PERLE a 'Stepping Stone' for the Next Generation ERLs

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1. Introduction

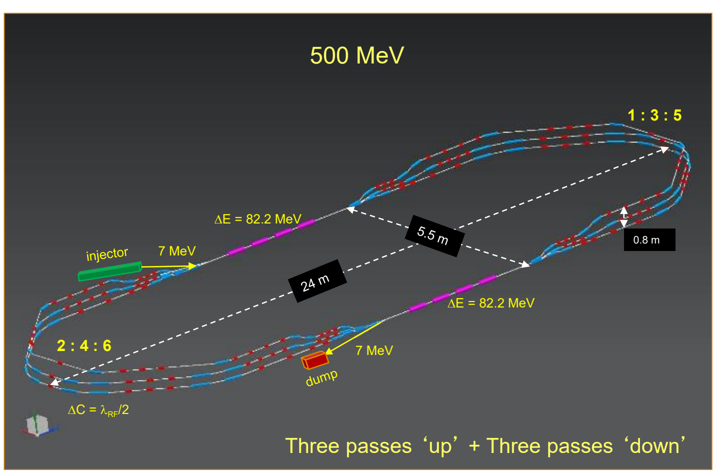
PERLE (Powerful ERL for Experiments) [1] is a novel Energy Recovery Linac (ERL) test facility, which has been designed to validate choices for a 50 GeV ERL foreseen in the design of the LHeC [2] and the FCC-eh, and to later serve a set of dedicated nuclear and particle physics experiments. Its main thrust is to probe high current, continuous wave (CW), multi-pass operation with superconducting cavities at 802 MHz (and perhaps testing other frequencies of interest). With very high transient beam power (~10 MW), PERLE offers an opportunity for controllable study of every beam dynamic effect of interest in the next generation of ERL design and become a 'stepping stone' between present state-of-art 1 MW ERLs and future 100 MW scale applications. PERLE design features flexible momentum compaction lattice architecture for six vertically stacked return arcs and a high current, 7 MeV, photo-injector. With only one pair of four cavity cryomodules, 500 MeV beam energy can be reached in three re-circulation passes, with beam currents of about 20 mA. The beam is decelerated in three consecutive passes back to the injection energy. Work on the engineering design of PERLE has just begun.

2. Motivation

Next generation collider applications [3], or light sources would greatly benefit from recirculated and energy recovered linacs. They offer CW or other high duty factor operation, high beam average current, low delivered beam energy spread, and low delivered beam emittance. CW beam acceleration with high accelerating gradient (>10-20 MV/m) generally requires a multi-pass Recirculating Linear Accelerator (RLA) consisting of superconducting accelerator structures. GeV-scale RLAs at 100 mA average current would ordinarily require at least 100 MW of installed RF power merely to accelerate the beam load. Energy recovery allows the RF beam loading of the cavities to be substantially lowered. and they provide linac quality/brightness beam at storage ring beam powers. The primary motivation for the use of energy recovery isto provide beams of very high virtual power while using only minimal installed RF power. The production of high beam power with reduced RF drive represents improved electrical efficiency (it is then a 'green' technology) and it results in significant cost reductions. PERLE would take performance from demonstrated 1 MW to the next, 10 MW level providing the experience and knowledge base for next generation systems such as high-energy colliders, EIC coolers and XFEL drivers.

3. PERLE – Overview

PERLE is a GeV-scale accelerator system invoking a unique combination of parameters, technology, and design choices. A schematic diagram of the accelerator system is illustrated below:



It will provide very high "virtual" beam power – the nominal power of the full-energy beam, after acceleration, and before any energy recovery – through a combination of high energy and moderately high current (a combination of relatively high CW micro-bunch repetition rate and bunch charge). PERLE uses a conventional accelerator beam transport system design – similar in many details to that of CEBAF [4] – distinguished from conventional systems by use of multiple passes and nearly entirely common beam transport for acceleration and energy recovery. It has a very large dynamic range, or energy recovery efficiency (the ratio of injection energy to full energy and/or full energy to final energy – after recovery [5]. PERLE offers opportunity to controllably study virtually every effect of interest in the next generation of ERL design.

4. PERLE's Impact, Demonstration Milestones

PERLE will advance the ERL frontier enhancing its performance, while limiting risk. It offers a high charge, high brightness bunches – allowing exploration of beam quality preservation with space charge (both the transverse and longitudinal), coherent synchrotron radiation (CSR), microbunching instability (μBI) [6], [7] and other collective effects. High current, charge, and beam power provides experience with power flow management, including halo formation and control, high power THz handling, RF heating, and mitigation of resistive wall. Use of conventional beam transport allows flexibility in the choice of working point [5], enabling development of algorithms for control of halo and independent adjustment of multiple beams undergoing common transport. The system enters a new power regime for diagnostic and control methods, supporting and motivating large dynamic range diagnostic and measurement methods in particular.

5. Outlook

A half-century of testing and application of ERL-based systems has resulted in considerable progress with energy-recovery technology, but numerous questions still remain. Next-generation systems thus have excellent opportunities to explore basic beam dynamical issues and resolve engineering challenges. PERLE combines beam energy, current, power, brightness, and operational flexibility in a combination unavailable in any other existing or proposed ERL. It can therefore support testing throughout an unmatched region of parameter space, providing the required technology base for the design of futures generations of accelerators, including high-energy colliders; the LHeC and FCC in particular.

References

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