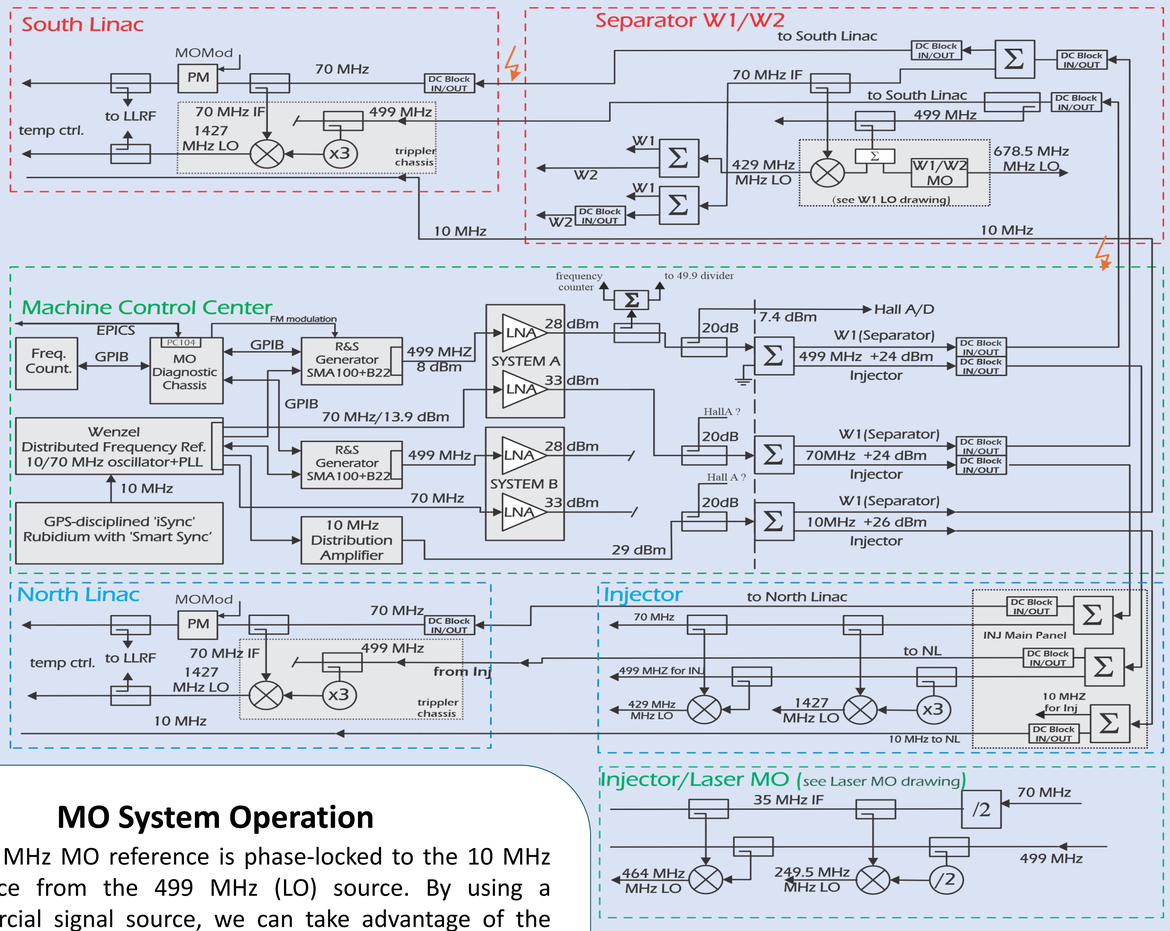
The CEBAF Accelerator MO System Upgrade*

Brad Cumbia, Tomasz Plawski, Joshua Settle
Jefferson Lab, Newport News Virginia, USA

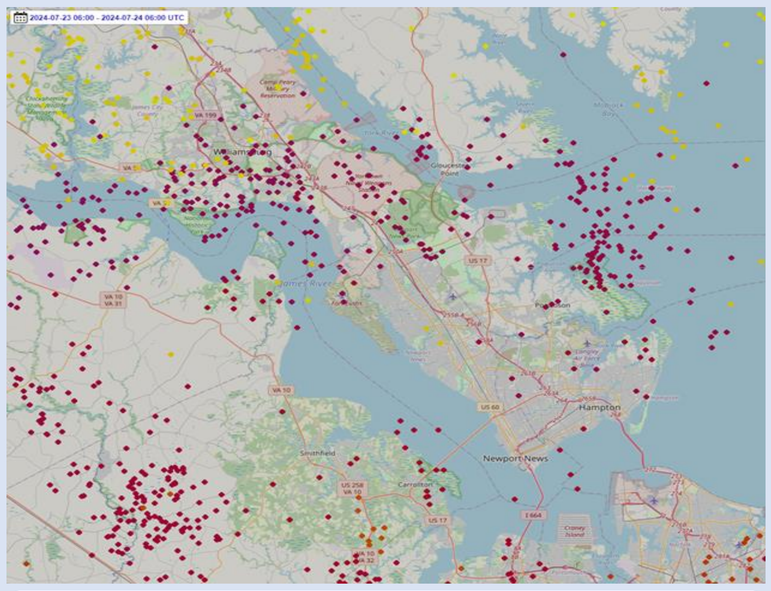
Abstract

The CEBAF accelerator at Jefferson Lab relies on precise frequency references distributed throughout the site. CEBAF's infrastructure has aged from decades of successful operation, and grounding issues have made the system susceptible to electromagnetic interference. This weakness is particularly noticeable during lightning storms. To address this, the Master Oscillator (MO) system [1] was upgraded by replacing some coaxial lines with modern RF over fiber (RFoF) systems. These fiber-optic links provide noise immunity and reliability, helping to preserve the integrity of its frequency references for the accelerator's LLRF systems. The poster will explain the specific modifications to the frequency distribution system, including the adoption of RF over fiber technology and the implementation process.



MO System Operation

The 70 MHz MO reference is phase-locked to the 10 MHz reference from the 499 MHz (LO) source. By using a commercial signal source, we can take advantage of the frequency modulation input and adjust the frequency for the path length variations [2]. The 499 MHz is multiplied by three in the service building and mixed with 70 MHz MO. The 1427 MHz signal is obtained, amplified, and distributed down the service building. The frequencies are upconverted at the LLRF controllers to drive the superconducting cavities.



Lightning map of Hampton Roads from 6 am 7/23/2024 through 6 am 7/24/2024

Thunderstorm lightning from multiple miles away causes local oscillator (LO) phase and amplitude transient and, consequently, a beam trip [3].

Actions:

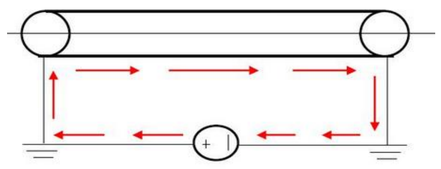
DC blocks added in multiple locations – ineffective

MO signal levels increased – overall ineffective

MO line surge protection – ineffective

Grounding measurement and improvement around affected service building – costly and ineffective

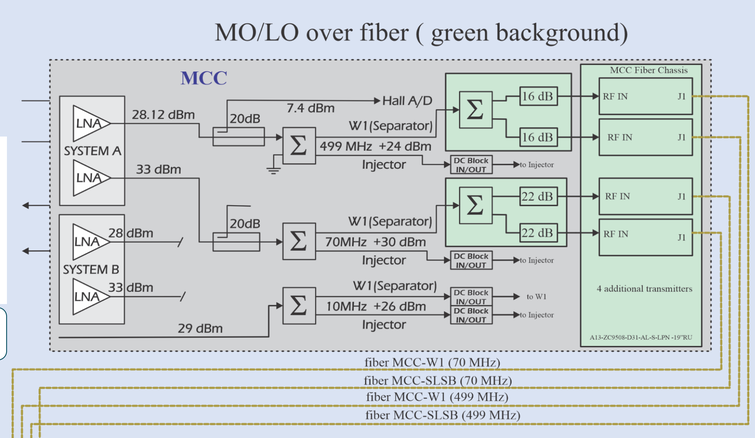
RF cables integrity check – no problem has been detected.

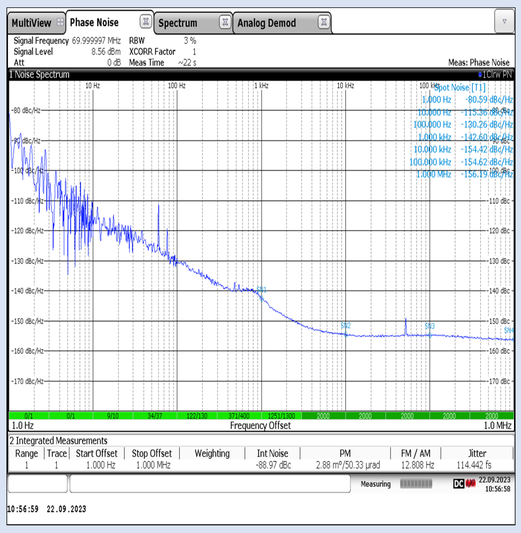


Implementing an RFoF System for Effective EMI and Ground Loop Elimination

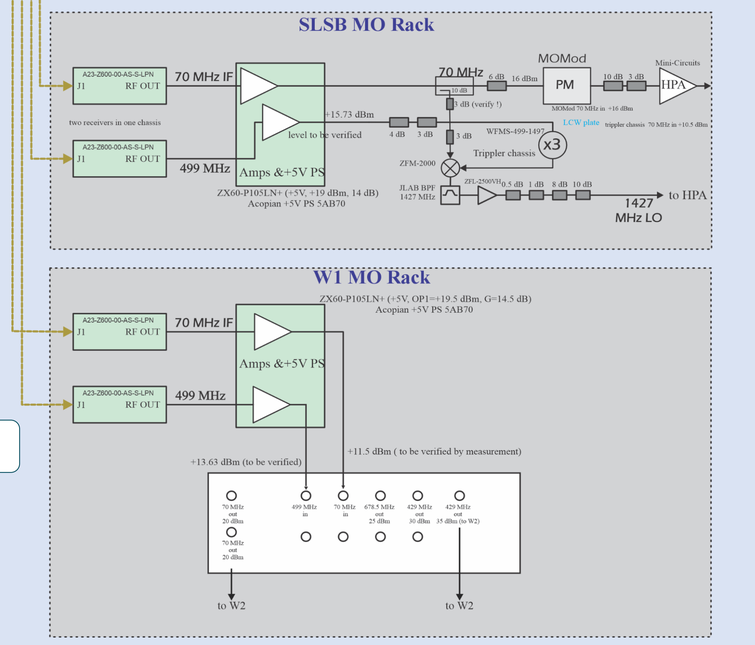
- Easy installation
- Transmission immune to electrical interference.
- Transmit signal over long distances with minimal signal loss.
- Eliminate troublesome ground loops
- Ultra-low noise levels
- Cost-effectiveness

Eight-channel RFoF transmitter





One-channel RFoF receiver



SUMMARY

Implementing RF over fiber has effectively resolved all lightning-related issues at Jefferson Lab. Monitoring both MO signals, 70 MHz and 499 MHz, did not detect any distortion during multiple summer thunderstorms (see lightning map). The phase noise performance is very satisfactory, with an integrated phase noise for the bandwidth of 1Hz-1 MHz ranging from 100-130 fs (2.9 mdeg for the 70 MHz signal). This primarily comes from the MO sources rather than being added by the RFoF system. We plan to run the accelerator for several months to gain more experience, and based on this, we plan to continue replacing copper cables with RF over fiber links.

REFERENCES

[1] T. E. Plawski, R. Bachimanchi, C. Hovater, and J. Musson, "The CEBAF Master Oscillator and Distribution Remodelling", in Proc. PAC'09, Vancouver, Canada, May 2009, paper TH6REP100, pp. 4186-4188.

[2] Hardy, D; Tang, J; Legg, R; Tiefenback, M; Crofford, M; Krafft, G A, "Automated path length and M56 measurements at Jefferson Lab", Conference: 17. IEEE particle accelerator conference, Vancouver, British Columbia (CA), 05/12/1997--05/16/1997

[3] J.R. Settle, "MO&LO Lightning Transient Monitoring", JLAB-TN-24-044 , 2024

*Authored by JSA, LLC under U.S. DOE Contract DE-AC05- 06OR23177 and DE-SC0005264. The U.S. Govt. retains a non-exclusive, paid-up, irrevocable, worldwide license to publish or reproduce this for U.S. Govt. purposes.