



“The US leads the world in quantum materials research today,” he says, “but we are now at a point of moving this to the next phase where it changes from being a largely academic physics activity to the beginnings of technology and the development of materials science, computer science, and so on, ecosystem around quantum information systems. It is important that the US continue significant investments in this area.”

“If we look at the history of electronics,” Guha says, “there comes a time in the trajectory of technology development when massive scale materials research is needed to propel forward feasibility demonstrations driven by physicists and electrical engineers. The time for that ramp up has arrived for quantum technology.”

As for government funding, “I’m not certain what financial investment the US needs to make in [quantum materials research] to maintain its lead—it is difficult to provide a ready number,” Guha says. “Europe has decided to invest €1 billion over the next 10 years and China—significantly more than that.”

Asked if a Manhattan Project-like approach to quantum materials research might be appropriate, Guha says, “There needs to be focused research here ... of a multi-disciplinary nature and which has a broad set of goals and milestones that are coordinated with discipline. A ‘Manhattan-project’ analogy applies in this context.”

According to Guha, evolving business models and the sheer expense and complexity of today’s research in quantum materials make it difficult for this task to be carried out by the large industrial R&D labs as was the case in the United States 50 years ago. Universities, by themselves, are also not the right places for this type of research. On the other hand, the US National Laboratories, with their large scientific, operational, and management infrastructure, and university and industrial R&D ecosystems around them, are the optimal locations for this type of goal-oriented research, he says.

“Take for example the challenging task of building a high brightness x-ray beamline, intended to be the most powerful 4th-generation storage ring-based light source facility in the world, that Argonne National Labs is undertaking. It involves exquisite levels of scientific design, engineering design, understanding of the basic science we wish to do, a commitment to operational discipline and efficiency, and costs in the hundreds of millions of dollars,” Guha says. “A task such as this that has so many scientific and engineering nuances, is one that the National Labs are primed for. A large program in Quantum Information Systems will benefit from this type of experience.”

Asked where the private sector fits into the quantum materials research needs, Guha says industry is contributing heavily

to quantum computing research “and this therefore includes some work in quantum materials research, most importantly work on superconducting qubits which has been the focus of the leading private sector companies in this space. However, in terms of work on a wide array of different quantum materials, there is a lot of untapped and unexplored opportunity.”

“Real quantum materials [for QISs] require synthesis,” J. Stephen Binkley, Deputy Director of the Office of Science at the US Department of Energy (DOE), told legislators at the October hearing. The DOE oversees operation of the National Laboratories, including ANL.

Binkley said the research challenges, while very large and complex, hold great promise. Resulting functionalities, he said, could include superconductivity and maintenance of quantum states in conditions approaching room temperature, so-called neuromorphic computing that mimics biological information processing, and other advances that would apply across many fields of science.

“Quantum information science technology is rapidly evolving,” Binkley said. “Federal coordination and investment is critical to continued US scientific leadership in this area with implications for not only advancing scientific discovery in a number of fields, but continued US economic competitiveness and national security.”

**William G. Schulz**

## EU use of critical raw materials needs improvement for circular economy

Critical raw materials are not used to their full extent as part of the circular economy and there are several opportunities for improvement to reuse and recycle these materials, according to a recent report, “Critical Raw Materials and the Circular Economy,” published by the EU Joint Research Centre.

The report provides a detailed analysis for some specific sectors, such as extractive waste, electric and electronic equipment, batteries, automotive, and renewable energy, describing the current

state of play for key critical raw materials and identifying a number of good practices in each sector.

The report concludes that for several economic sectors in the EU, the use of critical raw materials is far from being fully circular. The gaps are due to various factors, including the loss of materials during collection and recycling of end-of-life products.

The report identifies opportunities and formulates advice for future actions. It discusses policy actions at

the EU level to improve the legislative framework to increase the availability of secondary critical raw materials through improved waste collection and treatment.

The report also points to further R&D as key for making available more innovative, efficient, and cost-effective technologies for the extraction of critical raw materials.

The report argues that research and industry initiatives should also foster material-efficient solutions in the use of critical raw materials in various sectors and that not only recycling, but also reuse, product lifetime extension, and new business models be considered.