I.FAST

Innovation Fostering in Accelerator Science and Technology

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MILESTONE REPORT

Workshop on efficient RF sources

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ABSTRACT

RF sources are an important element in the power conversion chain of all types of accelerators. An international workshop on efficient RF sources was organised in Switzerland with the goal to promote exchange of ideas and to review new developments in the field of RF sources. New developments are ongoing for different types of sources, in particular klystrons, solid state amplifiers, magnetrons and inductive output tubes.

For more information on IFAST, its partners and contributors please see https://ifast-project.eu/

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Executive summary

A workshop on efficient RF sources with international participation was organised.

The RF sources relevant for particle accelerators were covered at the workshop, including klystrons, tetrodes, IOTs, magnetrons, solid state amplifiers. The program was ranging from concept studies to concrete and large construction projects.

New R&D on efficient RF sources is performed particularly for klystrons, magnetrons and solid state amplifiers.

Research institutions with accelerator facilities as well as industry companies active in this field were represented at the workshop.

1 Introduction

In the power conversion chain from Grid to beam, RF sources are an important element. Teams at many institutes are working on improving the energy efficiency of RF sources. There is a variety of vacuum-electronic devices and solid state amplifiers available for RF power production, and there is not a single concept evolved that is suitable for all applications. Within the I.FAST work package "Sustainable concepts and technologies" an international workshop was organized to review the ongoing R&D activities on efficient RF sources and to exchange ideas. The **w**orkshop on Efficient RF sources was held in Chateau de Bossey (Geneva, Switzerland) on the 4-5-6 July 2022. A number of experts from public and private sector participated in the meeting and in the discussions around the efficiency of klystrons, IOTs, Solid state amplifiers and RF systems in general. The organizing committee was formed by Nuria Catalan Lasheras (CERN) and Mike Seidel (PSI). The scientific program committee was chaired by Igor Syratchev (CERN).

This workshops follows in a series of successful workshops on the initiative of the EUCARD2 and ARIES EU-funded programs.

2 Content of the Workshop Program

The workshop started on Monday July 4 with a general overview on projects and lab reports with relevance for RF systems. The collider project CLIC and the latest conceptual improvements for grid-to-beam efficiency were presented, followed by an overview on RF aspects of the PSI facilities and the latest RF related developments for LHC.

The ESS project in Sweden is the biggest accelerator construction project ongoing in Europe. The project aims at very high average beam power of 5 MW, which results in advanced requirements for the efficiency and reliability of the linac RF systems. Three talks were dedicated to the development, the procurement and the performance assessment of the ESS RF systems. The speakers made clear that the overall reliability and maturity of concepts is most important for the delivery of an operational facility on a limited time scale. For example the concept of multi-beam inductive output tubes is promising in terms of efficiency, but the operational risks are judged too high for the ongoing ESS project.

The second session was dedicated to klystrons, and it started with review presentations on klystron technologies and the computer codes for simulating these RF sources. Several concrete high efficiency klystron developments were then presented, from the projects CEPC, LHC and the industry companies THALES, CPI, Canon. An entirely new concept of a multi-beam klystron with two separate high voltage stations was studied for the FCC project, and was presented in this session as well.

The third session was dedicated to tubes and inductive output tubes (IOTs). In particular the session had contributions on Tetrodes from CERN, RF Power stations at ESS and the study on IOTs at ESS. Another session on Tuesday had a contribution on various sources and magnetrons by the US company Calabazas Creek. Magnetrons are very efficient but phase-unstable RF sources, and for the latter reason these were never used for accelerators. However, in the US several development efforts are ongoing to make magnetrons suitable to drive even superconducting cavities. Another talk discussed the possibility to use a high temperature superconductor for realising a low power solenoid magnet for klystrons.

The morning session on Wednesday was dedicated to solid state amplifiers (SSA). It had contributions from Soleil, CERN and a team at Uppsala University. The Soleil machine pioneered the operational use of SSA for light sources many years ago, and in the presentation convincing experience was shown on the excellent long-term reliability of SSA in daily operation. Particularly for lower frequencies solid state amplifiers may provide efficient solutions in the future. Even high power sources of 1 MW and more can be realised, for example replacing Tetrode sources for CW applications.

After a discussion the workshop was wrapped up with a summary presentation addressing the trends in the field and highlights from the individual presentations.

3 Workshop Statistics

The workshop was organised as a in-person three day meeting in Chateau de Bossey near Geneva. In total 26 presentations were grouped in 5 thematic sessions. There were 36 registered participants. The talks are documented on the Indico website:

https://indico.cern.ch/event/1138197/timetable/#all.detailed

4 Summary and Conclusion

The relevance of energy efficiency and sustainability is broadly acknowledged at all institutions worldwide with accelerator driven research infrastructures. RF power sources present an important accelerator subsystem with potential to improve energy efficiency. The workshop impressively showed that energy efficiency is an important topic for all institutions today, and that significant research and development efforts are being made to achieve improvements.

The understanding of the beam dynamics in vacuum electronic devices has been much advanced, and with specialised computational tools the design of such RF sources can be optimised. This leads to a jump in the performance of klystrons at present, although these devices are available since 1940. The phase locked magnetron is another promising concept that is mainly developed at US institutions.

Since vacuum electronic devices are more and more replaced by semiconductor-based devices in industry, also the field of accelerators follows this trend to some extent. The development of high power transistors is pushed by industrial requirements, and the use of low loss GaN transistors is an example for that. SSA with very high efficiency seem to be feasible, and one can hope for the realisation of high power SSA installations in the future.

The participants agreed that a continuation of RF efficiency related workshops is desirable and supportive the developments in the field.

5 Relation to Other IFAST Work

Another task (11.2) in this work package is dedicated to the development and installation of an efficient klystron for the LHC. The klystron can fit into the same socket as the existing klystrons, thus providing an economic solution for reducing the power consumption of LHC.

Annex: Glossary

Acronym	Definition
IOT	Inductive Output Tube
SSA	Solid State Amplifier
GaN	Gallium-Nitrite (transistors)