progress state-of-the-art scattering techniques available at large international facilities. Mark has a relatively high publication rate, averaging over 7 articles per year, of which at least 2 per year appear in high-profile journals.

Qualifications

- PhD Condensed Matter Physics, University of Birmingham, 2007
- MASt Mathematics, University of Cambridge, 2003
- BSc (Hons) Theoretical Physics and Applied Mathematics, University of Birmingham, 2002

Biography

Mark Laver graduated with a BSc in Theoretical Physics and Applied Mathematics at the University of Birmingham in 2002.

A Taylor scholarship gratefully received from Corpus Christi College, Cambridge subsequently provided for further studies of theoretical methods, following Part III of the Mathematical Tripos, which Mark passed in 2003.

He commenced experimental investigations with a research project on flux lines in superconductors, following a doctoral programme organised by the University of Birmingham and the Institut Laue-Langevin in Grenoble.

In 2007, after obtaining his PhD, Mark worked as a beamline scientist at the NIST Center for Neutron Research (NCNR) in Gaithersburg, Maryland. He was part of a team responsible for the NCNR’s suite of small-angle neutron scattering instruments.

In 2009 he moved to the Paul Scherrer Institut, Switzerland, where he was co-responsible for the cold neutron triple-axis spectrometer RITA-II. This post was funded by the Niels Bohr Institute, Copenhagen and the Technical University of Denmark (DTU).

In 2013 Mark returned to Birmingham to accept a Birmingham Fellowship and is a Senior Lecturer in the School of Metallurgy and Materials.

Teaching

- Physics Laboratories
- Essentials of Quantum Mechanics

Postgraduate supervision

PhD projects are available. Please contact Mark for further details.

Research

Mark’s research activities are centred on the understanding and development of functional materials, in particular thermoelectrics, magnetostrictive and multiferroic systems, and superconductivity. He frequently investigates these materials using state-of-the-art scattering techniques available at large facilities worldwide, and contributes to the development of further powerful techniques. He serves on a number of committees and advisory panels at international facilities, one of these being the European Spallation Source, planned for construction in Lund.

Examples of specific research projects are outlined below.

Magnetostriction

Terfenol-D $Tb_{1-x}Dy_xFe_2$ exhibits a giant magnetostriction ~2000 ppm and is currently the leading material used by industry for magnetomechanical applications. Mark and scientists at the University of Maryland explored the morphotropic phase boundary (MPB) in this ferromagnetic material using both synchrotron X-ray and neutron diffraction. The results are highly topical in the light of progress – and controversy – surrounding the nature of the MPBs in ferroelectric materials, including the much-studied lead piezoelectrics. This project formed the bulk of the PhD thesis of Richard Bergstrom. After his thesis, Richard moved to California to work for SGB Labs,an optics company producing holographic displays.

- **Morphotropic phase boundaries in ferromagnets: $Tb_{1-x}Dy_xFe_2$ alloys (http://dx.doi.org/10.1103/PhysRevLett.111.017203)**
  R. Bergstrom Jr., M. Wuttig, J. Cullen, P. Zavalij, R. Briber, C. Dennis, V. O. Garlea, M. Laver
  Physical Review Letters **111**, 017203 (2013)

Iron-gallium alloys also exhibit a large magnetostriction ~400 ppm. While this is smaller than for Terfernol-D, iron-gallium possesses more favourable mechanical and magnetic properties, giving breath to new applications such as microactuators and artificial cilia. However the mechanism underpinning magnetostriction is open to controversy. Together with scientists at the University of Maryland, Mark demonstrated the existence of heterogeneities in iron-gallium that are distinctly magnetic. The heterogeneities are further found to couple to the magnetostriction, responding to both magnetic and strain fields. This project formed a large part of the PhD thesis of Chaitanya Mudivarthi. After obtaining his PhD in 2010, Chaitanya moved to Arizona to work for Intel.

- **Magnetostriction and magnetic heterogeneities in iron-gallium (http://dx.doi.org/10.1103/PhysRevLett.105.027202)**
  M. Laver, C. Mudivarthi, J. R. Cullen, A. B. Flatau, W.-C. Chen, S. M. Watson, M. Wuttig
  Physical Review Letters **105**, 027202 (2010)
- **Magnetic domain observations in Fe–Ga alloys (http://dx.doi.org/10.1016/j.jmmm.2010.01.027)**
  C. Mudivarthi, S.-M. Na, R. Schaefer, M. Laver, M. Wuttig, A. B. Flatau
  Journal of Magnetism and Magnetic Materials **322**, 2023–2026 (2010)
- **Origin of magnetostriction in Fe–Ga (http://dx.doi.org/10.1063/1.3359814)**
  C. Mudivarthi, M. Laver, J. Cullen, A. B. Flatau, M. Wuttig
  Journal of Applied Physics **107**, 09A957 (2010)

Nanostructuring of thermoelectrics

The performance of thermoelectric materials is quantified by a dimensionless figure of merit $ZT = \sigma S^2 T/k$ where σ is the electrical conductivity, S the Seebeck coefficient, T the temperature and k the thermal conductivity. A new paradigm in materials design has emerged following the realization that k may be strongly reduced – and ZT increased – through nanostructuring. In work on $(Bi,Sb_2)Te_3$ as part of an international collaboration, we observed that nanocrystalline domains generated by melt-spinning can scatter phonons,reducing k and leading to significant improvement of ZT.

- **The microstructure network and thermoelectric properties of bulk $(Bi,Sb_2)Te_3$ (http://dx.doi.org/10.1063/1.4752110)**
  W. Xie, D. A. Hitchcock, H. J. Kang, J. He, X. Tang, M. Laver, B. Hammouda
  Applied Physics Letters **101**, 113902 (2012)
- **Identifying the specific nanostructures responsible for the high thermoelectric performance of $(Bi,Sb_2)Te_3$ nanocomposites (http://dx.doi.org/10.1021/nl100804a)**
  W. Xie, J. He, H. J. Kang, X. Tang, S. Zhu, M. Laver, S. Wang, J. R. D. Copley, C. M. Brown, Q. Zhang, T. M. Tritt
  Nano Letters **10**, 3283-3289 (2010)

Multiferroic materials

The multiferroic material $BiFeO_3$ exhibits coupled ferroelectric and ferromagnetic order parameters at room temperature. BiFeO3 and related compounds augur well for applications from data storage to spintronics. However the observed ferromagnetism is weak. In collaboration with a team from Rutgers University and the NIST Center for Neutron Research, we resolved a long-standing question as to the nature of the magnetic structure in bulk $BiFeO_3$, where spins arrange antiferromagnetically but with a long-wavelength cycloid modulation superimposed. Our study using polarised neutrons unveils a small but crucial spin-density wave component to this modulation, representing a local ferromagnetic coupling. This represents an important step in our understanding of $BiFeO_3$ and of related multiferroic compounds wherethe magnetic modulation is suppressed.

- **Local weak ferromagnetism in single-crystalline ferroelectric $BiFeO_3$ (http://dx.doi.org/10.1103/PhysRevLett.107.207206)**
  M. Ramazanoglu, M. Laver, W. Ratcliff II, S. M. Watson, W. C. Chen, A. Jackson, K. Kothapalli, Seongsu Lee, S. W. Cheong, V. Kiryukhin
  Physical Review Letters **107**, 207206 (2011)

Flux lines in superconductors

Flux lines form within a Type-II superconductor in response to an applied magnetic field. Mark's interest in this area evolved during his PhD with Prof. Ted Forgan in the School of Physics and Astronomy. On the one hand, the flux line system provides a test-bed for theories of structural order in solids and glasses. One the other hand, the orientation and shape of a lattice of flux lines provide insights into the properties of the underlying superconducting state.

In one project, Ted and Mark examined the impact of a well-known mathematical theorem – the hairy ball theorem – upon the formation of flux line lattices in superconductors. The resulting topological effects are general to all Type-II superconductors, and help explain why unconventional flux line lattice shapes may manifest in conventional superconductors. Our study lays the foundation for angle-resolved studies of flux line lattice morphology to aid in the resolution of uncertainties in the physics of unconventional superconductors.

- **Magnetic flux lines in Type-II superconductors and the 'hairy ball' theorem (http://dx.doi.org/10.1038/ncomms1047)**
  M. Laver, E. M. Forgan
  Nature Communications **1**, 45 (2010)
- **Condensed Matter Physics webpages (http://www.cm.ph.bham.ac.uk/publications/publications.html)**

In another ongoing project, Mark is unravelling what happens to flux line correlations in the presence of disorder. Mark and scientists from the Paul Scherrer Institut have mapped out the interplay between magnetism and superconductivity in the $La_{2-x}Sr_xCuO_4$ family of superconductors, using chemical composition and applied field to tune the emergence of magnetism. Before magnetism completely suppresses superconductivity, it is initially found to cause a disordering in the arrangement of vortices .

Mark has also developed a numerical refinement technique to explore in detail the positional correlations between flux lines from neutron scattering data. This enables, for the first time, a direct test of the theories predicting what happens to flux line correlations in the presence of disorder. As part of his PhD project at DTU Risø, Rasmus Toft-Petersen has been extending Mark's method with data on superconducting vanadium. After obtaining his doctorate, Rasmus moved to Berlin to work as an instrument scientist on the FLEXX triple-axis spectrometer at the Helmholtz Zentrum Berlin (HZB).

- **Spin density wave induced disordering of the vortex lattice in superconducting $La_{2-x}Sr_xCuO_4$ (http://dx.doi.org/10.1103/PhysRevB.85.134520)**
  J. Chang, J. S. White, M. Laver, C. J. Bowell, S. P. Brown, A. T. Holmes, L. Maechler, S. Strässle, R. Gilardi, S. Gerber, T. Kurosawa, N. Momono, M. Oda, M. Ido, O. J. Lipscombe, S. M. Hayden, C. D. Dewhurst, R. Vavrin, J. Gavilano, J. Kohlbrecher, E. M. Forgan, J. Mesot
  Physical Review B **85**, 134520 (2012)
- **Uncovering flux line correlations in superconductors by reverse Monte Carlo refinement of neutron scattering data (http://dx.doi.org/10.1103/PhysRevLett.100.107001)**
  M. Laver, E. M. Forgan, A. B. Abrahamsen, C. Bowell, Th. Geue, R. Cubitt
  Physical Review Letters **100**, 107001 (2008)
- **FLEXX instrument at the HZB (http://www.helmholtz-berlin.de/pubbin/igama_output?modus=einzel&sprache=en&gid=1710&typoid=39942)**

Other research interests

- Magnetic nanoparticles
- Correlated electrons and superconductivity
- Frustrated magnetism

Publications

Book chapters:

- **Small-angle scattering of nanostructures and nanomaterials (http://dx.doi.org/10.1007/978-90-481-9751-4)**
  M. Laver chapter in Encyclopedia of Nanotechnology, B. Bhushan (ed.), Springer-Verlag(2012)

High-profile publications, in addition to those listed under Research:

- **Coexistence and competition of the short-range incommensurate antiferromagnetic order with the superconducting state of $BaFe_{2-x}Ni_xAs_2$ (http://dx.doi.org/10.1103/PhysRevLett.108.247002)**
  H. Luo, R. Zhang, M. Laver, Z. Yamani, M. Wang, X. Lu, M. Wang, Y. Chen, S. Li, S. Chang, J. W. Lynn, P. Dai
  Physical Review Letters **108**, 247002 (2012)
- **Chemically-driven nanoscopic magnetic phase separation at the $SrTiO_3$(001)/$La_{1-x}Sr_xCoO_3$ interface (http://dx.doi.org/10.1002/adma.201100417)**
  M. A. Torija, M. Sharma, J. Gazquez, M. Varela, C. He, J. Schmitt, J. A. Borchers, M. Laver, S. El-Khatib, C. Leighton
  Advanced Materials **23**, 2711–2715 (2011)
- **Exploring the fragile antiferromagnetic superconducting phase in CeCoIn5 (http://dx.doi.org/10.1103/PhysRevLett.105.187001)**
  E. Blackburn, P. Das, M. R. Eskildsen, E. M. Forgan, M. Laver, C. Niedermayer, C. Petrovic, J. S. White
  Physical Review Letters **105**, 187001 (2010)
- **Core-shell magnetic morphology of structurally uniform magnetite nanoparticles (http://dx.doi.org/10.1103/PhysRevLett.104.207203)**
  K. L. Krycka, R. A. Booth, C. R. Hogg, Y. Ijiri, J. A. Borchers, W. C. Chen, S. M. Watson, M. Laver, T. R. Gentile, L. R. Dedon, S. Harris, J. J. Rhyne, S. A. Majetich
  Physical Review Letters **104**, 207203 (2010)
- **Origin of electric-field-induced magnetization in multiferroic $HoMnO_3$ (http://dx.doi.org/10.1103/PhysRevLett.104.147204)**
  B. G. Ueland, J. W. Lynn, M. Laver, Y. J. Choi, S.-W. Cheong
  Physical Review Letters **104**, 147204 (2010)
- **Morphology of the superconducting vortex lattice in ultrapure niobium (http://dx.doi.org/10.1103/PhysRevLett.102.136408)**
  S. Mühlbauer, C. Pfleiderer, P. Böni, M. Laver, E. M. Forgan, D. Fort, U. Keiderling, G. Behr
  Physical Review Letters **102**, 136408 (2009)
- **Fermi surface and order parameter driven vortex lattice structure transitions in twin-free $YBa_2Cu_3O_7$ (http://dx.doi.org/10.1103/PhysRevLett.102.097001)**
  J. S. White, V. Hinkov, R. W. Heslop, R. J. Lycett, E. M. Forgan, C. Bowell, S. Strässle, A. B. Abrahamsen, M. Laver, C. D. Dewhurst, J. Kohlbrecher, J. L. Gavilano, J. Mesot, B. Keimer, A. Erb
  Physical Review Letters **102**, 097001 (2009)
- **Spontaneous symmetry-breaking vortex lattice transitions in pure niobium (http://dx.doi.org/10.1103/PhysRevLett.96.167002)**
  M. Laver, E. M. Forgan, S. P. Brown, D. Charalambous, D. Fort, C. Bowell, S. Ramos, R. J. Lycett, D. K. Christen, J. Kohlbrecher, C. D. Dewhurst, R. Cubitt
  Physical Review Letters **96**, 167002 (2006)

A **further list of publications (http://elibrary.bham.ac.uk/pure/people.asp?id=305729)** is available.