CEBAF Energy Recovery Experiment – Proposal

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Introduction – The Experiment

Physics Motivation

High energy (multi-GeV)/high current (hundreds of milli-Amperes) beams require GWatt-class RF systems in conventional linacs – a prohibitively expensive proposition. Energy recovery technique alleviates extreme RF power demands, improves linac efficiency and increases cost effectiveness.

Several newly proposed accelerator systems are based on high energy/high current Energy Recovering Linac (ERL) concept. ERLs are potentially powerful recirculating linear accelerators; they deliver beams of superior quality (short pulses, small emittances and energy spreads determined by the source) with efficiencies approaching those of storage rings. Apart from being used as high current injectors, they are being contemplated for a variety of other applications, such as the high brilliance storage rings (eg. Cornell ERL prototype), electron cooling devices for e-RHIC (at BNL) and linac-ring colliders for nuclear and particle physics (eg. ELIC and eRHIC).

The largest scale demonstration of energy recovery to date has taken place in the Jefferson Lab IR FEL where 5 mA of average beam current have been accelerated up to 50 MeV and the energy stored in the beam was recovered subsequently via deceleration and given back to the RF power source. Some of the ERL-based accelerator applications that are being proposed require beam currents of the order of 100 mAs. The beam energy for these applications ranges from the currently achieved 50 MeV up to 5 GeV. For example, the present design for ELIC, the Jefferson Lab proposal for a CEBAF-based Electron-Ion Collider (EIC), is based on electrons recirculating once through CEBAF, and gaining energy of about 5 GeV (assuming ~20 MV/m gradient and Upgrade-style cryomodules) and then colliding with 50-100 GeV light ions (stored in a separate storage ring). After the collisions the electrons are re-injected into CEBAF for deceleration and energy recovery.

There are several important accelerator physics and technology issues that must be resolved before any of these applications can be realized for the full benefit of nuclear physics applications. The Jlab FEL Upgrade, presently under construction and designed to accelerate 10 mA up to 150-200 MeV and then subjected to energy recovery, and the proposed Cornell/Jlab ERL Prototype, designed to accelerate 100 mA up to 100 MeV and then decelerated for energy recovery will be ideal test beds for the understanding of high current phenomena in ERL devices. However, in both these devices the energy will be limited to 100-200 MeV. Until the present proposal, there were no plans aimed to address issues related to beam quality preservation in systems with large final beam energy (up to 1 GeV) or large energy ratio between final and injected beams (up to factors of 40-80). Investigation of physics issues for such machines is warranted and timely. The proposed CEBAF-ER Experiment aims at showing just that – an operational feasibility of running a large-scale superconducting recirculating linac in energy recovery and current doubling modes. A full-scale demonstration of energy recovery would provide practical evidence of the usefulness of such machines for future projects. It will allow us to evaluate the limitations and ultimate performance of ERLs, including providing a unique opportunity to address an important regime of machine operation, in the context of preservation of

beam quality and management of beam phase space in a complex machine. Finally, together with the high-current experiments, CEBAF-ER will directly address the feasibility of ELIC.

"CEBAF-ER on the ERL Landscape" – A Complement to the Cornell ERL Prototype

	Current		
Energy/Size	"low" (< 1 mA)	"intermediate" (1-10 mA)	"high" (10-100 mA)
"low"/"small" (≤100 MeV / several 10s of m)	HEPL & CEBAF-FET recirculation (1993; 15 kW)	JLab IR Demo FEL (1999-2001, 250 kW)	Cornell ERL Prototype (~2006; 10 MW)
"intermediate"/"medium" (few 100's of MeV / ~100+ m long system)	Bates recirculator (1983; 15 kW)	JLab FEL Upgrade (~2003; 1 MW)	JLab 100 kW FEL (~2006, 20 MW)
"high" / "large" (~1 GeV & above / km-scale system)	CEBAF-ER (~2003; 170 kW)	Multipass CEBAF-ER: 5-10 GeV/20 mA (~2009 100-200 MW)	ELIC, eRHIC, JERBAL (~2012; 1 GW)