BENCHMARKING AND VALIDATION OF IFE DRIVER TECHNOLOGY

Topical areas: Drivers and Economics

V.S. Morozov and S.M. Cousineau

Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA

Introduction

The concept of accelerator-based inertial fusion energy (IFE) production places challenging constraints on the accelerator driver parameters and performance [1]. This is the case for both direct and indirect drive implosion modes as well as for all ignition scenarios. Moreover, the fast ignition mode requires a separate intense beam to heat the fuel to ignition. The accelerator driver challenges are two-fold including both technological and economic issues. The driver beam must deliver a large amount of energy in a small volume in a short period of time. Given the amount of energy, focal spot size, time scale, and beam range involved, the beams are operated in a space-charge dominated regime at non-relativistic energies. This raises questions associated with high-intensity beams such as beam dynamics with collective effects, intra-beam stripping in case of partially-stripped ions, scattering on the residual gas, beam losses, and aberration control. At the same time, for the economic aspect of the design, the driver has to have high availability, be capable of quick restoration, energy efficient, and operate at a high repletion rate.

Demonstration of key IFE driver technology components in the SNS linac

Many of the above questions associated with production, acceleration, and handling of high-intensity beams can be addressed at the Spallation Neutron Source (SNS) linac [2]. The SNS linac is currently the highest average power superconducting proton linac in the world. It has been reliably delivering a MW-level proton beam since its commissioning in 2006. It could be used as a prototype for testing some of the key IFE driver technologies. Some of its existing experience may also be extrapolated to the IFE driver parameters.

Admittedly, the beams choice for an IFE driver are singly charged heavy ions while the SNS accelerated hydrogen ions. However, the SNS linac faces many of the same issues as heavy ion linacs such as intra-beam stripping, scattering on the residual gas, space-charge dominated beam dynamics, cavity loading issues, and beam loss control. In addition, similarly to an envisioned IFE driver, the beam is non-relativistic in the SNS linac. The PyORBIT code [3] has been developed for simulating the dynamics of an ion beam including space charge interaction during acceleration of the beam in a linac. The code has been successfully benchmarked against experimental data. The SNS linac may also server as testbed for benchmarking other codes and theoretical predictions.

Using SRF technology is the most efficient way of accelerating high-intensity beams, since essentially all of the RF power is transferred to the beam instead of being wasted on cavity heating. Over the years of its operation, the SNS has accumulated extensive experience on the cost, reliability and practical aspects of operating a high-intensity SRF linac. The SNS linac has recently demonstrated an availability level of 95% with little energy margin and hardware redundancy. Techniques for fast recovery from a single-point hardware failure are currently being explored and implemented at the SNS. The practical operation experience at the SNS can be used to provide accurate estimates of the cost and efficiency of operating an IFE driver.

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[2] S. Henderson *et al.*, "The Spallation Neutron Source accelerator system design, Nucl. Instrum. Methods Phys. Res., Sect. A, **763**, 610 (2014).

[3] A.P. Shishlo, S.M. Cousineau, J.A. Holmes, and T. Gorlov, "The Particle Accelerator Simulation Code PyORBIT", Procedia Computer Science **51**, 1272 (2015).