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INDUSTRY AND ACCELERATOR SCIENCE, TECHNOLOGY, AND ENGINEERING – THE NEED TO INTEGRATE (BUILDING BRIDGES)

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Abstract

Finally, after two years of many virtual-only events, IPAC22, the International Particle Accelerator Conference 2022, could be held in person in Bangkok, Thailand, from June 12-17, 2022.

Following up on the conclusions reached in the Industrial Session of IPAC21, remotely hosted by the Laboratório Nacional de Luz Síncrotron (LNLS) in Campinas, Brazil, the industrial session of IPAC22 had the opportunity to renew the discussions along with new ideas and opportunities. At IPAC22 (Fig. 1), an innovative and integrated approach was adopted, and new impactful strategies were discussed and proposed to foster a true and realistic as well as effective and global accelerator ecosystem/network.

One key point of the session was that the collaborative and fertile environment between industry and research laboratories will continue to be crucial for the successful development and implementation of the technologies required in the next years. These collaborations and associated technological developments will have to satisfy and allow the progress foreseen in exponentially growing markets such as those of particle accelerators.

The session also discussed the importance of universities for basic and more advanced technology insertions into the labs and industry as well as for the workforce pipeline. Further, we also discussed the importance of interactions with governments and not-for-profits, e.g. professional societies, consortiums.

Enhanced across the board collaboration will be beneficial both for industry and for advancing the science, technology and engineering (STE): when well-integrated, accelerators help solve global problems, as proven in solving societal puzzles such as in developing the COVID vaccines, and the industry can grow, this brings in more tax income, more budgets for STE, more applications, etc. in a virtuous circle.

During the Industrial Session of IPAC22, much was discussed considering the different points of industry, laboratories, universities, and other collaborating entities. The aim was to generate and compile novel ideas and concrete actions on how best to implement and apply strategies that would help the integration and co-innovation between industry and collaborators for STE, with the purpose of building a global, collaborative accelerator economy: making accelerator-based research sustainable over the long-term, increasing at the same time the benefits of particle accelerators for society are the main challenges to the accelerator community in the century after next.

INTRODUCTION

Particle accelerators are at a crucial moment in their evolution. In this critical phase, innovation is drastically needed, to overcome the limitations in, for instance, the sustainability of large accelerator for fundamental research and in the integration of advanced data science and control for remotely-stationed medical accelerators, as well as to foster the ongoing transition of accelerator technologies towards STE and society.

Traditionally, innovation for particle accelerators and their peripherals takes place in scientific laboratories, possibly supported by a network of universities, and then either remains in the domain of the laboratory or is "transferred" to industry. This scheme worked quite well in the past but is now showing its limitations because on the one hand the breadth and complexity of new technologies feeding into new accelerators is beyond the capabilities of a single laboratory or national network, and on the other hand because the risk and costs of transforming ideas into "products" is often beyond what can be afforded by the shrinking budgets of public research institutions.

Times have changed: the particle accelerator community is entering the age of open innovation where ideas and know-how have to be shared between scientific institutions and companies, to improve high technology products and to identify new products and markets.

Creation of an innovation ecosystem based on community, trust, openness, creativity, connection is needed, with the long-term goal to create a common language and a common working ground between academia and industry, and to favor exchanges – in both directions.

Of course, to achieve these goals we must face many challenges. Administrative issues (on both sides!), rigid corporate culture in large companies, agreement on sharing of responsibilities and risks, IP management, keeping competition for series production, are among the many obstacles to overcome to create a real academia-industry innovation ecosystem. But for each of these problems there are solutions, and all problems can be solved if there is mutual trust and if we overcome the traditional mentality of industry as "supplier", and instead we go towards considering industry as a "co-innovator".

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Figure 1: IPAC22 Industrial Session, J. C. Rugsancharoenphol, H. Priem, E. Bradotti, M. Vretenar, S. Biedron, S. Sheehy, R. Geometrante.

Aware of the above challenging context, IPAC22 Industry Session goals were to analyse the actual situation from the points of view of laboratories, university, and industry, both small businesses and large multi-national ones, so to provide pioneering answers to the post pandemic issues, and to initiate and address concrete actions with major impacts on the creation of a collaborative habit were innovation in STE can exploit all its potentials, extending beyond the discovery science and spanning most of the aspects of our lives.

STYLES BUILDING A GLOBAL AND COLLABORATIVE ACCELERATOR ECONOMY

As part of the discussion resulting from IPAC22 industrial session, synchrotron technology was identified both as an enabling platform and as a stimulator of high precision/deep tech industry in Thailand (but also worldwide), as long as the development of the awareness of the importance of particle accelerator technology to industry is well understood.

In this context, building bridges between individuals both in lab-based- and university-based-STE and industry becomes extremely relevant, and a more integrated approach is needed. In fact, despite innovation based on accelerator-born technologies are proven to be useful for many different industries, sometimes the detachment and lack of inter-communication between labs and universities with industry could be an obstacle.

We believe that integration will benefit both worlds as additional funding, time-to-market (speed) concepts, and innovation will enter the science community. In return, this will significantly benefit innovation in market segments such as semiconductor, health, energy, and controls, expanding the industry business towards other markets.

This will increase the awareness of the importance of the accelerators and accelerator facilities worldwide as their technological improvements can be translated into a direct social and economic impact through innovative industrial applications.

This creates a virtuous circle beneficial for both industry and science as research generates innovation that generates economic growth that provides the resources to finance research).

A real academia-industry innovation ecosystem can create disruption, as happening in Australia where the existing national-scale collaboration in accelerator science ACAS, Australian Collaboration for Accelerator Science, is relaunched with industry members as a core player and a new laboratory (X-LAB) is developing industrial partnerships to enable translation of technologies.

The impact of disruptive accelerator technologies on human health and high technologies is becoming a reality while Australia is entering a new era for accelerator development and applications, including new activity in medical accelerators, space technologies, and advanced materials development.

Fostering a New Role of Industry in Big Science: I.FAST Example

In the last 10-20 years, the huge expansion and standardisation of particle accelerator technologies has created a

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wide pool of innovative companies specialised in accelerator technologies, in most cases run by scientists or engineers with an academic background. These companies are creative, flexible, innovative, continuously looking for new markets and new applications, and have the experience required to translate the ideas and needs of accelerators into innovative technologies for the accelerator and industrial markets. What is needed are schemes to support early involvement of industry in the R&D of new accelerator technologies, to profit of the experience, creativity, and result-oriented approach of industrial companies.

A good example in this direction is the new I.FAST (Innovation Fostering in Accelerator Science and Technology), an innovation-oriented programme to support particle accelerator R&D launched by the European Commission in 2021, for a duration of 4 years and a budget of 10 Meuros. Most of the activities within the project have one or more industrial partners that are fully "co-innovators", participating from the early stage in the R&D, and giving their contribution to the development of prototypes at different Technology Readiness Levels. Early participation of industry guarantees faster feedback on the technological requirements, and an easier adoption of industrial standards and technologies, resulting in simpler and less expensive final products – and a consistent sharing of ideas. I-FAST is a seed to propel innovation. We need to share this model globally.

The Quest for the Miniature Accelerator: Wishful Thinking, or a Key to Expanding the Particle Accelerator Market?

Particle accelerators have a wide potential to expand beyond their present boundaries; they are a unique tool to access the atomic and subatomic world with many applications in the medical, industrial, environmental, and security fields. Already now, out of the more than 30'000 accelerators in the world only 1% operate for fundamental research - 95% are used as everyday instruments for medicine and industry and the remaining 4% is used in applied research.

What is needed to make more applications accessible to accelerators? A key direction is the "miniature accelerator", an accelerator that is "transportable", requires minimum electrical power and minimum human set-up and intervention, and produces a "usable" beam of particles. The known applications of miniature accelerators are multiple, in medicine (cancer therapy and isotope production), and industry (ion beam analysis, neutron and X-ray radiography, beam treatment), but many more applications are under study and this field could grow drastically. We need to propel how fast this market can grow – the better the technologies, the faster they will go to market. Small ("miniature") accelerators can be excel-lent entry points for new companies entering the field, or for consortia of accelerator equipment producers willing to produce and commercialise a complete accelerator.

Present Status and Opportunities for Implementing Disruptive Technologies Arising in Particle Accelerator R&D Industrial Market

We need to realize, rather accept, that it is not just industry that contributes to the global accelerator industry. Industry, national and federal labs, academia, government, and Not-for-Profits (e.g. user organizations, professional societies, etc.), and international organizations are all contributors. Of utmost importance is to realize that the people, the people from a variety of disciplines, are what really makes a difference for the accelerator economy.

Here only are a few examples of the efforts made to grow the accelerator economy in the United States.

Many federal studies have expanded the legislative (Congressional) interest in accelerators [1-5]. Based on these studies and their findings, the Department of Energy (DOE) Office of Science (SC) just reorganized in part because of the need for US Accelerator activities. The new office, the Accelerator R&D And Production (ARDAP) Office - was recently established [6]. Calls for proposals for funding are expected to be released annually through this new ARDAP office.

There are plenty of opportunities for collaboration in this space. Laboratories play as centers of partnership to help seed industry. Places such as the Accelerator Test Facility (ATF) at Brookhaven National Laboratory (BNL) serve as test-beds for new facilities as well as for industry. The combination of electron and laser beams is unsurpassed the world over [7]. Facilities such as the Los Alamos Neutron Science Center (https://lansce.lanl.gov) are key facilities for materials science, radio-isotope production, and radiation effects testing [8,9] all critical to industry. The ongoing and planned activities at Brookhaven National Laboratory for radiation testing [10] and with Brookhaven and industrial collaborations for future radiation effects testing [11] are critical components of the lab, government and industrial triad. Unique laser-driven ion sources for radiation therapy due to the high-radiation doses in a short pulse are being explored through collaborations hosted at the Extreme-Light Infrastructures (ELI) in Prague at the ELI. Further, the semiconductor industry can benefit greatly from accelerator technologies from methods of lithography to critical dimension small x-ray scattering. One infrastructure at the BNL ATF is particularly interesting to novel materials studies. One of only a handful on the planet, access allows investigation of novel materials using MeV ultrafast electron diffraction (MUED) with pump-probe [12].

The reality is that access to many facilities is difficult as many are oversubscribed. This is the reason that many proposals are focusing on future, smaller facilities that might not offer every benefit of the larger user facilities with complimentary materials and computational resources, but do deliver beam useful for many studies. For instance, the UC-XFEL study [13] was critical and we are pursuing additional funding (Proposals submitted, Rosenzweig and Biedron et al., 2022.) to pursue the various systems and subsystems of this facility.

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Access is critical to accelerators. In fact, as Joel England pointed out on the first day of this conference, the accelerators on a chip are coming of age. Through the team that was funded by DOE (SLAC lab) and the Gordon and Betty Moore Foundation (NFP) with participants from

Universities (Stanford University, Purdue, Erlangen, TU Darmstadt, UCLA, Tel-Aviv University, Techion; Industry: Tech-X and Labs: SLAC, DESY, PSI, LLNL, they have developed accelerators through standard semiconductor industry fabrication processes [14]. These have great promise in many areas including industry, and the collaboration entities demonstrate the diversity of breadth of the expertise of the persons on this effort.

We also are trying to link to quantum information science systems with accelerators [15,16]. We are working on a storage-ring quantum device to serve part of the quantum revolution efforts. This is a collaboration between two laboratories, three universities, and industry.

The complimentary facilities for data science, such as the Argonne Leadership Computing Facility (https://www.alcf.anl.gov) are needed for data analysis, simulation, training of ML models, etc. This synergy between accelerator and laser facilities with computing facilities is well-documented [17].

One major area of opportunity for particle accelerators is sustainability.

Bridges, for instance, exist everywhere on the planet, but it is clear from recent incidents, such as that in Genoa, Italy as well as in Pennsylvania that infrastructure inspection is critical. Our colleagues in Japan have devised fairly compact technologies to accomplish infrastructure probes [18]. There are ripe opportunities for electron-beam-based remediation of wastewater and other waste streams [19]. Concepts such as accelerator driven or transmutation of nuclear systems [20] could enhance the proven utility of nuclear power energy systems [21].

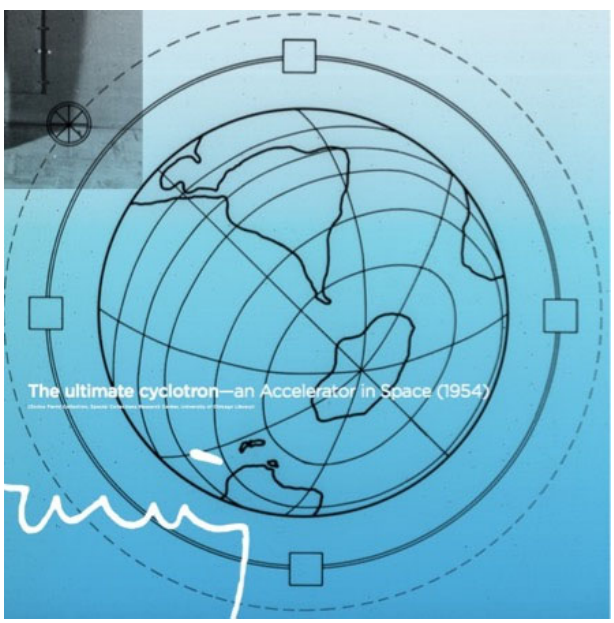

Figure 2: The Ultimate Cyclotron – an Accelerator in Space, courtesy the University of Chicago.

A model for university-laboratory-industry partnership is that of the National Science Foundation's Center for Bright Beams (https://cbb.cornell.edu) based out of Cornell. Specific deliverables are identified in each year's strategic plan for knowledge transfer, including to industry with its 8 university partners.

Disruptive technologies being with humans. Maybe Enrico Fermi [22] actually meant by his accelerator encompassing the Earth idea that accelerators (and other analytical research tools) would in a figurative way encompass the Earth (Fig. 2).

We need the people and collaborations and combining of resources to be disruptive to drive us to disruptive technologies.

IMMEDIATE ACTIONS TO ADDRESS

Both labs and industry, with their university partners are aiming at creating a real innovation ecosystem around particle accelerators, pushing from the open science to a new era of open innovation.

The long-term goal must be creating a common language and a common working ground between academia and industry, and to favour exchanges – in both directions.

To address these critical issues, we need innovation developed in a collaborative environment between laboratories and industry: the network of innovative companies is a crucial asset of the particle accelerator community

IPAC22 Industry Session team spurs to build of bridges between science and industry that will enable future innovation and future science programs and will develop awareness of how important particle accelerator technology is to industry and vice versa.

We have discussed and studied concrete actions to be taken and checked year after year, from one IPAC to the other, so to create a continuous flow of information and proposals throughout next Industry Sessions, to monitor the steps effectively taken and to plan the new ones.

Our conclusions and outputs are summarized in the following list:

- Have an annual IPAC technology transfer and partnership award open to nominations for industry as well as teams (e.g. industry, labs, academia, government, NFPs). Each person on the team would receive a plaque presented in the awards session. The committee would be led by an industry person with a mixture of industry, labs, academics, NFPs, and government persons.
- Have a small workshop as part of the conference with subject areas of discussion for sparking collaboration.
- Have training sessions on key business activities.
- Have the industry session as a main session, deconflict with other sessions. We need parentship across the board in general, all need to attend.
- Foster the submission of scientific papers from Industry - there are lots of scientists working in the companies publishing in quality archival journals.
- Foster more of "business related" papers, posters, and talks from the industry. It is important to know a thing

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or two from the other side of the fence such as the business model of target industry in order to commercialize the research
- Share documents such as model templates for IP agreements, memorandums of understanding, etc.
- A message to Industry: foster Industry aggregations/cooperation/consortia etc. which include start-up and small businesses.
- Promote diversity not only in terms of gender and minorities but including different educational backgrounds, essential for the development of new models of collaboration, innovation and business.

IPAC22 Industry Session team believes that IPAC could become the launch point for of a new style of Industry Session, to foster the integration between labs and companies with concrete actions.

This is not about wishful thinking, we want this session to be a valuable reality.

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