A position paper from the League of Accelerator-based Photon Sources (LEAPS)

"Strategic directions and technical developments needed for light source science to meet the goals and perspectives of the Innovative Advanced Materials Initiative"

The **Innovative Advanced Materials Initiative (IAM-I)**[1] aims to create a collaborative Europe-wide ecosystem that accelerates the development and deployment of sustainable innovative advanced materials and technologies for a digital circular economy, uniting stakeholders across all materials value chains and lifecycles. The **IAM4EU partnership** is supported by the European Commission to serve as a cornerstone of this ecosystem, fostering transnational collaboration and aligning efforts across research institutions, industries and policymakers to drive impactful innovation in advanced materials. By providing a unified framework for cooperation, IAM4EU ensures that stakeholders work in synergy to achieve the ambition rooted in the AMI-2030 Roadmap[2], published in December 2022 supported by the Strategic Materials Agenda (SMA)[2] and the Strategic Research & Innovation Agenda (SRIA)[1].
The **League of Accelerator-based Photon Sources (LEAPS)** federates the light source research infrastructure of Europe, including synchrotron facilities and free-electron lasers. LEAPS is much more than an alliance of light source facilities. LEAPS is the critical mass of 16 organisations able to coordinate tailored actions for multimodal analysis of advanced materials and establish industry-relevant standards for experiment protocols, ensuring the delivery of data and results essential to develop advanced materials. These facilities, in alignment with IAM-I objectives, are ready to support this vision by tailoring their strategic directions and technological developments to the overarching goals of the initiative. Together, IAM-I and IAM4EU, with LEAPS, can provide a transformative pathway toward a sustainable and innovative future for materials.

1. Strategic alignment of light source science with IAM-I vision

a. Sustainability and circular economy: Sustainable materials are essential for a circular economy, net-zero emissions and the competitiveness of European industry. Light sources facilities play a vital role by providing advanced tools to design decarbonised, resource-efficient and recyclable materials. Their in situ and operando techniques allow real-time monitoring of materials under working conditions, and support life-cycle assessments, offering precise insights into material degradation and sustainability.

b. Process optimisation and industrial relevance: Achieving IAM-I goals requires scalable manufacturing, zero-defect production and efficient lab-to-industry material transition. Light sources provide industrial platforms for high-throughput, real-time material monitoring under extreme conditions, benefiting sectors like automotive, aerospace and biotechnology. They have also developed specialised analytical tools and fast access for companies, including SMEs.

c. Data and AI driven accelerated discovery platforms: IAM-I and the AMI 2030 Roadmap highlight digital technologies like AI and machine learning in accelerating materials discovery. Light sources leverage AI for high-throughput data analysis, automating workflows and optimising beamline efficiency. Subsequently, the massive high-fidelity synchrotron data generated fuels discovery platforms, enabling predictive modelling, rapid materials identification and optimisation. This is critical to ensuring EU competitiveness in materials innovation, in particular considering significant recent US investments plan, by DoE and NIST[3].

2. Technical developments needed in light source science to support IAM-I objectives

a. In-situ and operando techniques: Enhancing in-situ and operando characterisation, watching real-time material behaviour observation under operational conditions, is vital to develop materials that support decarbonisation and sustainability goals. Expanding these capabilities at light sources will drive the creation of more durable, efficient materials, key to sustainable and circular economic models.

b. Autonomous and high-throughput beamlines: To meet rapid material development cycles, light source facilities will create autonomous beamlines capable of running high-throughput experiments. Using AI, these beamlines will rapidly process material samples, enabling accelerated discoveries in areas such as catalysis, pharmaceuticals and energy storage. High-throughput capabilities will also support the scale-up of manufacturing technologies and the increasing industrial demand for new materials.

3. Harmonisation with policy and industry standards

Harmonised norms and standards are central for materials development, particularly those that are safe and sustainable by design. Light sources are ready to collaborate with regulatory bodies and industry stakeholders to set benchmark testing protocols and ensure compliance with EU sustainability and safety regulations. This will help ensure that materials developed with synchrotron research meet both scientific and industrial standards.

4. Action plan and collaboration frameworks

Autonomous materials discovery can and is transforming new, advanced materials development. Europe has the best portfolio of light sources in the world, but investment as yet has not pushed them to the fore in this materials discovery by exploiting robotics, automation and AI. To successfully align synchrotron science with IAM-I objectives as expressed in the in the AMI 2030 Roadmap and following documents, the following steps are to be prioritised:

- Develop AI-driven platforms and autonomous beamlines for high-throughput material discovery.
- Create open access repositories for light source data, integrated with global material discovery platforms to enhance collaboration.
- Establish service platforms to support SME and start-up engagement in light source-based R&D.
- Enhance in-situ and operando techniques, particularly for sustainable materials and energy systems.
- Collaborate with regulatory bodies and stakeholders to set harmonised standards for safe and sustainable materials development.

Conclusion

Light-source research infrastructures are key to achieving IAM-I's goals. Leveraging AI-driven platforms, autonomous beamlines and sustainability-focused research, they can greatly accelerate material discovery and support Europe's shift to a digital, circular economy. The action plan aims to position light sources at the core of the commercial value chain by fostering innovation partnerships with industry through collaboration. Past experience shows that close industry partnerships deliver lasting impact. Strategic investments in these advancements can drive materials discovery, solidifying Europe's leadership in scientific and industrial innovation. However, increased investment and collaboration are essential to fully realise the potential of light sources and their support to Europe's scientific sovereignty.

[1] https://www.iam-i.eu
[2] https://www.ami2030.eu
[3] https://www.anl.gov/autonomous-discovery