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THE APS LINAC RF STATION UPGRADE STATUS*

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Abstract

The Advanced Photon Source (APS) linac has reliably delivered high-quality electron beams for over 30 years. To support the APS upgrade and ensure continued operation, a major refurbishment is underway. As part of this project, two of the linac's five operating radio frequency (RF) stations have been upgraded with solid-state modulator-powered klystrons and new digital low-level radio frequency (LLRF) systems. This upgrade has notably improved the linac's performance. This paper summarizes these improvements and describes our next plans.

INTRODUCTION

The Advanced Photon Source (APS) upgrade is demonstrating remarkable success, with the newly installed storage ring meeting its design specifications and setting a new record for electron beam emission [1]. These achievements mark a significant milestone in advancing the capabilities of the APS for cutting-edge scientific research.

To support the upgraded APS, the linear accelerator (linac) must deliver higher energy and maintain exceptional reliability [2]. However, many components of the existing APS linac have become outdated or obsolete. To address these challenges, a comprehensive refurbishment project is currently underway. This initiative aims to enhance the linac's performance and ensure greater stability, aligning with the demands of the upgraded APS.

The refurbishment project [3] includes several critical areas.

- **RF System Upgrade** upgrading RF stations to 50 MW capacity using new klystrons , solid-state modulators, and digital low level rf controls, enabling the linac to achieve higher energy and better stability [4].
- **RF guns development and installation** New RF guns were designed, tested and installed to replace the deteriorating Gen-III guns [5].
- **Magnet Power Supply Replacement** Replacing aging power supplies to ensure consistent and precise operation.
- **Timing System** Upgrading the timing system for better synchronization and control accuracy.

RF STATION UPGRADE

As shown in Fig. 1, a new RF station is developed to replace the old ones in the APS linac gallery. This involves replacing PFN-type modulators with Scandinova K400 solid-state modulators. In addition, Cannon E3712 klystrons,

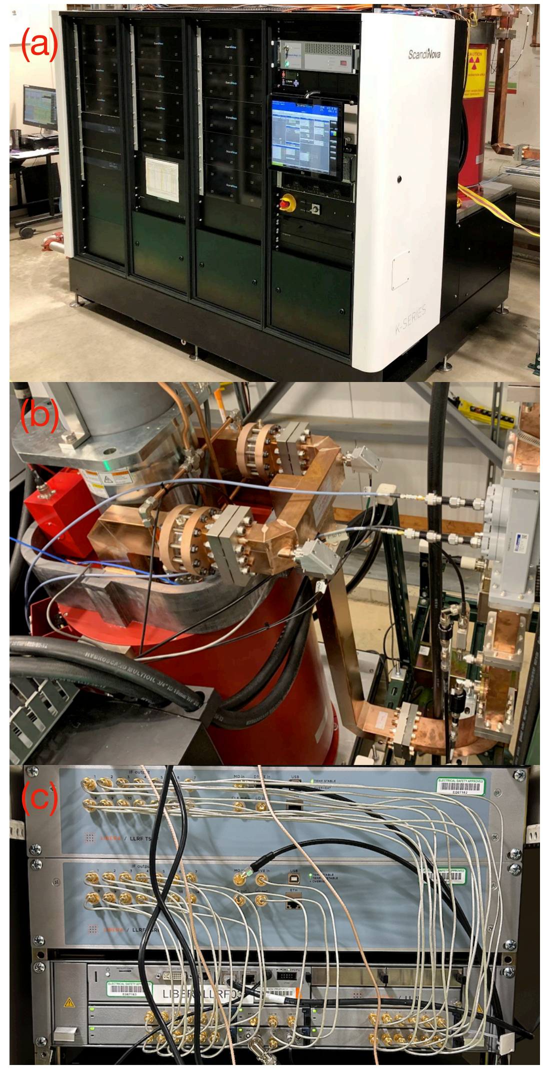

Figure 1: The New RF station consists of (a) Scandinova K400 modulator (b) Cannon E3712 klystron and (c) Libera DLLRF system.

which are capable of generating a peak power of 60 MW, are installed to replace the TH2128 klystrons. The obsolete analog LLRF systems are being replaced with state-of-the-art Libera Digital LLRF systems [6].

The APS linac setup is illustrated in Fig. 2. The electron beam is generated by one of two thermionic RF guns and is subsequently accelerated through three sectors of S-band accelerators, L2, L4 and L5. Each sector consists of four accelerating structures. The linac is powered by six RF stations, designated K1 through K6, with five stations (K1 through K5) currently in full operational mode. The RF stations K2, K4, and K5 power the linac sectors L2, L4, and L5 through SLED power compressors. K1 powers the

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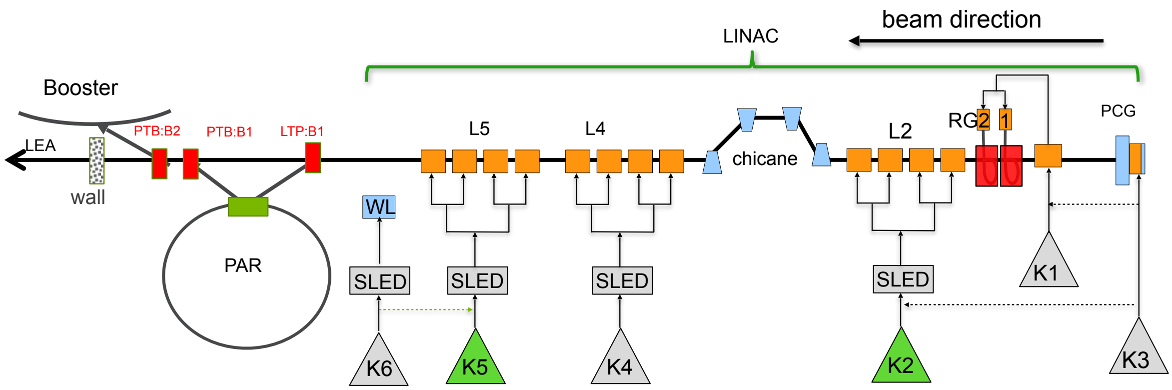

Figure 2: The APS Linac layout.

thermionic gun, while K3 can be used to power the photocathode gun or serve as a backup RF station for K1 or K2. K6 is currently a RF test station.

Two RF stations K2 and K5, marked in green, have been successfully upgraded to the new RF station configurations. As a result, eight of the twelve operational accelerating structures are now powered and controlled by the new RF stations. These upgrades led to significant improvements in both power output and system stability.

Table 1 summarizes the improvements in operational performance. The upgraded klystrons can operate at higher power levels with enhanced stability. In addition, The klystron output pulse flatness has been improved, which results in a higher gain factor and much stronger peak power in the SLED outputs. Both amp and phase noise level in the klystron output pulse has been reduced by more than 70 % . The improved system stability has also reduced the frequency of system trips.

Table 1: RF Station Performance Improvement

Parameter	Before	After
SLED Peak Power	100 MW	145 MW
SLED Gain Factor	4.9	5.9
Kly. Power	20.4 MW	24.6 MW
Kly. Amp. rms jitter	0.1 %	0.02 %
Kly. Pha. rms jitter	0.1 deg	0.025 deg

The digital LLRF systems provides much more precised and stable control compared to the previous analog systems. As a result, all RF waveforms are much more clearly resolved and the RF systems are much more easier to operate. The linac now is able to operate at 450 MeV and we plan to achieve even higher energy levels in the near future.

NEXT PLAN

The remaining RF stations will be upgraded in phases, with K4 scheduled as the next station to be replaced. To achieve higher linac energy level up to 550 MeV. We are considering to convert the K6 test station into full operational use. This transition will involve installing two or three additional accelerator structures downstream of the L5 section.

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