**Twenty years of the XMaS beamline**

In September 2017 some 60 participants gathered together at the ESRF, the European Synchrotron, in Grenoble (France) to celebrate 20 years of operation of the XMaS beamline (Figure 1). XMaS is a UK National Research Facility funded by the UK funding agency EPSRC[[1]](#footnote-1) and is one of the ESRF Collaborating Research Groups (CRG) beamlines. The project is managed by the Universities of Liverpool and Warwick. In the late nineties the acronym XMaS was originally coined to highlight the beamline’s predominant activity: diffraction studies of magnetic materials (hence **X**-ray **Ma**gnetic **S**cattering), but when magnetism gave way to more wide-ranging studies of materials the rather catchy and, by then, very familiar acronym was retained with the meaning **X**-ray **Ma**terials **S**cience.

**Description of the beamline**

The beamline sits on the soft end of the bending magnet BM28 corresponding to a critical energy of 9.6 keV. The first optical element is a water-cooled, double crystal (Si 111) monochromator, followed by a Rh-coated silicon toroidal mirror used to focus the beam some 25 metres downstream down to a 11-axis Huber diffractometer. The upper energy cut-off set by the focusing mirror is 15 keV while the low energy limit has recently been pushed down to 2.4 keV, stimulating significant interest from the spectroscopy community. In recent years XMaS has become well-known for its diversity of sample environments with cryostats operating down to 1K, furnaces up to 600K, magnetic fields up to 4 Tesla, electric fields up to 5 kV, plus controlled humidity and gaseous atmospheres for spectroscopy, in-situ growth of solar cells.

**The XMaS research portfolio**

Since 1997, XMaS has continually evolved to meet the needs of a broader interdisciplinary user community. The flexibility of the original design, coupled with technological developments has enabled new scientific challenges to be addressed. Nowadays, condensed matter physics remains the main activity of the beamline with a third of the awarded beam time (Figure 2). Soft matter represents 22% of the beam time, materials for energy, catalysis and physical chemistry 28%, healthcare technologies 6% and the final 11% is devoted to general materials science and beamline development. Beam time represents on average 130 user visits per year over 50% of which are by postdoctoral researchers and research students and 40% overall are new XMaS users.

**Once upon a time**

The conference was an ideal occasion for a retrospective of the scientific work conducted on XMaS over the past 20 years together with more recent work. It began with a welcoming address from the Director General of the ESRF, Francesco Sette, who emphasised the exciting opportunities afforded to all beamlines including XMaS by the forthcoming ESRF-EBS upgrade project[[2]](#footnote-2). That was followed by a talk from the EPSRC representative, Simon Crook, who described the National Research Facilities and their funding. XMaS has been ‘‘the joint longest running facility funded by EPSRC, being one of the first to move from a general grant to facility status’’ as quoted by Simon Crook. In total, EPSRC has invested just around ₤19M over the four operational phases of the beamline.

Such a conference could not have happened without a retrospective on how the project started and then evolved. The two originators of the beamline, Malcolm Cooper and Bill Stirling (Figure 3), described the early days of XMaS back in 1992 and how a “back of the envelope” estimated cost of less than ₤1M turned into a ₤2M bill when their two design engineers sat down and did some serious detailed planning. This led in turn to 3 years of construction work, culminating in the formal opening of the beamline on September 19th 1997. The current directors of the beamline, Chris Lucas and Tom Hase, then described how the project evolved through 4 funding cycles to become the EPSRC National Research Facility that it is today.

**The Condensed Matter core activity**

The first user group led by Forgan (Birmingham) came in April 1998. He has remained a regular user of the beamline ever since and with coworkers has recently observed on XMaS the first actual atomic displacements in an under-doped High-Tc superconductor, when superconductivity is suppressed by a charge density wave CDW [1]. Numerous talks also reminded the audience that the original goal of XMaS was to study magnetic materials and still is! The availability of low/high temperatures, magnetic and electric fields, polarisation conditioning and analysis, combined with the flexibility of the Huber diffractometer has enabled users to improve their understanding of the Dzyaloshinskii-Moriya interaction either by measuring its sign in weak ferromagnets [2,3] or by studying proximity induced magnetism in thin films [4,5].

**The Materials Science beamline**

The presentations given over the two-day conference illustrated how overall XMaS has expanded its research portfolio dramatically over the two decades. For example exploring the microcrystallinity of teeth and bones using monochromatic [6] and white beam [7] diffraction and even studying how copper ions act as contraceptive in an intra uterine device [8] not to mention understanding corrosion mechanisms in cultural heritage artefacts [9]. Today, in addition, we have users searching for novel functional materials to be used in the next generation of photovoltaics [10, Hardigree, Oxford], transistors [11, 12] and also those more interested in how nanoparticles could be utilised without detrimental effects on our body [13].

**XMaS becoming tender and attracting chemists**

In the last three years, access to sub 3 keV has attracted a new community interested in utilising x-ray absorption spectroscopy techniques to tackle environmental issues related to car exhausts and nuclear fuel disposal as examples. Newton [14] was the first user to exploit the low energy capability and sample environment of the XMaS beamline to investigate chemical and catalytic reactions. Users studying new catalysts *in-situ* [15, Sankar, UCL, 16], car batteries (Alfredsson, Kent) and glass ceramic materials for immobilisation of nuclear wastes [Hyatt, Sheffield and Bingham, Sheffield Hallam] come and use XMaS on a regular basis. Partnerships with B18 at Diamond Light Source and the UK Catalysis Hub at the Harwell Research Complex in Oxfordshire, have also been built.

**International Collaborations**

One notable XMaS collaboration over many years has been with Sectors 4 and 6 at the Advanced Photon Source (APS). Jonathan Lang (APS) illustrated how this collaboration has benefitted both facilities enormously with the development of new instrumentation and sample environment, and made possible several experiments. For example the XMaS in-vacuum magnet was shipped to APS to allow the study of FePd magnetic quantum wells at the Pd L3 edge [17]. Whilst at ESRF, Ryan and Kim investigated the origin of the magnetic state change in EuTiO3 [18] by exploiting the low temperature, electric field, 4 T superconducting magnet and polarisation dependence capabilities available at XMaS.

The beamline has also been heavily involved as a partner in the EMRP[[3]](#footnote-3) “Nanostrain” [12, 19] and “ADVENT” [20]. These programmes are a collaboration between Europe’s metrology experts, instrument scientists and global industry leaders, such as IBM, working together to develop innovative tools to measure strain accurately in piezoelectric materials at the nanoscale.

**The XMaS Outreach programme**

Kayleigh Lampard and Natacha Borrel (Warwick) presented a new outreach activity aiming to tackle the gender bias in the Physical Sciences. The purpose of the project named the *XMaS Scientist Experience* [21] is to encourage young women (17-18 year old) to consider careers in Science by showing them possible opportunities and as well as introducing them to female inspirational role models in an international setting. The prize of the national competition is a trip to visit the Grenoble research campus, tour the ESRF and XMaS beamline, take part in the ESRF Synchrotron@School Programme and meet scientists from different disciplines. The 4th edition has recently been launched.

The rich diversity of the research possibilities explains why XMaS remains the beamline of choice with many old and new users and is the reason XMaS can look forward to many more than its present 20 years of user activity. The full conference programme and photos are available at www.xmas.ac.uk/impact/meetings/xmas\_20/. More information on the beamline and research activities can be found on [www.xmas.ac.uk](http://www.xmas.ac.uk) and on the social media (@XMaSBeam).

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Figure 1: Some of the XMaS@20 attendees during a coffee break in the ESRF central building.

Figure 2: Evolution of the research portfolio on XMaS through the four operational phases.

Figure 3: The co-originators of the XMaS beamline, Bill Stirling (left) and Malcolm Cooper (right).

1. EPSRC: Engineering and Physical Sciences Research Council [↑](#footnote-ref-1)
2. EBS: Extremely Brilliant Source www.esrf.fr/about/upgrade [↑](#footnote-ref-2)
3. European Metrology Research Programme [↑](#footnote-ref-3)